UNIVERSITY OF CALIFORNIA, LOS ANGELES
OCTOBER 1, 2022

Bioengineering
Chemical and Biomolecular Engineering
Civil and Environmental Engineering
Computer Science
Electrical and Computer Engineering
Materials Science
Mechanical and Aerospace Engineering
Master of Engineering (MEng)
Master of Science in Engineering Online (MSOL)
ANNOUNCEMENT 2022-23

HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE

UNIVERSITY OF CALIFORNIA, LOS ANGELES
OCTOBER 1, 2022
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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: Yayun Du, Guofeng Zhang, and Zihao Dong of Professor Khalid Jawed’s laboratory work on a compact robot for precision weed management in flax and canola fields.
Welcome to UCLA, and welcome to the UCLA Henry Samueli School of Engineering and Applied Science.

UCLA Samueli offers a world-class education—a rigorous engineering and computer science curriculum to build fundamental knowledge, multidisciplinary collaborations with academia and industry, and a problemsolving approach to real-world challenges. The school has always been, and will continue to be, at the forefront of engineering and computer science. Across the school, we conduct groundbreaking research in areas such as quantum computing, next-generation robotics, sustainable environment and energy technologies, advanced materials and engineering in medicine.

From day one, UCLA Samueli students have opportunities to engage in hands-on research with world-renowned faculty, in state-of-the-art labs or in unique shared facilities such as the school’s newly renovated, 9,000-square-foot makerspace. Students also network with exceptional industry leaders, many of whom are UCLA Engineering alumni who continue to support our school by mentoring students and providing internship and career guidance.

There are more than 60 engineering student clubs and organizations, with students from all disciplines. These groups offer exciting options for you as you pursue your academic and extracurricular interests. And along the way, you will form friendships that will last a lifetime.

UCLA has a beautiful campus with many highly ranked programs in addition to engineering and computer science—in law, medicine, public policy, social sciences, physical sciences, arts and many more—all in one place. These disciplines bring an academic breadth to the campus as we work on multiple cross-disciplinary projects together.

Ultimately, what makes UCLA truly special is its people—most importantly, students like you with diverse backgrounds, talents, and perspectives. To create an environment where we can all succeed and work together, it’s important that everyone is able to be at their best. At UCLA Samueli, we are committed to creating an equitable and inclusive community where everyone in our diverse student body feels welcome.

As engineers and computer scientists, we are natural problem solvers. And there is no shortage of pressing problems to solve in the 21st century—from the need for accessible health care and quality education to the lack of a sustainable environment and responsible artificial intelligence. We need to address these and many other challenges by sharing our collective resources and adopting a collaborative approach that incorporates the best ideas of every discipline. Only by working together can we build a truly inclusive engineering community, where we celebrate our unique experiences and help one another engineer positive change that will benefit many generations to come.

On behalf of the entire UCLA Samueli community, welcome to our school. I wish you all great success, and Go Bruins!

Bruce S. Dunn
Interim Dean, Henry Samueli School of Engineering and Applied Science
Henry Samueli School of Engineering and Applied Science

Administrative Officers

Bruce S. Dunn, PhD, Professor and Interim Dean
Jia-Ming Liu, PhD, Professor and Associate Dean, Academic Personnel
Gregory J. Pottie, PhD, Professor and Associate Dean, Research and Physical Resources
Veronica J. Santos, PhD, Professor and Associate Dean, Diversity and Inclusion
Richard D. Wesel, PhD, Professor and Associate Dean, Academic and Student Affairs
Jenn-Ming Yang, PhD, Professor and Associate Dean, International Initiatives and Online Education
Jeffrey Goldman, PhD, Assistant Dean, Chief Financial Officer
Christine Wei-li Lee, MS, Assistant Dean, Chief Marketing Communications Officer
Panagiotis D. Christofides, PhD, Professor and Chair, Chemical and Biomolecular Engineering Department
Yu Huang, PhD, Professor and Chair, Materials Science and Engineering Department
Song Li, PhD, Professor and Chair, Bioengineering Department
Todd D. Millstein, PhD, Professor and Chair, Computer Science Department
Ertugrul Taciroglu, PhD, Professor and Chair, Civil and Environmental Engineering Department
C.-K. Ken Yang, PhD, Professor and Chair, Electrical and Computer Engineering Department
Xiaolin Zhong, PhD, Professor and Chair, Mechanical and Aerospace 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 370,000 patients from around the world come to the Ronald Reagan UCLA Medical Center for treatment. The 419-acre University campus houses the College of Letters and Science and 12 professional schools. There are more than 47,500 students enrolled in 137 undergraduate degree programs and more than 260 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 industry centers, and the UCLA Henry Samueli School of Engineering and Applied Science is uniquely situated as a hub of engineering research and professional training for this region and beyond.

The School

The 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 in honor of the generous support of the school’s triple alumnus Henry Samueli.

Counted among the faculty are more than 30 National Academy of Engineering members, and more than 80 recipients of the National Science Foundation’s early career award. While no ranking can fully capture the success of a leading public research institution, the school is consistently ranked in the top 10 among U.S. public engineering schools, and its online master’s program has consistently been ranked first or second nationally.

The goal of UCLA Samueli is to engineer as much positive change as possible through the impact that engineers and computer scientists 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.

UCLA Samueli is a tightly knit community of nearly 200 full-time faculty members, more than 6,500 undergraduate and graduate students, and 40,000 active alumni. Known as the birthplace of the Internet, UCLA Samueli is also where countless other fields took some of their first steps—from artificial intelligence to reverse osmosis, from mobile communications to human prosthetics. In 2021, UCLA became the first university to win an XPRIZE with a UCLA Samueli team awarded a $7.5 million grand prize in the NRG COSIA Carbon XPRIZE.

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 twenty-first 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.

UCLA Samueli 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, Mechanical 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 Science, Electrical and Computer Engineering, Manufacturing Engineering (MS only), Materials Science and Engineering, and Mechanical Engineering.

In addition, UCLA Samueli also offers the Engineer degree, which is more advanced than the regular master’s, but does not require the research effort and orientation involved in a doctoral dissertation.

The school has two self-supporting, professional degree programs. The online Master of Science in Engineering degree program includes 11 individual degrees. In 2021, the school launched a one-year, full-time, on-campus professional degree, the Master of Engineering. Seven cross-disciplinary areas of study are offered including artificial intelligence, autonomous systems, data science, digital health technology, green energy systems, Internet of Things (IoT) systems, and translational medicine.

**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 established in the Henry Samueli School of Engineering and Applied Science.

- L.M.K. Booher Chair in Engineering
- Collins Aerospace Term Chair for Excellence
- Collins Aerospace Term Chair for Innovation
- Vijay K. Dhir Chair in Engineering
- Englekirk Presidential Endowed Chair in Structural Engineering
- Traugott and Dorothea Frederking Endowed Chair
- Norman E. Friedmann Chair in Knowledge Sciences
- Armond and Elena Hairapetian Chair in Engineering and Medicine
- Tatsuo Itoh Endowed Chair in Electrical and Computer Engineering
- Leonard Kleinrock Chair in Computer Science
- Evalyn Knight Chair in Engineering
- Levi James Knight, Jr., Chair for Innovation
- Levi James Knight, Jr., Term Chair for Excellence
- Fang Lu Endowed Chair in Engineering
- J.M. Maguire Term Chair in Engineering
- Richard G. Newman AECOM Endowed Chair in Civil Engineering
- Nippon Sheet Glass Company Chair in Materials Science
- Northrop Grumman Chair in Electrical Engineering
- Northrop Grumman Chair in Electrical Engineering/Electromagnetics
- Northrop Grumman Opto-Electronic Chair in Electrical Engineering
- Mukund Padmanabhan Term Chair
- Muhund Padmanabhan Term Chair in Electrical Engineering
- Ralph M. Parsons Foundation Chair in Chemical Engineering
- Jonathan B. Postel Chair in Computer Systems
- Jonathan B. Postel Chair in Networking
- Pritzker Chair in Sustainability
- Raytheon Company Chair in Electrical Engineering
- Raytheon Company Chair in Mechanical Engineering
- Charles P. Reames Endowed Chair in Electrical Engineering
- Ben Rich Lockheed Martin Chair in Aeronautics
- Sabol-Scott Term Chair in Civil and Environmental Engineering
- John P. and Claudia H. Schauerman Endowed Chair in Engineering
- William Frederick Seyer Chair in Materials Electrochemistry
- Ronald and Valerie Sugar Dean of Henry Samueli School of Engineering and Applied Science
- Ronald and Valerie Sugar Endowed Chair in Engineering
- Symantec Term Chair in Computer Science
- Carol and Lawrence E. Tannas, Jr., Endowed Chair in Engineering
- Carol and Lawrence E. Tannas, Jr., Endowed Term Chair in Engineering
- William D. Van Vorst Chair in Chemical Engineering Education
- Volgenau Chair for Engineering Excellence
- Volgenau Chair for Engineering Innovation
- Volgenau Endowed Chair in Engineering
- Wintek Endowed Chair in Electrical Engineering
- Neria and Manizheh Yomtoubian Endowed Chair in Cancer and Risk Sciences

**The Engineering Profession**

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

**Aerospace Engineering**

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

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

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

The BS program in Aerospace Engineering emphasizes fundamental disciplines and therefore provides a solid base for professional career development in industry and graduate study in aerospace engineering. Graduate education prepares students for careers at the forefront of aerospace technology. The PhD degree provides a strong background for employment by government laboratories, such as NASA, and industrial research laboratories supported by the major aerospace companies. It also provides the appropriate background for academic careers.

**Bioengineering**

At the interface of engineering, medicine, and basic sciences, bioengineering has emerged and established itself internationally as an engineering discipline in its own right. Such an interdisciplinary education is necessary to develop a quantitative engineering approach to tackle complex medical and biological problems, as well as to invent and improve the ever-evolving experimental and computational tools that are required in this engineering approach. UCLA has a long history of fostering interdisciplinary training and is a superlative environment for bioengineers. UCLA boasts the top hospital in the western U.S., nationally ranked medical and engineering schools, and numerous nationally recognized programs in the basic sciences. Rigorously trained bioengineers are in demand in research institutions, academia,
and industry. Their careers may follow a bioengineering concentration, but the ability of bioengineers to cut across traditional boundaries will facilitate their innovation in new areas.

Chemical and Biomolecular Engineering

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

Major areas of fundamental interest within chemical engineering are

- 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
- 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
- Thermodynamics, which is fundamental to physical, chemical, and biological processes
- Process design and synthesis, which provide the overall framework and computing technology for integrating chemical engineering knowledge into industrial application and practice

Civil and Environmental Engineering

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

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

The curriculum leading to a BS 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 BS 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, information processing). 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 MS 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:

- 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.
• 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 MS or PhD 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 BS program in Mechanical Engineering 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 PhD degree provides a strong background for employment by government laboratories, industrial research laboratories, and academia.
Correspondence Directory

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5121 Engineering V
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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
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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
## Calendars

### Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2022</th>
<th>Winter 2023</th>
<th>Spring 2023</th>
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<tbody>
<tr>
<td>First day for continuing students to check MyUCLA for assigned</td>
<td>May 31</td>
<td>October 31</td>
<td>January 30</td>
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<tr>
<td>enrollment appointments</td>
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<tr>
<td>MyUCLA enrollment appointments begin</td>
<td>June 13</td>
<td>November 7</td>
<td>February 13</td>
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<tr>
<td>Quarter begins</td>
<td>September 19</td>
<td>January 4, 2023</td>
<td>March 29</td>
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<tr>
<td>Instruction begins</td>
<td>September 22</td>
<td>January 9</td>
<td>April 3</td>
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<tr>
<td>Registration fee payment deadline</td>
<td>September 23</td>
<td>January 6</td>
<td>March 30</td>
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<tr>
<td>Last day for undergraduates to add classes through MyUCLA</td>
<td>October 14</td>
<td>January 27</td>
<td>April 21</td>
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<tr>
<td>Last day for undergraduates to drop nonimpacted classes</td>
<td>October 21</td>
<td>February 3</td>
<td>April 28</td>
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<td>without transcript notation through MyUCLA</td>
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<td>Last day for undergraduates to change grading basis on optional</td>
<td>November 25</td>
<td>March 10</td>
<td>June 2</td>
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<td>P/NP courses without fee through MyUCLA</td>
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<td>Instruction ends</td>
<td>December 2</td>
<td>March 17</td>
<td>June 9</td>
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<tr>
<td>Final examinations</td>
<td>December 5–9</td>
<td>March 20–24</td>
<td>June 12–16</td>
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<td>Quarter ends</td>
<td>December 9</td>
<td>March 24</td>
<td>June 16</td>
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<tr>
<td>Engineering Commencement (tentative)</td>
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<td>June 17–18</td>
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<td>Academic and administrative holidays</td>
<td>September 5</td>
<td>January 16</td>
<td>March 31</td>
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<td>November 11</td>
<td>February 20</td>
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<td>December 23, 26</td>
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<td>December 30, 2022</td>
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<td>January 2, 2023</td>
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<tr>
<td>Winter campus closure (tentative)</td>
<td>December 12, 2022–January 2, 2023</td>
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</tbody>
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### Admission Calendar

<table>
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<tr>
<th>Event</th>
<th>Fall 2022</th>
<th>Winter 2023</th>
<th>Spring 2023</th>
</tr>
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<tbody>
<tr>
<td>Filing period for undergraduate applications: apply online at University of California Admissions</td>
<td>November 1–30, 2021</td>
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</tr>
<tr>
<td>Last day to file Application for Graduate Admission or readmission with complete credentials and application fee, online or with UCLA Graduate Diversity, Inclusion, and Admissions (DIA), 1248 Murphy Hall, Los Angeles, CA 90024-1419</td>
<td>Consult department</td>
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<tr>
<td>Last day to file Undergraduate Readmission Application (late applicants pay a late fee)</td>
<td>August 15</td>
<td>November 25</td>
<td>February 25</td>
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</table>

*Dates are subject to change; see UCLA Registrar’s Office calendars for most current information.*
General Information

Facilities and Services
Teaching and research facilities at UCLA Samueli are in Boelte Hall, Engineering IV, Engineering V, and Engineering VI, located in the southern part of the UCLA campus. Boelte Hall houses classrooms and laboratories for 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, three million e-books, 175,000 serial titles, two thousand databases and more than three million media resources. Materials are available through the digital UC Library Search, which contains records for all its holdings and other campus collections.

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 digital 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/Boelte location (formerly Engineering and Mathematical Sciences Collection), 8270 Boelte Hall, focuses on engineering, mathematics, statistics, astronomy, chemistry, physics, and atmospheric and oceanic sciences, and is the location of most librarian and staff offices. The library also offers laptop checkout, a group study room, two spaces for collaborative group work (the Learning Commons and the Research Commons), and quiet areas for study.

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

The SEL website 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 UC Library Search, 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 15 full-time positions and five 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.

Backups 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 several racked UPS for short-term power outages. Campus emergency power keeps critical equipment running during extended downtime.

Faculty and staff have access to Microsoft Office software at no charge through the Microsoft Consolidated Campus Agreement (MCCA). Adobe software is available to all faculty, staff, and students through a campuswide Adobe agreement. 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
Vârân Shahmirian, PhD, Director
Vivian Taslakian, MBA, 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, bio-technology 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 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 in-person and remote 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 10 a.m. to 2 p.m.) offer support in person or virtually with résumés, cover letters, and the job/internship search and interview 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 UCH i HIP or other plans that provide adequate coverage. Adequate medical insurance is a condition of registration. Students who waive UCH i HIP 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. UCH i HIP 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 UCH i HIP 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, note-taking, 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
Fees and Financial Support

Fees and Expenses

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 Policies and Regulations section 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 systemwide and campus-based fees, 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 non-resident fee waivers may be eligible to qualify for scholarships, UCLA grant aid, and additional state aid if they complete a California Dream Act application.

Applications for the following academic year are available in January. The priority application deadline for financial aid is March 2. To qualify for aid, students must also comply with standards for satisfactory academic progress; information is available on the Forms and Publications web page.

Federal, state, and University financial aid programs require that applicants be U.S. citizens or permanent residents. Financial aid is not available to international students with F-1 or F-2 student, G series, H series, J-1 or J-2 exchange visitor visas. Information on international students’ financial support options is available on the Apply for Aid web page.

Scholarships

Entering students apply for scholarships on their UC admission application. 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 Samuei 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 2021-22, the school awarded 189 undergraduate scholarship awards totaling more than $1 million. The majority of these scholarships are publicized in the summer, with additional scholarships promoted throughout the academic year as applicable. For more information on all available scholarships, see the school undergraduate scholarships web page.

Detailed information on other scholarships is available from Financial Aid and Scholarships.

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 noncitizens under-graduates in exceptional need of funds to attend post-high school educational institutions. Students who complete 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.

Loans

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.

First-time borrowers must complete a debt management session before funds are released. Loan recipients must complete an exit interview 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 loans and 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.
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 loan by the amount of the increase. Most community service positions are located off campus.

Details about the types of work-study programs and their requirements are available from Financial Aid and Scholarships.

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 inter-term 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 annual competition. Applicants should check the deadline for submitting the online application for admission and the Fellowship Application for Entering Graduate Students with their preferred department.

Need-Based Aid

Unlike support based solely on merit and administered by the school, the University also offers work-study and low-interest loans based exclusively on financial need. Need-based awards are administered by Financial Aid and Scholarships. Financial aid applicants must file the Free Application for Federal Student Aid (FAFSA).

Continuing graduate students should contact Financial Aid and Scholarships in December for information on application procedures for the following academic year.

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

School of Engineering Fellowships

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

- Atlantic Richfield Company (ARCO) Fellowship. Chemical and Biomolecular Engineering Department; supports study in chemical engineering
- Ball 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 Alyne Camp Fellowship. Supports graduate study in electrical and/or mechanical engineering, must be U.S. citizen
- Deutsch Company Fellowship. Supports engineering research on problems that aid small business in Southern California
- Electrical Engineering Graduate Fellowship. Supports master’s or doctoral study in electrical engineering
- Venky Harinarayan Fellowship. Supports doctoral study in computer science
- IBM Doctoral Fellowship. Supports doctoral study in computer science
- Intel Fellowship. Computer Science Department; supports doctoral study in selected areas of computer science
- The Kalosworks.org Fellowship. Supports graduate students in electrical engineering who have a GPA of at least 3.0 and have demonstrated financial need
- Les Knesel Scholarship Fund. Materials Science and Engineering Department; supports master’s or doctoral study in ceramic engineering
- Guru Krupa Foundation Fellowships in Electrical Engineering. Multiple fellowships to support graduate study with preference for those conducting research in integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering from the Indian Institutes of Technology (IIT) or the Indian Institute of Science, Bangalore
- T.H. Lin Graduate Fellowship. Civil and Environmental Engineering Department; supports study by an international student in structural mechanics
- Living Rocks Electrical Engineering Fellowship. Supports graduate study with preference for students conducting research in the areas of integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering from National Taiwan University, National Tsing Hua University, or National Chiao Tung University in Taiwan
- Living Spring Fellowship. Electrical and Computer Engineering Department; supports graduate students with preference for those conducting research in integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering from National Taiwan University, National Tsing Hua University, or National Chiao Tung University in Taiwan
- Microsoft Fellowship. Supports doctoral study in computer science
- National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM) Fellowships. Support study in engineering and science to highly qualified individuals from communities where human capital is virtually untapped
- Northrop Grumman Fellowship. Supports graduate study in mechanical and aerospace engineering
- H.J. Orchard Memorial Fellowship. Supports graduate study in electrical engineering
Qualcomm Innovation Fellowship. Supports doctoral students across a broad range of technical research areas based on Qualcomm core values of innovation, execution, and teamwork.

Raytheon Fellowship. Supports graduate study in electrical engineering with preference for U.S. citizens.

Martin Rubin Scholarship. Supports two undergraduate and/or graduate students pursuing degrees in civil engineering with an interest in transportation engineering.

Henry Samueli Fellowship. Electrical and Computer Engineering Department; supports master’s and doctoral students.

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

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

Dr. Robert K. Williamson Graduate Fellowship. Supports graduate study in mechanical and aerospace engineering.

Many other companies in the area also make arrangements for their employees to work part-time and to study at UCLA for advanced degrees in engineering or computer science. In addition, the Graduate Division offers other fellowship packages including the Dissertation Year, Eugene V. Cota-Robles, and Graduate Opportunity Fellowships.

Special Programs, Activities, and Awards

Center for Excellence in Engineering and Diversity (CEED)

The UCLA Samueli Center for Excellence in Engineering and Diversity (CEED) seeks to create a community of collaborative and sustainable partnerships that offer academic and professional development support to disadvantaged and underrepresented engineering and computer science undergraduate and graduate students. CEED also supports precollege students in local middle and high schools who are interested in science, computer science, engineering, mathematics, and technology by offering opportunities to learn through hands-on projects.

Precollege Outreach Programs

MESA College Prep Program. Through CEED, UCLA Samueli partners with middle and high school principals to implement the MESA College Prep services program, which focus on outreach and student development in engineering, mathematics, science, and computer science. At individual school sites, four mathematics and science teachers serve as College Prep advisors 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 local and regional engineering and science competitions and provides mathematics and science tutoring, computer science workshops, college admission workshops, 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.

The UCLA MESA Center currently serves students in 22 middle and high schools in the Los Angeles, Inglewood, and Centinela Valley unified school districts.

Undergraduate Programs

CEED currently supports some 365 underrepresented and educationally disadvantaged engineering students. Components of the undergraduate program include:

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

Freshman 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, time management, 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 PhD 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.

Structured Study Nights. Weekly tutoring sessions are provided for introductory mathematics, science, computer, and core engineering courses.

Career Development. Presentations by corporate representatives and field trips to major company locations are offered.

CEED students participate in a professional development workshop.
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 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

UCLA Samueli also participates in the NA-CME and GEM scholarships. The CEED Industry Advisory Board and alumni provide significant contributions to program services and scholarships. Information may be obtained from the CEED director.

Student Organizations

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

American Indian Science and Engineering Society (AISES)

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 enjoying 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 Women in Science and Engineering (WISE) Day with AISES and NSBE. By participating in campus events such as Career Day and Engineers Week, the organization’s growing membership strives to fulfill the needs of the individual and the community.

Women in Engineering

Women make up about 36 percent of the UCLA Samueli undergraduate enrollment and 24 percent of the graduate enrollment. Today’s opportunities for women in engineering are excellent, as both employers and educators try to change the image of engineering as a males-only field. Women engineers are in great demand in all fields of engineering.

Society of Women Engineers (SWE)

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

Student and Honorary Societies

Professionally related societies and activities at UCLA provide valuable experience in leadership, service, recreation, and personal satisfaction. The faculty of the school encourages students to participate in such activities and join the various organizations the faculty has set up to do that. Here are some of the many professional societies and organizations available at UCLA.

American Indian Science and Engineering Society (AISES)

American Institute of Aeronautics and Astronautics (AIAA)

American Institute of Chemical Engineers (AIChE)

American Society of Civil Engineers (ASCE)

American Society for Engineering Education (ASEE)

American Society for Engineering Education (ASEE)

American Society of Mechanical Engineers (ASME)

American Society of Mechanical Engineers (ASME)

American Water Works Association (AWWA)

Arab American Association of Engineers (AAAE)

Association for Computing Machinery (ACM)

Association for Computing Machinery (ACM)

Association for Computing Machinery—Women (ACM-W)

Bioengineering Graduate Association (BGA)

Biomedical Engineering Society (BMES)

Blockchain at UCLA

Bruin Consulting (Student-founded independent management consulting group)

Bruin Entrepreneurs (Startup UCLA group offering programs and events)

Bruin Home Solutions

Bruin Racing—Society of Automotive Engineers (SAE)

Baja SAE

Formula SAE

Supermileage

Bruin Spacecraft Group

Building Engineers and Mentors (BEAM)

California Geotechnical Engineers Association (CalGeo)

Chi Epsilon (Civil engineering honor society)

Design Create Solar

Earthquake Engineering Research Institute (EERI)—Structural Engineers Association of Southern California (SEAOSC)

Engineering Ambassador Program

Engineering and Entrepreneurial Group at UCLA

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)

exploretech.la
Graduate Student Association (CSA) (Campuswide group offering governance, social, academic, and community programs)
Graduate Student Committee of the Society of Women Engineers (GradSWE)
Institute of Electrical and Electronic Engineers (IEEE)
IEEE Electron Devices Society (EDS)
IEEE Electronics Packaging Society (EPS)
IEEE Women Advancing Technology through Teamwork (WATT)
Institute of Transportation Engineers (ITE)
International Society for Pharmaceutical Engineering (ISPE)
Korean-American Scientists and Engineers Association (BruinKSEA)
LA Blueprint
Materials Research Society (MRS)
MentorSEAS
National Society of Black Engineers (NSBE)
NoCode
Nova
Phi Sigma Rho (Engineering social sorority)
Pilipinos in Engineering and Science (PIES)
Queers in STEM (QSTEM)
Renewable Energy Association (REA)
Rocket Project at UCLA
Society of Asian Scientists and Engineers (SASE)
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
Undergraduate Student Association (USA) (Campuswide group offering governance, social, academic, and community programs)
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
Exceptionally promising juniors or seniors may be nominated as Departmental Scholars to pursue engineering bachelor’s and master’s degree programs simultaneously. Minimum qualifications include the completion of 24 courses (96 quarter units) at UCLA, or the equivalent at a similar institution; 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, see the Departmental Scholar Program web page.

Exceptional Student Admissions Program
There is an Exceptional Student Admissions Program (ESAP) for outstanding UCLA Samueli undergraduates who wish to enter the school graduate program upon completion of the BS degree. ESAP is an alternative to the Departmental Scholar Program. In contrast to that program, an ESAP-admitted student would be an enrolled graduate student and eligible for consideration of graduate fellowships and teaching assistant positions if available.
For eligibility criteria and graduate application deadlines, see 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, reli-
discrimination laws or University policies on discrimination on the 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 UCLA 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 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 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 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 Office by e-mail. Responsible employees include academic personnel, faculty members, and most other employees who are not defined as a confidential resource under the SVSH Policy.

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

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
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 enrolled course units, degrees and honors received, the most recent previous educational institution attended, participation in officially recognized activities (including intercollegiate athletics), and the name, weight, and height of participants on intercollegiate athletic teams.

As a matter of practice, UCLA does not publish student telephone numbers in the campus online 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 additional items in the category of public information, complete the UCLA FERPA Restriction Request form available from the Registrar’s Office, 1113 Murphy Hall.

Student records that are the subject of federal and state laws and University policies may be maintained in a variety of offices, including the Registrar’s Office, Office of Student Conduct, Career Center, Graduate Division, External Affairs Department, and offices of a student’s College or school and major department. Students are referred to the online UCLA Campus Directory, which lists all the offices that may maintain student records, together with each office 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 applicable federal and state laws and University policies may be requested from the Information Practices office by e-mail, or by calling 310-794-8741. Information concerning student hearing rights may be obtained from that office, and from the Office of Student Conduct, 1104 Murphy Hall.
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, Data Science Engineering, and Environmental Engineering:

- Bachelor of Science in Aerospace Engineering
- Bachelor of Science in Bioengineering
- Bachelor of Science in Chemical Engineering
- Bachelor of Science in Civil Engineering
- Bachelor of Science in Computer Engineering
- Bachelor of Science in Computer Science
- Bachelor of Science in Computer Science and Engineering
- Bachelor of Science in Electrical Engineering
- Bachelor of Science in Materials Engineering
- 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

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

Freshman applicants must meet the UC subject and scholarship requirements described on the undergraduate admission website. UC requirements specify a minimum of three years of mathematics, including the topics covered in elementary and advanced algebra and two- and three-dimensional geometry. Additional study in mathematics, concluding with calculus or precalculus in the senior year, is strongly recommended and typical for applicants to UCLA Samueli.

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 2022 fulfills UCLA Samueli requirements as indicated in 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.

Applications should have completed the following lower-division minimum subject requirements:

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.
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.
Advanced Placement (AP) Examination Credit

All units and course equivalents to AP examinations are lower division. If an AP examination has been given UCLA course equivalency (e.g., Economics 2), it may not be repeated at UCLA for units or grade points.

<table>
<thead>
<tr>
<th>AP EXAMINATION</th>
<th>SCORE</th>
<th>UCLA LOWER-DIVISION UNITS AND COURSE EQUIVALENTS</th>
<th>CREDIT ALLOWED FOR UNIVERSITY AND GE REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art History</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Art, Studio</td>
<td></td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>Drawing Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Biology</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 excess units plus 4 units</td>
<td>4 units may be applied toward Chemistry 20A</td>
</tr>
<tr>
<td>Computer Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Science A Test</td>
<td>3, 4, or 5</td>
<td>2 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science AB Test</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science Principles</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macroeconomics</td>
<td>3 or 4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Economics 2 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3 or 4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Economics 1 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing requirement</td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing requirement</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparative</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>Satisfies American History and Institutions</td>
</tr>
<tr>
<td>History</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>Satisfies American History and Institutions</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Languages and Literatures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
</tbody>
</table>

Table continues next page
<table>
<thead>
<tr>
<th>AP EXAMINATION</th>
<th>SCORE</th>
<th>AP EXAMINATION SCORE-TO-CREDIT CONVERSION (CONTINUED)</th>
<th>CREDIT ALLOWED FOR UNIVERSITY AND GE REQUIREMENTS</th>
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</thead>
<tbody>
<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 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>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>
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<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>
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<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: Electricity/Magnetism</td>
<td>3, 4, or 5</td>
<td>4 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</td>
<td>May be applied toward Physics 1A</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>
</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: Electrodynamics, Optics, and Special Relativity (5 units)
Physics 4AL. Physics Laboratory for Scientists and Engineers: Mechanics (2 units)
Physics 4BL. Physics Laboratory for Scientists and Engineers: Electricity and Magnetism (2 units)
The courses in chemistry, mathematics, and physics are those required as preparation for majors in these subjects. Transfer students should select equivalent courses required for engineering or physical sciences majors.

**Requirements for BS Degrees**
The Henry Samueli School of Engineering and Applied Science awards BS 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 BS 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-semester writing requirement—Writing I and Engineering Writing. Both courses must be taken for a letter grade, and students must receive a C or better grade in each (a C– grade is not acceptable).

Writing I

The Writing I requirement must be satisfied by the end of the second year of enrollment by completing English Composition 3, 3D, 3S, 3E, or 3SL with a C or better grade (a C– or Passed grade is not acceptable). The Writing I requirement may also be satisfied by scoring 4 or 5 on one of the College Board Advanced Placement Examinations in English; 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; completing a course equivalent to English Composition 3 with a C or better grade (a C– or Passed grade is not acceptable) taken at another institution; or 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 C or better grade (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 C or better grade (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 C or better grade (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 (P/NP) basis if they are in good academic standing and are additionally enrolled in nine letter-graded units. For details on P/NP grading, see Grades in the Academic Policies section 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 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 supply perspectives and intellectual skills necessary to comprehend and think critically about our situation in the world as human beings. In particular, courses furnish 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 that 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 Samueli GE requirements. The school does not accept partial IGETC.

Department Requirements
UCLA Samueli departments generally set two types of requirements that must be satisfied for award of a degree: preparation for the major (lower-division courses) and the major (upper-division courses). Preparation for the major courses should be completed before beginning upper-division work.

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

The Major
Students must complete their major with a scholarship grade-point average of at least 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. Units earned at any UC campus (through extension, summer, cross-campus, UCEAP, Intercampus Visitor Program, and regular academic year enrollment) are not included in the limitation. To convert semester units into quarter units, multiply the semester units by 1.5; for example, 12 semester units x 1.5 = 18 quarter units. To convert quarter units into semester units, multiply the quarter units by .666; for example, 12 quarter units x .666 = 7.99 or 8 semester units.

Foreign Language

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

Repetition of Courses

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

- 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.
- 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.
- 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.
- 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 second major must be outside the school (e.g., Electrical Engineering and Economics major). If approved, no more than 20 upper-division units may be shared by both majors. 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 minor and double major requests are considered, 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. First-year students are assigned a faculty adviser in their particular specialization.

In addition, 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 their academic counselor, as well as with their faculty adviser, to discuss curriculum requirements, programs of study, and any other academic matters of concern.

Curricula Planning Procedure

Students normally follow the curriculum in effect when they enter the school. California community college transfer students may also select the curriculum in the 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 2022-23 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 (GPA) at graduation that places them in the top 20 percent of the school (GPA of 3.812 or better) for cum laude, the top 10 percent (GPA of 3.898 or better) for magna cum laude, and the top five percent (GPA of 3.943 or better) for summa 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 3.812 GPA for cum laude, 3.898 for magna cum laude, and 3.943 for summa cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field upper-division courses. Upper-division courses that are not applied to a specific school BS degree requirement are excluded from these upper-division averages.
Graduate Programs

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

Also, a one-year program leading to a Certificate of Specialization is offered in various fields of engineering and applied science. Graduate degree information is updated annually at Program Requirements for UCLA Graduate Degrees.

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 MS)
- Engineering – Aerospace (online MS)
- Engineering – Computer Networking (online MS)
- Engineering – Electrical (online MS)
- Engineering – Electronic Materials (online MS)
- Engineering – Integrated Circuits (online MS)
- Engineering – Manufacturing and Design (online MS)
- Engineering – Materials Science (online MS)
- Engineering – Mechanical (online MS)
- Engineering – Signal Processing and Communications (online MS)
- Engineering – Structural Materials (online MS)

Master of Engineering Degree

The one-year Master of Engineering (MEng) is a self-supporting, professional degree designed to develop future engineering leaders. Tailored to those who wish to pursue technical management positions, the degree addresses the needs of both students and industry with high-tech skill set and management savvy. Students in the program develop technical mastery in emerging research areas, learning business and technology management skills while creating real-world projects with industry input.

Engineer Degree

The Engineer (Eng) degree is similar to the PhD 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 PhD 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).

Doctorate Degrees

The PhD programs prepare students for advanced study and research in the major areas of engineering and computer science. To complete the PhD 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 PhD student must obtain an overall grade-point average of 3.25.

Established Fields of Study for the PhD

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

Bioengineering Department
- Biomedical data sciences
- Biomedical devices and instrumentation
- Biomedical image processing
- Biosystems science and engineering
- Molecular, cellular, and tissue engineering
- 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

Concurrent Degree Program

A concurrent degree program between UCLA Samueli and the Anderson Graduate School of Management allows students to earn two master’s degrees simultaneously: the MBA and the MS in Computer Science. Contact the Office of Academic and Student Affairs for details.
• Structures (structural mechanics and earthquake engineering)
• Transportation engineering

Computer Science Department
• Artificial intelligence
• Computational systems biology
• Computer networks
• 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)
• 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 BS 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/PhD 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 MS degree is required for admission to the PhD program. Exceptional students, however, can be admitted to the PhD program without having an MS 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, PhD, Chair
Dino Di Carlo, PhD, Graduate Vice Chair
Jacob J. Schmidt, PhD, Undergraduate Vice Chair

Faculty Roster

Professors
Denise R. Aberle, MD
Corey W. Arnold, PhD
Pei-Yu Chiou, PhD
Mark S. Cohen, PhD, in Residence
Linda L. Demer, MD, PhD
Timothy J. Deming, PhD
Dino Di Carlo, PhD (Armond and Elena Hairapetian Professor of Engineering and Medicine)
Tzung K. Hsiao, MD, PhD, in Residence
Bahram Jalali, PhD (Fang Lu Endowed Professor of Engineering)
Daniel T. Kamei, PhD
Andrea M. Kasko, PhD
H. Pirouz Kavehpour, PhD
Debiao Li, PhD, in Residence
Song Li, PhD
Wentai Liu, PhD
Arash Naemi, PhD
Aydogan Ozcan, PhD (Volgenau Professor of Engineering Innovation)
Jacob Rosen, PhD
Jacob J. Schmidt, PhD
Vivek Shetty, DDS, DMD, Dent
Kalyanam Shivkumar, MD, PhD, in Residence
Maie St. John, MD, PhD
Ren Sun, PhD
Yi Tang, PhD (Ralph M. Parsons Foundation Professor of Chemical Engineering)
Michael A. Teitel, PhD
Cun-Yu Wang, DDS, PhD
Paul S. Weiss, PhD (Presidential Professor of Chemistry)
Gerard C.L. Wong, PhD
Benjamin M. Wu, DDS, PhD
Yang Yang, PhD

Professors Emeriti
Chih-Ming Ho, PhD (Ben Rich Lockheed Martin Professor Emeritus of Aeronautics)
Edward R.B. McCabe, MD, PhD (Mattiel Executive Endowed Professor Emeritus of Pediatrics)

Associate Professors
Elisa Franco, PhD
Liang Gao, PhD

William Hsu, PhD, in Residence
Dan Ruan, PhD, in Residence
Holden H. Wu, PhD, in Residence

Assistant Professors
Jun Chen, PhD
Tyler R. Citlles, PhD
Aaron S. Meyer, PhD
Jennifer L. Wilson, PhD

Adjunct Professors
James C.Y. Dunn, MD, PhD
Zhen Gu, PhD

Adjunct Associate Professors
Sophia N. Barbarie, PhD
Stephanie K. Seidlits, PhD
Bill J. Tawil, MBA, PhD

Adjunct Assistant Professors
Chase Linsley, PhD
George N. Saddik, PhD

Affiliated Faculty

Professors
Reza Ardehali, MD, PhD, in Residence (Cardiology)
Peyman Benharash, MD (Cardiothoracic Surgery)
Alex A.T. Blu, PhD (Radiological Sciences)
Gregory P. Carman, PhD (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Yang Chen, PhD (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Thomas Chou, PhD (Biobmathematics, Mathematics)
Joseph L. Demer, MD, PhD (Neurology, Ophthalmology)
Joseph J. DiStefano III, PhD (Computer Science, Medicine)
Thomas G. Graeber, PhD (Molecular and Medical Pharmacology)
Vijay Gupta, PhD (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Rajesh Kumar, PhD, in Residence (Anesthesiology and Perioperative Medicine, Radiological Sciences)
Y. Sungtaek Ju, PhD (Mechanical and Aerospace Engineering)
Jody E. Kreiman, PhD, in Residence (Surgery)
Rajesh Kumar, PhD, in Residence (Anesthesiology and Perioperative Medicine)
Min Lee, PhD (Dentistry)
Heather D. Maynard, PhD (Chemistry and Biochemistry)
Ichiro Nishimura, DDS, DMSc, DMD (Dentistry)
Matteo Pellegrini, PhD (Human Genetics, Molecular, Cell, and Developmental Biology)
Laurent Pillon, PhD (Mechanical and Aerospace Engineering)
Darío L. Ringach, PhD (Neurobiology, Psychology)
Ke Sheng, PhD (Radiation Oncology)
Chia B. Soo, MD (Plastic Surgery)

Ricky Taira, PhD, in Residence (Radiological Sciences)
Albert Thomas, PhD, in Residence (Radiological Sciences)
James G. Tidball, PhD (Integrative Biology and Physiology, Pathology and Laboratory Medicine)
Kang Ting, DMD, DMSc (Dentistry)
Hsiian-Rong Tseng, PhD (Molecular and Medical Pharmacology)
David Wong, PhD (Dentistry)
Lily Wu, PhD, MD (Molecular and Medical Pharmacology, Urology)
Xinshu Grace Xiao, PhD (Integrative Biology and Physiology)
Z. Hong Zhou, PhD (Microbiology, Immunology, and Molecular Genetics)

Professor Emeritus
William J. Kaiser, PhD (Electrical and Computer Engineering)

Associate Professors
Louis S. Bouchard, PhD (Chemistry and Biochemistry)
Robert N. Candler, PhD (Electrical and Computer Engineering, Mechanical and Aerospace Engineering)
Benjamin M. Ellinong, PhD (Radiology)
Daniel S. Levi, PhD (Pediatrics)
Zili Liu, PhD (Psychology)
Alireza Mosheriannia, DDS, PhD (Dentistry)
Amy C. Rowat, PhD (Integrative Biology and Physiology)
Veronica J. Santos, PhD (Mechanical and Aerospace Engineering)
Ladan Shams, PhD (Psychology)
Michael R. van Dam, PhD (Molecular and Medical Pharmacology)
Zhaoyan Zhang, PhD, in Residence (Head and Neck Surgery)

Assistant Professors
Daniel B. Aharoni, PhD, in Residence (Neurology)
Nasim Annabi, PhD (Chemical and Biomolecular Engineering)
Anthony G. Christodoulou, PhD, in Residence (Medicine)
Sam Emaninejad, PhD (Electrical and Computer Engineering)
Achuta Kadambi, PhD (Computer Science, Electrical and Computer Engineering)
Sotiris C. Masmansidis, PhD (Neurobiology)
René R. Sevag Packard, MD, PhD, in Residence (Cardiology, Physiology)
Jinyoung O. Park, PhD (Chemical and Biomolecular Engineering)
Behzad Sharif, PhD (Medicine)
Kyung Hyun Sung, PhD (Radiology)
Nanthia Suthana, PhD (Psychiatry and Biobehavioral Sciences)

Adjunct Professor
Robert D. Damoiseaux, PhD (Molecular and Medical Pharmacology)

Adjunct Assistant Professors
Tanuj Gulati, PhD (Medicine)
William F. Speier, PhD (Radiological Sciences)
Overview

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

The bioengineering program offers forward-looking courses dedicated to producing graduates who are well-grounded in the fundamental sciences and highly proficient in rigorous analytical engineering tools necessary for lifelong success in the wide range of possible bioengineering careers. Combined with a strong emphasis on research, the program provides a unique engineering educational experience that responds to the growing needs and demands of bioengineering.

Department Mission

The mission of the Bioengineering Department is to perform cutting-edge research that benefits society and to train future leaders in the wide range of possible bioengineering careers by producing graduates who are well-grounded in the fundamental sciences, adept at addressing open-ended problems, and highly proficient in rigorous analytical engineering tools necessary for lifelong success.

Undergraduate Study

Bioengineering BS

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

Capstone Major

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

Educational Objectives

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.

Learning Outcomes

The Bioengineering major has the following learning outcomes:

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

Preparation for the Major

Required: Bioengineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Civil and Environmental Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20; Life Sciences 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, 175, 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, 121, C131, C139A, C139B, CM140, CM145, C147, M153, C155, CM178, CM179, 180L, M182, C183, CM185, CM186, CM187, 199 (8 units maximum) Three of the major field elective courses and the three technical breadth courses may also be selected from one of the following tracks. Bioengineering majors cannot take bioengineering technical breadth courses to fulfill the technical breadth requirement.

Biomaterials and Regenerative Medicine: Bioengineering C104, C105, CM140, C147, C183, C185, 199 (8 units maximum), Materials Science and Engineering 104, 110, 111, 120, 130, 132, 143A, 150, 151, 160, 161. The above materials science and engineering
courses may be used to satisfy the technical breadth requirement.

**Biomedical Devices:** Bioengineering C131, M1S3, 199 (8 units maximum), Electrical and Computer Engineering 102, Mechanical and Aerospace Engineering C187L. The electrical and computer engineering or mechanical and aerospace engineering courses listed above may be used to satisfy the technical breadth requirement.

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

For information on UC, school, and general education requirements, see **Requirements for BS Degrees** on page 21 or the **GE Requirement** web page.

**Graduate Study**

For admission information, see Graduate Programs **Admission** on page 27.

The following introductory information is based on 2022-23 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 Bioengineering Department offers Master of Science (MS) and Doctor of Philosophy (PhD) degrees in Bioengineering.

**Bioengineering MS**

**Course Requirements**

A minimum of 13 courses (44 units) is required.

For the comprehensive plan, at least 11 courses must be from the 200 series, three of which must be Bioengineering 299 courses. Students must also take one 495 course. One 100-series course may be applied toward the total course and unit requirement. No units of 500-series courses may be applied toward the minimum course requirements.

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, MS 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 PhD**

**Course Requirements**

To complete the PhD 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 MS 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, PhD 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. All committee nominations and reconstitutions adhere to the **Minimum Standards for Doctoral Committee Constitution**.

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

**Fields of Study**

**Biomedical Data Sciences**

The biomedical data sciences (BDS) field trains students to be experts in the use of computational, statistical, and machine learning tools for solving biomedical problems. BDS is intended for science and engineering students interested in how data science tools can operate alongside other areas of bioengineering to solve problems in areas including pattern recognition, prediction, control, measurement, and visualization. Students are trained in the algorithmic and statistical fundamentals of the field. Directed interdisciplinary training prepares students to be practitioners in the application of data science to analyze clinical imaging, molecular and cellular systems, medical devices, electronic health record data, and the many other areas of biomedicine that routinely generate data. In parallel to learning fundamentals, students develop expertise in these application areas, providing them additional expertise in real-world problem solving. In total, this area fosters the development of students who go on to become data scientists with the unique ability to actively interface with practitioners in other areas of bioengineering and medicine.

**Biomedical Devices and Instrumentation**

The biomedical devices and instrumentation (BDI) 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 microelectronic 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.

Biomedical Image Processing

The biomedical imaging (Bi) field consists of the following two subfields: biomedical imaging hardware development (BIHHD) and biomedical signal and image processing (BSIP).

Biomedical Imaging Hardware Development (BIHHD)

The BIHHD subfield prepares students for a career in developing imaging hardware for medical diagnosis and intervention applications. Students learn the physical basis of biomedical imaging modalities such as optical imaging, CT, and MRI. The students will also be trained with hands-on experiences to build state-of-the-art imaging devices and test their performance in real-world medical imaging scenarios. Through the structured curriculum and lab activities, the students experience the excitement of cutting-edge hardware research, hone skills in analytical thinking and communications, and gain knowledge of imaging techniques that are used in the biomedical field.

Biomedical Signal and Image Processing (BSIP)

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

Molecular, Cellular, and Tissue Engineering

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

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

Neuroengineering

The neuroengineering (NE) field is designed to enable students with a background in biological sciences to develop and execute projects that make use of state-of-the-art technology, including microelectromechanical systems (MEMS), signal processing, and photonics. Students with a background in engineering develop and execute projects that address problems that have a neuroscientific base, including locomotion and pattern generation, central control of movement, and the processing of sensory information. Trainees develop the capacity for the multidisciplinary teamwork, in intellectually and socially diverse settings, that is necessary for new scientific insights and dramatic technological progress in the twenty-first century. Students take a curriculum designed to encourage cross-fertilization of neuroscience and engineering. The goal is for neuroscientists and engineers to speak each others’ language and move comfortably among the intellectual domains of the two fields.

Faculty Areas of Thesis Guidance

Professors

Denise R. Aberle, MD (U. Kansas, 1979)
Medical imaging informatics; imaging-based clinical trials, medical data visualization
Corey W. Arnold, PhD (UCLA, 2009)
Computational medical imaging, machine learning, quantitative phenotyping, disease prediction, graphical modeling, natural language processing, data visualization
Pei-Yu Chien, PhD (UC Berkeley, 2005)
Optofluidics systems
Mark S. Cohen, PhD (Rockefeller, 1985)
Rapid methods of MRI imaging, fusion of electrophysiology and fMRI, advanced approaches to MRI data analysis, ultra-low field MRI using SQUID detection, low energy focused ultrasound for neurostimulation
Linda L. Demer, MD, PhD (Johns Hopkins, 1983)
Vascular biology, biomaterialization, vascular calcification, microvascular anatomy
Timothy J. Deming, PhD (UC Berkeley, 1993)
Polymer synthesis, polymer processing, supramolecular materials, organometallic catalysis, biomimetic materials, polypeptides
Dino Di Carlo, PhD (UC Berkeley, 2006)
Microfluidics, biomedical microdevices, cellular diagnostics, cell analysis and engineering
Tzung K. Hsiai, MD (U. Chicago, 1993), PhD (UCLA, 2001)
Cardiovascular mechanotransduction, MEMS and nanosensors, vascular endothelial dynamics, molecular imaging of atherosclerotic lesions, reactive nitrogen species (RNS) and reactive oxygen species (ROS)
Bahram Jalali, PhD (Columbia, 1989)
RF photonics, fiber-optic integrated circuits, integrated optics, microwave photonics
Daniel T. Kamei, PhD (MIT, 2001)
Molecular cell bioengineering, rational design of molecular therapeutics, systems-level analyses of cellular processes, drug delivery, diagnostics
Andrea M. Kasko, PhD (U. Akron, 2004)
Polymer synthesis, biomaterials, tissue engineering, cell-material interactions
H. Pirouz Kavehpour, PhD (MIT, 2003)
Microscale fluid mechanics, transport phenomena in biological systems, physics of contact line phenomena, complex fluids, non-isothermal flows, micro- and nano-heat guides, microtribology
Chang-Jin (CJ) Kim, PhD (UC Berkeley, 1991)
Microelectromechanical systems: micro/nano fabrication technologies, structures, actuators, devices, and systems; microfluidics involving surface tension (especially droplets)
Debiao Li, PhD (U. Virginia, 1992)
Development and clinical application of fast MR imaging techniques for the evaluation of the cardiovascular system
Song Li, PhD (UC San Diego, 1997)
Stern cell engineering, tissue engineering and vascular remodeling, mechanobiology/ mechanotransduction
Wentai Liu, PhD (U. Michigan, 1983)
Neural engineering
Arash Naeim, MD (UCLA, 1995), PhD (RAND Graduate School, 2002)
Remote monitoring, wearable sensors, big data analytics, clinical informatics, health care analytics
Bioengineering Courses

Lower-Division Courses

10. Introduction to Bioengineering. (2) Lecture, two hours; discussion, one hour; outside study, three hours. Preparation: high school biology, chemistry, mathematics, physics. Introduction to scientific and technological bases for established and emerging subfields of bioengineering, including biocomputing and bioengineering, introduction to cellular and molecular biology, principles of bioinformatics, and data analysis.

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 the supervision of a faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper-Division Courses

100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 32A, Physics 1A. Fundamental basis for analysis and design of biological and biomedical devices and systems. Classical and statistical thermodynamics, introduction to basic mechanisms. Analysis of diffusion of drugs, coupled with computational and engineering mathematics approaches. Concurrently scheduled with course C201. Letter grading.


C102. Human Physiological Systems for Bioengineering I. (4) Formerly numbered CMCE 102. Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Broad overview of basic biological activities and organization of human body in system (organ/ tissue) system to system basis, with particular emphasis on molecular basis. Modeling of functional aspects of physiological systems. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course C202. Letter grading.

C104. Physical Chemistry of Biomacromolecules. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 30A, Life Sciences 7A. To understand biological materials and design synthetic replacements, it is imperative to understand their physical chemistry. Protein chemistry is used to understand the structure of protein, secondary and tertiary structures, and molecular stability. Importance of applying engineering principles to the design of delivery systems.
pies to problems involving biomacromolecules such as protein conformation, chain attributes, 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; laboratory, three hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry is science of coupling molecules in a wide range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of bioconjugates are used in delivering pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including choice and design of conjugate linkers depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers. Presentation 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 132B. Physics. Emphasis on depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrophotonic phenomena. Concepts of voltage jumps, quantum complexity to ultimate limit of sensitivity, action potentials and signal propagation in nerves. Topics include Nernst/Plank and Poisson/Boltzmann equations, Donnai equilibrium, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course 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 polymerizations. Presentation of applications of use of different polymerization techniques. Concepts of step-growth polymerization, ring-opening polymerization, and condensation 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)

170. Cell Engineering and Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Preparation: general background on cell biology, calculus, and differential equations. Comprehensive introduction to cell engineering. Topics include quantitative and experimental analysis of cell behavior such as cell growth, migration and differentiation, biomaterial fabrication, cell-material interactions, cell signaling, tissue remodeling, and immunomodulation/immunostimulation. Letter grading.

175. Machine Learning and Data-Driven Modeling in Bioengineering. (4) Formerly numbered C175. Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: Civil Engineering M20 or Mechanical Engineering M20. Computer Science 31, Mathematics 32B, 33A. Overview of foundational data analysis and machine-learning methods in bioengineering, focusing on how these methods are applied in experimental observations. Topics include probabilities, distributions, cross-validation, analysis of variance, reproducible computational workflows, dimensionality reduction, regression, hidden Markov models, and clustering. Students gain theoretical and practical knowledge of data analysis and machine-learning methods relevant to bioengineering. Application of these methods to experimental data from bioengineering projects, and the opportunity to use a sufficiently familiar with these techniques to design studies incorporating such analyses, execute analysis, and work in teams using similar approaches, and ensure correctness through intermediate checks using arbitrarily strong microchannels. Concurrently scheduled with course C255. Letter grading. (F)

165EW. Bioengineering Ethics. (4) Lecture, four hours; discussion, three hours; outside study, five hours. All professions have ethical rules that derive from moral theory. Bioethics is well-established discipline that addresses ethical problems about life, such as when life begins and ends, or how, ultimately, should we end life? At what cost should it be maintained? Unlike physicians, bioengineers do not make these decisions in practice. Engineering ethics addresses ethical problems about producing devices from molecules to bridges, such as when do concerns about risk outweigh concerns about cost? When are weapons too dangerous to design? At what point does benefit of committing to building devices outweigh need for more scientific confirmation of their effectiveness? Bioengineers must be aware of consequences of applying such devices to all living systems, and research and work within engineering environments. Satisfies engineering writing requirement. Letter grading. (Not offered 2022-23)

165Q. Wearable Biotechnologies. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Practice of human health care may be on cusp of revolution, driven by unprecedented level of personalization enabled by advances in technology, specifically, transformation of wearable devices from curiosities that provide qualitative information for fitness enthusiasts to sophisticated systems that produce clinical-grade data for physicians. Introduction of cutting-edge research in wearable biotechnologies. Addresses fundamentals, materials, processes, and devices for wearable biotech, showcasing key applications including device fabrication, manufacturing, and research and development. Concurrently scheduled with course C266. Letter grading.

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


180. System Integration in Biology, Engineering, and Medicine I. (4) Lecture, three hours; discussion, two hours; outside study, six hours. Requisites: courses 100, 110, 120, Life Sciences 7A, Physics 1C. Corequisite: course 180L. Part I of two-part series. Molecular basis of normal physiology and pathophysiology, and engineering principles of cardiovascular and pulmonary systems. Fundamental engineering principles of selected medical therapeutic devices. Letter grading. Mr. Wu (W)

180L. System Integration in Biology, Engineering, and Medicine I Laboratory. (4) Lecture, four hours; laboratory, four hours; clinical visits, four hours; outside study, three hours. Corequisite: course 180. Hands-on experimentation and clinical applications of selected medical therapeutic devices associated with cardiovascular and pulmonary disorders. Letter grading. (Sp)

M182. Dynamic Biosystem Modeling and Simulation Methodology. (4) Same as Computer Science M182. Lecture, four hours; discussion, one hour; laboratory, two hours; outside study, five hours. Requisites: Life Sciences 30A and 30B, or Mathematics 3A and 3B, or 31A and 31B. Recommended requisite or concurrent: Mathematics 105C. Undergraduate students in life, computational, engineering, and mathematical sciences. Active learning approach. Introduction to explicit modeling and simulation of dynamic biologic systems, and methodology for transforming biology, biochemistry, and physiology into system diagrams, graphs, and mathematical expressions for studying their behavior. Structural models, formulated from basic conservation laws and feedback control concepts, 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.

C183. Targeted Drug Delivery and Controlled Drug Release. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. New therapies require complex delivery systems for the effective delivery of drugs and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug delivery systems and relevant pharmacokinetics. Application of engineering principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of novel drug delivery systems that can provide spatial and temporal control of drug release. Introduction to biomaterials with specialized structural and interface properties. Exploration of both chemistry of materials and physical presentation of devices and compounds used in delivery and release. Concurrently scheduled with course C283. Letter grading.

M184. Introduction to Computational and Systems Biology. (2) Same as Computational and Systems Biology M184 and Computer Science M184. Lecture, two hours; outside study, four hours. Enforced requisite: 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 3B or 31B. Survey course designed to introduce students to computational and systems modeling and simulation in biology and medicine, providing motivation, flavor, culture, and cutting-edge contributions in computational biosciences and aiming for more in-depth analysis for focused students with computational and systems biology interests. Presentations by individual UCLA researchers discussing their active computational and systems biology research. P/NP grading.
C185. 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 approaches 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 and Ecological Engineering M186, and Biological and Molecular Biophysics M186.) Lecture, four hours; laboratory, two hours; discussion, one hour. Requisites: Life Sciences 30A, 30B, Mathematics 32A or M32T, 33A, or Mathematics 31A, 31B, 32A or M32T, 33A, and 33B. Dynamic biosystem modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Intermediate linear and nonlinear control system, multicompartimental, epidemiological, pharmacokinetic, and other biomodeling methods applied to life sciences problems at molecular, cellular, organ, and population levels. Both theory and computer modeling, with focus on translating biomodeling goals and data into dynamical mathematical models, and implementing them for simulation, quantification, and analysis. Numerical simulation of models with parameter estimation and search algorithms, with model discrimination and analysis and software exercises in PC laboratory assignments. Concurrently scheduled with course C285. Letter grading.

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. Enforced requisites: course CM186 or CM188. Research communication for graduate students in computational and systems biology. Writing and presentation skills needed to communicate research results in the research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Critiques of oral presentations and written progress reports explain how to proceed with search for research results. Major emphasis on effective research reports and design of oral presentation. Credit will not be awarded for both CM187 and CM188. Concurrently scheduled with course CM287. Letter grading.

188. Special Courses in Bioengineering. (4) Lecture; four hours; discussion, one hour; outside study, seven hours. Special topics in bioengineering for undergraduate students taught on experimental or temporal basis, such as those taught by resident and visiting faculty members. May be repeated for credit with topic or instructor change. Letter grading. (F,W,Sp)


188SB. Individual Studies for USIE Facilitators. (2) Tutorial, to be arranged. Enforced requisite: course CS188A. Limited to junior/senior USIE facilitators. Individual study in regularly scheduled meetings with faculty mentor while facilitating USIE 88S course. Individual may be required mentor required. May not be repeated. Letter grading.

194. Research Group Seminars in Bioengineering. (2) Seminar, three hours. Limited to bioengineering undergraduate students who are part of research group. Credit may be repeated for credit. Letter grading.

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

Graduate Courses

C201. Engineering Principles for Drug Delivery. (4) Lecture; four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 33B, Physics 1B. Application of engineering principles to problems in drug delivery. Topics include degradable versus nondegradable polymer to enhance its stability in serum. Wide variety in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electronic and dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Poisson/Boltzmann approximations. Mechanisms of G protein-linked, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, and axon integration. Concurrently scheduled with course C106. Letter grading.

C202. Human Physiological Systems for Biomegi- ning I. (4) (Formerly numbered CM202.) Lecture; three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Enrollment restricted to six chemical science majors. Broad overview of basic biological activities and organization of human body in system (organ/tissue) to system basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course C101. Letter grading. Mr. Kamei (F)

C204. Physical Chemistry of Biomacromolecules. (4) Lecture; three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 30A, Life Sciences 7A. To understand biological materials and molecular machines at a fundamental level, it is imperative to understand their physical chemistry. Biomacromolecules such as protein or DNA can be analyzed and characterized by applying fundamentals of polymer physical chemistry. Investigation of polymer structure and conformation, bulk and solution thermodynamics and phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as protein conformation, 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 gene chip, or one protein may be coupled to one polymer to engineer a biocomposite. Wide variety of bioconjugates are used in delivery of pharmaceutica, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including bioconjugation linkers depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers. Presentation and discussion of design and synthesis of synthetic bioconjugates for some specific applications. Concurrently scheduled with course C105. Letter grading. Mr. Deming (F)

C206. Topics in Bioelectricity for Biologists. (4) Lecture; three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20B, Life Sciences 7A, Mathematics 1B. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electronic and dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Poisson/Boltzmann approximations. Mechanisms of G protein-linked, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, and axon integration. Concurrently scheduled with course C106. Letter grading. Mr. Schmidt (F)

C207. Polymer Chemistry for Biologists. (4) Lecture; four hours; discussion; one hour; outside study, seven hours. Requisites: course C204 or C225. 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 C107. Letter grading. Mr. Deming (W)

M209. Signal and Image Processing for Biomed- ice. (4) (Same as Physics and Biology M209.) Requisites: three of physics or mathematics or CA or IL or ME or EC or Culculus or linear algebra and undergraduate probability. Mathematics and statistical fundamentals prevalent in biomedial physics studies. Notion and basic des- scriptions of linear shift-invariance and point spread functions in continuous and discrete time. Sampling theory and Fourier analysis. Signal representation of vector spaces, projection theorem, and least-squares approximations. Discussion of signal subspace methods and correlation of signal subspace with principal component analysis, and independent component analysis. Basic ideas in inverse problems and optimi- zation. Application in medical and signal processing. Development of emergent geometric intuition behind mathematics and statistics. Light derivations and MATLAB programming. S/U or letter grading.

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

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

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

M219. Principles and Applications of Magnetic Resonance Imaging. (4) (Same as Physics and Biomedicine M219.) Lecture, three hours; dis- cussion, one hour. Principles and applications of magnetic resonance (MR), physics, and image formation. Emphasis on hardware, Bloch equations, analytic expressions, image contrast mechanisms, spin and gradient echoes, imaging through tissue, structure of pulse sequences, and various scanning pa- rameters. Introduction to advanced techniques in rapid imaging, quantitative imaging, and spectroscopy. Letter grading.

220. Introduction to Medical Informatics. (2) Lecture, two hours; outside study, four hours. Designed for graduate students. Introduction to research topics and issues in medical informatics for students new to field. Definition of this emerging field of study, current research efforts, and future directions in research. Key issues in medical informatics to expose students to different application domains, such as information system architectures, data and process modeling, information extraction and representations, information retrieval and visualization, health services research, telemedicine. Emphasis on current research en- deavors and applications. S/U grading. Mr. Kangarloo (F)

221. Human Anatomy and Physiology for Medical Imaging. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on understand- ing and visualization of anatomy and physiology through medical images. Topics relevant to acquisition, representation, and display of anatomical knowledge in computerized clinical applications. Topics include chest, cardiac, neurology, gastrointes- tinal/genitourinary, endocrine, and musculoskeletal systems. Introduction to basic imaging physics (mag- netic resonance, computed tomography, ultrasound, computed radiography) to provide context for im- aging modalities predominantly used to view human anatomy. Geared toward nonphysicists who require more formal understanding of human anatomy/physiology. Letter grading. Mr. El-Saden (F)

223A-223B-223C. Programming Laboratories for Medical and Imaging Informatics I, II, III. (4-4-4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Programming laboratories to support coursework in other medical and imaging informatics core curric- ulum courses. Exposure to programming concepts and application of current tools. Letter grading. (Same as Computer Science C223A.) Lecture, four hours; outside study, eight hours. Designed for gradu- ate students. Issues related to medical knowledge representation and its application in healthcare pro- cesses. Topics include data structures used for rep- resentation (linked lists, stacks, queues, linked- based models), different data models for representing spatio-temporal information, rule-based implementa- tions, current statistical methods for discovery of knowledge (unsupervised and supervised learning and hierarchically classification), and basic information re- trieval. Review of work in constructing ontologies, with focus on problems in implementation and defini- tion. Common medical ontologies, coding schemes, and standardized indices/terminologies (SNOMED, UMLS). Letter grading. Mr. Taia (Sp)

224. Physics and Informatics of Medical Imaging. (4) Lecture, four hours; outside study, eight hours. Required. Requisites: Mathematics 33A, 33B. Designed for graduate students. Introduction to principles of med- ical imaging and imaging informatics for nonphysi- cists. Course covers medical imaging principles X ray, computed tomography (CT), and magnetic reso- nance (MR). Topics include signal generation, local- ization, and quantization. Image representation and analysis techniques such as Markov random fields, spatial characterization (atases), denoising, energy, representations, and clinical imaging workstation de- sign. Provides basic understanding of issues related to basic medical image acquisition and analysis. Cur- rent research in medical informatics, concepts and applications of new and emerging modalities. Letter grading. Mr. Moriya (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 various advances in field, such as con- tent-based image retrieval, computer-aided detection/diagnosis, and imaging genomics. Introduction to core concepts in information retrieval (IR), re- viewing seminal papers on evaluating IR systems and their use in medicine (e.g., teaching files, case-based retrieval). Expose students to new applications of techniques for image feature extraction and processing, feature rep- resentation, indexing and querying, and classification (machine/deep learning). Review of current applica- tions of these techniques and ongoing challenges. Letter grading. Mr. Moriya (Sp)

225. Bioprocesses and Bioprocess Engineering. (4) (Same as Chemical Engineering CM225.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: Chemical Engineering 101G. Separation strategies, unit opera- tions, and economic factors used to design pro- cesses for isolating and purifying materials like white cells, endotoxins, proteins, and other macromolecules that are products of biological reactors. Letter grading. Mr. Monbouquette (W)

226. Medical Knowledge Representation. (4) (Same as Information Studies M253.) Seminar, four hours; outside study, eight hours. Designed for grad- uate students. Issues related to medical knowledge representation and its application in healthcare pro- cesses (Bayes theorem, decision trees). Study de- sign, hypothesis testing, and estimation. Focus on technical advances in medical decision support sys- tems and expert systems with review of basic and current research. Introduction to common statistical and decision-making software packages to familiar- ize students with current tools. Letter grading.

M229. Advanced Topics in Magnetic Resonance Imaging. (4) (Same as Physics and Biology in Med-icine M229.) Lecture, four hours. Requisite: course M219. Designed for students interested in pursuing research related to development or translation of new magnetic resonance imaging (MRI) technique. Basics tools and understanding of recent MRI developments that have had high impact on field, involve novel pulse sequence design or new MRI constructs, and enable imaging of anatomy or function in way that surpasses what is currently possible with any modality. Topics include in-depth sequence simula- tion, RF pulse design, rapid image acquisition, par- allel imaging, compressed sensing, image recon- struction and processing, motion encoding and com- pensation, chemical-shift imaging and understanding, and understanding/avoiding artifacts. Programming exercises with MATLAB to provide hands-on experience. Letter grading.

C231. Nanopore Sensing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100A, 120, Life Sciences 7A, Physics 1A, 1B, 1C. Analytical methods based on measurements of fluctuating ionic conductance through artificial or protein nanochannels. Physics of pore conductance. Applications to single molecule and DNA sequence detection. Recent lit- erature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrical measurements in elec- trically biased nanopore channels that are formed through pores and GHK equation, patch clamp and single channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C131. Letter grading. Mr. Schmidt (F)

M233A. Medtech Innovation I: Entrepreneurial Op- portunities in Medical Technology. (4) (Same as Management M271A.) Lecture, four hours; outside study, nine hours. Designed for graduate and profes- sional students in engineering, dentistry, design, law, management, and medicine. Focus on understanding human needs, unmet clinical needs, and developing products through these needs using various acceptance cri- teria, and selecting promising needs for which poten- tial medtech solutions are explored. Students work in teams to conduct traditional research and develop- ment processes to invent and implement new med- tech 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. Shivkumar (W)

M233B. Medtech Innovation II: Prototyping and New Venture Development. (4) (Same as Manage- ment M271B.) Lecture, four hours; outside study, nine hours. Requisite: course M233A. Designed for graduate and professional students in engineering, dentistry, design, law, management, and medicine. Development of medtech solutions for unmet clinical needs previously identified in course M233A. Steps necessary to commercialize viable medtech solu- tions. Exploration of concept selection, business plan development, intellectual property, financing, and product development strategies, and device prototyping. Letter grading. Mr. Liu, Mr. Shivkumar, 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 dif- ferent types of interactions that exist between bio-
molecules, such as van der Waals interactions, entropic forces, hydrogen bonding, ionic interactions, hydrophobic interactions, hydration and solvation interactions, polymer-mediated interactions, depletion interactions, molecular recognition, and others. Illustrating how to use 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 engineering. An example such as those involving drug delivery and tissue engineering. May be taken independently for credit. Concurrently scheduled with course C139A. Letter grading. Mr. Wong (W)

C239B. Biomolecular Materials Science II. (4) Lecture, four hours; outside study, seven hours. Course C239A is not a prerequisite for C239B. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different basic types of biomolecules, with emphasis on nucleic acids, proteins, and lipids. Study of how biological and biomimetic systems organize into their functional forms via self-assembly and how these structures impart biological function. Illustration of these ideas using examples from bioengineering and biomedical engineering. Case study on current topics, including drug delivery, drug targeting, cancer therapy, emerging pathogens, and relation of self-assembly to disease states. May be taken independently for credit. Concurrently scheduled with course C139A. Letter grading. Mr. Wong (W)

CM240. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM240.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanical and Aerospace 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, heat transfer, heat and mass transport. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading. Mr. Gupta (W)

CM245. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering CM245.) Lecture, four hours; discussion, one hour; outside study, seven hours. Selected topics in molecular biology that form foundation of biotechnology and biomedical engineering. Genes, gene therapy, cancer targeting, emerging pathogens, and relation of self-assembly to disease states. May be taken independently for credit. Concurrently scheduled with course C145. Letter grading. Mr. Liao (F)

CM247. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM202, Chemistry 20A, 20B, 20L, Life Sciences 7A. Overview of central topics of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include bioreactors, cell source, delivery methods, gene therapy, tissue selection, engineering, and validation of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course C147. Letter grading. Mr. Wu (W)

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

M250B. Microelectromechanical Systems (MEMS) and Nanoelectromechanical Systems (NEMS) Fabrication. (4) (Same as Electrical and Computer Engineering M250B and Mechanical and Aerospace Engineering M250B.) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course CM153. Advanced discussion of micro- and nanofabrication processes used to construct MEMS. Coverage of many lithographic techniques, 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. Chandler (Sp)

M252. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Electrical and Computer Engineering M252 and Mechanical and 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. Describing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. Wu (W)

C255. Fluid-Particle and Fluid-Structure Interactions in Microflows. (4) Lecture, four hours; laboratory, one hour; outside study, seven hours. Enforced requisite: course 110. Introduction to Navier-Stokes equations, assumptions, and simplifications. Analytical framework for calculating simple flows and numerical methods to solve and gain intuition for complex flows. Forces on particles in Stokes flow and finite-inertia flows. Flows induced around particles with and without finite inertia and implications for particle-particle interactions. Secondary flows induced by structures and particles in confined flows. Particle dynamics in microfluidic systems: single particle; field-flow fractionation, inertial focusing, structure-induced separations. Application concepts in internal biological flows and separations for biotechnology. Helps students become familiar with fluid mechanics vocabulary and techniques, design and model microfluidic systems to manipulate fluids, cells, and particles, and develop strong intuition for how fluid and particles behave in arbitrarily structured microfluidic devices. Prerequisites: M245 or equivalent for fundamentals. Letter grading. Mr. Di Carlo (Sp)

256. Drug Delivery Devices: Innovation and Translation. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Introduction to modern trends in drug delivery devices and relevant biomedical applications. Topics provide comprehensive and critical examination of current and emerging research and development on drug delivery devices, with emphasis on innovation and translation. Topics include bioreponsive drug delivery systems, drug delivery reservoirs, MEMS and micro/nanorobots for drug delivery, nanomedicine-device combination products, and development and regulation of drug delivery devices. Students acquire theoretical and practical knowledge of drug delivery devices. Students gain ability to identify advanced approaches, emerging technologies, and different therapeutics for treating variety of diseases; and propose methods and relevant experiments to validate efficacy of certain drug delivery devices. Letter grading.

M260. Neuroengineering. (4) (Same as Electrical and Computer Engineering M260 and Neuroscience M206.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 5C. Introduction to principles and techniques of neural and computer science. Overview of neural computer systems and neural network architectures. Prerequisite: knowledge of basic neuroscience. Letter grading.


C266. Wearable Bioelectronics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Practice of human health care may be on cusp of revolution, driven by unprecedented level of personalization enabled by advances in technology, specifically, transformation of wearable devices from consumer products to medical devices. Wearable bioelectronics provide fitness enthusiasts to sophisticated systems that produce clinical-grade data for physicians. Introduction of cutting-edge research in field of wearable bioelectronics. Addresses fundamental concepts of microfluidics, and devices for wearable bioelectronics, showcasing key applications including device fabrication, manufacturing, and health-care applications. Concurrently scheduled with course C166. Letter grading.

271. Biotechnology of Cellular Therapeutics. (4) Lecture, four hours. Examination of how to design cells and cellular systems to perform therapeutic tasks in complex physiological environments. Discussion of immune system as case study of engineering functionality based on certain required specifications (e.g., not attacking self, recognition of pathogens, preventing cancer). Discussion also of methods and technologies used to generate, modify, separate, and analyze cells, which—just like in chemical synthesis and purification of drugs—are important to creating therapies with well-defined properties based on cells.

M273. Micro- and Nanoscale Biosensing for Molecular Diagnostics. (4) (Same as Electrical and Computer Engineering M275.) Lecture; four hours; discussion, one hour; outside study, seven hours. Covers state-of-art and emerging biosensors in context of molecular diagnostics. Students learn relevant biology and biochemistry pertinent to molecular diagnostics. Students gain thorough understanding of interfaces between bioparticles, biofluids, and electronics. Topics include biosensor performance parameters, modes of detection, sample preparation challenges, microfluidics, and emerging wearable biosensing platforms, as well as proteomics, genomics, and DNA sequencing technologies. Letter grading.

275. Machine Learning and Data-Driven Modeling in Bioengineering. (4) (Formerly numbered C275.) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: Mathematics M250A or Mechanical and Aerospace Engineering M20 or Computer Science 31, Mathematics 32B, 33A. Overview of foundational data analysis and machine-learning methods in biomedicine on how these techniques can be applied to interpret experimental observations. Topics include probabilities, distributions, cross-validation, analysis of variance, regression, machine learning, dimensionality reduction, regression, hidden Markov models, and clustering. Students gain theoretical and practical knowledge of data analysis and machine-
learning methods relevant to bioengineering. Application of these methods to experimental data from engineering studies. Students become sufficiently familiar with these techniques to design studies incorporating such analyses, execute analysis, and work in teams to present findings and ensure correctness of their results. Letter grading.

CM278. Introduction to Biomaterials. (4) (Same as Materials Science CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: CM200 or 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 and biological behaviors including chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM178. Letter grading. Ms. Kasko (W)

CM286. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Computer Science CM286.) Lecture, four hours; laboratory, two hours; discussion, one hour. Requisites: Life Sciences 30A, 30B, Mathematics 32A or M23T, 33A, and 33B; or Mathematics 31A, 31B, 32A or M23T, 33A, and 33B. Dynamic bio-system modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Intermediate linear and nonlinear control system, multicompartamental, epidemiological, pharmacokinetic, and other biomodeling methods applied to life sciences problems at molecular, cellular, organ, and population levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into dynamic mathematical simulation of biological systems, for them for simulation, quantification, and analysis. Numerical simulation, optimization, and parameter identifiability and search algorithms, with model discrimination and analyses of 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; discussion, two hours; outside study, eight hours. Requisites: course M182 or CM286 or Computational and Systems Biology M150; and research experience (course 198, Computational and Systems Biology 199, Computer Science 199, or equivalent). 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 reading of current literature and written progress reports explain how to proceed with searching for recent research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM187. Letter grading. Mr. DiStefano (Sp)

CM289A-295K. Seminars: Research Topics in Bioengineering. (2 each) Seminar, two hours; outside study, four hours. Limited to bioengineering graduate students. Advanced study and analysis of current topics in bioengineering. Discussion of current research and literature in bioengineering. Student presentation of projects in research specialty. May be repeated for credit. S/U grading.

CM296A. Advanced Modeling Methodology for Dynamic Biomedical Systems. (4) (Same as Computer Science M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisites: Electrical Engineering 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Development of dynamic systems modeling methodology for physiological, biomedical, pharmaceutical, chemical, and related systems. Control systems, multicompartamental, noncompartamental, and input/output models, linear and nonlinear. Emphasis on model applications, limitations, and relevance in biomedicals and other limited data environments. Problem solving in PC laboratory. Letter grading. Mr. DiStefano (F)

CM296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Same as Biomatics M270, Computer Science M296B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisites: course CM286 or BM200. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano (W)

CM296C. 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. Requisites: course M296B. Research techniques and experience on special topics involving biomodeling, modeling in biological and medical sciences. Review and critique of literature. Research problem solving and formu-
Chemical Engineering BS

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

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

Capstone Major

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.

Educational Objectives

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 MS or PhD 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.

Learning Outcomes

The Chemical Engineering major has the following learning outcomes:

- Application of knowledge of mathematics, physics, chemistry, biology, and chemical and biological engineering, especially to integration of molecular- to micro-scale information into macro-scale analysis and design of chemical and biochemical processes and products
- Design of a chemical or biological system, component, or process that meets technical and economical design objectives with consideration of environmental, social, and ethical issues, as well as sustainable development goals
- Identification, formulation, and solution of complex chemical and biological engineering problems
- Function as a productive member of a multidisciplinary team
- Effective oral and written communication

Chemical Engineering Core Option

Preparation for the Major

Required: Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 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 three elective courses (8 units) from Bioengineering 105, 109, Chemical Engineering 112, 118, 121, 128, 135, 140.

For information on UC, school, and general education requirements, see Requirements for BS Degrees on page 21 or the GE Requirement web page.

Biomedical Engineering Option

Preparation for the Major

Required: Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109; 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 105, 109, Chemical Engineering 112, Chemistry and Biochemistry 105, 153A, or C159 (another chemical engineering elective may be substituted with approval of the faculty adviser).

For information on UC, school, and general education requirements, see Requirements for BS Degrees on page 21 or the GE Requirement web page.
Semiconductor Manufacturing Engineering Option

Preparation for the Major

Required: Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104C, 104CL, 106, 107, 109, 116; 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 BS Degrees on page 21 or the GE Requirement web page.

Graduate Study

For admission information, see Graduate Programs Admission on page 27.

For additional information regarding the BS, MS, and PhD in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure.

The following introductory information is based on 2022-23 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 (MS) and Doctor of Philosophy (PhD) degrees in Chemical Engineering.

Chemical Engineering MS

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 MS 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, M116L, M133A, 199, Electrical and Computer Engineering 101, 103, 105A, 105D, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Semiconductor Manufacturing Specialization

Students are required to complete 10 courses (44 units) with a minimum 3.0 grade-point average overall and in the graduate courses. A minimum of five 200-series courses (20 units) are required, including Chemical Engineering 270 and 270R. Students also are required to take courses 104C, 104CL, Electrical and Computer Engineering 123A, and Materials Science and Engineering 121. In addition, two departmental elective courses and two electrical and computer engineering or materials science and engineering electives must be selected, with a minimum of two at the 200 level. Approved elective courses include Chemical Engineering CM214, C218, C219, 223, C240, Electrical and Computer Engineering 221A, 221B, 223, 224, Materials Science and Engineering 210, 223.

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

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

Comprehensive Examination Plan

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

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

Thesis Plan

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

Chemical Engineering PhD

Major Fields or Subdisciplines
Consult the department.

Course Requirements
All PhD 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 department Office no later than one term after successful completion of the preliminary oral examination.

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

Students must select the transport phenomena core area and either the thermodynamics core area or reaction engineering core area or both. If they select only one of thermodynamics or reaction engineering, they must also select either the biomolecular engineering or engineering mathematics core area. The PWE is offered at the end of winter quarter of each academic year and is graded by a faculty committee. Students must take the PWE in their first year. If they fail the PWE on the first attempt, they can retake it for a second time the following spring quarter. Students who fail both attempts are not allowed to continue in the PhD 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 extruder and multilayer laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and phospholipids 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 anticaner, 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-the-art atomic-scale modeling software used to understand the properties of solids and the catalytic reactivity of surfaces, nanoparticles, and clusters. Codes include VASP, CP2K, and SIESTA. Applications domains are linked with chemistry and energy challenges and range from heterogeneous catalysis to photocatalysis, electrocatalysis, depollution, and electricity storage. Origi-
nal simulation methods, developed by the researchers, are available for the modeling of electrocatalysis. A high-performance cluster is available for research and teaching. Campuswide computers are also available to laboratory researchers.

**Electrochemical Engineering and Catalysis Laboratories**

With instrumentation such as rotating ring-disk electrodes, electrochemical packed-bed flow reactors, gas chromatographs, potentiostats, and function generators, the laboratories are used to study metal, alloy, and semiconductor corrosion processes, electro-deposition and electroless deposition of metals, alloys, and semiconductors for GMR and MEMS applications, electrochemical energy conversion (fuel cells) and storage (batteries), and bioelectrochemical processes and biomedical systems. The electroorganic synthesis facility is for the development of electrochemical processes to transform biomass-derived organic compounds into useful chemicals, fuels, and pharmaceuticals. The catalysis facility is equipped to support various types of catalysis projects, including catalytic hydrocarbon oxidation, selective catalytic reduction of NOx, and Fischer-Tropsch synthesis.

**Electronic Materials Processing Laboratory**

The laboratory focuses on the synthesis and patterning of multifunctional complex oxide films and nanostructures with tailored electronic, chemical, thermal, mechanical, and biological properties. Experimental and theoretical studies are combined to understand the process chemistry and surface kinetics in atomic layer deposition, plasma etching and deposition processes, gas-phase surface functionalization, and solution phase synthesis. Novel devices including advanced microelectronics, optoelectronics, chemical sensors, and energy storage devices are realized at nano-dimensions as the technologies become more enabling based on these fundamental studies. The laboratory is equipped with a state-of-the-art advanced rapid thermal processing facility with in-situ vapor phase processing and atomic layer deposition capabilities; advanced plasma processing tools including thin film deposition and etching; and diagnostics including optical emissions spectroscopy, Langmuir probe, and 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.

**Materials and Plasma Chemistry Laboratory**

The laboratory is equipped with state-of-the-art instruments for studying the molecular processes that occur during chemical vapor deposition (CVD) and plasma processing. CVD is a key technology for synthesizing advanced electronic and optical devices, including solid-state lasers, infrared, visible, and ultraviolet detectors and emitters, solar cells, heterojunction bipolar transistors, and high-electron mobility transistors. The laboratory houses a commercial CVD reactor for the synthesis of III-V compound semiconductors. This tool is interfaced to an ultrahigh vacuum system equipped with scanning tunneling microscopy, low-energy electron diffraction; infrared spectroscopy and X-ray photoelectron spectroscopy. This apparatus characterizes the atomic structure of compound semiconductor heterojunction interfaces and determines the kinetics of CVD reactions on these surfaces. The atmospheric plasma laboratory is equipped with multiple plasma sources and state-of-the-art diagnostic tools. The plasmas generate, at low temperature, beams of atoms and radicals well-suited for surface treatment, cleaning, etching, deposition, and sterilization. Applications are in the biomedical, electronics, and aerospace fields. The laboratory is unique in that it characterizes the reactive species generated in atmospheric plasmas and their chemical interactions with surfaces.

**Nanoparticle Technology and Air Quality Engineering Laboratory**

Modern particle technology focuses on particles in the nanometer (nm) size range with applications to air pollution control and commercial production of fine particles. Particles with diameters between 1 and 100 nm are of interest both as individual particles and in the form of aggregate structures. The 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.

**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, QAMS, MATLAB, CPLEX, and Lindo. Software for simulation of chemical engineering systems includes HYSYS for process simulation and CACHE-FUJITSU for molecular calculations. UCLA-developed software for heat/power integration and reactor network attainable region construction is also available.

**Faculty Areas of Thesis Guidance**

**Professors**

Jane P. Chang, PhD (MIT, 1998)  
*Materials processing, gas-phase and surface reaction, plasma enhanced chemistries, atomic layer deposition, chemical microelectromechanical systems, and computational surface chemistry*

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

Yoram Cohen, PhD (U. Delaware, 1981)  
*Water treatment and desalination, separation processes, membrane science and technology, surface nanostructuring, pollutant transport nanomaterials and exposure assessment*

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

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

Yunfeng Lu, PhD (U. New Mexico, 1998)  
*Semiconductor manufacturing and nanotechnology*

Vasilios I. Manoussiouthakis, PhD (Rensselaer, 1986)  
*Process systems engineering: modeling, simulation, design, optimization, and control*

Harold G. Monbouquette, PhD (North Carolina State, 1987)  
*Biochemical engineering, biosensors, nanotechnology*

Stanley J. Osher, PhD (New York U., 1966)  
*Computational science, image processing, information science*

Philippe Sautet, PhD (U. Paris XI Orsay, France, 1989)  
*First principles atomic scale simulations; quantum chemistry; applications to heterogeneous catalysis: active sites and reaction mechanisms, nanomaterials for depollution and energy transformation, molecules at surfaces*

Yi Tang, PhD (Caltech, 2002)  
*Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel anti-biotics/antitumor products*

**Professors Emeriti**

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

Kendall N. Houk, PhD (Harvard, 1968)  
*Computational chemistry, enzyme design, investigation of reaction mechanisms, design of materials and processes*

Louis J. Ignarro, PhD (U. Minnesota, 1966)  
*Regulation and modulation of NO production*

Evald L. Knuth, PhD (Caltech, 1953)  
*Molecular dynamics, thermodynamics, combustion, applications to air pollution control and combustion efficiency*

*Metabolic engineering, synthetic biology, bioenergy*

Selm M. Senkan, PhD (MIT, 1977)  
*Reaction engineering, combinatorial catalysis, combustion, laser pyrolysis, real-time detection, quantum chemistry*

A.R. Frank Wazzan, PhD (UC Berkeley, 1963)  
*Fast reactors, nuclear fuel element modeling, stability and transition of boundary layers, heat transfer*

**Associate Professors**

Irene A. Chen, MD, PhD (Harvard, 2007)  
*Synthetic living systems, in vitro evolution, molecular biophysics, phage nanotechnology, microbiome*

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

Dante A. Simonetti, PhD (U. Wisconsin-Madison, 2008)  
*Heterogeneous catalysis and adsorption, catalytic reaction engineering and kinetics, design of reactive materials, materials characterization*

**Assistant Professors**

Nasim Annabi, PhD (U. Sydney, Australia, 2010)  
*Biomaterials, tissue engineering, 3D bioprinting, microfabrication, nanocomposite hydrogels for drug/gene delivery, surgical sealants/adhesives/glues, conductive hydrogels for heart tissue regeneration*

Carissa N. Eisler, PhD (Caltech, 2016)  
*Light and energy transport in nanomaterials, nanophotonics, renewable energy*

Yuzhang Li, PhD (Stanford, 2018)  
*Electrochemical energy storage, electrocatalysis, nanomaterials synthesis and characterization, in situ transmission electron microscopy, cryogenic electron microscopy, carbon capture*

Carlos G. Morales-Guio, PhD (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, PhD (Princeton, 2016)  
*Cancer metabolism, membrane engineering, bioenergy, systems biology, metabolomics*

Joseph D. Peterson, PhD (UC Santa Barbara, 2018)  
*Complex fluids; polymers, emulsions, and dense suspensions; microstructure formation and relaxation in systems far from equilibrium; population balance equations and their integration into rheological models; sustainability applications; polymer recycling, polymer-based meat analogs, etc.; continuum models, controlled approximations, and efficient numerical methods*

Samavanya Srivastava, PhD (Cornell, 2014)  
*Soft materials, self-assembly, polymer chemistry and polymer physics, scattering rheology*

Thaiesha A. Wright, PhD (Miami U. Ohio, 2020)  
*Biomaterials, protein engineering, polymer chemistry*

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**Chemical Engineering Courses**

**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.

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

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 115A. Fundamentals of modern biomolecular engineering. Topics include structure and function of biomolecules, central dogma of molecular biology, cellular information and energy processing.
and experimental methods, with strong emphasis on applications in medicine, industry, and bioengineering. Letter grading. Ms. Chen, Mr. Tang (W)

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 faculty guidance. Letter or 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), Physics 1A, Introduction to analysis and design of industrial chemical processes. Material and energy balances. Introduction to programming in MATLAB. Letter grading. Mr. Li, Mr. Monbouquette (F)

101A. Transport Phenomena I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 109. Introduction to analysis of fluid flow in chemical, biological, material, and molecular processes. Fundamentals of momentum, energy, and mass balance. Letter grading. Ms. Chang (Sp)

101B. Transport Phenomena II: Heat Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101A. Introduction to analysis of heat transfer in chemical, biological, material, and molecular processes. Fundamentals of thermal analysis and of separation processes such as distillation, gas absorption, filtration, and reverse osmosis. Letter grading. Mr. Monbouquette (Sp)

102A. Thermodynamics I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to thermodynamics of chemical and biochemical processes. Work, energy, heat, and first law of thermodynamics. Statistical thermodynamics. Second law, entropy, and free energy. Ideal and real gases, properties of mixtures. Thermodynamics of single-phase and two-phase systems. Fick law of diffusion, diffusion in chemically reacting flows, interphase mass transfer, species transport, Fick law of diffusion, diffusion in nonideal solutions, mass transport phenomena, thermodynamics of complex chemical reactions. Letter grading. Mr. Cohen, Mr. Srivastava (Sp)


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

104A. Chemical and Biomolecular Engineering Laboratory I. (6) Lecture, four hours; laboratory, six hours; outside study, four hours. Enforced requisite: course 100. Enforced corequisite: course 101B. Recommended: course 102B. Investigation of basic transport phenomena; determinations of experimental parameters; collection of data for statistical analysis and individually written technical reports and group presentations. Design and performance of one experimental/simulation study of transport, separation, or another aspect of chemical and biomolecular engineering. Letter grading. Mr. Giou, Mr. Lu (F)

104B. Chemical and Biomolecular Engineering Laboratory II. (6) Lecture, four hours; laboratory, eight hours; outside study, four hours; other, two hours. Enforced requisite: courses 101C, 103, 104A. Course consists of four experiments in chemical engineering and applications of computer methods to chemical engineering design problems; use of simulation programs as automated method of performing steady state material and energy balance calculations. Letter grading. Ms. Chang, Mr. Eisler (F)

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

104CL. Semiconductor Processing Laboratory. (3) Laboratory, four hours; outside study, five hours. Enforced requisite: course 101C. Enforced corequisite: course 104A. Hands-on experience in the experimental aspects of semiconductor device fabrication. Letter grading. Ms. Chen, Mr. Srivastava (Sp)

104D. Molecular Biotechnology Laboratory: From Gene to Product. (6) Lecture, two hours; laboratory, eight hours; outside study, eight hours. Enforced requisite: courses 101C, 125. Integration of molecular and engineering techniques in modern biotechnology. Cloning of protein-coding gene into plasmid vector; transformation of host cell to produce protein product; cell culture; experimental studies on isotope labeling of bioreactor broth to purify recombinant protein; expression and purification of recombinant protein. Letter grading. Ms. Chen, Mr. Park, Mr. Simonetti, Mr. Srivastava (Sp)

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

106. Process Dynamics and Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 101C, 102B. Introduction to application of some mathematical and computer 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. Li, Mr. Morales Guio (Sp)

107. Process Dynamics and Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 101C, 102B. Integration of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering and simple economic principles for purposes of design of chemical processes and evaluating alternatives. Letter grading. Mr. Li, Mr. Morales Guio (W)

108. Process Chemical Computer-Aided Design and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 103 (or C125), 104A, 105 (or C115). Integration of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering and simple economic principles for purposes of design of chemical processes and evaluating alternatives. Letter grading.}

109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 103 (or C125), 106 (or C115), 108A, 108B. Integration of computer-based 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. Li, Mr. Morales Guio (Sp)

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

111. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 103 (or C125), 110. Integration of cryogenics and cryoengineering 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 C211. Letter grading.

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

113. Air Pollution Engineering. (4) Lecture, four hours; preparation, two hours; outside study, six hours. Enforced requisite: courses 101C, 102B. Integration of air pollution engineering principles to study of atmospheric pollutants, air pollution standards, air pollution sources and control technology, and relationship of air quality to emission sources. Links air pollution to multimedia environmental assessment. Letter grading. (Not offered 2022-23)
CM114. Electrochemical Processes. (4) Same as Materials Science CM114. Lectures, four hours; discussion, one hour; outside study, seven hours. Requisites: course 102B, Mechanical and Aerospace Engineering 105A (or Materials Science 130). Fundamentals of electrochemistry and electrochemical applications to industrial electrochemical processes. Primary emphasis on fundamental approach to analyze electrochemical processes. Specific topics include electrodes on metals and semiconductors, electrochemistry, electrodeposition, electroless deposition, electrosynthesis, fuel cells, aqueous and non-aqueous batteries, solid-state electrochemistry. May be concurrently scheduled with course CM214. Letter grading.

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

C116. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to surfaces and interfaces of engineering materials, particularly catalytic 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 engineering applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C216. Letter grading. Mr. Lu (Sp)

C118. Multimedia Environmental Assessment. (4) Lecture, four hours; discussion, one hour; preparation, two hours; outside study, five hours. Recommended requisites: courses 101C, 102B. Pollutant sources, environmental fate, pollution, transport and fate of chemical pollutants in environment, intermedia transfers of pollutants, multimedia modeling of chemical partitioning in environment, exposure assessment and fundamentals of risk assessment, risk reduction strategies. Concurrently scheduled with course C218. Letter grading. Mr. Cohen (Sp)


C121. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology, with emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective membranes and models of membrane transport and separation activity. Examples derived from various fields/applications, including biotechnology, microelectronics, chemical processes, sensors, and biomedicine devices. Concurrently scheduled with course C221. Letter grading. Mr. Manousiouthakis

C124. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 45, Introduction to design and synthesis of bioactive materials and molecular recognition sites, in vitro cell culture, and drug delivery. Biological principles of cellular microenvironment and design of extracellular matrix analogs using biological and engineering principles. Biomaterials for growth factor, and DNA and siRNA delivery as therapeutics and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C224. Letter grading. Ms. Annabi (W)

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

CM127. Synthetic Biology for Biofuels. (4) Same as Chemistry CM127. Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Chemistry 153A. Engineering microorganisms for complex phenotype is common goal of metabolic engineering and synthetic biology. Production of advanced biofuels involves designing and constructing novel metabolic networks in cells. Such efforts require profound understanding of biochemistry, protein structure, and biological regulations and are aided by tools of molecular biology. Fundamentals of metabolic biochemistry, protein structure and function, and bioinformatics. Use of systems modeling for metabolic networks to design microorganisms for energy applications. Concurrently scheduled with course CM227. Letter grading.

C128. Hydrogen. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 106A. Production, distribution, and use of hydrogen. Various methods of production, including production through methane steam reforming, electrolysis, and thermochemical cycles. Description in detail of several uses of hydrogen, including transportation and hydrogen fuel cells. Concurrently scheduled with course C228. Letter grading.

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 state stabilizing interconnected systems, and small gain theorems, (3) design of nonlinear and robust controllers for various classes of nonlinear systems, (4) model predictive control of linear and nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of distributed parameter systems. Concurrently scheduled with course CM235. Letter grading.

C140. Fundamentals of Aerosol Technology. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 101C. Technology of particulate gas systems with applications to gas cleaning, commercial production of fine particles, and catalysis. Particle transport and deposition, optical properties, experimental methods, dynamics and control of particle formation processes. Concurrently scheduled with course C240. Letter grading.

CM145. Molecular Biotechnology for Engineers. (4) Same as Bioengineering CM145. Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 45. Selected topics in molecular biology that form foundation of biotechnology and chemical and biological industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and aptamer-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM245. Letter grading.

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) Same as Bioengineering M153, Electrical and Computer Engineering M153, and Mechanical and Aerospace Engineering M153B. Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4AL. Introduction to general manufacturing methods, mechanisms, constraints, and microfabrication and nanofabrication. Focus on concepts, physics, and instruments of various microfabrication and nanofabrication techniques that have been broadly applied in industry and academia, including various photolithography techniques, physical vapor deposition and chemical vapor deposition, and chemical and chemical etching methods. Hands-on experience for fabricating microstructures and nanostuctures in modern clean-room environment. Letter grading. (F)

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

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

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

Graduate Courses

200. Advanced Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102B. Phenomenological and statistical thermodynamics of chemical and physical systems with engineering applications. Presentation of role of atomic and molecular spectra and intermolecular forces in interpretation of thermodynamic properties of gases, liquids, solids, and plasmas. 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 2022-23)

210. Advanced Chemical Reaction Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101C, 106. Principles of chemical reactor analysis and design. Particular emphasis on simultaneous effects of chemical reaction and mass transfer on noncatalytic and catalytic reactions in fixed and fluidized beds. Letter grading. Mr. Simonetti (W)
C211. Cryogenics and Low-Temperature Processes. (4) Discussion, one hour; outside study, seven hours. Fundamentals of cryogenics and cryoenineering science pertaining to industrial low-temperature processes. Basic approaches to analysis and design of cryo systems and their behavior. Concurrently scheduled with course C119. Letter grading. Mr. Manousiouthakis

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

C221. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Fundamentals of membrane science and technology, with emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationships between structure and performance of porous and membrane materials and their separation characteristics. Use of nanotechnology for design of selective membranes and models of membrane transport with micro/nanofluidic systems. Letter grading. Ms. Annabi (Sp)


222B. Stochastic Optimization and Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Advanced treatment of stochastic processes and applications to real-world systems. Stochastic optimization, stochastic linear and dynamic programming. S/U or letter grading. Mr. Manousiouthakis

223. Design for Environment. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Principles of environmental design, methods for introducing sustainable engineering concepts into the design process. Topics include assessment of energy, water, and waste management; design for efficiency; design for recycling; design for biocompatibility; design for aesthetics. Letter grading. Ms. Annabi (W)


C232. Bioprocesses and Bioprocess Engineering. (4) (Same as Bioengineering M225.) 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 biomaterials. Use of cell culture methods, design of bioreactors, and selection of downstream processing and purification technologies. Letter grading. Ms. Annabi (Sp)

C236. Advanced Biofuels. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course CM145. Introduction of vi-

ruuses and their varied roles in biotechnology, from application of viral enzymes used to combat viral infectious diseases. Basic concepts of virology. Focus on use of viruses, including bacteriophages, and viral proteins as tools in biotechnology. Examples include baculovirus-based nanomaterials, and viral vectors for gene delivery, and vaccines. Covers case studies of viral diseases and biotechnological strategies for diagnosis, prevention, and treatment of human immunodeficiency virus and coronaviruses. Students conduct literature searches and write paper on relevant topic of their choice. Concurrently scheduled with course C126. Letter grading. Mr. Cohen (W)

C222. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM227.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Chemistry 153A. Engineering microorganisms for complex phenotype that is a common goal of metabolic engi neering and synthetic biology. Production of advanced biofuels involves designing and constructing novel metabolic networks in cells. Such efforts require profound understanding of biochemistry, protein, and genome and systems biology and are aided by tools in bioinformatics, systems biology, and molecular biology. Fundamentals of synthetic biology, protein structure and function, and bioinformatic use of synthetic biology and systems biology. Course will design microorganisms for energy applications. Concurrently scheduled with course CM127. S/U or letter grading.

C229. Hydrogen. (4) Lecture, four hours; outside study, seven hours. Enforced requisite: Chemistry 20A. Electronic, physical, and chemical properties of hydrogen. Various methods of production, including production through steam reforming, electrolysis, and thermochemical cycles. Description in depth of several uses of hydro- gen, including hydrogen combustion and hydrogen fuel cells. Concurrently scheduled with course C128. Letter grading. Ms. Annabi (Sp)


C232. Bioprocesses and Bioprocess Engineering. (4) (Same as Bioengineering M225.) 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 biomaterials. Use of cell culture methods, design of bioreactors, and selection of downstream processing and purification technologies. Letter grading. Ms. Annabi (Sp)
236. Chemical Vapor Deposition. (4) Lecture, four hours; outside study, eight hours. Required: course 107. Introduction to chemical vapor deposition processes. Topics include reactor design, surface morphology, and cleaning of materials. Examination of atomic, molecular, and ionic phenomena involved in plasma and ion-beam processing of semiconductors, etc. Letter grading. Ms. Chang

2235. 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 control systems, (2) input to state stability for interconnected systems, and small gain theorems, (3) design of nonlinear and robust controllers for various classes of nonlinear systems, (4) model predictive control of nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of distributed parameter systems. Concurrently scheduled with course C135. Letter grading. Mr. Cohen

2236. Chemical Vapor Deposition. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 210, C216. Chemical vapor deposition is widely used to deposit thin films that comprise microelectronic devices. Topics include reactor design, surface phenomena, gas and surface chemical kinetics, structure and composition of deposited films, and relationship between process conditions and film properties. Letter grading. Ms. Chang

2240. Fundamentals of Aerosol Technology. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 101C. Technology of particle/gas systems with applications to gas cleaning, commercial particulate processes, and industrial applications. Particle transport and deposition, optical properties, experimental methods, dynamics and control of particle formation processes. Concurrently scheduled with course CI140. Lecture, four hours; outside study, eight hours. Requisites: courses 140, 240, 245. Letter grading. Ms. Chen (F)

246. Systems Biology: Intracellular Network Identification and Analysis. (4) Lecture, four hours; outside study, seven hours. Select topics in molecular biology that form foundation of modern biological and biomedical research today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading. Ms. Chen (F)


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


270R. Advanced Research in Semiconductor Manufacturing. (6) Laboratory, nine hours; outside study, nine hours. Limited to graduate chemical engineering students in MS semiconductor manufacturing direction. Students perform experiments on semiconductor materials and devices. Letter grading.

M280A. Linear Dynamic Systems. (4) (Same as Electrical and Computer Engineering M242A and Mechanical and Aerospace Engineering M270A.) 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, singular values, Cayley/Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle. Connections with transfer function techniques. Letter grading.

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


283C. Analysis and Control of Infinite Dimensional Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M280A, M282A. Designed for graduate students. Introduction to advanced dynamical analysis and 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 theorems); (2) nonlinear model reduction (linear and nonlinear Galerkin method, proper orthogonal decomposition); (3) nonlinear and robust control of nonlinear hyperbolic and parabolic partial differential equations (PDEs); (4) applications to transport-reaction processes. Letter grading. Mr. Christofides


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

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, teaching assistant (TA) or fellow training and teaching in chemical engineering. May be arranged in advance by department. Lectures, discussions, student presentations, and topics in areas of current interest 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 seminar on communicating chemical engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of grading, advising, and rapport workshop. S/U grading. Ms. Eisler (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 classroom for benefit of student learning. S/U grading. (W)

597B. Preparation for PhD Preliminary Examinations. (2 to 16) Seminar, may be repeated for credit. 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. Preparation for MS comprehensive examination. Letter grading. (F,W,Sp)

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

597D. Preparation for PhD Oral Qualifying Examination. (2 to 16) Seminar, to be arranged. Limited to graduate chemical engineering students. Preparation for oral qualifying examination, including preliminatory research on dissertation. S/U grading.
Civil and Environmental Engineering

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Overview

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 undergraduate curriculum leads to a BS 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, MS and PhD degree programs are offered in the areas of civil engineering materials, environmental engineering, geotechnical engineering, hydrology and water resources engineering, and structures (including structural/earthquake engineering and structural mechanics). In these areas, research is being done on a variety of problems ranging from basic physics and mechanics problems to critical problems in earthquake engineering and in the development of new technologies for pollution control and water distribution and treatment.

Department Mission

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

Civil Engineering BS
The civil engineering program is accredited by the Engineering Accreditation Commission of ABET.

Capstone Major
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.

Educational Objectives
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.

Learning Outcomes
The Civil Engineering major has the following learning outcomes:

- Understanding of, and ability to apply, basic mathematical and scientific concepts that underlie the field
- Ability to contribute meaningfully to design projects
- Critical thinking skills, problem-solving abilities, and familiarity with computational procedures essential to the field
- Ability to work productively as a member of a team
- Effective oral and written communication skills

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 1, M20 (or Computer Science 31); Mathematics 31A, 31B, 32A, 32B, 33A, 33B (or Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C, 4A; one natural science course selected from Civil and Environmental Engineering SBXP, Earth, Planetary, and Space Sciences 3, 15, 16, 17, 20, Environment 12, Life Sciences 7A, Microbiology, Immunology, and Molecular Genetics 5, 6, or Neuroscience 10.

The Major
Required: Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A, Civil and Environmental Engineering 91 (or Mechanical and Aerospace Engineering 101), 102, 103, C104 (or Materials Science and Engineering 104), 108, 110 (or C111), 120, 135A, 150, 153, 190, Mechanical and Aerospace Engineering 103; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and at least eight major field elective courses (32 units) from the lists below with at least two design courses, one of which must be a capstone design course and two of which must be laboratory courses. The laboratory courses must be taken from two distinct areas (both 120L and 129L may be taken to satisfy the two-laboratory requirement). Courses applied toward the required course requirement may not also be applied toward the major field elective requirement.

Civil Engineering Materials: Civil and Environmental Engineering C104, C105, C106, C111, C112; laboratory course: 108L.

Environmental Engineering: Civil and Environmental Engineering 154, 155, C159, 164, M165, M166; laboratory courses: 156A, 156B; capstone design courses: 157B, 157C.

Geotechnical Engineering: Civil and Environmental Engineering 125; laboratory courses: 120L, 129L; design courses: 121, C123 (capstone).


Structural Engineering and Mechanics: Civil and Environmental Engineering 125, 130, 135B, M135C, C137, 142; laboratory courses: 108L, 135L, 140L; design courses: 141, 143, 144 (capstone), 147 (capstone), 148.

Transportation Engineering: Civil and Environmental Engineering 180, C181, C182, C185, C186.

Addition Elective Options: Courses selected from an approved list available in the UCLA Samueli Office of Academic and Student Affairs.

For information on UC, school, and general education requirements, see Requirements for BS Degrees on page 21 or the GE Requirement web page.

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.

Admission
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.

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


Policies
Credit for Chemical Engineering 102A and Mechanical and Aerospace Engineering 105A is not allowed.

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 admission information, see Graduate Programs Admission on page 27.
The following introductory information is based on 2022-23 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 (MS) and Doctor of Philosophy (PhD) degrees in Civil Engineering.

**Civil Engineering MS**

**Course Requirements**

There are two plans of study that lead to the MS degree: the thesis plan and the capstone plan (comprehensive examination). For both plans, 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 graduate level (200 series). In the thesis plan, seven of the nine must be upper-division (100-series) or graduate-level (200-series) courses. The remaining two may be 598 courses involving work on the thesis. In the capstone plan (comprehensive examination), 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 recommended to be quantitative in nature. In addition, MS students must enroll in a Civil and Environmental Engineering 200 seminar each quarter. A minimum 3.0 grade-point average is required in all coursework and 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 MS 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 MS degree offers eight fields of specialization that have specific course requirements.

**Civil Engineering Materials**

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

**Required Graduate Courses.** Two courses must be selected from Civil and Environmental Engineering C204, C205, 226, 253, 258A, 261B, M262A, 263A, 266, 267.

**Other Elective Courses.** Remaining courses (at least two) must be selected from Chemical Engineering 102A, 102B, 200, C219, 223, 230, 270, Chemistry and Biochemistry 103, 110A, 110B, 113A, C213B, C215A, C215B, C215C, C223A, C223B, C226A, C275, 276B, 277, Civil and Environmental Engineering 110, M135C, 153, 154, 155, 157A, 157B, 157C, 157L, M165, 226, 250A through 250D, 251C, 251D, 252, 253, 254A, 255A, 255B, 258A, 258B, 258C, 259, 260, 261A, 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, and biochemistry, computer science, Earth and space sciences, electrical and computer engineering, and environmental health sciences are commonly approved to satisfy course requirements. No more than two courses may be applied outside of civil and environmental engineering unless pre-approved for exceptional circumstances. No more than two undergraduate courses may be applied toward the nine-course requirement unless pre-approved for exceptional circumstances.

**Environmental Engineering**

**Required Preparatory Courses.** Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 151 or 153; Mathematics 32A, 32B, 38B (or Mechanical and Aerospace Engineering 82); Mechanical and Aerospace Engineering 103; Physics 1A, 1B, 4AL.

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

**Approved Elective Courses.** Civil and Environmental Engineering 110, 151, 152, 154, 155, 157A, 157B, 157C, 157L, M165, 226, 250A through 250D, 251C, 251D, 252, 253, 254A, 255A, 255B, 258A, 258B, 258C, 259, 260, 261A, 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, 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, C228, C239, 245.
Other Elective Courses. Other elective courses may be taken with prior approval from the faculty adviser.

Hydrology and Water Resources Engineering

Required Preparatory Courses. Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 32A, 32B, 33B (or Mechanical and Aerospace Engineering 82); Mechanical and Aerospace Engineering 103; Physics 1A/4A-L, 1B.

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

Approved Elective Courses. Civil and Environmental Engineering 110, 151, 152, 154, 155, 157A, 157B, 157C, 157L, M165, 226, 250A, 250B, 250C, 250D, 251C, 251D, 252, 253, 254A, 255A, 255B, 258A, 259, 260, 261A, 261B, M262A, 263A, 263B, 266, or other elective approved courses 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.

Structural/Earthquake Engineering

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


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 analysis (Civil and Environmental Engineering 135A, 135B), steel or concrete design (course 141 or 142). Other undergraduate preparation could include Civil and Environmental Engineering C104, 120, 121, 140L, and Materials Science and Engineering 104.

Required Graduate Courses. Civil and Environmental Engineering C204, M230A (or 243A), 235A, C282.

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


Transportation Engineering

Required Preparatory Courses. Knowledge of calculus, linear algebra, and differential equations; Civil and Environmental Engineering 180, or equivalent course or professional experience; Geography 7, Urban Planning 205A, or equivalent professional experiences. These preparatory courses may be taken while enrolled in the MS program, but may not count toward the required nine degree program courses.

Required Graduate Courses. Civil and Environmental Engineering C281, C286; Civil and Environmental Engineering C285 or Urban Planning M253; Urban Planning 206B; and one course from Urban Planning C251, 254, M255, M256, or M258.

Elective Courses. Any four courses not counted as a required course selected from Civil and Environmental Engineering C285, C211, Urban Planning C251, M253, 254, M256, M258.

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

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 for 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

Every master’s degree thesis plan requires the completion of an approved thesis that demonstrates the student’s ability to perform original, independent research. 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 MS thesis committee reviews and approves the thesis. No oral examination is required.

**Time-to-Degree**

The normative duration for full-time students in the MS program on the comprehensive examination track is four quarters and on the thesis track is six quarters. The maximum time allowed for completing the MS degree is three years from the time of admission to the MS 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 PhD**

**Major Fields or Subdisciplines**

Civil engineering materials, environmental engineering, geotechnical engineering, hydrology and water resources engineering, structural/earthquake engineering, structural mechanics, and transportation engineering.

**Course Requirements**

PhD students are required to take five courses that serve as the basis for the written portion of the preliminary examination. If comparable courses have been completed elsewhere, the students may satisfy this requirement with approval of the adviser. Students take a minimum of four additional courses, as defined in their PhD program of study, which must be approved by the student’s adviser. A minimum 3.25 grade-point average is required in all coursework. In addition, PhD students must enroll in a Civil and Environmental Engineering 200 seminar each quarter until they advance to candidacy. At least 50 percent of coursework applied toward the PhD 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 PhD program. Students may not take the examination more than twice.

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

After passing the written preliminary examination and substantially completing all minor field coursework, students take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination. The student must confirm with the committee the expectations of deliverables for the prospectus including, but not limited to, written documents and an oral presentation.

Students nominate a doctoral committee prior to taking the University Oral Qualifying Examination. Students are required to meet with committee members once per year (summer through spring) after advancement to candidacy until graduation. Meetings may be one on one or as a group and members may participate remotely. Students will provide documentation of meetings annually to the 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 PhD program, after completing an MS degree, is 12 quarters. The maximum time allowed for completing the PhD degree, after completing the MS 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 factor cements and concretes, reducing the carbon footprint of construction materials, and increasing the service life of civil engineering infrastructure.

**Environmental Engineering**

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

Transportation Engineering
Research in transportation engineering covers various topics including traffic system operations and control, intelligent transportation systems, transportation network system analysis, travel behavior and demand modeling, resilient infrastructure systems and health monitoring, and highway safety. Specifically, the program focuses on new mobility technologies and systems and considers the intersection of travel behavior, economics, engineering, regulation, and infrastructure as technology and business forces lead to new mobility options such as automated and connected vehicles, electric vehicles, vehicle/ride sharing, and micromobility.

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 hydrochemical 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 portal frame, and a water intake/outlet tower for a reservoir. Two electromagnetic exciters, each with a 30-pound dynamic force rating, are available for generating steady state forced vibrations. A number of accelerometers, LVDTs (displacement transducers), and potentiometers are available for measuring the motions of the structure. A laboratory view-based computer-controlled dynamic data acquisition system, an oscilloscope, and a spectrum analyzer are used to visualize and record the motion of the model structures.

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 Mo-
tion 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 microscopy, 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.

Laboratory for the Chemistry of Construction Materials (LC2)

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.

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 servo-hydraulic controllers are used to apply monotonic or cyclic loads. The area is serviced by two cranes. The facilities are capable of testing large-scale structural components under a variety of axial and lateral loadings.

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

Mobility Laboratory

The Mobility Lab is dedicated to harnessing system theories and tools—such as artificial intelligence, control theory, robotics, machine learning, and optimization—to innovate and develop advanced mobility technologies and solutions for smart cities, particularly intelligent vehicular and transportation systems. It conducts extensive research, with support from government agencies (such as federal and state transportation departments, and the National Science Foundation) and private sectors into improving transportation system sustainability with advanced technologies and management solutions. The lab also leverages the university environment, and works with external partners, to perform research and development; and to prepare a future workforce for competitive advantage in advanced vehicular technologies, vehicle automation, and electrification; urban analytics for future mobility and smart cities; and resilient, secure, and smart transportation and logistics infrastructure.

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 complex nano- and micro-structure property relationships in materials at a fundamental level. To this end, it uses a computational physical/material science approach supported by experiments.

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

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, PhD, PE (UC Berkeley, 1981)
Structural engineering, earthquake engineering, engineering seismology

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

Mekonnen Gebremichael, PhD (U. Iowa, 2004)
Remote sensing of hydrology, watershed hydrologic modeling, hydroclimate, stochastic processes and scaling

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

Jenni A. Jay, PhD (MIT, 1999)
Aquatic chemistry, environmental microbiology

Jiann-Wen Woody Ju, PhD, PE (UC Berkeley, 1986)
Damage mechanics, mechanics of composite materials, computational plasticity, micromechanics, concrete modeling and durability, computational mechanics
Civil and Environmental Engineering Courses

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.

Regan Patterson, PhD (UC Berkeley, 2019) 

91. Statics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 31A, 31B, Physics 1A. Newtonian mechanics, two-dimensional motions. Letter grading.

Mathieu Bauchy, PhD (U. Pierre et Marie Curie, France, 2012) 

Yves Troesch, PhD, PE (UCLA, 1961) 

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

20. Introduction to Computer Programming with MATLAB. (4) (Same as Mechanical and Aerospace Engineering M20.) Lecture, two hours; discussion, two hours; laboratory, two hours; outside study, six hours. Requisites: Mathematics 33A. Fundamentals of programming and programming tools. MATLAB computing environment. Basic data types and control structures. Input/output, functions. Data visualization. MATLAB-based data structures. Development of efficient codes. Introduction to object-oriented programming. Examples and exercises from engineering, mathematics, and physical sciences. Letter grading.

Issam Najm, PhD, PE (U. Illinois Urbana-Champaign, 2012) 

Jiaqi Ma, PhD (U. Virginia, 2014) 

Timu W. Gallien, PhD (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 observational tools.

Emotion-based earthquake engineering, seismic design, evaluation and retrofit, enhanced seismic performance systems, building community resilience.

Ting W. Gallien, PhD (UC Irvine, 2012) 

Transportation engineering, connected and automated vehicles, mobility systems, transportation systems resilience, intelligent transportation systems.

David Jassby, PhD (Duke, 2011) 

Water treatment and desalination, membrane separation processes, membrane material fabrication, electrochemistry, environmental applications of nanotechnology.

Jiang Ma, PhD (U. Virginia, 2014) 

Geotechnical engineering, earthquake engineering, engineering seismology. 

Ertugrul Taciroglu, PhD (University of 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, PhD, PE (UC Berkeley, 1988) 

Earthquake engineering, design methodologies, seismic evaluation and retrofit, large-scale laboratory and field testing.

William W.-G. Yeh, PhD, NAE (Stanford, 1967) 

Hydrology and optimization of water resources systems.

Jian Zhang, PhD (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, PhD, PE (UC Berkeley, 1962) 

Structural mechanics, structural dynamics, finite element methods, numerical methods and mechanics of composite materials.

Lewis P. Felton, PhD (Carnegie Institute of Technology, 1964) 

Structural analysis, structural mechanics, automated optimum structural design, including reliability-based design.

Michael E. Petley, PhD, PE (Caltech, 1963) 

Experimental mechanics, special emphasis on application of modern optical techniques.

Richard L. Perrine, PhD (Stanford, 1953) 

Resource and environmental problems—chemical, petroleum, or hydrological; physics of flow through porous media; transport phenomena.

Moshe F. Rubinstein, PhD (UCLA, 1961) 

Systems analysis and design, problem-solving and decision-making models.

Keith D. Stolzenbach, PhD, PE (MIT, 1971) 

Environmental fluid mechanics, fate and transport of pollutants, dynamics of particles.

Mladen Vucetic, PhD (Rensselaer, 1986) 

Geotechnical engineering, soil dynamics, geotechnical earthquake engineering, experimental studies of static and cyclic soil properties.

Associate Professors

Mathieu Bauchy, PhD (U. Pierre et Marie Curie, France, 2012) 

Development of high-performance and sustainable glasses and cementitious materials for infrastructure and handled devices applications; multiscale simulations of materials.

Henry V. Burton, PhD, SE (Stanford, 2014) 

Performance-based earthquake engineering, seismic design, evaluation and retrofit, enhanced seismic performance systems, building community resilience.

Ting W. Gallien, PhD (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 observational tools.

David Jassby, PhD (Duke, 2011) 

Water treatment and desalination, membrane separation processes, membrane material fabrication, electrochemistry, environmental applications of nanotechnology.

Jiang Ma, PhD (U. Virginia, 2014) 

Transportation engineering, connected and automated vehicles, mobility systems, transportation systems resilience, intelligent transportation systems.

Assistant Professors

Tierra S. Bills, PhD (UC Berkeley, 2013) 

Transit accessibility, transportation equity analysis, emerging data for travel modeling.

Sanjay Mohanty, PhD (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.

Regan Patterson, PhD (UC Berkeley, 2019) 

Social equity and environmental sustainability in transportation.

Adjunct Professor

Thomas Sabol, PhD, SE (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, PhD, PE (UCLA, 1989) 

Hydraulics, groundwater hydrology, advanced engineering economics, stochastic processes.

Issam Najm, PhD, PE (U. Illinois Urbana-Champaign, 1990) 

Water chemistry; physical and chemical processes in drinking water treatment.


Water chemistry; physical and chemical processes in drinking water treatment.

Upper-Division Courses

102. Dynamics of Particles and Bodies. (2) Lecture, two hours; discussion, two hours; outside study, two hours. Requisites: course 91 or Mechanical and Aerospace Engineering 111P. Introduction to fundamentals of dynamics of single particles, system of particles, and rigid bodies. Topics include kinematics and kinetics of particles, work and energy, impulse and momentum, multiples systems, kinematics and kinetics of rigid bodies in two- and three-dimensional motions. Letter grading.

Richard L. Perrine, PhD (Stanford, 1953) 

Resource and environmental problems—chemical, petroleum, or hydrological; physics of flow through porous media; transport phenomena.

Moshe F. Rubinstein, PhD (UCLA, 1961) 

Systems analysis and design, problem-solving and decision-making models.

Keith D. Stolzenbach, PhD, PE (MIT, 1971) 

Environmental fluid mechanics, fate and transport of pollutants, dynamics of particles.

Mladen Vucetic, PhD (Rensselaer, 1986) 

Geotechnical engineering, soil dynamics, geotechnical earthquake engineering, experimental studies of static and cyclic soil properties.

Associate Professors

Mathieu Bauchy, PhD (U. Pierre et Marie Curie, France, 2012) 

Development of high-performance and sustainable glasses and cementitious materials for infrastructure and handled devices applications; multiscale simulations of materials.

Henry V. Burton, PhD, SE (Stanford, 2014) 

Performance-based earthquake engineering, seismic design, evaluation and retrofit, enhanced seismic performance systems, building community resilience.

Ting W. Gallien, PhD (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 observational tools.

David Jassby, PhD (Duke, 2011) 

Water treatment and desalination, membrane separation processes, membrane material fabrication, electrochemistry, environmental applications of nanotechnology.

Jiang Ma, PhD (U. Virginia, 2014) 

Transportation engineering, connected and automated vehicles, mobility systems, transportation systems resilience, intelligent transportation systems.

Assistant Professors

Tierra S. Bills, PhD (UC Berkeley, 2013) 

Transit accessibility, transportation equity analysis, emerging data for travel modeling.

Sanjay Mohanty, PhD (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.

Regan Patterson, PhD (UC Berkeley, 2019) 

Social equity and environmental sustainability in transportation.

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Donald R. Kendall, PhD, PE (UCLA, 1989) 

Hydraulics, groundwater hydrology, advanced engineering economics, stochastic processes.

Issam Najm, PhD, PE (U. Illinois Urbana-Champaign, 1990) 

Water chemistry; physical and chemical processes in drinking water treatment.


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Water chemistry; physical and chemical processes in drinking water treatment.
102. Applied Numerical Computing and Modeling in Civil Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course M20 (or Computer Science 31), Mathematics 33B or Mechanical and Aerospace Engineering 101. May be taken concurrently. Introduction to numerical computing with specific applications in civil and environmental engineering. Topics include error and computer arithmetic, basic programming, numerical integration and differentiation, solution of systems of linear and nonlinear equations, numerical solution of ordinary and partial differential equations. Letter grading.

Mr. Margulis, Mr. Taciroglu (Sp)


Mr. Sant (W)


Mr. Bauchy (Not offered 2022-23)

C106. Modeling and Simulation of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 91 or Mechanical and Aerospace Engineering 101, Chemistry 20A, 20B, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Provides fundamental understanding of modeling and numerical simulations for civil engineering materials based on practical examples and applications. By course end, students are expected to be able to independently run simulations at scale relevant to targeted problems. Concurrently scheduled with course C206. Letter grading.

Mr. Bauchy (Sp)


Mr. Bauchy, Ms. Zhang (W)

108L. Experimental Structural Mechanics. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite: course 108. Structural mechanics experiments and laboratory experiments in various structural mechanics testing of metals (steel, aluminum, brass), high-strength plastics, and concrete (cylinders, beams, columns). Direct compression, direct tension, ductile and nondestructive elastic. Elastic buckling of columns. Fracture mechanics testing and fracture toughness. Splitting tension and flexural tension, Elastic, plastic, and fracture behavior. ASTM and AASHTO cyclic load design of columns, size effects. Letter grading.

Mr. Ju (W)

110. Introduction to Probability and Statistics for Engineers. (4) Lecture, four hours; discussion, one hour (when scheduled); outside study, seven hours. Requisite: Mathematics M20 or 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 engineering, civil and environmental data analysis, risk and reliability analysis, and project design under uncertainty. Topics include basic probability concepts, random variables and analytical probability distributions, estimation, confidence intervals, hypothesis testing, and Bayesian concepts. Letter grading.

Ms. Jay (Sp)

C111. Machine Learning and Artificial Intelligence for Civil Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course M20, Chemistry 20A, 20B, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Theoretical and practical training in tools to analyze design and data for civil engineering problems. Focus on practice and problem-solving skills. By course end, students are expected to be able to independently run machine learning experiments. Concurrently scheduled with course C211. Letter grading.

Mr. Bauchy (F)

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

Mr. Brandenberg (F)

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

Mr. Brandenberg (W)


Mr. Stewart (W)

C123. Advanced Geotechnical Design. (4) Formerly numbered 123.) Lecture, two hours; active learning, two hours; discussion, two hours; outside study, six hours. Requisite: course 121. Slope stability analysis, including limit equilibrium procedures, finite element method, seepage analysis, and advanced topics such as rapid drawdown, construction of embankments on soft soil, and seismic slope stability. Lateral earth retention systems including gravity walls and excavation support systems. Capstone design project involving appropriate engineering standards and realistic constraints. Concurrently scheduled with course C223. Letter grading.


Mr. Bozorgnia (Sp)

C128. Geohazards and Infrastructure Resilience. (4) Lecture, four hours; outside study, eight hours. Requisite: course 128. Introduction to geohazards, focusing on the impact of geologic hazards on landform and surface water, and properties of soil and rock. Geohazards include earthquakes, landslides, rock avalanches, and landslides. Effects of geologic processes on civil infrastructure and risk assessment procedures to promote resilience. Concurrently scheduled with course C228. Letter grading.

Mr. Stewart (F)


Ms. Gallien (Sp)

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

Mr. Taciroglu (Sp)

135A. Elementary Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 135A. Analysis of truss and frame structures using matrix methods; matrix force methods; and frame displacement method; analysis concepts based on theorem of virtual work; moment distribution. Letter grading.

Mr. Ju (F)

135B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 135A. Analysis of truss and frame structures using matrix methods; matrix force methods; and frame displacement method; analysis concepts based on theorem of virtual work; moment distribution. Letter grading.

Mr. Taciroglu, Mr. Wallace (W)

M135C. Introduction to Finite Element Methods. (4) Same as Mechanical Engineering M168.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 130 or Mechanical and Aerospace Engineering 158A or 168A. 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 Galerkin’s method; finite element method; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postprocessing techniques; term projects with computers. Letter grading.

Mr. Taciroglu (Sp)

135L. Structural Design and Testing Laboratory. (4) Lecture, two hours; laboratory, five hours; outside study, four hours. Requisites: course 130, 135A, 135B. Limited enrollment. Computer-aided optimum design, construction, instrumentation, and test of small-scale model structure. Use of computer-based data acquisition and stress analysis systems for comparison of experimental and theoretically predicted behavior. Letter grading.

Mr. Burton (F,Sp)

C137. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 135B. Basic structural dynamics course for civil engineering students.
Elastic free and forced vibrations of 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 of beams. Concurrently scheduled with course C239. Letter grading. Mr. Tacioglu (F)

137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Required or corequisite: course 137. Calibration of internal and external dynamic measurement equipment. Determination of natural frequencies and damping factors from free vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibration tests. Simultaneous laboratory and computer analysis. Letter grading. Mr. Wallace (Not offered 2022-23)

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

141. Steel Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: 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 processes. Letter grading. Mr. Wallace (F)


142L. Reinforced Concrete Structural Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: courses 135B, 141, 190. Open-channel flow, including one-dimensional transport modeling, with focus on use of industry standards. Letter grading. Mr. Yeh (Not offered 2022-23)

143. Design of Prestressed Concrete Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: courses 135A, 142. Equivalent loads and allowable flexure stresses in determinate and indeterminate systems. Flexural and shear strength design, including secondary effects in indeterminate systems. Design of indeterminate post-tensioned beam using both hand calculations and commercially available computer program. Discussion of external post-tensioning, one- and two-way slab systems. Letter grading. Mr. Wallace (Sp)

144. Structural Systems Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: courses 141 or 142, and 190. Design course for civil engineering students, with focus on design and performance of complete building structural systems. Environmental Building Side (ECOS) 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. Required: courses 135B, 141, 190. Role of structural engineer, role of architect and other discipline professionals 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. Wallace (W)

148. Wood and Timber Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: courses 108, 135A. Properties and behavior of wood and wood products, analysis and design of wood and timber structural members subjected to flexural, shear, and axial stresses; connections, fasteners, and detailing; and light-framed wood shear walls and diaphragms. Letter grading. Mr. Burton (Not offered 2022-23)

150. Introduction to Hydrology. (4) Lecture, four hours; discussion, one hour, six hours. Enforced requisites: course M20 (or Computer Science 31), Mechanical and Aerospace Engineering 103. Study of hydrologic cycle and relevant atmospheric processes. Balance, rainfall-runoff, evaporation, precipitation, irrigation, evaporation, vegetation transpiration, groundwater flow, storm runoff, and flood processes. Letter grading. Mr. Margulis (F)

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

152. Hydraulic and Hydrologic Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 150, 151, 190. Analysis and design of hydraulic and hydrologic systems, including stormwater management systems, potable and recycled water distribution systems, wastewater collection systems, and constructed wetlands. Description of hydrologic components, including reading/interpreting professional drawings and documents, environmental impact reports, permitting, agency coordination, and engineering ethics. Presentations on alternative design engineering technologies, use of engineering economics, and preparation of written engineering reports. Letter grading. Mr. Margulis (Sp)

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

154. Chemical Fate and Transport in Aquatic Environments. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 153. Fundamental physical, chemical, and biological principles governing the transport and fate of chemicals in surface waters and groundwater. Topics include physical transport in various aquatic environments, air-water exchange, acid-base equilibrium, sorption, biodegradation, and bioaccumulation. Practical quantitative problems solved considering both reaction and transport of chemicals in environment. Letter grading. Ms. Jay (W)

155. Unit Operations and Processes for Water and Wastewater Treatment. (4) Lecture, two hours; outside study, six hours. Required: course 153. Biological, chemical, and physical methods used to modify water quality. Fundamentals of the design, governing, and analysis of systems for water and wastewater treatment systems. Field trip. Letter grading. Mr. Jassby (F)

156A. Environmental Chemistry Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Recommended requisite: course 153 (may be taken concurrently). Chemistry 20A, 20B. Basic laboratory techniques in analytical chemistry related to water and wastewater analysis. Selected experiments include analysis of solids, nitrogen species, oxygen demand, and chlorine residual, that are used in water and wastewater treatment analysis. Letter grading. Mr. Stenstrom (W)

156B. Environmental Engineering Unit Operations and Processes Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Required: Chemistry 20A, 20B. Characterization and analysis of water and wastewater samples for inorganic and organic constituents. Selected experiments include analysis of solids, nitrogen species, oxygen demand, and chlorine residual, that are used in water and wastewater treatment analysis. Letter grading. Mr. Yeh (Not offered 2022-23)

157A. Hydrologic Modeling. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: courses 150 or 151. Introduction to hydrologic modeling. Topics selected from areas of (1) open-channel flow, including one-dimensional steady flow and unsteady flow, (2) pipe flow and water distribution systems, (3) rainfall-runoff modeling, and (4) groundwater flow and contaminant transport modeling, with focus on use of industry and/or research standard models with locally relevant applications. Letter grading. Mr. Stenstrom (Sp)

157B. Design of Water Treatment Plants. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: courses 150, 151. Water quality standards and regulations, overview of water treatment plants, design of unit operations, predesign of water treatment plants, hydraulics of plants, process control, and cost estimation. Letter grading. Mr. Yeh (Not offered 2022-23)

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

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

C158. Coastal Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: course 151 and Mechanical and Aerospace Engineering 103. Covers coastal water levels (tides, storm, surge), sediment, climate variability, storms, sea level rise, resistance, surface gravity waves (characteristics, transformation, spectra), coastal processes (overtopping, erosion, flooding), coastal protection (walls, nourishment, groins, beach protection), coastal infrastructure, coastal modeling. Concurrently scheduled with course C258. Letter grading. Ms. Gallien (Sp)

C159. Green Infrastructure. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: courses 150, 153. Overview of fundamental science, engineering, and ecological principles to design, prevent, mitigate, and manage environmental, ecological, and social impacts of natural systems. Letter grading. Mr. Yeh (Sp)
signing green infrastructure for stormwater management. Students design green infrastructure projects with current practices, perform engineering calculations to calculate its performance, and develop critical thinking skills needed to design innovative or futuristic green infrastructures that would not only mitigate adverse impact of climate change, but also remain resilient under extreme weather conditions expected during climate change. Concurrently scheduled with course C282. Letter grading. Mr. Mohanty (Sp)

M164. Sustainable Waste Management. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 153. Introduction to environmental engineering. Management of solid wastes, some hazardous and municipal solid waste management technologies with particular emphasis on reuse of some wastes for alternative applications or 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. Mohanty (W)

M165. Environmental Nanotechnology: Implications and Applications. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course M103. Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: 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 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 water and energy 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 microbial interaction, health microbiology, pattern recognition. Letter grading. Ms. Mahendra (Not offered 2022-23)

M166L. Environmental Microbiology Laboratory. (2) (Same as Environmental Health Sciences M166L.) Lecture, two hours; discussion, two hours; outside study, two hours. Requisite: course M166 (may be taken concurrently). General laboratory practice within environmental microbiology, sampling of environmental samples, classical and modern molecular techniques for enumeration of microbes from environmen- tal samples, techniques for determination of microbial activity in environmental samples, laboratory setups for studying environmental biotechnology. Letter grading. Ms. Mahendra (Not offered 2022-23)

170. Introduction to Construction Management. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to construction engineering as a design function, 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 controls. Letter grading. Mr. Sant (Sp)

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, alignment, cross sections, and pavement. Letter grading. Mr. Ma (Sp)

C181. Traffic Engineering Systems: Operations and Control. 181A. Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 180. Traffic operations including traffic data collection and analysis, safety and crash studies, traffic flow theory, high-capacity analysis, signalized intersection design and analysis, and simulation modeling. Students gain understanding of basic traffic flow theory, learn to conduct traffic counts and surveys, and to apply capacity and high-capacity analysis methods and simulation modeling for both highway and signalized intersections. Concurrently scheduled with course C281. Letter grading. Mr. Ma (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, 108, 120. Materials Science 104. Correlation, analysis, and metrication of aspects of pavement design, including materials selection and traffic volume and loading. Special attention to aspects of pavement distress/ deterioration of these into pavements 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. Ma (W)

C185. Transportation Systems Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 180. Transportation researchers and practitioners are motivated by desire to control movement of people or goods from place to place. Such interactions become more intricate as new technologies emerge. To explore and perceive these intricate interactions, understanding of essential nature of transportation systems to analyze and optimally design such systems is needed more than ever. Introduction to fundamental concepts, methods, and principles underlying transportation systems analysis. Inclu- sive topics include system analysis, graphs, and how to focus on one level of system analysis: traveler behavior and network. Concurrently scheduled with course C285. Letter grading.

C186. Transportation Systems Planning. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 180. Introduction to basic elements of intelligent transportation systems (ITS), focusing on technological, systems, and institutional aspects. Topics include systems engineering processes, advanced travel information systems, transportation network operations, commercial vehicle operations and intermodal freight, public trans- portation applications, ITS and regional strategic transportation planning, travel demand management, electronic toll collection, and road-pricing, connected and automated vehicles (CAV), data access and exchange, cybersecurity for ITS, and other smart mobility technologies. Concurrently scheduled with course C286. Letter grading. Mr. Ma (Sp)

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.

190. Professional Practice. (2) Lecture, two hours; discussion; one hour; outside study, three hours. Requisite: one course from 121, 141, 142, 151, 155 (may be taken concurrently). Sustainability in design (e.g., LEED certification for building projects), professional licensure (PE, SE, and GC), project management (proposals, scheduling, and budgeting), business, public policy, leadership, ethics, earthquake loads, wind loads, load combinations, and environ- mental impact reports. Letter grading. Mr. Burton (F)

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

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

Graduate Courses

200. Civil and Environmental Engineering Graduate Seminar. (2) Seminar, four hours; outside study, two hours. Various topics in civil and environmental engineering that may include earthquake engineering, environmental engineering, geotechnical engineering, hydrology and water resources engineering, materials engineering, structural engineering, and mechanical engineering. May be repeated for credit with approval. Individual content required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (FW,Sp)

C205. Structure and Properties of Amorphous 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 and concrete chemical reactions, microstructure, properties of plastic and hardened concrete, chemical admixtures, and quality control and acceptance testing. Development and testing of fundamentals for complete understanding of overall response of all civil engineering materials. By end of term, successful utilization of fundamental materials science concepts to understand design, analyze, and describe engineering performance of civil engineering materials. Concurrently scheduled with course C104. Letter grading. Mr. Sant (W)


C207. Modeling and Simulation of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Requisites: Chemistry and Biochemistry 20A, 20B, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Provides fundamental understanding of modeling and numerical simulations for civil engineering materials. Largely focused on practical examples and applications. By course end, students are expected to be able to independently run simulations relevant to targeted problems. Concurrently scheduled with course C106. Letter grading. Mr. Bauchy (Sp)

C211. Machine Learning and Artificial Intelligence for Civil Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Theoretical and practical introduction to artificial intelligence and machine learning for civil engineering problems.
Focus on practice and problem-solving skills. By course end, student should be able to: (4)Hours; outside study, eight hours. Requisite: course 120. State of stress. Consolidation and settlement analysis. Shear strength of granular and cohesive soils. In situ and laboratory methods for soil property evaluation. Letter grading. Mr. Brandenberg (F).


222. Introduction to Soil Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Review of earthquake engineering. Inertial and kinematic interaction on earthquake ground motions. Soil-structure interaction, including analysis of simple structures. Lateral earth retention systems including gravity, anchored, soil-nailed, driven pile and drilled shaft foundations under vertical and lateral loading. Construction considerations. Letter grading. Mr. Brandenberg (W).

223. Advanced Geotechnical Design. (4) (Formerly numbered 223.) Lecture, two hours; active learning, two hours; discussion, two hours; outside study, six hours. Requisite: course 220. Slope stability analysis, including limit equilibrium procedures; finite element method, seepage analysis, and advanced topics such as rapid drawdown, construction of embankments on soft soil, and seismic slope stability. Lateral earth retention systems including gravity walls and excavation support systems. Advanced analysis methods and design project involving real landslide problems. Emphasis on preparation of professional engineering documents such as proposals, work acknowledgements, figures, plans, and reports. Concurrently scheduled with course C123. Letter grading. Mr. Brandenberg (W).


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

226. Geoenvironmental Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Field of geoenvironmental engineering involves application of geotechnical principles to environmental problems. Topics include environmental regulations, waste characterization, geosynthetics, solid waste landfills, subsurface barrier walls, and disposal of high water content materials. Letter grading. Mr. Stewart (Not offered 2022-23).
243B. Response and Design of Reinforced Concrete Structural Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 235A. Information on corrosion behavior of reinforced concrete buildings to earthquake ground motions. Topics include use of elastic and inelastic response spectra, role of strength, stiffness, ductility, and redundancy of structural systems, and the importance of earthquake-resistant design features. Letter grading. Mr. Wallace (F).

244. Structural Reliability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to concepts and applications of structural reliability. Topics include computer programs for first- and second-order estimates of failure probabilities; methods of failure probability analysis based on various analytical reliability methods, using reliability tools to calibrate simplified building codes, and performing reliability calculations related to performance-based engineering. Letter grading. Mr. Burton (W).

245. Earthquake Ground Motion Characterization. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Corequisite: course C137 or 248. Earthquake fundamentals, including plate tectonics, fault types, seismic waves, and magnitude scales. Characterization of earthquake source, including magnitude, frequency, 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. Bozorgnia (W).

246. Structural Response to Ground Motions. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: 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).

247. Earthquake Hazard Mitigation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: courses 130, and M237A or 248. Concepts of earthquake risk assessment, liquefaction, isostatic and hysteretic behavior, elastic and plastic behavior of ground, bearing capacity and bending, buckling of beams, 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. Mr. Zhang (Sp).

250A. Surface Water Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 150. In-depth study of surface water hydrology, including discussion and interaction of major topics such as rainfall and evaporation, soil and infiltration properties, runoff and snowmelt processes. Introduction to rainfall-runoff modeling, floods, and policy issues involved in water resource engineering and management. Letter grading. Mr. Gebrimichael (Sp).


250C. Hydrometeorology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 110. In-depth study of hydrometeorological processes. Role of hydrology in climate system, precipitation and evaporation processes, atmospheric radiation, exchange of mass between atmosphere and vegetation, and vegetation surface and overlooking atmosphere, flux and transport in turbulent boundary layer, basic remote sensing principles. Letter grading. Mr. Yeh (Not offered 2022–23).

250D. Water Resources Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 151. Application of mathematical programming techniques to water resources systems. Topics include optimization techniques for new and existing construction, flood control, irrigation systems, and water transportation. Letter grading. Mr. Wallace (Sp).


251B. Contaminant Transport in Groundwater. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 250A, 251B. Introduction to mathematical models of groundwater contaminant transport. Topics include water flow, remediation design, software packages and applications. Letter grading. Mr. Yeh (Not offered 2022–23).

251C. Remote Sensing with Hydrological Applications. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 250A, 250C. Introduction to basic physical concepts of remote sensing as they relate to surface and atmospheric hydrologic processes. Applications include radiative transfer modeling and retrieval of hydrologically relevant parameters like topography, soil moisture, snow properties, vegetation, and precipitation. Letter grading. Mr. Gebrimichael (Sp).

251D. Hydrologic Data Assimilation. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 250A, 250C. Introduction to basic concepts of inverse problems in hydrology and application of various data assimilation techniques to improving hydrologic predictions. Letter grading. Mr. Yeh (Not offered 2022–23).


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

255A. Physical and Chemical Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: courses 155, 254A. Fundamentals of environmental engineering microbiology; kinetics of microbial growth and biological oxidation; applications for activated sludge, gas transfer, fixed-film processes, aerobic and anaerobic digestion, sludge disposal, and biological nutrient removal. Letter grading. Mr. Stenstrom (W).

258A. Membrane Separations in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Applications of membrane separations to desalination, water reclamation, brine disposal, and ultrapure water. Emphasis on reverse osmosis, ultrafiltration, electrodialysis, 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. Requisite: courses 150, 153. Overview of sustainable science, engineering, and ecological principles to designing green infrastructure for stormwater management. Students design a small to large-scale green infrastructure project based on current practices and perform engineering calculations to calculate its performance, and develop critical thinking skills needed to design innovative or futuristic projects that can mitigate adverse impact of climate change, but also remain resilient under extreme weather conditions expected during climate change. Concurrently scheduled with course C159. Letter grading. Mr. Mohanty (Sp).

260. Advanced Topics in Hydrology and Water Resources. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 250A, 250B, 250D. Current research topics in inverse problem of water parameter estimation, experimental design, and computational use of surface and groundwater, multiobjective water resource planning, and optimization of water resource systems. Topics may vary from term to term. Letter grading. Mr. Yeh (Not offered 2022–23).


261A. Advanced Water Treatment Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. In-depth coverage of advanced water treatment processes, including advanced oxidation processes, photolysis, electrochemical treat-
M261. Advanced Biological Processes for Water and Wastewater Treatment. (4) Lecture; four hours; outside study; eight hours. Requisite: course 255B. In-depth treatment of selected topics related to biological treatment of waters and wastewaters, such as biodegradation of xenobiotics, pharmaceuticals, emerging pollutants, toxicity, and nutrients. Discussion of theoretical concepts, experimental observations, and recent literature. Application to important and emerging environmental problems. Letter grading. Mr. Jassby (Sp)

M262A. Introduction to Atmospheric Chemistry. (4) Same as Atmospheric and Oceanic Sciences M203A.) Lecture, three hours. Requisite for undergraduates: Chemistry 20B. Principles of chemical kinetics, thermodynamics, spectroscopy, and photochemistry; chemical composition and history of Earth’s atmosphere; biogeochemical cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere, upper atmosphere chemistry, and climate; sources and effects of particulate pollution; chemistry and climate. S/U or letter grading. (F)

M262B. Atmospheric Diffusion and Air Pollution. (4) Same as Atmospheric and Oceanic Sciences M224B.) Lecture, three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban complex; meteorological factors and air pollution potential; meteorological aspects of air pollution. S/U or letter grading. (Not offered 2022-23)

263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Transport processes in surface water, groundwater, and atmosphere. Emphasis on exchanges across phase boundaries: sediment/water interface; air/water gas exchange; particles, droplets, and bubbles; small-scale dispersion and mixing; effect of reactions on transport; linkages between physical, chemical, and biological processes. Letter grading. Mr. Stozenbach (Not offered 2022-23)

263B. Advanced Topics in Transport at Environmental Interfaces. (4) Lecture, four hours; outside study, eight hours. Requisite: course 263A. In-depth treatment of selected topics involving transport phenomena at environmental interfaces between solid, liquid, and gas phases, such as aquatic sediments, porous aggregates, active canopies. Discussion of theoretical models and experimental observations. Application to important environmental engineering problems. Letter grading. Mr. Stozenbach (Not offered 2022-23)

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

267. Environmental Applications of Geochemical Modeling. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Geochemical modeling is important tool for predicting environmental impacts of contamination. Hands-on experience in modeling using geochemical software packages commonly found in environmental consulting industry to gain better understanding of governing geochemical principles pertaining to movement and transformation of contaminants. Types of modeling include mass balance, reaction network, inverse mass balance, and reactive transport modeling. Case studies involve acid mine drainage, nuclear waste disposal, bioavailability and risk assessment, mine tailings and mining waste, deep well injection, landfill leachate, and microbial respiration. Research/modeling project required. Letter grading. Ms. Jay (Not offered 2022-23)

C281. Traffic Engineering Systems: Operations and Control. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 180. Traffic operations including traffic data collection and analysis, safety and crash studies, traffic flow theory, highway capacity analysis, signalized intersection design and analysis, and simulation modeling. Students gain understanding of traffic flow theory, learn to conduct traffic data collection and analysis, and to apply capacity analysis methods and simulation modeling for both highway and signalized intersection. Concurrently scheduled with course C181. Letter grading. Mr. Ma (F)

C282. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Correlation, analysis, and metricalization of aspects of pavement design, including materials selection and traffic loading and volume. Special attention to aspects of pavement distress/serviceability and factoring of these into metrics of pavement performance. Discussion of potential choices of pavement materials (i.e., asphalt and concrete) and their specific strengths and weaknesses in paving applications. Unification and correlation of different variables that influence pavement performance and highlight their relevance in pavement design. Concurrently scheduled with course C182. Letter grading. Mr. May (F)

C285. Transportation Systems Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 180. Transportation researchers and practitioners are motivated by desire to explain spatial interactions that resulted in movement of people or goods from one place to another. Such interactions become more intricate as new technologies emerge. To explore and perceive these intricate interactions, understanding of essential nature of transportation systems to analyze and optimally design such systems is needed more than ever. Introduction to fundamental concepts, methods, and principles underlying transportation systems analysis. Includes two modules, each of which focuses on one level of system analysis: traveler behavior and network. Concurrently scheduled with course C185. Letter grading. Mr. Ma (W)

C286. Intelligent Transportation Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 180. Introduction to basic elements of intelligent transportation systems (ITS), focusing on technological, systems, and institutional aspects. Topics include systems engineering processes, advanced traveler information systems, transportation network operations, commercial vehicle operations and intermodal freight, public transportation applications, ITS regional strategic transportation planning, travel demand management, electronic toll collection, and road pricing, connected and automated vehicles (CAV), data access and exchange, cybersecurity for ITS, and other smart mobility technologies. Concurrently scheduled with course C186. Letter grading. Mr. Ma (Sp)

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

298. Seminar: Engineering. (2 to 4) Seminar, 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.

397A. 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.

397B. Preparation for PhD Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Reading and preparation for PhD comprehensive examinations. S/U grading.

397C. Preparation for PhD Oral Qualifying Examination. (2 to 18) Tutorial, to be arranged. Limited to graduate civil engineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

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

399. Research 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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Senior Lecturers SOE
Paul R. Eggert, PhD
David A. Smallberg, MS

Adjunct Professors
David E. Heckerman, PhD
Van Jacobsen, MS
Alan C. Kay, PhD

Adjunct Associate Professors
Carey S. Nachenberg, MS
Giovanni Pau, PhD
Ramin Ramezani, PhD

Adjunct Assistant Professor
Ravi Netravali, PhD

Overview

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 computers and digital systems. The programs offer comprehensive and integrated studies of subjects in computer system architecture, computer networks, distributed computer systems, programming languages and software systems, information and data management, artificial intelligence, computer science theory, computational systems biology and bioinformatics, and computer vision and graphics.

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

The BS 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 Samuel offers MS and PhD 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 MS in Computer Science and the MBA (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.

Undergraduate Study

Computer Science and Engineering BS

The computer science and engineering curriculum at UCLA provides students with 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. The curriculum covers all aspects of computer systems from electronic design through logic design, MSI, LSI, and VLSI concepts; device utilization, machine language design, implementation and programming, operating system concepts, systems programming, networking fundamentals, and higher-level language skills; and their application. Students...
are prepared for employment in a wide spectrum of high-technology industries. The computer science and engineering program is accredited by the Computing Accreditation Commission and the Engineering Accreditation Commission of ABET.

**Capstone Major**

The Computer Science and Engineering major is a designated capstone major. Computer Science and Engineering students complete 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.

**Educational Objectives**

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

**Learning Outcomes**

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

- Application of basic mathematical and scientific concepts that underlie the modern field
- Design of a software or digital hardware system, component, or process to meet desired needs within realistic constraints
- Function productively with others on a team, including those with different 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; Electrical and Computer Engineering 3; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, and 4AL or 4BL.

**The Major**

Required: Computer Science 111, 118, 131, M151B, M152A, 180, 181, Electrical and Computer Engineering 100, 102, 115C; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 170E, or Statistics 100A; one capstone design course (Computer Science 152B); a minimum of 4 units and one elective course selected from Electrical and Computer Engineering 101A through M185; a minimum of 12 units and three elective courses selected from Computer Science 111 through CM187, and up to 8 units of Computer Science 188; and 12 units of technical breadth courses selected from an approved list available in the Office of Academic and Student Affairs. Students who want to deepen their knowledge of electrical engineering are encouraged to select that discipline as their technical breadth area.

For information on UC, school, and general education requirements, see Requirements for BS Degrees on page 21 or the GE Requirement web page.

**Policies**

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

A multiple-listed (M) course offered in another department may be used instead of the same computer science course (e.g., Electrical and Computer Engineering M116C may be taken instead of Computer Science M116). Credit is applied automatically.

**Computer Science BS**

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, compiler construction, and artificial intelligence. Majors are prepared for employment in a wide range of industrial and business environments.

The computer science program is accredited by the Computing Accreditation Commission of ABET.
Capstone Major

The Computer Science major is a designated capstone major. 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.

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

Learning Outcomes
The Computer Science major has the following learning outcomes:

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

Preparation for the Major

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

The Major

Required: Computer Science 111, 118, 131, M151B, M152A, 180, 181; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 170E, or Statistics 100A; one capstone software engineering or design course from Computer Science 130 or 152B; a minimum of 20 units and five elective courses selected from Computer Science 111 through CM187, and up to 8 units of Computer Science 188; a minimum of 12 units and three science and technology courses (not used to satisfy other requirements) that may include 12 units of upper-division computer science courses or 12 units of courses selected from an approved list available in the Office of Academic and Student Affairs; and 12 units of technical breadth courses selected from an approved list available in the Office of Academic and Student Affairs.

Students must take at least one course from Computer Science 130 or 132. Computer Science 130 or 152B may be applied as an elective only if it is not taken as the capstone course.

For information on UC, school, and general education requirements, see Requirements for BS Degrees on page 21 or the GE Requirement web page.

Policies
Credit is not allowed for both Computer Science 170A and Electrical and Computer Engineering 133A unless at least one of them is applied as part of the science and technology requirement or as part of the technical breadth area. A petition may be submitted to consider four units of Computer Science 194 or 199 for an elective. Credit is not guaranteed and subject to vice chair review.

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

Computer Engineering BS

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

Capstone Major

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.

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; (4) continue to learn as part of a graduate program or otherwise in the world of constantly evolving technology.

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 96I; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, and 4AL or 4BL.
The Major

Required: Computer Science 111, 118 (or Electrical and Computer Engineering 132B), M151B (or Electrical and Computer Engineering M116C), M152A (or Electrical and Computer Engineering M116L), 180; Electrical and Computer Engineering 100, 102, 113, 115C; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 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 BS Degrees on page 21 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, 115C, 132A, 132A, 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 are also free to design ad hoc tracks. The technical breadth area requirement provides an opportunity to combine elective courses in electrical and computer engineering and computer science with those from another UCLA Samueli major to produce a specialization in an interdisciplinary domain. As noted above, students can also select a technical breadth area in either Electrical and Computer Engineering or Computer Science to deepen their knowledge in either discipline.

Bioinformatics Minor

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

Admission

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 through Message Center.

Steps to apply are outlined on the Office of Academic and Student Affairs website. Information about the minor and the application are available on the minor website.

The Minor

Required Lower-Division Courses (17 units minimum): Computer Science 32 or Program in Computing 10C, Life Sciences 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 CH44, Mathematics 170A, 170E, Microbiology, Immunology, and Molecular Genetics 132, Molecular, Cell, and Developmental Biology 144, 187AL, Physiological Science 125, Statistics 100A, 100B.

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

Policies

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.

Data Science Engineering Minor

The minor is intended to expose students to the entire data science life cycle from both foundational and application perspectives. The foundational courses provide the engineering skills to collect, clean, and store data; analyze and draw inference from data; and take action and
make decisions. A wide-ranging list of interdisciplinary courses focuses on various data-science applications using these skills.

**Admission**

To apply for the minor, students must have an overall grade-point average of 3.0 or better, have completed or be in the process of completing in the present quarter the two lower-division required courses with the grade B- or better, and file a petition through Message Center. Steps to apply are outlined on the Office of Academic and Student Affairs website. Information about the minor and the application are available on the minor website.

**The Minor**

**Required Lower-Division Courses (8 units minimum):** Computer Science 32, Mathematics 33A.

**Required Upper-Division Courses (12 units minimum):** One course from Civil and Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 170E, or Statistics 100A; Computer Science M148 or Electrical and Computer Engineering M148, Computer Science 145 or M146 or Computer Engineering M146.

**Elective Upper-Division Courses (8 units minimum):** Two courses from Computer Science M119, CM121, CM122, CM124, 143, 145 or M146 (if not taken as a required course), 161, 180, M182, Electrical and Computer Engineering 102, 113, 114, M119, 133A, M146 (if not taken as a required course), C147, 183DA and 183DB (both must be taken), Mechanical and Aerospace Engineering C137, 185; Statistics 100B, 115, 170, or C180.

**Policies**

Variable topics courses may be taken as topics apply. Transfer credit for any of the above is subject to approval; consult with the undergraduate counselors before enrolling in any courses for the minor.

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

Each minor course must be taken for a letter grade, and student must have a minimum grade of C 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 admission information, see Graduate Programs Admission on page 27.

The following introductory information is based on 2022-23 program requirements for UCLA graduate degrees. Complete program requirements are available at Program Requirements for UCLA Graduate Degrees.

**Computer Science MS**

**Course Requirements**

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

**Undergraduate Courses.** No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 133, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

**Breadth Requirement.** MS 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, 131L, 132, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

**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 MS degree is expected. There is no examination under the thesis plan.

**Computer Science MS/ Master of Business Administration**

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 MS in Computer Science and the MBA (Master of Business Administration) in three academic years. Students should request application materials from both the MBA Admissions Office, John E. Anderson Graduate School of Management, and the Department of Computer Science.

**Computer Science PhD**

**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 PhD research. The basic program of study for the PhD 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 PhD 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 PhD 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, as well as the current literature in the area of specialization. Guidelines for course selection in each minor 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 included in the minor field, are required. By petition and administrative approval, a minor field may be satisfied by examination.

Breadth Requirement. PhD 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 PhD 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 MS 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 advisor, must be explicitly acknowledged in detail. Prior to submission, the paper must be accepted by the student’s advisor on a cover page with the advisor’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:

• 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)

• 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

• Knowledge representation and qualitative reasoning. Analysis of tasks such as common-sense reasoning and qualitative physics. Here the deductive chains are short, but the amount of knowledge that potentially may be brought to bear is very large

• Machine learning. Study of the means by which a computer can automatically improve its performance on a task by acquiring knowledge about the domain

• Natural language processing. Symbolic, statistical, and artificial neural network approaches to text comprehension and generation

• 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

• 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

- **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

### Computational Systems Biology

The computational systems biology (CSB) field can be selected as a major or minor field for the PhD or as a specialization area for the MS degree in Computer Science.

Graduate studies and research in the CSB field are focused on computational modeling and analysis of biological systems and biological data.

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

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

### Computer Networks

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

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

### Resource Allocation

A central problem in the design and evaluation of computer networks deals with the allocation of resources among competing demands (e.g., wireless channel bandwidth allocation to backlogged stations). In fact, resource allocation is a significant element in most of the technical (and non-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 intentionally to a certain body of knowledge emphasizing the intertwining 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.

- **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.

- **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.

- **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.

- **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.

- **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.

### 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 are at work in the fields of artificial intelligence, computational systems biology, computer systems architecture, graphics and vision, information and data management, network systems, software systems, and computer science.
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 multsource data in networks of partial beliefs; learning, the structuring and parameterizing of links in belief networks to form a representation consistent with a stream of observations; constraint processing, including intelligent backtracking, learning while searching, temporal reasoning, etc.; graphoids, the characterization of informational dependencies, and their graph representations; and default reasoning, use of qualitative probabilistic reasoning to draw plausible and defeasible conclusions from incomplete information.

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.

Machine Intelligence (MINT) Group
Aditya Grover, Director
The MINT group conducts research along two main thrusts: foundational research in machine learning, including topics in probabilistic reasoning, statistical inference, graphs and network science, reinforcement learning, and deep learning; and applications of artificial intelligence for accelerating scientific discovery, with a focus on sustainable development and climate change.

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, 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.

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 methodologic interface between structural and computational biomodeling with laboratory data, or computational systems biology, with a focus on integrated approaches for solving complex biosystem problems from sparse biodata (e.g., in physiology, medicine, and pharmacology), as well as voluminous biodata (e.g., from genomic libraries and DNA array data).

**Computational Genetics Laboratory**
Eleazar Eskin, Director

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 Sankararaman, 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 such as neuromorphic computing and quantum computing; and customizable domain-specific computing with applications to multiple domains such as machine learning, big data analytics, and bioinformatics.

**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)**
Demetris 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 climate change by monitoring the behavior of animals and plants. Analysis of images of the human body can be used both for diagnostic purposes and for planning interventions.

**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 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.

**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; but 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.

**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

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

Large-Scale Systems Group

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)

Miryung 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 2001 with researchers from several laboratories in the Computer Science, and Electrical and Computer Engineering, departments. It serves as a forum for intelligent-agent researchers and visionaries from academia, industry, and government, with an interdisciplinary focus on fields such as engineering, medicine, biology, and social sciences. Information and technology are exchanged through symposia, seminars, short courses, and collaboration in joint research projects sponsored by government and industry.

Research projects include use of unmanned autonomous vehicles, coordination of vehicles into computing clouds, and integration of body sensors and smart phones into m-health systems. Ongoing research encompasses personal and body networks, cognitive radios, ad hoc multi-hop 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. 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; and actively exploring the use of emerging computing technologies, such as neuromorphic and quantum computing. It also develops highly automated compilation tools and runtime management software for customizable heterogeneous platforms, including multicore CPUs, many-core GPUs, FPGAs, and quantum computers. By combining these capabilities, CDSC researchers are able to deliver a supercomputer-in-a-box or -in-a-cluster. This approach has been successfully applied to multiple application domains such as machine learning, big data analytics, medical imaging, and bioinformatics.

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 opportu-
nities 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 (Bioengineering), Director; Bruce Dobkin (Medicine/Neurology), William Kaiser (Electrical and Computer Engineering), Gregory J. Pottie (Electrical and Computer Engineering), Co-Directors

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

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

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

**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 gigabit Ethernet to the desktop with a gigabit backbone connection. The department LAN is connected to the campus gigabit backbone. An 802.11ac 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, configures routers, switches, and network monitoring tools. The software group administers the department UNIX servers, providing storage space and backup for department users.

**Faculty Areas of Thesis Guidance**

**Professors**

Junghoo (John) Cho, PhD (Stanford, 2002) *Databases, web technologies, information discovery and integration*

Jason (Jingsheng) Cong, PhD (U. Illinois, 1990) *Electronic design automation, energy-efficient computing, customized computing for big-data applications, highly scalable algorithms, quantum computing*

Adnan Y. Darwiche, PhD (Stanford, 1993) *Knowledge representation and automated reasoning (symbolic and probabilistic), applications to diagnosis, prediction, planning, and verification*

Joseph J. DiStefano III, PhD (UCLA, 1966) *Dynamic biosystems modeling methodology, simulation, clinical therapy and experiment design optimization; pharmacokinetics (PK), pharmacodynamics (PD), physiologically based PK (PKPD), epidemiological modeling*

Eleazar Eskin, PhD (Columbia, 2002) *Bioinformatics, genetics, genomics, machine learning*

Eliezer M. Gafni, PhD (MIT, 1982) *Computer communication, networks, mathematical programming algorithms*

Eran Halperin, PhD (Tel Aviv U., Israel, 2000) *Computational biology, population genetics, statistical genetics and epigenetics, machine learning, algorithms*

Miryung Kim, PhD (U. Washington, 2008) *Software engineering specifically on software evolution*

Richard E. Korf, PhD (Carnegie Mellon, 1983) *Problem solving, heuristic search, planning in artificial intelligence*

Songwu Lu, PhD (U. Illinois, 1999) *Integrated-service support over heterogeneous networks, e.g., mobile computing environments, Internet and ActiveNet: networking and computing, wireless communications and networks, computer communication networks, dynamic game theory, dynamic systems, neural networks, and information economics*

Todd D. Millstein, PhD (U. Washington, 2003) *Programming language design, static type systems, formal methods, software model checking, compilers*

Stanley J. Osher, PhD (New York U., 1966) *Scientific computing and applied mathematics*

*Rafail Ostrovsky, PhD (MIT, 1992) *Theoretical computer science algorithms, cryptography, complexity theory, randomization, network protocols, geometric algorithms, data mining*

Jens Palsberg, PhD (Aarhus U., Denmark, 1992) *Compilers, embedded systems, programming languages*

Miodrag Potkonjak, PhD (UC Berkeley, 1991) *Computer-aided analysis and synthesis of system level designs, behavioral synthesis, and interaction between high-performance application-specific computations and communications*

Glen D. Reinman, PhD (UC San Diego, 2001) *Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, multicore and multiprocessor design*

Amit Sahai, PhD (MIT, 2000) *Theoretical computer science, cryptography, computer security, algorithms, error-correcting codes and learning theory*

Majid Sarrafzadeh, PhD (U. Illinois, 1987) *Computer engineering, embedded systems, VLSI CAD, algorithms*

Stefano Soatto, PhD (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 fil-
terating; human-computer interaction; visualization;
Mani B. Srivastava, PhD (UC Berkeley, 1992)
IoT, edge computing, and human-cyber-physical
Mani B. Srivastava, PhD (UC Berkeley, 1992)
IoT, edge computing, and human-cyber-physical
resource-constrained systems; security and privacy;
Demetri Terzopoulos, PhD (MIT, 1984)
Network algorithmics, network verification
George Varghese, PhD (MIT, 1993)
Computer graphics, computer vision, medical
Wei Wang, PhD (UCLA, 1999)
Data mining, bioinformatics and computational
Lixia Zhang, PhD (MIT, 1989)
Network computer, Internet architecture, protocol
designs and security and resiliency of large-
scale systems
Sung-Chun Zhu, PhD (Harvard, 1996)
Computer vision, statistical modeling and computing,
vision and visual arts, art, machine learning
Harry Xu (Ohio State, 2011)
Programming languages, compilers, runtime systems,
distributed systems, big data systems, databases,
software and analytics, software engineering
Professors Emeriti
Algirdas A. Avizienis, PhD (U. Illinois, 1960)
Digital computer architecture and design,
fault-tolerant computing, digital arithmetic
Rajiv L. Bagrodia, PhD (U. Texas, 1987)
Wireless networks, nomadic computing, parallel
programming, performance evaluation of computer
and communication systems
Alfonso F. Cardenas, PhD (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
Jack W. Carlyle, PhD (UC Berkeley, 1961)
Communication, computation theory and practice,
algorithms and complexity, discrete
discrete system theory, developmental and probabilistic
Wesley W. Chu, PhD (Stanford, 1966)
Distributed computing, distributed database,
memory management, computer communications,
performance measurement and evaluation
for distributed systems and multiswitch packet-switched systems
Michael G. Dyer, PhD (Yale, 1982)
Artificial intelligence; natural language processing;
connectionist, cognitive, and animat-
modeling
Milos D. Ercegovac, PhD (U. Illinois, 1975)
Application-specific architectures, digital computer arithmetic,
digital design, low-power systems, reconfigurable systems
Sheila A. Greibach, PhD (Harvard, 1963)
Theoretical computer science, computational complexity,
algorithm schemes and semantics, formal languages, automata,
computability
Leonard Kleinrock, PhD (MIT, 1963)
Computer networks, computer-communication systems,
resource sharing and allocation, computer systems modeling analysis and
design, queuing systems theory and applications,
performance evaluation of congestion-prone systems, performance evaluation and
design of distributed multi-access packet-switching systems, wireless networks, mobile
computing, nomadic computing, and distributed and parallel processing systems
Allen Klüner, PhD (UC Berkeley, 1966)
Pattern recognition, picture processing, biomedical applications, mathematical modeling
Lawrence P. McNamee, PhD (U. Pittsburgh, 1964)
Computer graphics, discrete simulation, digital
filtering design, LSI fabrication techniques, printed circuit board
design
Richard R. Munzt, PhD (Princeton, 1969)
Multiuser systems, database systems, data mining
D. Stott Parker, Jr., PhD (U. Illinois, 1978)
Data mining, information modeling, scientific computing,
bioinformatics, database and knowledge-based systems
Judea Pearl, PhD (Polytechnic Institute of
Brooklyn, 1965)
Artificial intelligence, philosophy of science, reasoning under uncertainty, causal inference,
causal and counterfactual analysis
David A. Rennels, PhD (UCLA, 1973)
Digital communication and design, fault-tolerant computing, digital arithmetic
Mihaela van der Schaar, PhD (Eindhoven University of
Technology, Netherlands, 2001)
Multimedia processing and compression, multimedia networking, multimedia communications,
multimedia architectures, enterprise multimedia streaming, mobile and ubiquitous computing
Carlo A. Zaniolo, PhD (UCLA, 1976)
Knowledge bases and deductive databases, parallel execution of PROLOG programs, formal software specifications, distributed systems, big data, artificial intelligence, and computational biology
Associate Professors
Kai-Wei Chang, PhD (U. Illinois Urbana-Cham-
paign, 2015)
Tractable machine learning methods for complex and big data, statistical approaches to natural language processing
Jason Ernst, PhD (UCLA, 2008)
Computational biology, bioinformatics, machine learning
Alyson K. Fletcher, PhD (UC Berkeley, 2006)
Applied mathematics including inverse problems, statistical physics, dynamical systems, machine learning, information theory
Quanquan Gu, PhD (U. Illinois Urbana-Cham-
paign, 2014)
Machine learning, high-dimensional statistical inference, optimization, data mining
Che-Jui Hsieh, PhD (U. Texas Austin, 2015)
Fast and scalable algorithms for large-scale machine learning (deep learning), fast prediction and model compression for big ML models, low-rank models for recommender systems, theoretical analysis of optimization algorithms, security for machine learning
Raghu Meka, PhD (U. Texas Austin, 2011)
Complexity theory, pseudorandomness, algorithms, learning probability and data mining
Anthony J. Nowatzki, PhD (U. Wisconsin Madison, 2016)
Hardware/software co-design, modeling, and optimization
Alexander Sherstov, PhD (U. Texas Austin, 2009)
Complexity theory with a focus on communication and circuit complexity, computational learning theory, quantum computing
Yizhou Sun, PhD (U. Illinois Urbana-Champaign, 2012)
Information and social network analysis, data mining, database systems, statistics, information retrieval, machine learning and network science
Yuval Tamir, PhD (UC Berkeley, 1985)
Computer systems, software systems, computer architecture, parallel and distributed systems, dependable systems, network design automation, cloud computing, operating systems, system-level virtualization, interconnection networks and switches, multicore architectures
Guy Van den Broeck, PhD (Katholieke Universiteit Leuven, Belgium, 2013)
Machine learning (statistical relational learning), knowledge representation and reasoning (graphical models, lifted probabilistic inference), applications of probabilistic reasoning and learning (probabilistic programming, probabilistic databases), artificial intelligence
Assistant Professors
Omid Abari, PhD (MIT, 2018)
Internet of Things (IoT), wireless networking, mobile systems, software/hardware systems, human-computer interaction (HCI)
Aditya Grover, PhD (Stanford, 2020)
Statistical machine learning, reinforcement learning, probabilistic graphical models, graph and network science, artificial intelligence for scientific discovery, sustainability and climate change
Achuta Kadambi, PhD (MIT, 2018)
Computational imaging, computer vision, robotics, medical devices
Baharan Mirzakarami, PhD (ETH Zürich, Switzerland, 2017)
Large-scale machine learning, data/model compression, optimization, approximation algorithms
Nanyun (Violet) Peng, PhD (Johns Hopkins, 2017)
Natural language processing, artificial intelligence, information extraction, multilingual natural language understanding, narrative understanding and generation, figurative language generation
Sriram Sankararaman, PhD (UC Berkeley, 2010)
Computational biology, computational/statistical genomics, statistical machine learning probabilistic graphical models, Bayesian statistics
F. Reza Sezal, PhD (U. Liège, Belgium, 2008)
Stroke and traumatic brain injuries (TBI) using brain mapping of imaging and biosignals (MR, CT, X-ray angiography, TCD, and ICP); development of machine learning and computer vision algorithms to improve neurocritical care and bring understanding of neurological disorders
Bolei Zhu, PhD (MIT, 2018)
Computer vision, machine learning, artificial intelligence
Senior Lecturers SOE
Paul R. Egger, PhD (UCLA, 1980)
Programming languages, operating systems principles, compilers, Internet
David A. Smalley, MS (UCLA, 1978)
Programming languages, software development
Adjunct Professors
David E. Heckerman, PhD (UCLA, 1979)
Machine learning, artificial intelligence, learning from data, graphical models, data analysis and visualization in biology and medicine
Van Jacobson, MS (U. Arizona, 1972)
Named data network (NDN), content-centric networking
Alan Kay, PhD (U. Utah, 1969)
Object-oriented programming, personal computing, graphical user interfaces
Bioinformatics Courses

Lower-Division Courses

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

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

Upper-Division Courses

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 Courses

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.

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.

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 abstraction.

Upper-Division Courses


M51A. Logic Design of Digital Systems. (4) (Same as Electrical and Computer Engineering M516.) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading.

M2121. 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 Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A. Designed for students from biological sciences and medical school. Introduction to bioinformatics and methodologies, with emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms.

Concurrently scheduled with course CM221. P/NP or letter grading.

Mr. Pimentel (W)
CM122. Algorithms in Bioinformatics. (4) (Same as Chemistry M116C.) Lecture, four hours; discussion, two hours. Requisites: course 32 or Program in Computing 10C with grade of C− or better, and one course from Civil Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170E, or Statistics 100A. Course CM121 is not requisite to CM122. Designed for engineering students as well as students from biological sciences who wish to learn about bioinformatics. Computer applications of algorithmic approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM222. Letter grading. (Not offered 2022-23)

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, Mathematics 33A, and one course from Civil Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, Mathematics 170E, or Statistics 100A. Designed for engineering students as well as students from other disciplines interested in computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Topics include basic concepts of information security necessary for students to understand risks and mitigation approaches related to systems and data. Topics include secure systems, encryption, key management, security and privacy threats and risk analysis, access control and authentication/authorization, cryptography, network security, secure application design, and ethics and law. Letter grading. Mr. Reinman, Mr. Sankararaman (Sp)

C131A. Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 131. How different programming language paradigms provide dramatically different ways of thinking about computation and offer trade-offs on many dimensions, such as modularity, extensibility, expressiveness, and safety. Concrete exploration of three major programming paradigms: imperative, functional, and logic programming—by prototyping implementations of languages in each. Analysis of prototypes to shed light on design and structural properties of each language and paradigm and to allow easy comparison against one another. Hands-on experience implementing new abstractions, both as stand-alone languages and as libraries in existing languages. Concurrently scheduled with course C237A. Letter grading. (Not offered 2022-23)

C137B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced requisite: course C137A. Study of various programming language design history and research literature, that attempt to address problems of software systems that are bloated, buggy, and difficult to maintain and extend despite trend in computing toward ever higher levels of abstraction for programming. Hands-on experience designing, prototyping, and evaluating new languages, language abstractions, and/or programming environments. Concurrently scheduled with course C237B. Letter grading. Mr. Mr. Mirzasoleiman (W)

C137E. Introduction to Machine Learning. (4) (Same as Electrical and Computer Engineering M146.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 32 or Program in Computing 10C, Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A or Mathematics 170A or 170E or Statistics 100A; Mathematics 33A. Introduction to breadth of data science. Foundations for modeling data and understanding the principles and tools for data analysis, and application of tools and models to data gathering and analysis. Topics include statistical foundations, regression, classification, kernel methods, clustering, expectation maximization, principal components analysis, reinforcement learning and deep learning. Letter grading. Mr. Chang, Mr. Grover, Mr. Sankararaman (FW,Sp)

M148. Introduction to Data Science. (4) (Same as Electrical and Computer Engineering M148.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 31 or Program in Computing 10A, and 10B, and one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, Mathematics 170E, or Statistics 100A. How to analyze data in real world so as to understand corresponding phenomenon. Covers topics in machine learning, data analytics, and scientific computing, including data analysis, feature selection, data engineer, model selection, and prediction methodologies. Letter grading. Ms. Mirzasoleiman (W)

M151B. Computer Systems Architecture. (4) (Same as Electrical and Computer Engineering M151B.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 33, and M51A or Electrical and Computer Engineering M151C. Recommended: courses 111, and M152A or Electrical and Computer Engineering M116L. Computer system organization and design, implementation of CPU datapath and control, instruction set design, memory hierarchy (caches, main memory, virtual memory), organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading. Mr. Mr. Reinman, Mr. Tamir (W,Sp)

M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical and Computer Engineering M152A.) Laboratory, four hours; discussion, two hours; outside study, six hours. Requisites: course M51A or Electrical and Computer Engineering M151C. Introduction to design, implementation, and debugging of digital logic circuits, use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits using programmed array logic, design projects. Letter grading. Mr. Sarrafzadeh (FW,Sp)

M152B. Digital Design Project Laboratory. (2) Laboratory, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M151B or Electrical and Computer Engineering M151C. Special topics in the design, implementation, and testing of complex digital systems using field-programmable gate arrays (e.g., process-ors, special-purpose processors, and input/output interfaces). Students work in teams to develop and implement designs and to document and present their work. Letter grading. Mr. Sarrafzadeh (FW,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 how to represent knowledge in artificial intelligence. Introduction to Lisp with regular programming assignments. State-space and problem reduction methods, brute-force and heuristic search, planning techniques, two-phase look-ahead structures including predicate logic, production systems, semantic nets and primitives, frames, scripts. Special topics in natural language processing, expert
74B. Introduction to Computer Graphics: Three-Dimensional 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 and light to capture shape and appearance of real objects and scenes. Provides simple way to acquire three-dimensional models of uncalibrated detail and employs computer-generated imagery (CGI) to produce high-quality animation (reverse engineering and postprocessing of movies, generation of realistic synthetic objects and characters) to medicine (modelling of biological structures from imaging data), mixed reality (augmentation of video and haptics), digital cinema and entertainment, homomorphic encryption, private information retrieval and voting protocols, message authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, and two-party secure communication with static security. Letter grading. (Not offered 2022-23)

M184. Introduction to Computational and Systems Biology. (Same as Bioengineering M184 and Computational and Systems Biology M184.) Lecture, two hours; outside study, four hours. Enforced requisite: 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 modeling and simulation in biology and medicine, providing motivation, flavor, culture, and cutting-edge contributions in computational biology and engineering and aiming for in more informed basis for focused studies by students with computational and systems biology interests. Presentations by non-individual UCLA researchers discussing their active computational and systems biology research. P/NP grading.

Mr. Eskin (F)

CM186. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Bioengineering CM186, Computational and Systems Biology M186, and Ecology and Evolutionary Biology M178.) Lecture, four hours; laboratory, two hours; discussion, one hour. Enrolled requisite: Life Sciences 30A, 30B, Mathematics 32A or 32T, 33A, and 33B; or Mathematics 31A, 31B, 32A or 32T, 33A, and 33B. Dynamic system modeling and computer simulation methods for studying biological/medical processes and systems at multiple levels of organization. Intermediate linear and nonlinear control system, multicompartamental, epidemiological, pharmacokinetic, and other biomodeling methods applied to life sciences problems at molecular, cellular, organ, and population levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into dynamical mathematical models, and implementing them for simulation, quantification, and analysis. Numerical simulation, optimization, and parameter identifiability and sensitivity analysis algorithms, and online application and analysis and software exercises in PC laboratory assignments. Concurrently scheduled with course CM286. Letter grading. Mr. DiStefano (Sp)

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. Requisites: course CM182 or CM186 or Computational and Systems Biology M150; and research experience (course 199, Bioengineering 199, Computational and Systems Biology 199, or equivalent). Closely directed, interactive, and real research experience in active quantitative research laboratories. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Critiques of oral presentations and writing skills. Explain how to present with research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM287. P/NP grading. (Not offered 2022-23)

188. Special Courses in Computer Science. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Special topics in computer science for undergraduate students taught on experimental or temporary basis, such as taught by resident and visiting faculty members. May be repeated for credit with topic or instructor change. Letter grading. (F,W,Sp)
188A. Individual Studies for USIE Facilitators. (1) Tutorial, to be arranged. Enforced prerequisite: course 188BS. Enforced corequisite: Honors Colloquium 101E. Limited to junior/senior USIE facilitators. Individual study in regularly scheduled meetings with faculty mentor to discuss selected USIE seniors' topics. Contact preparatory reading and begin preparation of syllabus. Individual contract with faculty mentor required. May not be repeated. Letter grading.

188B. Individual Studies for USIE Facilitators. (1) Tutorial, to be arranged. Enforced prerequisite: course 188BS. Limited to junior/senior USIE facilitators. Individual study in regularly scheduled meetings with faculty mentor while facilitating USIE 88S course. Individual contract with faculty mentor required. May not be repeated. Letter grading.

188SC. Individual Studies for USIE Facilitators. (2) Tutorial, to be arranged. Enforced prerequisite: course 188BS. Limited to junior/senior USIE facilitators. Individual study in regularly scheduled meetings with faculty mentor while facilitating USIE 88S course. Individual contract with faculty mentor required. May not be repeated. 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 192A (may be taken concurrently), and at least one term of experience in science content in which collaborative learning theory is practiced and refined under supervision of instructors. With instructor guidance, students apply pedagogical principles based on current education research, assist with development of innovative instructional materials, and receive frequent feedback on their progress. May be repeated four times for credit. Letter grading.

M192A. Introduction to Collaborative Learning Theory and Practice. (1) Formerly numbered 192A. (Same as Chemistry M192E, Life Sciences M192A, Mathematics M192A, and Physics M192S.) Seminar, one hour. Training seminar for undergraduate students who are selected for learning assistant (LA) program. Exploration of current topics in pedagogy and education research focused on methods of learning and their practical application in small-group settings. Students practice communication skills with frequent assessment of and feedback on progress. Letter grading. (F,WSp)

194. Research Group Seminars: Computer Science. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. May be repeated for credit. Letter grading. (F,WSp)

199. Directed Research in Computer Science. (2-8) Seminar, four hours; outside study, eight hours. Enforced prerequisite: course 112. Directed research in computer science. Individual contract with faculty mentor required. May not be repeated. Letter grading. (Not offered 2022-23)

203. Health Analytics. (4) Lecture, four hours; outside study, eight hours. Recommended: statistics and probability, numerical methods, knowledge in programming languages. Applied data analytics course, with focus on healthcare data, to learn under- and analyze health data. Project-based course to learn about best practices in health data collection and validation. Exploration of various machine learning and data science tools to learn underlying structure of datasets to solve healthcare problems. Different machine learning concepts and algorithms, statistical models, and building of data-driven models. Big data analytics and tools for handling structured and unstructured data sets. Letter grading. Mr. Sarrafzadeh (W)


M213A. Embedded Systems. (4) Same as Electrical and Computer Engineering M202A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced prerequisite: course 211. Design and analysis of computer and electrical systems for embedded applications. Topics include hardware and software platforms for embedded systems, techniques for modeling and specification of system behavior, software organization and system scheduling, real-time communication and packet scheduling, low-power and energy-aware system design, timing synchronization, fault tolerance and debugging, and techniques for hardware and software architecture optimization. Theoretical foundations as well as practical design methods. Letter grading. (Not offered 2022-23)

M213B. Energy-Aware Computing and Cyber-Physical Systems. (4) Same as Electrical and Computer Engineering M202B.) Lecture, four hours; outside study, eight hours. Required: course M51A or Electrical and Computer Engineering 16B. Recommended: courses 111, and M115B or Electrical and Computer Engineering M116C. System-level management and cross-layer methods for power and energy consumption in computing and communication at various scales including multiprocessor, mobile, personal, enterprise, and data-center scale. Computer networking, sensing, and control technologies and algorithms for improving energy sustainability. Human-machine interaction, user models. Topics include modeling of energy consumption, energy sources, and energy storage; dynamic power management; power-performance scaling and energy proportionality; duty-cycling; power-aware scheduling; low-power modeling and management; thermal management; sensing of power consumption. Letter grading. (Not offered 2022-23)

214. Big Data Systems. (4) Lecture, four hours; discussion, two hours; outside study. Enforced prerequisite: course 111. Modern computing has entered era of big data. Introduction to concepts and state-of-art in modern big data systems. Study of current computer storage and network, which generate and analyze data. Exploration of various systems, which provide foundation for other systems. Discussion of systems built for specific kinds of workloads, such as processing of streaming data, relational data, business data, graph data, as well as machine learning. Letter grading.

216. Network Algorithmics. (4) Lecture, four hours; outside study, eight hours. Recommended prerequisite: course 211. Overview of basic data structures, algorithms, and design techniques. Fundamental structures, including trees, binary heaps, hash tables, graphs, and basic graph algorithms. Models of network devices and hardware design. Principles for efficient implementation. Lookup algorithms (exact match, prefix lookups, advanced data structures). Traffic measurement and network security. Letter grading. (Not offered 2022-23)

217A. 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 cross-layer methods for power and energy management. Letter grading. Mr. Zhang (F)

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 cross-layer methods for power and energy management. Letter grading. Ms. Zhang (W)


219. Current Topics in Computer System Modeling Analysis. (4) Lecture, eight hours; outside study, four hours. Review of current literature in area of computer system modeling. Each instructor has developed special proficiency as consequence of research interests. Students report on select topics. May be repeated for credit with consent of instructor. Mr. Abhari, Mr. Lu, Mr. Varghese (W,Sp)

CM221. Introduction to Bioinformatics. (4) Same as Bioinformatics M221, Chemistry CM260A, and Human Genetics M260A.) Lecture, four hours; discussion, two hours. Requisite: Bioinformatics M221, Computer Science M222A, and Informatics 260A.) Recommended: Biocomputing, Computational and Statistical Biophysics 221, and/or Introduction to Bioinformatics 221. Hours. Recommended: Bioinformatics computing skills. Enforced prerequisite: courses 199 and 202. Introduction to bioinformatics and methodologies, computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment. Recommended: Bioinformatics 312 or Introduction to Genomics 312. Letter grading. Mr. Pimentel (W)

CM222. Algorithms in Bioinformatics. (4) Same as Bioinformatics M222 and Chemistry CM260B.) Lecture, four hours; discussion, two hours. Requisites: course 32 or Program in Bioinformatics and Computer Science 12, grade of C– or better, and one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 110, Mathematics 120A, Mathematics 120B, or Statistics 100A. This course provides an introduction to the field of bioinformatics and its applications in the life sciences. Students will learn the principles and techniques of bioinformatics, including sequence analysis, protein structure prediction, and genome assembly. The course will also cover a variety of bioinformatics tools and software used in the field. Letter grading. (Not offered 2022-23)
M229S. Seminar: Current Topics in Bioinformatics, genomics, and computational biology students as well as students from biological sciences and medical school. Introduction to 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 dynamic programming, database searching, and genomic sequence alignment. Focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Computational techniques include dynamic programming, database searching, and genomic sequence alignment.
developed special proficiency as consequence of re-
search interests. May be repeated for credit with con-
tinue. (Not offered 2022-23)
240A. Databases and Knowledge Bases. (4) Lec-
ture, four hours; outside study, eight hours. Requi-
sites: courses 143, 240A. Logical models for data and
knowledge representation. Rule-based
languages and nonmonotonic reasoning. Temporal que-
ries, spatial queries, and uncertainty in deductive da-
tabases and object relational databases (ORDBs). Abstract data types and user-defined column func-
tions in ORDBs. (S)
Semistruc-
tured information. Letter grading. (Not offered 2022-23)
240B. Advanced Data and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requi-
sites: courses 143, 240A. Logical models for data and
knowledge representation. Rule-based languages and nonmonotonic reasoning. Temporal queries, spatial queries, and uncertainty in deductive databases and object relational databases (ORDBs). Abstract data types and user-defined column functions in ORDBs. (S)
Semistructured information. Letter grading. (Not offered 2022-23)
241B. Pictorial and Multimedia Database Manage-
ment. (4) Lecture, three and one half hours; discus-
sion, 30 minutes; laboratory, one hour; outside study
seven hours. Requisite: course 143. Multimedia data: alphanumeric, long text, images/pictures, video, voice. Multimedia information systems requirements. Data modeling, index structures, access methods, and search through internet by alphanumeric, image, video, and audio content. Querying, visual languages, and communication. Database design and organization, logical and physical design, data compression, multimedia streaming. Other topics at discretion of in-
structor. Letter grading. (Not offered 2022-23)
244A. Distributed Database Systems. (4) Lecture,
four hours; outside study, eight hours. File allocation, intelligent directory design, transaction management, distributed database architectures. Advanced topic, four hours; outside study, eight hours. Letter grading. (Not offered 2022-23)
245. Big Data Analytics. (4) Lecture, four hours; dis-
cussion, two hours; outside study, six hours. Requi-
sites: course 143 or 180 or equivalent. With unprece-
tented rate at which data is being collected today, almost all fields of human endeavor, there is emerging economic and scientific need to extract useful information from it. Data analytics is process of automating decision making, clustering, associa-
tions, 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 ana-
ytics and latest advances, as well as wide spectrum of applications such as bioinformatics, E-commerce, environmental study, financial market study, multi-
data mining algorithms, network monitoring, social media analysis. Letter grading. (Not offered 2022-23)
246. Web Information Management. (4) Lecture,
four hours; discussion, two hours; outside study, six
hours. Requisites: courses 112, 143, 180, 181. De-
sign for graduate students. Scale of Web data re-
quires novel algorithms and principles for their man-
ger and retrieval. Study of Web characteristics and new methods. Systems that merge Web structures and knowledge need to build computer systems suitable for Web environment. Topics include Web measuring techniques, large-scale data mining algorithms, efficient page refresh-
techniques, Web search algorithms, and query processing techniques on independent data sources. Letter grading. (Not offered 2022-23)
247. Advanced Data Mining. (4) Lecture, four hours;
discussion, two hours; outside study, six hours. Requi-
site: course 145 or M146 or equivalent. Introduction of concepts, algorithms, and techniques of data mining on different types of datasets, covering basic
scalability of machine learning algorithms on large data. Emphasized optimization variants of poly-time, distributed training, federated learning, data summarization, robust learning, neural network pruning, neural architecture search, neural network quantization. Letter grading.

261A. Problem Solving and Search. (4) Lecture; four hours; outside study, eight hours. Requisite: course 180. In-depth treatment of systematic problem-solving search algorithms in artificial intelligence, including problem spaces, brute-force search, heuristic search, linear-space algorithms, real-time search, heuristic evaluation functions, two-player games, and constraint-satisfaction problems. Letter grading. (Not offered 2022-23)

262A. Learning and Reasoning with Bayesian Networks. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Requisite: course 112 or Electrical Engineering 131A. Review of several formalisms for representing and managing uncertainty in reasoning systems; presentation of comprehensive description of Bayesian inference using belief networks representation. Letter grading.

Mr. Darwiche (W)

M262C. Current Topics in Causal Modeling, Inference, and Reasoning. (4) Same as Statistics M241A. Lecture; four hours; outside study, eight hours. Requisite: one graduate probability or statistics course such as course 210A, 210B, 202B, 205B, or 208B, and a general view of Bayesian networks, causal Bayesian networks, and structural equations. Learning causal structures from data. Identifying causal effects. Covariate adjustment in experimental and nonparametric models. Simpson paradox and confounding control. Logic and algorithmization of counterfactuals. Probabilities of counterfactuals. Direct and indirect effects. Probabilities of causation. Identifying causes of events. Letter grading. (Not offered 2022-23)

262Z. Current Topics in Cognitive Systems. (4) Lecture; four hours; outside study, eight hours. Requisite: one from course 262A, 262B, 262C, 262D, 265A, 269A, 276A, 276B, 276C, 276D, or Electrical Engineering 131A. Recent trends in NLP. Students gain ability to apply NLP techniques in text-orientated applications, and recent trends in NLP. May be repeated for credit with topic change. Letter grading. (Not offered 2022-23)

263A. Language and Thought. (4) Lecture; four hours; outside study, six hours. Natural language processing (NLP) enables computers to understand and process human language. NLP techniques have been widely used in many applications, including machine translation, question answering, machine summarization, and information extraction. Study of fundamental elements and recent trends in NLP. Students gain ability to apply NLP techniques in text-oriented applications, understand machine learning and algorithms used in NLP, and propose new approaches to solve NLP problems. Letter grading. Mr. Chang, Ms. Peng (Sp)

263C. Animats-Based Modeling. (4) Lecture; four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Introduction to natural language processing (NLP), with emphasis on semantics. Presentation of process models for variety of tasks, including question answering, paraphrasing, machine translation, word-sense disambiguation, narrative and editorial comprehension. Examination of both symbolic and statistical approaches to language processing and acquisition. Letter grading. (Not offered 2022-23)

268S. Seminar: Computational Neuroscience. (2) Seminar; two hours; outside study, four hours. Discussion of advanced topics and current research in computational neuroscience. Neural networks and connectionism as paradigms for parallel and concurrent computing. Applications of perception, vision, multimodal sensory integration, and robotics. May be repeated for credit. S/U grading. (Not offered 2022-23)

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

C274C. Computer Animation. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Enforced requisite: course 174A. Introduction to computer animation, including basic principles of character modeling, forward and inverse kinematics, forward and inverse dynamics, motion capture animation techniques, physics-based animation of particles and systems, and motor control. Concurrently scheduled with course C174C. Letter grading. (Not offered 2022-23)

275. Artificial Life for Computer Graphics and Vision. (4) Lecture; four hours; outside study, eight hours. Enforced requisite: course 174A. Recommended: course 161. Investigation of important role that concepts from artificial life, emerging discipline that spans computational and life sciences, can play in construction of advanced computer graphics and vision models for virtual reality, animation, interactive games, active vision, sensor networks, medical image analysis, etc. Focus on comprehensive models that can realistically emulate variety of living things (plants and animals) from lower animals to humans. Exposure to effective computational modeling of natural phenomena of life and their incorporation into sophisticated, self-animating graphical entities. Specific topics include modeling plants using L-systems, biomechanical simulation and control, behavioral animation, reinforcement and neural-network learning of locomotion, cognitive modeling, animal artificial humans, human facial animation, and artificial evolution. Letter grading. (Not offered 2022-23)

M276A. Pattern Recognition and Machine Learning. (4) Same as Statistics M231A.) Lecture; four hours; discussion, two hours; outside study, six hours. Enforced requisite: one from course 262A, Statistics 200B, or 202B. Requisite: one graduate probability or statistics course (e.g., course 210A, 210B, 202B). Introduction to theory, parametric and nonparametric learning, clustering and classification, pattern recognition, decision trees, neural networks, medical image analysis, etc. Focus on comprehensive models that can realistically emulate variety of living things (plants and animals) from lower animals to humans. Exposure to effective computational modeling of natural phenomena of life and their incorporation into sophisticated, self-animating graphical entities. Specific topics include modeling plants using L-systems, biomechanical simulation and control, behavioral animation, reinforcement and neural-network learning of locomotion, cognitive modeling, animal artificial humans, human facial animation, and artificial evolution. Letter grading. (Not offered 2022-23)

280A-280D. Approximation Algorithms. (4 each) Lecture; four hours; outside study, eight hours. Requisite: course 180. Additional requisites for each offering announced in advance by department. Selections from design, analysis, optimization, and implementation of algorithms; computational complexity and general theory of algorithms; algorithms for particular application areas. Subtitles of some current sections: Principles of Design and Analysis (280A); Distributed Algorithms (280B); Graphs and Networks (280C). May be repeated for credit with consent of instructor and topic change. Letter grading. (Not offered 2022-23)
CM286. Computational Systems Biology: Modeling and inference in biological systems. (4) (Same as Bioengineering CM286.) Lecture, four hours; laboratory, two hours; discussion, one hour. Requisites: Life Sciences 32A, 30B, Mathematics 23A, 23B, 31A, 31B, 32A or 32T, 33A, and 33B; or Mathematics 51A, 51B, 51C, 51D, 131A, 131B, 132A or 132T, 133A, and 133B. Dynamic bio-system modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization: intracellular and extracellular linear and nonlinear control system, multicompartmental, epidemiological, pharmacokinetic, and other biomodeling methods applied to life sciences problems at molecular, cellular, organ, and population levels. Emphasis on theory and data-driven modeling, with focus on translating biomodeling goals and data into dynamical mathematical models, and implementing them for simulation, quantification, and analysis. Numerical simulation, optimization, and parameter identifiability and analysis and software exercises in PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading. Mr. D’Safero (Sp).

CM287. Research Communication in Computational and Systems Biology. (4) (Same as Bioengineering CM287.) Lecture, four hours; outside study, eight hours. Requisites: course M182 or CM286 or Computational and Systems Biology 199; and research experience (course 199, Bioengineering 199, Computational and Systems Biology 199, or equivalent). Closely directed, interactive, and real research experience in actions biology research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Etiquettes of oral presentations and written progress reports and how to proceed with search for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM187. Letter grading. (Not offered 2022-23)

288S. Seminar: Theoretical Computer Science. (2) Seminar, two hours; outside study, six hours. Requisites: courses 280A, 280A. Intended for students undertaking thesis research. Discussion of advanced topics and current research in such areas as algorithms and complexity models for parallel and concurrent computation, and formal language and automata theory. May be repeated for credit. S/U grading. (Not offered 2022-23)

288A. Current Topics in Computer Theory. (4) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer theory in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. Letter grading. (Not offered 2022-23)

289A. Current Topics in Computer Theory: Randomized Algorithms. (4) Lecture, four hours; outside study, eight hours. Basic concepts and design techniques for randomized algorithms, such as probabilistic analysis, Markov chains, 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 2022-23)

289G. Current Topics in Computer Theory. (4) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer theory in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. Letter grading. (Not offered 2022-23)

M296A. Advanced Modeling Methodology for Dynamic Biomedical Systems. (4) (Same as Bioengineering M296A, and Medicine M270A) Lecture, four hours; outside study, eight hours. Requisites: Electrical Engineering 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Development of dynamic system models via methodology for physiological, biomedical, pharmaceutical, chemical, and related systems. Control system, multicompartamental, noncompartmental, and input/output models, linear and nonlinear analysis on model applications, limitations, and relevance in biomedical sciences and other limited data environments. Problem solving in PC laboratory. Letter grading. (Not offered 2022-23)

M296B. Optional Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Same as Bioengineering M296B, Biomathematics M270, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisites: models, output models, limit horns, population. Emphasis on use of selected topics. Letter grading. (Not offered 2022-23)

M296C. Advanced Topics and Research in Biological Systems Modeling. (4) (Same as Bioengineering M296C and Medicine M270E) Lecture, four hours; outside study, eight hours. Requisite: course M296B. Research techniques and experience on special topics involving models, modeling methods, and model/computing in biological and medical sciences. Review and critique of literature. Research problem searching and formulation; approaches to solutions. Individual MS- and PhD-level project training. Letter grading. (Not offered 2022-23)

M296D. Introduction to Computational Cardiologia. (4) (Same as Bioengineering M296D) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac electro-physiological processes. Ionic models of action potential (AP). Theory of AP propagation in one-dimensional and two-dimensional tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading. (Not offered 2022-23)

298. Research Seminar: Computer Science. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate computer science students. Discussion of advanced topics and current research in algorithmic processes that describe and
transform information: theory, analysis, design, efficiency, implementation, and application. May be repeated for credit. S/U grading.
495. Teaching Assistant Training Seminar. (2) 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.

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Graduate Studies

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Electrical and Computer Engineering Department / 85
Overview

Electrical and computer engineers are responsible for inventions that have revolutionized our society, such as the electrical grid, telecommunication, 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. It 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; School of Education and Information Studies; School of Theater, Film, and Television; and College of Letters and Science.

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.

Research

The primary areas in the department are circuits and embedded systems, computer engineering, physical and wave electronics, and signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, computer vision, control systems, cybersecurity, electromagnetics, embedded computer networking, embedded computing systems, engineering optimization, integrated circuits and systems, machine learning, micromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

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.

Undergraduate Study

Computer Engineering BS

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

Capstone Major

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.

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; (4) continue to learn as part of a graduate program or otherwise in the world of constantly evolving technology.

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 96I; 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), M131B (or Electrical and Computer Engineering M116C), M152A (or Electrical and Computer Engineering M116L), 180; Electrical and Computer Engineering 100, 102, 113, 115C; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 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 BS Degrees on page 21 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.

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

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

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

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

**Electrical Engineering BS**

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.

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

**Capstone Major**

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.

**Educational Objectives**

The electrical engineering curriculum provides an excellent background for either graduate study or employment. Undergraduate education in the department provides students with (1) fundamental knowledge in mathematics, physical sciences, and electrical engineering; (2) the opportunity to specialize in specific areas of inter-
est 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.

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, 113A; six core courses selected from Computer Science 33, Electrical and Computer Engineering 101B, 115A, 121B, 123A, 133A, 141, 170A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 12 units of major field elective courses, at least 8 of which must be upper-division electrical and computer engineering courses—the remaining 4 units may be from upper-division electrical and computer engineering courses or from another UCLA Samueli department; and one two-term electrical and computer engineering capstone design course (8 units).

Electrical and Computer Engineering 100 and CM182 may not satisfy elective credit. For information on UC, school, and general education requirements, see Requirements for BS Degrees on page 21 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, 134, 141, and 142 and 8 capstone design units from 113DA/113DB or 184DA/184DB.

Electromagnetic Systems: Topics include the fundamentals of electromagnetic wave propagation in guided systems and free space, antennas, and radio systems. Students might take 12 units selected from Electrical and Computer Engineering 101B, 162A, 163A, and 163C and 8 capstone design units from 163DA/163DB or 164DA/164DB.

Embedded Computing: The study of compact systems that include collections of integrated circuits that interact with the physical world for purposes such as sensing and control in applications as diverse as appliances, automobiles, and medicine. Students might take 12 units selected from Electrical and Computer Engineering 115A, 115C, M116C, M116L, M119, and 142 and 8 capstone design units from 180DA/180DB or 183DA/183DB.

Integrated Circuits: The study of how to achieve large-scale integration of thousands to billions of computational, memory, and sensing elements in single or multicircuit modules. Students might take 12 units selected from Electrical and Computer Engineering 115A, 115AL, 115B, 115C, and 115E and 8 capstone design units from 164DA/164DB or 183DA/183DB.

Photonics and Plasma Electronics: The study of how to manipulate light and plasmas to create devices such as those that enable high-speed optical communication systems. Students might take 12 units selected from Electrical and Computer Engineering 170A, 170B, 170C, and M185 and 8 capstone design units from 173DA/173DB.

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 microscopic 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, 101, 102, and 110 and/or 12 units from Computer Science CM121, Electrical and Computer Engineering 114, 133B, 134, and 176 and 8 capstone design units from 180DA/180DB.

Computer Engineering (CE) concentrates on the part of the hardware/software stack related to the design of new processors and the operation of embedded systems. Students might take a 12-unit technical breadth area in computer science such as Computer Science 111, 117, 130, and 180 and/or 12 units of electives from Electrical and Computer Engineering 115C, M116C, M116L, M119, 132B, and M146 and 8 capstone design units from 113DA/113DB or 180DA/180DB or 183DA/183DB.

Cyber Physical Systems (CPS) refer to networked systems that include sensors and actuators that interact with the physical world. They blend embedded systems with networking and control and include, for example, robotic systems and the Internet of things (IoT). Students might take a 12-unit technical breadth area in computer science such as Computer Science 111, 117, and 180 and/or 12 units of electives from Electrical and Computer Engineering M116C, 132B, and M142 and 8 capstone design units from 183DA/183DB.
Data Science Engineering Minor

The minor is intended to expose students to the entire data science life cycle from both foundational and application perspectives. The foundational courses provide the engineering skills to collect, cleanse, and store data; analyze and draw inference from data; and take action and make decisions. A wide-ranging list of interdisciplinary courses focuses on various data-science applications using these skills.

Admission

To apply for the minor, students must have an overall grade-point average of 3.0 or better, have completed or be in the process of completing the present quarter the two lower-division required courses with the grade B- or better, and file a petition through Message Center. Steps to apply are available from the Office of Academic and Student Affairs website. Information about the minor and the application are available on the minor website.

The Minor

Required Lower-Division Courses (8 units minimum): Computer Science 32, Mathematics 33A.

Required Upper-Division Courses (12 units minimum): One course from Civil and Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 170E, or Statistics 100A; Computer Science M148 or Electrical and Computer Engineering M148; Computer Science 145 or M146 or Electrical and Computer Engineering M146.

Elective Upper-Division Courses (8 units minimum): Two courses from Computer Science M119, CM121, CM122, CM124, 143, 145 or M146 (if not taken as a required course), 161, 180, M182, Electrical and Computer Engineering 102, 113, 114, M119, 133A, M146 (if not taken as a required course), C147, 183DA and 183DB (both must be taken), Mechanical and Aerospace Engineering C137, 185, Statistics 100B, 115, 170, or C180.

Policies

Variable topics courses may be taken as topics apply.

Transfer credit for any of the above is subject to approval; consult with the undergraduate counselors before enrolling in any courses for the minor.

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

Each minor course must be taken for a letter grade, and student must have a minimum grade of C 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 admission information, see Graduate Programs Admission on page 27.

The following introductory information is based on 2022-23 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 (MS) and Doctor of Philosophy (PhD) degrees in Electrical and Computer Engineering.

Electrical and Computer Engineering MS

Areas of Study

Students may pursue specialization across three major areas of study: (1) circuits and electronic 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 computer systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. Students must select a number of formal graduate courses to serve as their major and minor fields of study according to the requirements listed below for the thesis (seven courses) and non-thesis (eight courses) options. The selected courses must be approved by the faculty adviser.

Course Requirements

Students may select either the thesis plan or the non-thesis (comprehensive examination) plan. The selection of courses is tailored to the professional objectives of the students and must meet the requirements stated below. The courses should be selected and approved in consultation with the faculty adviser. Departures from the stated requirements are considered only in exceptional cases and must be approved by the departmental graduate adviser.

The minimum requirements for the MS degree are as follows:

1. **Requisite**: BS degree in Electrical Engineering or a related field

2. All MS program requirements should be completed within two academic years from admission into the MS 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 MS thesis, (e) no other 500-level courses, other seminar courses, nor Electrical and Computer Engineering 296 or 375 may be applied toward the course requirements, and (f) an MS thesis completed under the direction of the faculty adviser to a standard that is approved by a committee of three faculty members.

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 MS 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 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 MS 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 undergradu-
ate 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.

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 implementation of large-scale digital processors for communications and signal processing, hardware-software codesign, and computer-aided design methodologies. Courses include Computer Science 251A, 252A, Electrical and Computer Engineering 215A through 215E, M216A, 221A, 221B.

**Physical and Wave Electronics Area Tracks**

1. **Electromagnetics Track.** Courses deal with electromagnetic theory, propagation and scattering, antenna theory and design, microwave and millimeter wave circuits, printed circuit antennas, integrated and fiber optics, microwave-optical interaction, antenna measurement, and diagnostics, numerical and asymptotic techniques, satellite and personal communication antennas, periodic structures, genetic algorithms, and optimization techniques. Courses include Electrical and Computer Engineering 221C, 260A, 260B, 261, 262, 263, 266, 270.


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 determininistic linear and nonlinear systems; stochastic control; Kalman filtering; stability theory of linear and nonlinear feedback control systems; computer-aided design of control systems; optimization theory, including linear and nonlinear programming; convex optimization and engineering applications; numerical methods; nonconvex programming; associated network flow and graph problems; renewal theory; Markov chains; stochastic dynamic programming; and queuing theory. Courses include Electrical and Computer Engineering 205A, M208B, M208C, 210B, 236A, 236B, 236C, M237, M240A, M240C, 241A, M242A.


**Ad Hoc Tracks**

In consultation with their faculty advisers, students may petition for an ad hoc track tailored to their professional objectives. This may comprise graduate courses from established tracks, from across areas, and even from outside electrical and computer engineering. The petition must justify how the selection of courses in the ad hoc track forms a coherent set of courses, and how the proposed ad hoc track serves the professional objectives. The petition must be approved by the faculty adviser and the departmental graduate adviser.

**Comprehensive Examination Plan**

The MS 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 MS 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 MS individual study program is administered by the faculty member directing the course, the director of the area to which the students belong, and the vice chair of Graduate Affairs. Students who fail the examination may be reexamined once with consent of the vice chair of Graduate Affairs.

**Electrical and Computer Engineering PhD**

**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 PhD 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 PhD degree are as follows:

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

2. All PhD program requirements should be completed within five academic years from admission into the PhD 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 PhD 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 PhD 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 PhD dissertation under the direction of the faculty adviser; and (h) defend the PhD 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 MS degree requirements may not be applied toward the PhD 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 PhD program, all courses should be completed and the PhD preliminary examination should be passed. It is strongly recommended that students take the PhD 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 PhD preliminary examination

9. Students admitted originally to the MS program in the Electrical and Computer Engineering Department must complete all MS program requirements with a grade-point average of at least 3.5 to be considered for admission into the PhD program. Only after admission into the program can students take the PhD 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. 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 PhD preliminary examination in the department. The purpose of the examination is to assess student competency in the discipline, knowledge of the fundamentals, and potential for independent research. Students admitted originally to the MS program in the Electrical and Computer Engineering Department must complete all MS program requirements with a grade-point average of at least 3.5 to be considered for admission into the PhD program. Only after admission into the program can students take the PhD preliminary examination, which is held three times every year. Students are examined by a group of faculty members in their general area of study. 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 PhD 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. 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 (CEELN) 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; medical electronics; 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 National Development and Reform Commission as a U.S.–China EcoPartner. CERC–LA plans to have satellite offices in other cities including Shanghai and Beijing.

**Circuits Laboratories**

The 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 10/10011000 clean-room facility that supports graduate research and teaching. The facility includes the Nanolab, 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 investigate 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 undergraduates 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 spectograph 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 CO 2 radiation of 68.1TF (double precision). DAWSON 2 consists of 96 HP L390 nodes, each with 12 Intel X6550 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 for a total of 1152 CPUs and 288 GPUs; and three Nvidia M2070s GPUs and 18 GB of global memory; and three Nvidia M2070s GPUs and 18 GB of global memory.

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 Fusion Energy, and high-energy-density plasma science. DAWSON 2 consists of 96 HP L390 nodes, each with 12 Intel X6550 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 Pananas. Peak system performance is approximately 300TF/150TF (single/double precision) with a measured linpack performance of 68TF (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 characterization studies; thin film and characterization equipment; deep-level transient spectroscopy instruments; computerized capacitance-voltage and other characterization equipment, including doping density profiling systems; low-temperature facilities for material and device physics studies in cryogenic temperatures; optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices; and characterization equipment for high-speed devices, including high magnetic field facilities for magnetotransport measurement of heterostructures. The laboratory facilities are available to faculty, staff, and graduate students for their research.

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

- Algorithmic Research in Network Information Laboratory (Fragouli)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
- BioPhotonics Laboratory (Ozcan)
- CMOS Research Laboratory (Woo)
- Communication Circuits Laboratory (Razavi)
- Complex Networks Group (Roychowdhury)
- Cyber-Physical Systems Laboratory (Tabuada)
- Device Research Laboratory (K. Wang)
- Digital Microwave Laboratory (E. Wang)
- Energy and Electronic Design Automation Laboratory (He)
- High-Performance Mixed Mode Circuit Design Group (Yang)
- High-Speed Electronics Laboratory (Chang)
- Information Theory and Systems Laboratory (LiCOS) (Diggavi)
- Integrated Circuits and Systems Laboratory (Abidi)
- Interconnected and Integrated Bioelectronics Laboratory (I2BL) (Emanueljed)
- Laboratory for Embedded Machines and Ubiquitous Robotics (Mehta)
- Laser-Plasma Group (Joshi)
- Mesoscopic Optics and Quantum Electronics Laboratory (Wong)
- Nanoelectronics Research Center (Candler)
- NanoSystems CAD Laboratory (Gupta)
- 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)
- Quantum Biology Tech (QuBiT) (Aiello)
- Quantum Light-Matter Cooperative (Q-LMC) (Carbajo)
- Robust Information Systems Laboratory (Dolecek)
- Secure Systems and Architectures (SSysArch) (Sehatbakhsh)
- Security and Privacy Laboratory (Tian)
- 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)
Faculty Areas of Thesis Guidance

Professors

Asad A. Abidi, PhD (UC Berkeley, 1981)
High-performance analog electronics, device modeling

Abeer A.H. Alwan, PhD (MIT, 1992)
Computational medical imaging, machine learning, image segmentation, and computer vision

Aydogan Ozcan, PhD (Stanford, 2005)
Microscopy, microfluidics, and microscale systems design

Behzad Razavi, PhD (Stanford, 1992)
Circuit design, mixed-signal circuits, and embedded systems

Vahid R. Roychowdhury, PhD (Stanford, 1989)
Circuit design, mixed-signal circuits, and embedded systems

Corey W. Arnold, PhD (UCLA, 2009)
High-performance analog electronics, device modeling

Danijela Cabric, PhD (UC Berkeley, 2007)
Wireless communications systems design, cognitive radio networks, and VLSI architectures

Dwight C. Streit, PhD, NAE (UCLA, 1986)
Optimization in engineering and applications

Erdinç I. Altunbas, PhD (UC Berkeley, 1984)
Optical communications, quantum systems, and quantum computing

Ferdi McMahan, PhD (UCLA, 2010)
Network coding, information theory, and cryptography

Geoffrey Yeakel, PhD (UCLA, 2010)
Wireless communications, signal processing, and machine learning

Behnoosh Bayat, PhD (UC Berkeley, 1985)
Circuit design, mixed-signal circuits, and embedded systems

Christina Fragouli, PhD (UCLA, 2000)
Coding theory and algorithms applications

Katsushi Arisaka, PhD (U. Tokyo, Japan, 1985)
Circuit design, mixed-signal circuits, and embedded systems

Michael A. Noll, PhD (UCLA, 2001)
High-performance analog electronics, device modeling

Majid Sarrafzadeh, PhD (U. Illinois, 1987)
Circuit design, mixed-signal circuits, and embedded systems

Mona Jarrahi, PhD (Stanford, 2007)
Circuit design, mixed-signal circuits, and embedded systems

Mona Jarrahi, PhD (Stanford, 2007)
Circuit design, mixed-signal circuits, and embedded systems

Subramanian S. Iyer, PhD (UC Berkeley, 1992)
Circuit design, mixed-signal circuits, and embedded systems

Subramanian S. Iyer, PhD (UC Berkeley, 1992)
Circuit design, mixed-signal circuits, and embedded systems

Vahid R. Roychowdhury, PhD (Stanford, 1989)
Circuit design, mixed-signal circuits, and embedded systems

Warren B. Mori, PhD (UCLA, 1987)
Circuit design, mixed-signal circuits, and embedded systems

Abeer A.H. Alwan, PhD (MIT, 1992)
Computational medical imaging, machine learning, image segmentation, and computer vision

Rafael E. Blau, PhD (UCLA, 2010)
Information theory and algorithms applications

Rafael E. Blau, PhD (UCLA, 2010)
Information theory and algorithms applications

Robert N. Candler, PhD (Stanford, 2006)
MEMS/NEMS for compact free-electron lasers, optical devices, and nanoscale systems

Robert N. Candler, PhD (Stanford, 2006)
MEMS/NEMS for compact free-electron lasers, optical devices, and nanoscale systems

Samuel J. Stine, PhD (UCLA, 2009)
Information theory and algorithms applications

Samuel J. Stine, PhD (UCLA, 2009)
Information theory and algorithms applications

Sudhakar Pamarti, PhD (UC San Diego, 2003)
Circuit design, mixed-signal circuits, and embedded systems

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Circuit design, mixed-signal circuits, and embedded systems

Sudhakar Pamarti, PhD (UC San Diego, 2003)
Circuit design, mixed-signal circuits, and embedded systems

Sudhakar Pamarti, PhD (UC San Diego, 2003)
Circuit design, mixed-signal circuits, and embedded systems

Yahya Rahmat-Samii, PhD (U. Illinois, 1975)
Circuit design, mixed-signal circuits, and embedded systems

Yahya Rahmat-Samii, PhD (U. Illinois, 1975)
Circuit design, mixed-signal circuits, and embedded systems

Yahya Rahmat-Samii, PhD (U. Illinois, 1975)
Circuit design, mixed-signal circuits, and embedded systems

Yongwei Yang, PhD (UCLA, 1995)
Information theory and algorithms applications

Yongwei Yang, PhD (UCLA, 1995)
Information theory and algorithms applications

Yongwei Yang, PhD (UCLA, 1995)
Information theory and algorithms applications
Chee Wei Wong, Sc.D (MIT, 2003)
Ultrastable nonlinear optics, quantum communications and computing, chip-scale optoelectronics, precision measurements and sensing

Jason C.S. Woe, PhD (Stanford, 1987)
Solid-state technology, CMOS and bipolar device/circuit optimization, novel device design, modeling of integrated circuits, VLSI fabrication

C.-K. Ken Yang, PhD (Stanford, 1998)
High-performance VLSI design, digital and mixed-signal circuit design

Lixia Zhang, PhD (MIT, 1989)
Computer network, Internet architecture, protocol design, security and resiliency of large-scale systems

Professors Emeriti

Frederick G. Allen, PhD (Harvard, 1956)
Semiconductor physics, solid-state devices, surface physics

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

Babak Daneshfar, PhD (UCLA, 1993)
Digital VLSI communication systems, high-performance communications integrated circuits for wireless applications

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

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

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

Bahram Jalali, PhD (Columbia, 1989)
RF photonics, integrated optics, fiber optic integrated circuits

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

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

Dee-Son Pan, PhD (Caltech, 1977)
New semiconductor devices for millimeter and RF power generation and amplification, transport in high symmetry semiconductor devices, generic device modeling

Izhak Rubin, PhD (Princeton, 1970)
Telecommunications and computer communications systems and networks, mobile wireless networks, multimedia IP networks, UAV/UAV-aided networks, integrated system and network management, C4ISR systems and networks, optical networks, network simulation and analysis, traffic modeling and engineering

Ali H. Sayed, PhD (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

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

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

*Donald M. Wilberg, PhD (Caltech, 1965)
Identification and control, especially of aero-space, biomedical, mechanical, and nuclear processes, modeling and simulation of respiratory and cardiovascular systems

Alan N. Willson, Jr, PhD (Syracuse, 1967)
Theory and application of digital signal processing, including VLSI implementations, digital filter design, nonlinear circuit theory

Kung Yao, PhD (Princeton, 1965)
Communication theory, signal and array processing, sensor system, wireless communications systems, VLSI and systolic algorithms

Associate Professors

Aydn Babakhani, PhD (Caltech, 2008)
Millimeter-wave/terahertz integrated circuits, wirelessly powered single-chip circuits

Sam Emaminejad, PhD (Stanford, 2014)
Biological and chemical sensors, wearable and flexible electronics, MEMS and NEMS fabrication microfluidics, Internet of Things devices, terahertz identification for personalized/precision medicine

Alyson K. Fletcher, PhD (UC Berkeley, 2006)
Network neuroscience, machine learning, complex system theory, graphical models, statistical physics and inference, identification of neural systems

Assistant Professors

Omid Abari, PhD (MIT, 2017)
Internet of Things (IoT), wireless networking, mobile systems, software-hardware systems, human-computer interaction (HCI)

Clarice D. Aiello, PhD (MIT, 2014)
Experimental quantum sensing and control, experimental quantum biology, nanobioelectronics

Sergio Carbajo, PhD (U. Hamburg, Germany, 2015)
Ultrafast and nonlinear optics, quantum optics, accelerators and X-ray free electron lasers, quantum electrodynamics, physical chemistry, light-matter interactions

Xiang Anthony Chen, PhD (Carnegie Mellon, 2017)
Human-computer interaction, sensing and interaction techniques, intelligent interactive systems, computational design and fabrication

Achuta Kadambi, PhD (MIT, 2018)
Computational imaging, computer vision, robotics, medical devices

Jonathan C. Kao, PhD (Stanford, 2016)
Computational neuroscience, neural engineering, machine learning

Ankur Mehta, PhD (UC Berkeley, 2012)
Robotics and electromechanical systems design, fabrication, and control; wireless sensor networks hardware and applications; systems, teleoperation systems, integration

Nader Sehatbakhsh, PhD (Georgia Tech, 2020)
Security and privacy, computer architecture, embedded and IoT systems, hardware security, trustworthy AI/ML

Yuan Tian, PhD (Carnegie Mellon, 2017)
Security and privacy, cyber-physical systems, machine learning security and privacy, human-centered security and privacy

Lin F. Yang, PhD (Johns Hopkins, 2017)
Foundations for AI, machine learning theories and applications, reinforcement learning, statistical learning, big data algorithms, optimization control

* Also Professor Emeritus of Anesthesiology

Yang Zhang (Carnegie Mellon, 2020)
Human-computer interaction, sensing and interaction techniques, Internet of Things (IoT), digital health, accessibility

Adjunct Professors

Danish Divsalar, PhD (UCLA, 1978)
Information theory, communication theory, bandwidth-efficient combined coding modulation techniques, spread spectrum systems and mutual user interference cancellation for CDMA, turbo codes, binary and nonbinary LDPC codes, iterative decoding

Dan M. Goebel, PhD (UCLA, 1981)
Electric propulsion, high-efficiency ion and Hall thrusters, cathodes, high-voltage engineering, microwave devices and microwave communications, pulsed power

Mark F. Gyure, PhD (University of Colorado, 1990)
Statistical mechanics, phase transitions, inhomogeneous materials, dielectric breakdown

Asad M. Madni, PhD (California Coast, 1987)
Development and commercialization of intelligent sensors and systems, RF and microwave instrumentation, signal processing

Adjunct Associate Professor

Chi On Chui, PhD (Stanford, 2004)
Nanoelectronic and optoelectronic devices and technology, heterogeneous semiconductor-devices, monolithic integration of heterogeneous technology, exploratory nanotechnology

Adjunct Assistant Professor

Shervin Moloudi, PhD (UCLA, 2008)
Telecommunication analog and high-frequency circuit design

Electrical and Computer Engineering Courses

Lower-Division Courses

1. Undergraduate Seminar. (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. 

Mr. Jalali, Mr. Williams (F,Sp)

2H. Physics for Electrical Engineers. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: Physics 1C. Introduction to concepts of modern physics necessary to understand solid-state devices, including elementary quantum theory, Fermi energies, and levels of electrons in solids. Discussion of electrical properties of semiconductors leading to operation of junction devices. Letter grading.

Mr. Jalali, Mr. Williams (F,Sp)

2H. Physics for Electrical Engineers (Honors). (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: Physics 1C. Honors course parallel to course 2. Letter grading.

Mr. Williams (W)

3. Introduction to Electrical Engineering. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Introduction to field of electrical engineering. Basic circuits techniques with application to explanation of electrical engineering inventions such as telecommunication and electrical grid, automatic computing and control, and enabling device tech-

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Mr. Pottie (F,Sp)

10. Circuit Theory I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 (or Computer Science 1 or Materials Science 10), course 29L, Physics 1A. Corequisites: course 11L (enforced only for Computer Science and Engineering and Electrical Engineering majors), Mathematics 33B. Introduction to linear circuit analysis. Basic circuit properties, ideal transformers, Kirchhoff laws, node and loop analysis, first-order circuits, second-order circuits, Thévenin and Norton theorem, sinusoidal steady state. Letter grading.

Mr. Pamarti (F)

10H. Circuit Theory I (Honors). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. For advanced corequisite: course 10. Enforced requisite: course 10L. Time-variant fields and Maxwell equations, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radiation and resonant cavities. Letter grading.

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


Ms. Cabric, Ms. Fragouli (F,W)

110. Circuit Theory II. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. For advanced corequisite: course 10. Time-variant fields and Maxwell equations, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radiation and resonant cavities. Letter grading.

Mr. Pamarti (F)


Ms. Srivastava (F,Sp)

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of critical and creative 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.

89. Honors Seminars. (1) Seminar, three hours. Limited to 20 students. Designed as adjunct to lower-division lecture course. Exploration of topics in greater depth through supplemental readings, papers, or other activities as a part of lecture course material. May be applied toward honors credit for eligible students. Honors content noted on transcript. P/NP or letter grading.

Mr. Pottie

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

Upper-Division Courses

100. Electrical and Electronic Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Mathematics 33A, 33B or Mechanical Engineering 82, Physics 1C. Not open for credit to students with credit for course 110. Electrical quantities, linear circuit elements, circuit principles, signal waveforms, transient and steady state, operational amplifiers, semiconductors, J FETs and MOSFETs. Small-signal models, and operational amplifiers. Letter grading.

Mr. Razavi (F,Sp)

101A. Engineering Electromagnetics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. For advanced corequisite: course 101A. Time-variant fields and Maxwell equations, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radiation and resonant cavities. Letter grading.

Mr. Tabuada (F)

113D. Digital Signal Processing Design. (4) Lecture, four hours; discussion, one hour; outside study, six hours. Enforced requisite: course 113. Real-time implementation of digital signal processing algorithms on digital processor chips. Experiments in 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 algorithms for communications, radar, medical and other imaging, speech, music, or video using DSP hardware. In progress grading (credit to be given only on completion of full course). Letter grading.

Mr. Danesh farad (W)

113B. Digital Signal Processing Design I. (4) Laboratory, four hours; outside study, eight hours. For advanced corequisite: courses 113, 113DA. Real-time implementation of digital signal processing algorithms on digital processor chips. Letter grading. Letter grading.

Mr. Alwan (F)

114. Speech and Image Processing Systems Design. (4) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. For advanced corequisite: course 113. Design principles of speech and image processing systems. Speech production, analysis, and modeling in first half of course; design techniques for image enhancement, filtering, and transformation in second half. Lectures supplemented by laboratory implementation of speech and image processing tasks. Letter grading.

Ms. Abidi (Not offered 2022-23)

115A. Analog Electronic Circuits I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. For advanced corequisite: course 110. Review of basic circuit operation and topological and operational analysis of basic components: diode, transistor, and MOS transistors. Equivalent circuits and models of semiconductor devices. Analysis and design of single-stage amplifiers. DC biasing circuits. Small-signal analysis. Operational amplifier systems. Letter grading.

Mr. Abidi (F,Sp)

115AL. Analog Electronics Laboratory I. (2) Laboratory, four hours; outside study, two hours. For advanced corequisite: courses 110L or 111L. Experimental determination of device and circuit characteristics, including single-stage diode circuits, single-stage amplifiers, compound transistor stages, effect of feedback on single-stage amplifiers, operational amplifiers, and operational amplifier circuits. Introduction to hands-on design experience based on individual projects, including design and implementation tools. Letter grading.

Mr. Abidi (Not offered 2022-23)

115B. Analog Electronic Circuits II. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. For advanced corequisite: course 115A. Analysis and design of differential amplifiers in bipolar and CMOS technologies. Current mirrors and active loads. Frequency response of amplifiers. Feedback and its properties. Stability issues and frequency compensation. Letter grading.

Mr. Abidi (W)

115C. Digital Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. For advanced corequisite: course 115. Development of interconnection and packaging of inter-connected power systems. Development of appropriate models for interconnected power systems and learning how to perform power flow, economic dispatch, and short circuit analysis and introduction to power system transient dynamics. Letter grading.

Mr. Markovic, Mr. Yang (W,Sp)

115E. Design Studies in Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. For advanced corequisite: course 115. Design studies in the areas of power electronics, communication circuits, computer system design, computer-aided simulation of digital circuits. Letter grading.

Mr. Markovic, Mr. Yang (W,Sp)

115F. Design Studies in Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. For advanced corequisite: course 115. Design studies in the areas of power electronics, communication circuits, computer system design, computer-aided simulation of digital circuits. Letter grading.

Mr. Markovic, Mr. Yang (W,Sp)

115G. Design Studies in Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. For advanced corequisite: course 115. Design studies in the areas of power electronics, communication circuits, computer system design, computer-aided simulation of digital circuits. Letter grading.

Mr. Markovic, Mr. Yang (W,Sp)
Bibliography

128. Principles of Nanoelectronics. (4) Lecture, four hours; discussion, one hour; outside study, four hours. Requires: Physics 1C. Introduction to fundamentals of nanoscience for electronics nanosystems. Principal topics include: electron charge, electron confinement, quantum mechanical approximations for single and multi-electron systems. Emphasis on both theoretical and experimental analysis of transportation phenomena in nanoscale devices.

131A. Probability and Statistics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requires: course 102 (enforced), Mathematics 32B, 33B. Introduction to basic concepts of probability, including random variables and vectors, distributions and multivariate distributions, characteristic functions, and limit theorems. Applications to communication, control, and signal processing. Introduction to computer simulation and generation of random events. Letter grading.

132A. Introduction to Communication Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requires: course 102, 113, 131A. Review of basic probability, basics of information theory, fundamental limits on communication, signal-design tradeoffs for digital communications, basics of error control coding, intersymbol interference channels and orthogonal frequency division multiplexing (OFDM). Letter grading. Mr. Digavi (W)

132B. Data Communications and Telecommunication Networks. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requires: course 131A. Layered communication architectures. Queueing system modeling and analysis. Error control, flow and congestion control. Packet switched, circuit switching, and routing. Network performance evaluation. Multiprocessor communications: TDMA, FDMA, polling, random access. Local, metropolitan, wide area, integrated services networks. Letter grading. Mr. Rubin (F)


134. Graph Theory in Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Basics of graph theory, including trees, bipartite graphs, and distance labeling, five planar graphs and networks. Emphasis on reducing real-world engineering problems to graph theory formulations. Letter grading. Ms. Fragouli (Sp)

141. Principles of Feedback Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requires: course 102. Mathematical modeling of control physical systems in form of differential equations and transfer functions. Design problems, systematic derivation 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. Abidi (Sp)

142. Linear Systems: State-Space Approach. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requires: course 102. State-space methods of linear system analysis and synthesis with applications to networks, control, and system modeling. Letter grading. Mr. Tabuada (Not offered 2022-23)

C143A. Neural Signal Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requires: course 131A, Mathematics 33A. Topics include fundamental properties of electrical activity in neurons; technology for measuring neural activity; spiking statistics and Poisson processes; general models and classification; resonance and Kalman filtering; principal components analysis, factor analysis, and expectation maximization. Concurrently scheduled with course C243A. Letter grading. Mr. Kao (W)

M146. Introduction to Machine Learning. (4) (Same as Computer Science M146) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: course 131A or Civil and Environmental Engineering 110, Mathematics 170A or 170E or Statistics 100A; Computer Science 32 or Program in Computing 10C; Mathematics 33A. Introduction to breadth of data science. Foundations for modern data science, with emphasis on broad tools for exploratory data analysis, and application of tools and models to data gathering and analysis. Topics include statistical foundations, regression, classification, kernel methods, clustering, expectation maximization, principal components analysis, decision theory, reinforcement learning and deep learning. Letter grading. Mr. Kao (W)

C147. Neural Networks and Deep Learning. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: courses 131A, 133A or 205A, and M146, or equivalent. Review of machine learning concepts; maximum likelihood; supervised classification; neural networks; 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; short-term memory and gated recurrent units; variational autoencoders; generative adversarial networks; adversarial examples and training. Concurrently scheduled with course C247. Letter grading. Mr. Kao (W)

M148. Introduction to Data Science. (4) (Same as Computer Science M148) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: one course from 131A, Civil and Environmental Engineering 110, Mathematics 170A, Mathematics 170E, or Statistics 100A, and Computer Science 31 or Program in Computing 10A, and 10B. How to analyze data arising in real world to draw conclusions and understand corresponding phenomenon. Covers topics in machine learning, data analytics, and statistical modeling classically employed for prediction, comprehensive, hands-on overview of data science domain by blending theoretical and practical instruction. Data science lifecycle: data selection and cleaning, feature engineering, model selection, and prediction methodology. Letter grading. Mr. Kao (W)

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) (Same as Bioengineering M153, Chemical Engineering M153, and Mechanical and Aerospace Engineering M138B) Lecture, three hours; laboratory, four hours; outside study, five hours. Requires: Chemistry 20A, Physics 1A, 1B, 1C, 4AL. Introduction to general manufacturing methods, mechanisms, constrains, and micro-
interference, multipath fading, ray bending, and other
phenomena. Letter grading.
Mr. Rahmat-Samii (Sp)

162A. Wireless Communication Links and Antennas. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101B. Basic properties of transmitting and receiving antennas and antenna arrays. Friis transmission formula, radar equations, cell-site and mobile antennas, bandwidth budget. Noise in communication systems (transmission line theory, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other
propagation phenomena. Letter grading.
Mr. Rahmat-Samii (Sp)

163A. Introductory Microwave Concepts. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101B. Transmission line description of waveguides, impedance matching techniques, power dividers, multiplexers, couplers, active devices, transistor amplifier design. Letter grading. Mr. Babakhani (F)

163C. Introduction to Microwave Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 163DA. Theory and design of modern microwave systems such as satellite communication systems, radar systems, microwave sensors, and biological applications of microwaves. Letter grading. Mr. Y.E. Wang (W)

163DA. Microwave and Wireless Design I. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisites: courses 101A, 101B. Course 163DA is enforced requisite to 163DB. Limited to senior Electrical Engineering majors. Design and analysis of microwave and millimeter wave circuits and systems, with emphasis on both theoretical foundations and hands-on experience. Design of radio frequency transceivers and their building blocks according to given specifications or in form of open-ended problems. Introduction to advanced topics related to projects through lecture and laboratories. Creation by students of end-to-end systems in application context, manages testing and optimization metrics related to cost, performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations of project results. In Progress grading (credit to be given only on completion of course 163DB).
Mr. Y.E. Wang (W)

163DB. Microwave and Wireless Design II. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisites: courses 101A, 101B, 163DA. Limited to senior Electrical Engineering majors. Design of radio frequency circuits and systems, with emphasis on both theoretical foundations and hands-on experience. Design of radio frequency transceivers and their building blocks according to given specifications or in form of open-ended problems. Introduction to advanced topics related to projects through lecture and laboratories. Creation by students of end-to-end systems in application context, manages testing and optimization metrics related to cost, performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations of project results. In Progress grading (credit to be given only on completion of course 163DB).
Mr. Y.E. Wang (W)

164DA-164DB. Radio Frequency Design Project I, II. (4-4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisite: course 115B. Course 164DA is enforced requisite to 164DB. Limited to senior Electrical Engineering majors. Design of radio frequency circuits and systems, with emphasis on both theoretical foundations and hands-on experience. Design of radio frequency transceivers and their building blocks according to given specifications or in form of open-ended problems. Introduction to advanced topics related to projects through lecture and laboratories. Creation by students of end-to-end systems in application context, manages testing and optimization metrics related to cost, performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations of project results. In Progress grading (credit to be given only on completion of course 164DB). Mr. Mehta (W)

180A-D. Systems Design. (4) Limited to senior Electrical Engineering majors. Advanced systems design integrating communications, control, and signal processing subsystems. Introduction to advanced topics related to projects through lecture and laboratories. Open to 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. 180A. Lecture, two hours; laboratory, four hours; outside study, six hours. In Progress grading (credit to be given only on completion of course 180DB). 180B. Laboratory, five hours; outside study, six hours. Enforced requisite: course 180DA. Completion of projects begun in course 180A. Letter grading.
Mr. Pottle (180A in FW; 180B in Sp)

181BDA. Honors Thesis. (4–4) Tutorial, one hour; outside study, 11 hours. Limited to seniors. Research by individuals or small teams under supervision of faculty mentor, leading to composition and presentation of honors thesis. Study of fundamentals of modern research and development: project conception, planning, development and testing; design iteration cycle; research and data documentation standards; how to read technical literature. Planning, execution, and documentation of an open-ended research development project.
Mr. Villasenor (Not offered 2022-23)

CM182. Science, Technology, and Public Policy. (4) [Same as Political Science C172] Lecture, five hours. Recent and continuing advances in science and technology are raising profound important public policy issues. Consideration of selection of critical policy issues, each of which has substantial ethical, social, economic, political, scientific, and technological aspects. Concurrently scheduled with course CM282. Letter grading.
Mr. Villasenor (Not offered 2022-23)

183DA. Design of Robotic Systems I. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 102. Recommended: courses 141, 142. Course 183DA is enforced requisite to 183DB. Limited to senior Electrical Engineering majors. Topics in robotic design include integrated electromechanical design, design for manufacturing (DFM), design software, and design automation. Topics in robotic manufacturing include materials, sensors and actuators, programming, and rapid prototyping. Topics in control include manipulation, motion and path planning, learning and adaptation, and human-robot interaction. Additional topics may include distributed and multi-robot systems, bio-inspired robotics, project management, and societal implications. Open-ended research/development projects. Limited to senior Electrical Engineering majors. Topics in robotic design include integrated electromechanical design, design for manufacturing (DFM), design software, and design automation. Topics in robotic manufacturing include materials, sensors and actuators, programming, and rapid prototyping. Topics in control include manipulation, motion and path planning, learning and adaptation, and human-robot interaction. Additional topics may include dis-
troubled and multi-robot systems, bio-inspired ro-
botics, perception, and social interactions. Open-ended projects vary annually. Students create and analyze robotic systems for various applications. Oral and written presentation of project results is required. Letter grading. (Enforced requisite: course M16, 110, 110L. Course 184DA is enforced requisite to 184DB. Course 184DA is prerequisite to 184DB.) Mr. M. Briggs (Not offered 2022-23) M185. Introduction to Plasma Electronics. (4) (Same as Physics M112.) Lecture, three hours; discussion, one hour. Enforced requisites: courses M16, 110, 110L. Course 184DA is enforced requisite to 184DB. Course 184DA is prerequisite to 184DB. Lecture runs long to give students intensive experience on hardware design, microcontroller programming, and project coordination. Several projects based on autonomous robots that traverse small mazes and courses offered yearly and target regional competitions. Students may submit proposals that are evaluated and approved by faculty members. Topics include sensing circuits and amplifier-based design, microcontroller programming, feedback control, actuation, and motor control. In Progress (184DA) and letter (184DB) grading. Mr. He (Not offered 2022-23) M190. Advanced Honors Seminars. (1) Seminar, three hours. Limited to 20 students. Designed as ad-junct to undergraduate lecture course. Exploration of topics in greater depth through supplemental readings, papers, or other activities and led by lecture course instructor. May be applied toward honors credit for eligible students. Honors content noted on transcript. P/NP or letter grading. (F,W,S) M194. Research Group Seminars: Electrical Engineering. (2 to 4) Seminar, four hours; discussion, two hours; outside study, six hours. Special topics in electrical engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be re-peted once for credit with topic or instructor change. Letter grading. (F,W,S) M209AS. Special Topics in Circuits and Embedded Systems. (4) (Same as Mathematics M268B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Special topics in one or more aspects of circuits and embedded systems, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RFICs); electronic design automation; wireless communication circuits and systems, embedded architectures; embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. S/U or letter grading. (Not offered 2022-23) M209BS. Seminar: Circuits and Embedded Systems. (2 to 4) 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 circuits and embedded systems, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RFICs); electronic design automation; wireless communication circuits and systems; embedded processor software; embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. S/U or letter grading. Mr. Razavi (W) M210A. Adaptation and Learning. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: prior training in probability theory, random processes, and linear algebra. Recommended requisites: courses 205A, 241A. Mean-square error estimation and filters, least-squares estimation and filters, steepest-descent algorithms, stochastic-gradient algorithms, convergence, stability, tracking, and performance, algorithms for adap-
tion and learning, adaptive filters, learning and classification, optimization. Letter grading. (Not offered 2022-23) M210B. Inference over Networks. (4) Lecture, four hours; outside study, eight hours. Preparation: prior training in probability theory, random processes, and linear algebra. Enforced requisite: course 210A. Adaptation, learning, estimation, and detection over networks. Steepest-descent algo-
rithms, stochastic-gradient algorithms, convergence, stability, tracking, and performance, algorithms for distrib-
uted optimization, online and distributed adaptation and learning. Synchronous and asynchronous net-
work behavior: incremental, consensus, diffusion, and gossip strategies. Letter grading. (Not offered 2022-23) M211A. Digital Image Processing I. (4) Lecture, three hours; discussion, one hour; laboratory, four hours; outside study, four hours. Preparation: courses 205A, 241A. Fundamentals of digital image processing theory and tech-

201D. Design in Nanoscale Technologies. (4) Lecture, four hours; laboratory, four hours; discussion, one hour. Enforced requisite: course 115C. Challenges of digital circuit design and layout in deeply scaled technologies, with focus on design-manufacturing interactions. Sum-
maries of design and fabrication flows; basic manu-
facturing flow; lithographic patterning, resolution en-
hancement, and mask preparation; yield and varia-
tion modeling; circuit reliability and aging issues; design rule and lithography; layout design man-
ufacturing; test structures and process control; circuit and architecture methods for variability mitigation. Letter grading. Mr. Gupta (Not offered 2022-23) M202A. Embedded Systems. (4) (Same as Com-
pute Science M213A.) Lecture, four hours; discus-
sion, one hour; outside study, seven hours. Designed for graduate computer science and electrical engi-
neering students. Methodologies and technologies for design of embedded systems. Topics include hardware and software platforms for embedded sys-
tems, techniques for modeling and specification of system behavior, software organization, real-time op-
erating system scheduling, real-time communication and packet scheduling, low-power battery and en-
ergy-aware system design, timing synchronization, fault tolerance and debugging, and techniques for hardware and software architecture optimization. Thoroughly discuss as well as present and code design methods. Letter grading. (F) M202B. Energy-Aware Computing and Cyber-
Physical Systems. (4) (Same as Computer Science M213B.) Lecture, four hours; outside study, eight hours. Preparation: one course from Computer Science M51A. Recommended: course M116C or Computer Science M151B, and Computer Science 111. System-level management and cross-layer methods for power and energy consumption in computing and communication at various scales ranging across em-
bodied, mobile, personal, enterprise, and data-
center scale. Computing, networking, sensing, and control technologies for improving energy sustainability in human-cyber-physical sys-
tems. Topics include modeling of energy consump-
tion, energy sources, and energy storage; dynamic power management; power-performance scaling and energy proportionality; duty-cycling; power-aware scheduling; low-power protocols; battery modeling and management; thermal management; sensing of power consumption. Mr. Srivastava (F) M202C. Networked Embedded Systems Design. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Designed for graduate computer science students. Students will be trained in combination of networked embedded systems de-
sign combining embedded hardware platform, em-
bodied operating system, and hardware/software in-
terface. Essential graduate student background for research and industry career paths in wireless de-
vices for applications ranging from conventional wire-
less mobile devices to new area of wireless health. Laboratory design modules and course projects based on state-of-art embedded hardware platform. Letter grading. Mr. Kaiser (Not offered 2022-23) 205A. Matrix Analysis for Scientists and Engi-
eers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: one undergraduate linear algebra course. Designed for first-
year graduate students in all branches of engi-
neering, science, and related disciplines. Introduction to matrix theory and linear algebra, language in which virtually all of modern science and engineering is conducted. Review of matrices taught in undergrad-
uate courses and introduction to graduate-level topics. Mr. Vander Vorst (F) M206. Machine Perception. (4) (Same as Computer Science M268B.) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for grad-
uate students. Computational aspects of processing visual and other sensory information by neural-net architectures. Letter grading. Mr. He (Not offered 2022-23)
niques. Topics include two-dimensional linear system theory, implementation of IIR and FIR structures, design and implementation of digital filters. Limit cycles. Over- flow oscillations. Discrete random signals. Wave digi- tals filters. Letter grading. Mr. Pamarti (Sp)

212A. Theory and Design of Digital Filters. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 113. Approxima- tion of filter specifications. Use of design charts. Structures for recursive digital filters. FIR filter design techniques. Realization structures. Use of computer programs. Letter grading. Mr. Karambali, Mr. Villasenor (Not offered 2022-23)


214B. Advanced Topics in Speech Processing. (4) Lecture, three hours; discussion, one hour; computer assignments, two hours; outside study, six hours. Requisite: course 212A. Advanced techniques used in various speech-processing applications, with focus on speech recognition by humans and ma- chines. Physiology and psychoacoustics of human perception. Artificial neural networks (ANNs) and Hidden Markov Models (HMM) for automatic speech recognition systems, pattern classification, and search algorithms. Aids for hearing impaired. Letter grading. Ms. Alwan (W)

215A. Analog Integrated Circuit Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 115B. Analysis and design of analog integrated circuits. MOS and bipolar device structures and models, single-stage and differ- ential amplifiers, noise, feedback, operational ampli- fiers, offset and distortion, sampling devices and discrete-time circuits, bandgap references. Letter grading. Mr. Abidi, Mr. Razavi (F)


215C. Analysis and Design of RF Circuits and Sys- tems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 215A. Principles of RF circuit and system design, with em- phasis on monolithic implementation in VLSI technol- ogies. Basic concepts, communications background, transceiver architectures, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading. Mr. Abidi, Mr. Razavi (W)

215D. Analog Microsystem Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 215A. Analysis and design of data conversion interfaces and filters. Sam- pling circuits and architectures, A/D conversion tech- niques, A/D converters, switched-capacitor circuits, precision techniques, discrete- and continuous-time filters. Letter grading. Mr. Abidi, Mr. Razavi (Sp)

215E. Signaling and Synchronization. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: courses 215A and-design and design of circuits for synchronization and communication for VLSI systems. Use of both digital and analog design tech- niques to improve data rate of electronics between functional blocks, chips, and systems. Advanced clocking methodologies, phase-locked loop design for clock generation, and high-performance wire-line transmitters, receivers, and timing recovery circuits. Letter grading. Mr. Pamarti (Sp)

216A. Design of VLSI Circuits and Systems. (4) Seminar, four hours; discussion, four hours; discussion, two hours; laboratory, four hours; outside study, two hours. Requisite: courses M16 or Computer Science M51A, and 115A. Recommended: course 215C. Design and analysis of VLSI systems and VLSI circuits. Design techniques for VLSI circuits. VLSI architectures and VLSI design tools. Letter grading. Mr. Markovic (F)

216B. VLSI Signal Processing. (4) Lecture, four hours; outside study, eight hours. Advanced concepts in VLSI signal processing, with emphasis on architec- ture design and optimization within block-based de- scription that can be mapped to hardware. Funda- mental 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 (W)

216C. LSI in Computer System Design. (4) (Same as Computer Science M255C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course M216A, LSI/VLSI design and architecture, and computer systems. In-depth studies of VLSI architectures and VLSI design tools. Letter grading. (Not offered 2022-23)

217. Biomedical Imaging. (4) (Same as Bioengi- neering M217.) Lecture, three hours; discussion, one hour; outside study, courses 114 or 211A. Optical imaging modalities in biomedici- ne. Other nonoptical imaging modalities discussed briefly for comparison purposes. Letter grading. Ms. Alwan (Sp, alternate years)

218. Network Economics and Game Theory. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Discussion of how different co- operative and noncooperative games among agents can be constructed to model, analyze, optimize, and shape emerging interactions among users in different networks and system settings. How strategic agents can successfully compete with each other for limited and time-varying resources by optimizing their deci- sion process and learning from their past interaction with other agents. To determine their optimal actions in these distributed, informationally decentralized en- vironments, agents need to learn and model directly or implicitly other agents’ responses to their actions. Discussion of existing multilayer learning techniques and learning in games, including adjustment pro- cesses for learning equilibria, fictitious play, regret- learning, and more. Letter grading. (Not offered 2022-23)

219. Large-Scale Data Mining: Models and Algo- rithms. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 219A. Large-scale data mining algorithms, summary statistics, and techniques for analysis of large-scale data. Dimensionality reduction, regression models, classification, clustering, and pattern recognition. Introduction to advanced data mining techniques and algorithms for large-scale data. Letter grading. Mr. Roychowdhury (W)

220A. Detection and Estimation in Communica- tion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Applications of estimation and detection concepts in communication and signal processing; random signal estimation, detection, and hypothesis testing; linear and nonlinear systems; detection and estimation in signal processing simulation and analysis; mean square (MS) and maximum likelihood (ML) estimations and algorithms; detection under ML, Bayes, and Neyman/Pearson (NP) criteria; signal-to- noise ratio (SNR) and error probability evaluations. In- troduction to Monte Carlo simulations. Letter grading. Mr. Yao (Not offered 2022-23)


Mr. Rubin (W)

232E. Large-Scale Social and Complex Networks: Design and Algorithms. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Requisite: course 131A. Fundamentals information compression, trans- mission, processing, and learning. Topics include limits and algorithms for lossless data compression, connections to model estimation and learning, channel capacity, rate versus distortion in lossy compression, and basics of information theory for networks. Letter grading.

Dr. Diggavi (F)

231B. Network Information Theory. (4) Lecture, four hours; outside study, eight hours. Enforced re- quisite: course 231A. Point-to-point multiple-input, multiple-output (MIMO) wireless channels: capacity and outage; single-hop networks: multiple access, broadcast, interference, and relay channels; channels and sources with side-information; basics of multilayered lossy data compression; basics of network information flow over general noisy networks. Letter grading.

Dr. Diggavi (Not offered 2022-23)

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A or equivalent. Analysis, design, and implementation of error control codes and decoding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading.

Mr. Wiesel (Sp)

232A. Stochastic Modeling with Applications to Telecommunication Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Stochastic processes as applied to study of telecommunication systems, traffic engineering, business, and management. Discrete-time and continuous-time Markov chain processes. Renewal processes, regenerative processes, Markov-renewal, semi-Markov and semiregenerative stochastic processes. Decision process and optimization in queues, traffic and queueing analysis of basic telecommunication and computer communication networks, Internet, and management systems. Letter grading.

Mr. Rubin (Not offered 2022-23)

232B. Queuing Systems and Intelligent Transportation Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A or equivalent. Modeling, analysis, and design of queuing systems; traffic and signal control; computer network congestion; repeated queues; and design of intelligent transportation systems, communications networks, autonomous vehicular networks, business and management systems. Markovian and non-Markovian queueing models. Applications to traffic engineering, transportation and autonomous vehicular systems; computer communications, management and business systems. Letter grading.

Mr. Rubin (Not offered 2022-23)


Mr. Vandenberghe (W)


Mr. Vandenberghe (Not offered 2022-23)


Ms. Dolecek (Not offered 2022-23)

239AS. Special Topics in Signals and Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Key concepts, principles, and algorithms of online learning and learning how to make decisions under uncertainty in broad context, including Markov decision processes, optimal stopping, reinforcement learning, structural results for online learning, multiarmed bandits learning, multiagent learning, multiagent deep learning. Letter grading.

F

(Not offered 2022-23)

249B. Seminar: Signals and Systems. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and recent developments in the area of signals and systems, such as communications, control, image processing, theory, multimedia, computer networking, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U or letter grading.

Ms. Dolecek (FSp)

M240A. Linear Dynamic Systems. (4) Same as Chemical Engineering M280A and Mechanical and Aerospace Engineering M270A). Lecture; four hours; outside study, eight hours. Requisite: course 141 or Mechanical and Aerospace Engineering 171A. State-space description of linear time-invariant (LTI) and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvalues and eigenvectors, singular values, Cayley/ Hamilton theorem. Jordan form of state matrices; stability, controllability, observability, realizability, and minimality. Stabilization design via state-
feedback and observers; separation principle. Con-
nections with transfer function techniques. Letter
grading.
Mr. Tabuada (F)
M240C. Optimal Control. (4) (Same as Chemical
Engineering M280C and Mechanical and Aerospace
Engineering M270C.) Lecture, four hours; outside
study, eight hours. Requisite: course 240B. Applica-
tions of variational methods, Pontryagin maximum
principle, Hamilton/Jacobi/Bellman equation (dy-
namic programming) to optimal control of dynamic
systems modeled by nonlinear ordinary differential
equations. Letter grading.
Mr. Tabuada (Not offered 2022-23)
241A. Stochastic Processes. (4) Lecture, four hours;
discussion, one hour; outside study, seven hours.
Requisites: course 131A, Requisite. Probability, pro-
Axiomatic development, expectation, convergence of
random processes: stationarity, power spectral den-
sity. Response of linear systems to random inputs.
Basics of estimation. Special random processes,
Markov processes, martingales, etc. Letter grading.
Mr. Diggavi (Not offered 2022-23)
M242A. Nonlinear Dynamic Systems. (4) (Same as
Chemical Engineering M265A and Mechanical and
Aerospace Engineering M220A.) Lecture, four hours;
outside study, eight hours. Requisite: course M240A
or Chemical Engineering M260A or Mechanical and
Aerospace Engineering M220A. State-space tech-
niques for studying solutions of time-varying,
nonlinear differential equations. Lyapunov theo-
rem, input-to-state stability and small-gain theorem.
Letter grading.
Mr. Tabuada (W)
C243A. 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;
genenerative models and classification; regression
and Kalman filtering; principal components analysis,
factor analysis, and expectation maximization. Con-
currently scheduled with course C143A. Letter
grading.
Mr. Kao (Sp)
(4) Lecture, four hours; discussion, one hour; outside
study, seven hours. Enforced requisites: course
131A, Mathematics 33A. Introduction to fundamen-
tals of statistical machine learning. Overview of sev-
eral widely used methods: linear regression, logis-
tic regression, support vector machines, decision
trees, neural networks, kernel methods, etc. Letter
grading.
Mr. Markovic (Not offered 2022-23)
M254C. Seminar: Systems, Dynamics, and Control
Topics. (2) (Same as Chemical Engineering M257
and Mechanical and Aerospace Engineering M257A.)
Seminars by faculty members, guest lecturers, and
graduates. Letter grading. (F)
Mr. Kao (W)
M248S. Seminar: Systems, Dynamics, and Control
Topics. (2) (Same as Chemical Engineering M257
and Mechanical and Aerospace Engineering M257A.)
Seminars by faculty members, guest lecturers, and
graduates. Letter grading. (F)
Mr. Kao (W)
M250B. Microelectromechanical Systems (MEMS)
Fabrication. (4) (Same as Bioengineering M250B
and Mechanical and Aerospace Engineering M280B.)
Lecture, three hours; discussion, one hour; outside
study, eight hours. Enforced requisite: course M153S.
Advanced discussion of micromachining processes
used to construct MEMS. Coverage of many litho-
graphic, deposition, and etching processes, as well as
their combination in process integration. Materials
issues such as chemical resistance, corrosion, me-
chanical, and electrical properties. MEMS packaging
and testing topics. Letter grading.
Mr. Candler (Not offered 2022-23)
M252. Microelectromechanical Systems (MEMS)
Device Physics and Design. (4) (Same as Bioengi-
neering M252 and Mechanical and Aerospace Engi-
neering M280B.) Lecture, four hours; discussion,
one hour; outside study, seven hours. Introduction to
MEMS design. Design methods, design rules, sen-
sing and actuation mechanisms, microsensors, and
microactuators. Design of MEMS to be pro-
duced with both foundry and nonfoundry processes.
Computer-aided design for MEMS. Design project re-
quired. Letter grading.
Mr. Candler (Sp)
M255. Neuroengineering. (4) (Same as Bioengi-
neering M260 and Neuroscience M206.) Lecture, four
hours; laboratory, three hours; outside study, five
hours. Requisites: Mathematics 32A, Physics 1B or
SC. Introduction to principles and technologies of
bioelectrical signal processing and stimulation. Topics
include bioelectricity, electrophysiology (action poten-
tials, local field potentials, EEG, ECoG), intracerebral
and extracellular recording, microelectrode technol-
ogy, neural signal processing (neural signal frequency
bands, filtering, spike detection, spike sorting, stim-
ulation artifact removal), brain-computer interfaces,
deep-brain stimulation, and prosthetics. Letter
grading.
Mr. Markovic (Not offered 2022-23)
M256A-M256B. Introduction to Probabilistic Flow-
ing. (2-2-2) (Same as Bioengineering M261A-M261B
and Neuroscience M261C.) Lecture, two hours; dis-
cussion, two hours; outside study, eight hours. Re-
quisites: courses 162A, 162B. Topics include forward
and backward Markov Chains, coupling techniques,
polymerization, evolutionary dynamics, simulation
of interacting processes, rare events (Geometric
Brownian motion), stochastic partial differential
and integro-differential equations, and their appli-
cations. Letter grading.
Mr. Candler (Sp)
M257. Nanoscience and Technology. (4) (Same as
Mechanical and Aerospace Engineering M287L.)
Lecture, four hours; outside study, eight hours. Intro-
duction to fundamentals of nanoscale science and
technology: transport, interfacial chemistry, con-
duction, chemical bonding and nanostructures, top-
ology and bottom-up (self-assembly) nanofabrica-
tion; nanocharacterization; nanomaterials, nanoelec-
tronics, and nanobiotechnology. Design and en-
troduction to new knowledge and techniques in nano-
areas to understand scientific principles behind nano-
techology and inspire students to create new ideas
in multidisciplinary nano science and technology.
Letter grading.
Mr. Cheung (Not offered 2022-23)
260A. Advanced Engineering Electrodynamics.
(4) Lecture, four hours; discussion, one hour; outside
study, seven hours. Requisites: courses 101B, 162A.
Advanced treatment of engineering electrodynamics
and their applications to modern engineering prob-
lems. Vector calculus in generalized coordinate
system; Solutions of wave equation and special func-
tions, Reflection, transmission, and polarization; Vector
potential, duality, reciprocity, and equivalence
theorems. Scattering from objects: cylinder, half-plane,
along with polarizations, including geometry cross-section
characterization. Green's functions in electromagnetics
and dyadic calculus. Letter grading.
Mr. Rahmat-Samii (F)
260B. Advanced Engineering Electrodynamics.
(4) Lecture, four hours; discussion, one hour; outside
study, seven hours. Requisites: courses 101B, 162A, 260A.
Advanced treatment of concepts and numerical techniques
in electromodynamics and their applications to modern en-
gineering and bioengineering problems. Differential curvatures
and surfaces. Geometrical optics and geometrical
theory of diffraction. Physical optics techniques. As-
ymptotic techniques and uniform theories. Integral
equations in electromagnetic scattering. Nonlinear
Mr. Rahmat-Samii (W)
261. Microwave and Millimeter Wave Circuits. (4)
Lecture, four hours; discussion, one hour; outside
study, seven hours. Requisite: course 163A. Rectan-
gular and circular waveguides, microstrip, stripline,
finite-, and dielectric waveguide distributed circuits,
with applications in microwave and millimeter wave
circuits. Letter grading.
Mr. Rahmat-Samii (W)
262. Antenna Theory and Design. (4) Lecture, four
hours; discussion, one hour; outside study, seven
hours. Requisite: course 162A. Antenna patterns.
Sum and difference patterns. Optimum designs for
rectangular and circular apertures. Arbitrary side lobe
topography. Discrete arrays. Mutual coupling. Design
Mr. Rahmat-Samii (Not offered 2022-23)
263. Reflector Antennas Synthesis, Analysis, and
Measurement. (4) Lecture, four hours; outside study,
seven hours. Requisites: courses 162A, 262A, 266B.
Reflector pattern analysis techniques. Single and multi-
reflector antenna configurations. Reflector synthesis
and design techniques. Reflector feeds. Reflector
tolerance studies, including systematic and random errors.
Array-fed reflector antennas. Near-field measurement
techniques. Compact range concepts. Microwave di-
agnostic techniques. Modern satellite and ground an-
tenna applications. Letter grading.
Mr. Rahmat-Samii (Sp)
266. Computational Methods for Electromagne-
tics. (4) Lecture, four hours; discussion, one hour;
outside study, seven hours. Requisites: courses 162A,
162B, 266A. Computational methods for differential
and integral equations: finite-difference, finite-
volume methods. Application of the method of
moments. Topics include transmission lines, resonators, integrated
circuits, solid-state device modeling, electromagnetic
scattering and antennas. Letter grading.
Mr. Rahmat-Samii (Sp)
270. Applied Quantum Mechanics. (4) Lecture, four
hours; discussion, one hour; outside study, seven
hours. Preparation: modern physics (or course 123A),
linear algebra, and ordinary differential equations.
Principles of quantum mechanics for applications
in lasers, solid-state physics, and nonlinear optics.
Topics include: quantum mechanics, observables, ob-
servables, Schrödinger equation, uncertainty prin-
ciple, central force problems, Hilbert spaces, WK
approximation, matrix mechanics, density matrix for-
malism, and radiation theory. Letter grading.
Mr. Candler (F)
271. Classical Laser Theory. (4) Lecture, four hours;
outside study, eight hours. Enforced requisite: course
170A. Microscopic and macroscopic laser phe-
nomena and propagation of optical pulses using
Mr. Candler (F)
272. Dynamics of Lasers. (4) Lecture, four hours;
outside study, eight hours. Requisite: course 271.
Ultrafast laser pulse characteristics, generation, and
measurement. Gain switching, Q switching, cavity
dumping, active and passive locking, Pulse compression and soliton pulse
formation. Nonlinear pulse generation: soliton laser, additive-pulse mode

274. Optical Communication and Sensing Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 170A and 170B or equivalent. Top-down introduction to physical layer design in fiber optic communication systems, including Telecom, Datacom, and CATV. Fundamentals of digital and analog optical communication systems, fiber transmission characteristics, and optical modulation techniques, including direct and external modulation and computer-aided design. Architectural-level design of fiber optic transceiver circuits, including preamplifier, quantizer, clock and data recovery, laser driver, and predistortion circuits. Letter grading. Mr. Jalali (Sp)

M275. Micro- and Nanoscale Biosensing for Molecular Diagnostics. (4) (Same as Bioengineering M275.) Lecture, four hours; discussion, one hour; outside study, seven hours. Covers state-of-art and emerging biosensors in context of molecular diagnostics. Students learn relevant biology and biochemistry pertinent to molecular diagnostics. Students gain thorough understanding of interfaces between bioparticles, biofluids, and electronics. Topics include biosensor performance parameters, modes of detection, sample preparation challenges, microfluidics, lab-on-chip biosensing platforms, as well as proteomics, genomics, and DNA sequencing technologies. Letter grading. Mr. Emaminejad (Sp)

279AS. Special Topics in Physical and Wave Electronics. (4) Lecture, four hours; discussion, on hour; outside study, seven hours. Special topics in one or more aspects of physical and wave electronics, such as electromagnetics, microwave and millimeter wave circuits, semiconductor electronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U or letter grading. Mr. Y. Wang (Esp)

279BS. Seminar: Physical and Wave Electronics. (2 to 4) 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, such as electromagnetics, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading. Mr. Y. Wang (Not offered 2022-23)

279CS. Clean Green IGERT Brown-Bag Seminar. (1) Seminar, one hour. Required of students in Clean Energy for Green Industry (IGERT) Research. Literature seminar presented by graduate students and experts from around country who conduct research in energy harvest, storage, and conservation. S/U grading. Mr. Y. Wang (Not offered 2022-23)

CM282. Science, Technology, and Public Policy. (4) (Same as Public Policy CM282.) Lecture, three hours. Recent and continuing advances in science and technology are raising profoundly important public issues. This course will take a multidisciplinary view of critical policy issues, each of which has substantial ethical, social, economic, political, scientific, and technological aspects. Concurrently scheduled with course CM182. Letter grading. Mr. Villasenor (Not offered 2022-23)

285A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101A, and M185 or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave propagation, plasma oscillations on electron waves, hydromagnetic waves, drift waves. Rayleigh/Taylor, Kelvin/Helmholtz, universal, and streaming instabilities. Application to experiments in fully and partially ionized gases. Letter grading. Mr. Mori (Not offered 2022-23)

285B. Advanced Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M185, and 285A or Physics M222A. Interaction of intense electromagnetic waves with plasmas: waves in inhomogeneous and bounded plasmas, nonlinear wave coupling and damping, parametric instabilities, anomalous resistivity, shock waves, echoes, laser heating. Emphasis on experimental considerations and techniques. Letter grading. Mr. Joshi (Not offered 2022-23)

M287. Fusion Plasma Physics and Analysis. (4) (Same as Mechanical and Aerospace Engineering M287B.) Lecture, four hours; outside study, eight hours. Fundamentals of plasmas at thermonuclear burning conditions. Fokker/Planck equation and applications to heating by neutral beams, RF, and fusionneutral beam production, synchronous, and inverse radiation processes. Plasma surface interactions. Fluid description of burning plasma. Dynamics, stability, and control. Applications in tokomaks, tandem mirror, and field reversed concepts. Letter grading. Mr. Chen, Mr. Joshi (Not offered 2022-23)

M293. Intellectual Property for Technology Entrepreneurs and Managers. (2) (Same as Management M247.) Seminar; two hours; outside study, four hours. Introduction to intellectual property (IP) in context of technology products and markets. Topics include best practices to put in place before product development starts, how to develop high-value patents, the money available for licensing and defensive IP litigation considerations, trade secrets, opportunities and pitfalls of open source software, trademarks, managing copyright in increasingly complex content ecosystems, and adopting IP strategies to globalized markets. Includes case studies inipired by complex IP questions facing technology companies today. S/U or letter grading. Mr. Villasenor (Not offered 2022-23)

295. Academic Technical Writing for Electrical Engineers. (3) Seminar, three hours. Designed for electrical engineering PhD students who have completed preliminary examinations. Students read models of good writing and learn to make rhetorical observations as they write their own papers. They learn to develop and refine their academic and technical writing skills by writing and revising conference and journal papers, and practice writing for and speaking to various audiences, including potential students, engineers outside their specific fields, and nonengineers (colleagues outside field, policymakers, etc.). Students write in variety of genres, all related to their professional development as electrical engineers. Emphasis on writing as vital way to communicate precise technical and professional information in distinct contexts, directly resulting in specific outcomes. S/U grading. (F,Sp)

296. Seminar: Research Topics in Electrical Engineering. (2) Seminar, two hours; outside study, four hours. Advanced study and analysis of current topics in electrical engineering. Discussion of current research and literature in research specialty of faculty member teaching course. May be repeated for credit. S/U grading.

297. Seminar Series: Electrical Engineering. (1) Seminar, 90 minutes; outside study, 90 minutes. Limited to graduate electrical engineering students. Weekly seminars and discussions by invited speakers on research topics of heightened interest. S/U grading. (Not offered 2022-23)

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate electrical engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. S/U or letter grading. (Not offered 2022-23)

299. MS Project Seminar. (4) 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.

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprenticeship 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)

M495. Teaching Preparation Seminar: Teaching and Writing Pedagogies for Electrical Engineers. (2) (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 a TA appointment. Seminar on pedagogy and logistics of being a TA with emphasis on student-centered teaching, clear communication, and multimodal teaching and learning. S/U grading. Ms. Avan (F)

596. Directed Individual or Tutorial Studies. (2 to 16) Tutorial, to be arranged. Limited to graduate electrical engineering 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 electrical engineering students. Supervised study and preparation of MS comprehensive examination. S/U grading.

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


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

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Department website

Yu Huang, PhD, Chair
Jaime Marian, PhD, Vice Chair
Ya-Hong Xie, PhD, Vice Chair

Faculty Roster

Professors
Gregory P. Carman, PhD (Ben Rich-Lockheed Martin Professor of Advanced Aerospace Technologies)
Jane P. Chang, PhD (William Frederick Seyer Professor of Materials Electrochemistry)
Yong Chen, PhD
Bruce S. Dunn, PhD (Nippon Sheet Glass Company Professor of Materials Science)
Mark S. Goorsky, PhD
Vijay Gupta, PhD
Ximin He, PhD
Yu Huang, PhD (Traugott and Dorothea Frederking Endowed Professor)
Subramanian S. Iyer, PhD
Ioanna Kakoulli, DPhil
Richard B. Kaner, PhD
Xiaochun Li, PhD
Jaime Marian, PhD
Ali Mosleh, PhD, NAE (Evalyn Knight Professor of Engineering)
Qibing Pei, PhD
Gaurav N. Sant, PhD (Henry Samuei Fellow)
Dwight C. Streit, PhD, NAE
Sarah H. Tolbert, PhD
Kang L. Wang, PhD (Raytheon Company Professor of Electrical Engineering)
Yinmin (Morris) Wang, PhD
Paul S. Weiss, PhD (Presidential Professor of Chemistry)
Benjamin M. Wu, DDS, PhD
Ya-Hong Xie, PhD
Jenn-Ming Yang, PhD (Collins Aerospace Term Professor of Excellence)
Yang Yang, PhD (Carol and Lawrence E. Tannas, Jr., Endowed Professor of Engineering)

Professors Emeriti
Alan J. Ardell, PhD
Nasr M. Ghoniem, PhD
Kanji Ono, PhD

Assistant Professors
Amartya Banerjee, PhD
Aaswath P. Raman, PhD

Adjunct Associate Professors
Eric P. Bescher, PhD
Sergey Prikhodko, PhD

Adjunct Assistant Professors
Magdalena Balonis-Sant, PhD
Marta Pozuelo, PhD

Overview

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 BS 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 cultivate 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 Study

Materials Engineering BS

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.

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

Capstone Major

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.

Educational Objectives

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.
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, 131, 131L, 132, 143A, 150, 160; one upper-division mathematics course selected from Civil and Environmental Engineering 103, Electrical and Computer Engineering 102, Mathematics 132, Mechanical and Aerospace Engineering 182B, 182C; two laboratory courses (4 units) from Material 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 105, 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 BS Degrees on page 21 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); Physics 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, 131, 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 105, C111, C112, 143A, or 162.

Graduate Study
For admission information, see Graduate Programs Admissions on page 27.

The following introductory information is based on 2022-23 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 (MS) and Doctor of Philosophy (PhD) degrees in Materials Science and Engineering.

Materials Science and Engineering MS
Areas of Study
There are three main areas in the MS 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 Engineering PhD

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 PhD 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 PhD 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 PhD 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 PhD program, students take the oral preliminary examination that encompasses the body of knowledge in materials science equivalent to that expected of a bachelor’s degree. If students opt not to take courses, a written preliminary examination in the major field is required. Students may not take an examination more than twice. After passing both preliminary examinations, students take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. Faculty members holding joint appointments with the department are considered inside members.

Fields of Study

Ceramics and Ceramic Processing

The ceramics and ceramic processing field is designed for students interested in ceramics and glasses, including electronic materials. As in the case of metallurgy, primary and secondary fabrication processes such as vapor deposition, sintering, melt forming, or extrusion strongly influence the microstructure and properties of ceramic components used in structural, electronic, or biological applications. Formal course and research programs emphasize the coupling of processing treatments, microstructure, and properties.

Electronic and Optical Materials

The electronic and optical materials field provides an area of study in the science and technology of electronic materials that includes semiconductors, optical ceramics, and thin films (metal, dielectric, and multi-layer) for electronic and optoelectronic applications. Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications that include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/optical properties in these materials systems.

Structural Materials

The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.
Facilities

Facilities in the Materials Science and Engineering Department include:

- Ceramic Processing Laboratory
- Glass and Ceramics Research Laboratories
- Mechanical Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Microscopy laboratories with a transmission electron microscope (100 kV); access to several field-emission transmission electron microscopes (80–300 kV); and a scanning electron microscope equipped with a quantitation chemical/compositional analyzer, stereo microscope, microcameras, 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

Facility Areas of Thesis Guidance

Professors

Gregory P. Carman, PhD (Virginia Tech, 1991)
Electromagnetoelasticity models and characteristics of thin film shape memory, nanoscale multiferroics, magnetoelastic and piezoelectric materials

Jane P. Chang, PhD (MIT, 1998)
Materials processing, gas-phase and surface reaction, plasma enhanced chemistries, atomic layer deposition, chemical microelectromechanical systems, and computational surface chemistry

Yong Chen, PhD (UC Berkeley, 1996)
Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, micrometer and nanoscale electronics, mechanical, optical, biological, and sensing devices, circuits and systems

Bruce S. Dunn, PhD (UCLA, 1974)
Synthesis and characterization of electrochemical materials, energy storage, sol-gel materials and chemistry

Mark S. Goorsky, PhD (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, PhD (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

Ximin He, PhD (U. Cambridge, England, 2011)
Biologically inspired materials based on stimuli-responsive polymers and micro-/nanostructure fabrication for applications in biomedicine, environment, and energy

Yu Huang, PhD (Harvard, 2003)
Nanomaterial fabrication and development, bio-nano structures

Subramanian S. Iyer, PhD (UCLA, 1981)
System scaling technology, advanced packaging and 3D integration, technologies and techniques for memory subsystem integration and neuromorphic computing

Chemical and physical properties of non-metallic archaeological materials; alteration processes in archaeological vitreous materials and pigments

Richard B. Kaner, PhD (U. Pennsylvania, 1984)
Synthesis, characterization, and applications of superhard metals, conducting polymers, metal-organic frameworks, and nanomaterials

Xiaochun Li, PhD (Stanford, 2001)
Sacrificing (science-driven manufacturing), super metals by nanoparticles self-dispersion, scalable nanomanufacturing, smart manufacturing, additive manufacturing

Jaime Marian, PhD (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, PhD, 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, PhD (Chinese Academy of Sciences, China, 1990)
Electroactive polymers through molecular design and nano-engineering for electronic devices and artifical muscles

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

Dwight C. Streit, PhD, NAE (UCLA, 1986)
Properties of electronic materials, characterization techniques, correlation of material and device performance

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

Kang L. Wang, PhD (MIT, 1970)
Nanoscale physics, materials and devices nanoelectronics, magnetics and photonics, nonlinear interactions of correlated devices and nanosystems

Yimin (Morris) Wang, PhD (Johns Hopkins, 2000)
Mechanical behavior of nanostructured metals and additively manufactured materials, laser-materials interactions, materials under extreme conditions, fusion science and technology, lithium-ion batteries and supercapacitors

Paul S. Weiss, PhD (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 microscopy and atomic-scale control and measurement of composition and properties in membranes

Benjamin M. Wu, DDS (U. Pacific, 1987), PhD (MIT, 1997)
Processing, characterization, and controlled delivery of biological molecules of bioerodible polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

Ya-Hong Xie, PhD (UCLA, 1986)
Physical properties and device application of graphene and other van der Waals materials; semiconductor physics, heterostructures, and devices; epitaxy of semiconductor thin films; nanofabrication

Jenn-Ming Yang, PhD (U. Delaware, 1986)
Nanomechanical testing of nanostructured materials, ceramic and ceramic matrix composites, hybrid materials and composites, material synthesis and processing

Yang Yang, PhD (U. Massachusetts Lowell, 1992)
Organic and inorganic semiconductor materials and devices with emphasis on solution processes; fundamental understanding of material properties of electronic devices (LEDs, FVs, TFT, sensors)

Professors Emeriti

Alan J. Ardell, PhD (Stanford, 1964)
Irradiation-induced precipitation, high-temperature deformation of solids, electron microscopy, physical metallurgy of aluminum/lithium alloys, precipitation hardening

Nasr M. Ghoniem, PhD (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

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

Assistant Professors

Amaury Banerjee, PhD (U. Minnesota, 2013)
Computational materials science, first principles methods, discovery and simulation of novel materials, electronic materials, energy materials, multiscale methods and algorithms, mechanics of materials and structures, numerical methods and scientific computation

Aaswath P. Raman, PhD (Stanford, 2013)
Metamaterials, optical and photonic materials, nanophotonics, plasmonics, thermal sciences, energy systems, computational methods

Adjoint Associate Professors

Eric P. Beschler, PhD (UCLA, 1987)
Advanced cementitious materials, sol-gel materials, organic/inorganic hybrids

Sergey Prikhodko, PhD (Kurdyumov Institute for Metal Physics NASU, Ukraine, 1994)
Characterization of materials by means of microscopes and spectrosopes

Adjoint Assistant Professors

Magdalena Balonis-Sant, PhD (U. Aberdeen, Scotland, 2010)
Development of functional materials for extending the service life of concrete infrastructure, design of new cementation agents with reduced CO2 footprint, conservation and protection of cultural heritage

Marta Pozuelo, PhD (Complutense U. Madrid, Spain, 2004)
In situ nanomechanical characterization of metallic materials
Materials Science and Engineering Department

Materials Science and Engineering Courses

Lower-Division Courses

10. Freshman Seminar: New Materials. (1) Seminar, one hour; outside study, two hours. Preparation: high school chemistry and physics. Not open to students with credit for course 104. Introduction to basic concepts of materials science and new materials vital to modern technology. M. structural engineers explain various materials discussed in conjunction with such applications as biomedical sensors, pollution control, and microelectronics. Letter grading. (F)

13L. Cultural (Materials) Science Investigations in Art and Archaeology. (6) Laboratory, four hours; discussion, two hours; site visits, four hours; outside study, five days. Focus on 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 interaction with environment. Experimental techniques and analysis of materials through X-ray fluorescence, X-ray powder diffraction (XRPD); fiber optic transmission spectroscopy (FORS); and forensic multiplescanner imaging. Letter grading.

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

33W. Materials Structure and Technology in Archaeology and Architecture. (6) Formerly numbered 33L. Laboratory, two hours; discussion, one hour; outside study, nine hours. Requisites: English Composition 3. Exploration of three classes of materials and composites, and relationships that exist between structural elements of materials and their properties: vitreous materials, building material binders, and pigments and colorants. Through study of ancient materials and technology in archaeology and architecture, exploration of relationships among processing, structure, properties, and performance for: vitreous materials—ceramics, glasses, and glazes; building material binders—calcium carbonate, clay and cementitious materials, and asphalt; and pigments and colorants (natural and synthetic organic, inorganic, and organic-inorganic hybrids). Through reverse engineering processes, exploration of ancient engineering materials (their micro/nano structure and physical, chemical, and mechanical properties), and their durability and sustainability as time-proven examples of technology innovation and/or invention. Letter grading.

90L. Physical Measurement in Materials Engineering. (2) Laboratory, four hours; outside study, two hours. Various physical measurement methods used in materials science and engineering: mechanical, thermal, electrical, magnetic, and optical techniques. Letter grading. (W/Sp)

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

Upper-Division Courses

104. Science of Engineering Materials. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20B, 20L, Physics 1A. Corequisite: Physics 1B. General introduction to different classes used in engineering designs: metals, ceramics, plastics, and composites, relationship between structure (crystals and microstructure) and properties of technological materials illustrating material differences and their applications in engineering. Letter grading. Mr. Dunn (F,WSp)

105. Principles of Nanoscience and Nanotechnology. (4) Formerly numbered M105S. 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 technologies at sub-microscopic levels. New phenomena that emerge in very small systems (typically with feature sizes below few hundred nanometers) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties, electron transport, structural stability, self-assembly, templated assembly and applications of various nanostructures such as quantum dots, nanoparticles, quantum wires, quantum wells and multilayers, carbon nanotubes. Letter grading. (F)

110. Introduction to Materials Characterization A (Crystal Structure, Nanostructures, and X-Ray Scattering). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 104. Modern methods of materials characterization: fundamentals of crystallography, properties of X-rays, X-ray scattering; powder method, Laue method; determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray spectroscopy; design of materials characterization procedures. Letter grading. Mr. Goorsky (F)

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

C111. Introduction to Materials Characterization B (Electron Microscopy). (4) Formerly numbered 111L. Lecture, four hours; outside study, eight hours. Characterization of microstructure and microchemistry of materials: transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy; emissive and reflective modes; chemical analysis; electron optics of both instruments. Concurrently scheduled with course C211. Letter grading. (W)

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


120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, five hours. Enforced requisites: courses 104, 110 (or Chemistry 113A). Introduction to electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory, free electron wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading. Mr. Y. Yang (W)

121. Materials Science of Semiconductors. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 120. Structure and properties of elemental and compound semiconductors. Electrical and optical properties, defect chemistry, and doping. Electronic materials analysis and characterization, including electrical, optical, and ion-beam techniques. Basic FET, microwave and GaAs, GaP and GaAs compound band-gap engineering, development of new materials for optoelectronic applications. Letter grading. Ms. Huang (Sp)

121L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes to 1 hour 30 minutes; laboratory, two hours; outside study, three hours. Enforced corequisite: course 121. Experiments conducted on materials characterization, including measurement of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading. Mr. Goorsky (Sp)

122. Principles of Electronic Materials Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: 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, and metalorganic materials and dielectrics. Letter grading. Mr. Goorsky (W)

130. Phase Relations in Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 104. Summary of thermodynamic laws, equilibrium criteria, solution thermodynamics, mass-action law, binary and ternary phase diagrams, glass transitions. Letter grading. Mr. Xie (F)

131. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 130 or Chemistry 110A. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decomposition, design of heat treatment processes of alloys, growth of intermediate phases, gas-solids reactions, design of oxidation-resistant alloys, recrystallization, and grain growth. Letter grading.

131L. Diffusion and Diffusion-Controlled Reactions Laboratory. (2) Laboratory, two hours; outside study, four hours. Enforced corequisite: course 131. Design of heat-treating cycles and performing experiments to study interdiffusion and intermediate phases, recrystallization, and grain growth in metals. Analysis of data. Comparison of results with theory. Letter grading. (W)


140A. Materials Selection and Engineering Design A. (3) Lecture, two hours; laboratory, two hours; outside study, five hours. Concurrently scheduled with courses 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 (W)

140B. Materials Selection and Engineering Design B. (Formerly numbered 114. (3) Lecture, two hours; laboratory, two hours; outside study, five hours. Enforced requisite: 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
141L. Computer Methods and Instrumentation in Materials Science. (2) Laboratory, four hours. Preparation: knowledge of BASIC or C or assembly language. Limited to students majoring in Science and Engineering majors. Interface and control techniques, real-time data acquisition and processing, computer-aided testing. Letter grading. Mr. Marian (W) 143A. Mechanical Behavior of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 104, Mechanical and Aerospace Engineering 101. Plastic flow of metals, including the effects of temperature on stress-strain behavior. Dynamic and quasi-static tests, yield strength, creep, fracture toughness, fatigue, and creep. Letter grading. Mr. Marian (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; elastic, plastic, and fracture toughness. Letter grading. Mr. Wei (W) 151. Structure and Properties of Composite Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: one of the two courses from 143A, 150, 160. Requisite: course 104. Relationship between structure and mechanical properties of composite materials with fiber and particulate reinforcement. Properties of fiber, matrix, and interfaces. Selection of macrostructures and material systems. Letter grading. Mr. J-M. Yang (Sp) 160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: Enforced 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. Requisite: course 160. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and electronics. Processing operations, including modern techniques of powder synthesis, greenware forming, sintering, glass melting, microstructural properties relations in ceramics, fracture analysis and design with ceramics. Letter grading. Mr. Dunn (Not offered 2022-23) 161L. Laboratory in Ceramics. (2) Laboratory, four hours. Requisite: course 160. Recommended corequisite: course 161. Preparation of common ceramic glasses and attaining of specific properties through process control for engineering applications. Quantitative characterization and selection of raw materials. Slip casting and extrusion of clay bodies. Sintering of powders. Glass melting and fabrication. Determination of chemical and physical properties. Letter grading. Mr. Dunn (Sp) 162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 160, Physics 1C. Utilization of ceramics in microelectronics; thick film and thin film resistors, capacitors, and substrates; design and processing of electronic ceramics. Fracture mechanics and magnetic ceramics: ferroelectric ceramics and electro-optic devices; optical waveguide applications and designs. Letter grading. Mr. Dunn (Not offered 2022-23) CM163. Electrochemical Processes. (4) Same as Chemical Engineering 163B. 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 experimental approach to analyze electrochemical processes. Specific topics include reactions on metal and semiconductor surfaces, electrodeposition, electroless deposition, electrochemistry, fuel cells, aqueous and non-aqueous batteries, solid-state electrochemistry. May be concurrently scheduled with course 163B. Letter grading. 170. Engaging Elements of Communication: Oral Communication. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive presentation skills provided by building on strengths of individual personal styles in creation of positive interpersonal relations. Skill set prepares students for different types of academic and professional presentations for wide range of audiences. Learning environment is highly supportive and interactive as it helps students creatively develop and greatly expand effectiveness of their communication and presentation skills. Letter grading. Mr. Xie (Not offered 2022-23) 171. Engaging Elements of Communication: Writing for Technical Community. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive technical writing skills on subjects specific to field of materials science and engineering. Students write review term paper in selected subject field of materials science and engineering from given set of journal publications. Instruction leads students through several crucial steps, including brainstorming, choosing title, coming up with outline, concise writing of abstract, conclusion, and final polishing. Other subjects include writing style, word choices, and grammar. Letter grading. Mr. Xie (Not offered 2022-23) CM180. Introduction to Biomaterials. (4) Same as Bioengineering CM178. Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties and load-bearing capacity, chemical, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM280. Letter grading. Mr. Wu (Not offered 2022-23) 188. Special Courses: Materials Science and Engineering (4) Seminar. Three hours; outside study, eight hours. Special topics in materials science and engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. (Not offered 2022-23) 194. Research Group Seminars: Materials Science and Engineering. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field or of research of faculty members or students. May be repeated for credit. Graduate students only. Letter grading. Occasional field trips may be arranged. May be repeated for credit with 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. Requisite: course 120. Lattice dynamics and thermal properties of solids, classical and quantized free-electron theory, electrons in a periodic potential, transport in semiconductors, dielectric and magnetic properties of solids. Letter grading. Mr. Y. Yang (F) 201. Principles of Materials Science II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Principles of thermodynamics and statistical mechanics in physical and chemical phenomena in materials. Finite-temperature properties of single-component and multi-component systems, equations of state, thermodynamic potentials and their derivatives, phase diagrams, and other equilibrium properties. First-order and second-order phase transitions in liquids and solids. Introduction to classical and modern theories of critical phenomena and irreversible processes and entropy generation. Letter grading. Ms. He (F) 210. Diffraction Methods in Science of Materials. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Requisite: course 120. Theory of diffraction of waves (X rays, electrons, and neutrons) in crystalline and noncrystalline materials. Long- and short-range order in crystals, structural effects of processing, deformation, and radiation damage to arrangements of atoms in liquids and amorphous solids. Letter grading. Ms. Goorsky (Sp, odd years) C211. Introduction to Materials Characterization B (Electron Microscopy). (4) Formerly numbered 211. Lecture, four hours; outside study, eight hours. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projections, direct observations of reflections, crystal replicas; scanning electron microscopy: emissive and reflective modes; chemical analysis; electron optics of both instruments. Concurrently scheduled with course C111. Letter grading. C212. Cultural Materials Science II: Characterization Methods in Conservation of Materials. (4) Formerly numbered CM212.) Lecture, four hours. Preparation: general chemistry, inorganic and organic chemistry, materials science. Principles and methods of materials characterization in conservation: optical and electron microscopy, X-ray and electron spectroscopy, X-ray diffraction, infrared spectroscopy, reflected and transmitted spectroscopy, chromatography, design of archaeological and ethnographic materials characterization procedures. Concurrently scheduled with course C112. Letter grading. Ms. Kakoulli (Not offered 2022-23) M213. Cultural Materials Science I: Analytical Imaging and Documentation in Conservation of Materials. (4) Same as Conservation M215.) Lecture, two hours; laboratory, two hours. Basic and advanced techniques in digital photography, computer-aided recording tools, and scientific imaging to determine and document condition (defects) and technological features of archaeological and ethnographic materials. Development of basic theoretical knowledge on imaging and photonics technology and practical skills on conservation photo-documentation, analytical (forensic) photography, and advanced new imaging technologies. Letter grading. Ms. Kakoulli 213L. Cultural Materials Science Laboratory: Technical Study. (4) Formerly numbered M213L.) Lecture, four hours; laboratory, four hours. Requisites: course 110, M213 (or 216) and 214 or one course from Conservation 260 through 263. Corequisite: course C212. Research-based laboratory through object-based problem-solving approach in conserving materials science. Experimental techniques, characterization, and analysis of archaeological and ethnographic materials

221. Science of Electronic Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: knowledge of basic concepts from physics and chemistry. Intrinsic attributes and resistance to weathering. Causes, sources, and mechanisms of deterioration (physical, chemical, and biochemical). Letter grading. Mr. Goorsky (Sp)

222. Growth and Processing of Electronic Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: knowledge of basic concepts from physics and chemistry. Intrinsic attributes and resistance to weathering. Causes, sources, and mechanisms of deterioration (physical, chemical, and biochemical). Letter grading. Mr. Goorsky (Sp)

223. Materials Science of Thin Films. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: knowledge of basic concepts from physics and chemistry. Intrinsic attributes and resistance to weathering. Causes, sources, and mechanisms of deterioration (physical, chemical, and biochemical). Letter grading. Mr. Goorsky (Sp)

243A. Fracture of Structural Materials. (4) Lecture, four hours; laboratory, two hours; outside study, four hours. Requisite: course 143A. Engineering and scientific aspects of crack nucleation, slow crack growth, and unstable fracture. Fracture mechanics, dislocation models, fatigue, fracture in reactive environments, alloy development, fracture-safe design. Letter grading. Mr. Xie (F, odd years)

246A. Mechanical Properties of Nonmetallic Crystalline Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 143A. Elastic and plastic behavior of crystals, geometrical and energetic considerations, mechanisms of yielding, work hardening, and other strengthening. Letter grading. Mr. Xie (F, odd years)

250B. Advanced Composite 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 structure and characterization. Topics include conjugated polymers; heavily doped, highly conducting polymers; applications as processable metals and in various electrical, optical, and electrochemical devices. Synthesis of organic polymers for organic light-emitting diodes, solar cells, thin-film transistors. Introduction to emerging field of organic electronics. Letter grading. Mr. Pei (F)

253. Biopsired 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 macroscale, properties and characterizations, and real-life applications. Letter grading.

256. Electrochemical Processes. (4) Same as Chemical Engineering CM214.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 139 (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 analyze electrochemical processes. Specific topics include electrochemical reactions on metal and semiconductor surfaces, electrodeposition, electrodess, and solid-state electrochemistry. May be concurrently scheduled with course CM163. Letter grading.


262. 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 structure and characterization. Topics include conjugated polymers; heavily doped, highly conducting polymers; applications as processable metals and in various electrical, optical, and electrochemical devices. Synthesis of organic polymers for organic light-emitting diodes, solar cells, thin-film transistors. Introduction to emerging field of organic electronics. Letter grading. Mr. Pei (F)

263. Computer Simulations of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: BS in Materials Science and Engineering. Requisite: course 151. Fabrication methods, structure and properties of advanced composite materials. Fibers, matrix, and processing. Mechanical, chemical, and nondestructive characterization techniques. Letter grading. Mr. Y. Yang

265. Advanced Composite Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: BS in Materials Science and Engineering. Requisite: course 151. Fabrication methods, structure and properties of advanced composite materials. Fibers, matrix, and processing. Mechanical, chemical, and nondestructive characterization techniques. Letter grading. Mr. Y. Yang

266. Chemistry of Soft Materials. (4) Lecture, four hours. Introduction to organic soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft materials: organic molecules, synthetic polymers, and biomolecules and biomaterials. Extensive discussion and description of structure-property relationship, spectroscopic and experimental techniques, and preparation methods for various soft materials. Letter grading.


268. Advanced Composite Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: BS in Materials Science and Engineering. Requisite: course 151. Fabrication methods, structure and properties of advanced composite materials. Fibers, matrix, and processing. Mechanical, chemical, and nondestructive characterization techniques. Letter grading. Mr. Y. Yang


270. Computer Simulations of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: BS in Materials Science and Engineering. Requisite: course 151. Fabrication methods, structure and properties of advanced composite materials. Fibers, matrix, and processing. Mechanical, chemical, and nondestructive characterization techniques. Letter grading. Mr. Y. Yang


272. Computer Simulations of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: BS in Materials Science and Engineering. Requisite: course 151. Fabrication methods, structure and properties of advanced composite materials. Fibers, matrix, and processing. Mechanical, chemical, and nondestructive characterization techniques. Letter grading. Mr. Y. Yang
amphibolites, visible intergranular minerals, and aplitic quartz veins. The metamorphic foliation is parallel to the contact between the amphibolite and the aplitic quartz veins. The foliation is defined by the alignment of mica, quartz, and feldspar crystals, which is typically foliated in the amphibolite. The aplitic quartz veins cut across the foliation in the amphibolite, indicating a later stage of metamorphic activity.

271. Electronic Structure of Materials. (4)
Lecture, four hours; outside study, eight hours. Preparation: basic knowledge of quantum mechanics. Recommended requisite: course 200. Introduction to modern first-principles electronic structure calculations for various types of modern materials. Properties of electronic 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 (W)

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 phenomena that emerge only in very small systems, using simple concepts from quantum mechanics and thermodynamics. Topics include structure and electronic properties of quantum dots, wires, nanotubes, and multilayers, self-assembly on surfaces and in liquid solutions, mechanical properties of nanostructured metamaterials, molecular electronics, 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 278B. Lecture, three hours; discussion, two hours; outside study, seven hours. Required: 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 2022-23)

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 overviews of topics prior to lecture. Class discussions follow each presentation. May be repeated for credit. S/U grading. Mr. J.-M. Yang

296. Seminar: Advanced Topics in Materials Science and Engineering. (2) Seminar, two hours; outside study, four hours. Advanced study and analysis of current topics in materials science and engineering. Discussion of current research and literature in research specialty of faculty members teaching course. May be repeated for credit. S/U grading.

M297B. Material Processing in Manufacturing. (4) Same as Mechanical and Aerospace Engineering 297B. Lecture, four hours; outside study, eight hours. Enforced requisite: Mechanical and Aerospace Engineering 183A. Thermodynamics, principles of material processing: phase equilibria and transitions, transport mechanisms of heat and mass, nucleation and growth of microstructure. Applications in casting/solidification, welding, consolidation, chemical vapor deposition, infiltration, composites. Letter grading.

M297C. Composites Manufacturing. (4) Same as Mechanical and Aerospace Engineering 297C. Lecture, four hours; outside study, eight hours. Required: course 151, Mechanical and Aerospace Engineering 166C. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/compression molding, filament winding, pultrusion, resin transfer molding, injection molding, extrusion, fiber orientations, woven, braided, filament wound. Letter grading.

298. Seminar: Engineering. (2 to 12) Seminar, to be arranged. Limited to graduate materials science and engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading.

375. Teaching Apprentice Practicum. (1 to 2) 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. 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 students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

598. Research for and Preparation of MS Thesis. (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

Xiaolin Zhong, PhD, Chair
Jonathan B. Hopkins, PhD, Vice Chair
Yongjie Hu, PhD, Vice Chair
Chang-Jin (CJ) Kim, PhD, Vice Chair

Faculty Roster

Professors
Andrea L. Bertozzi, PhD (Betsy Wood Knapp Professor of Innovation and Creativity)
Robert N. Candler, PhD
Gregory P. Carman, PhD (Ben Rich-Lockheed Martin Professor of Advanced Aerospace Technologies)
Yong Chen, PhD
Eric Pei-Yu Chiou, PhD
Vijay K. Dhir, PhD
Dino Di Carlo, PhD
Jeffrey D. Eldridge, PhD
Timothy F. Fisher, PhD
Rajit Gadhi, PhD
Vijay Gupta, PhD
Dennis W. Hong, PhD
Jonathan B. Hopkins, PhD
Jean-Pierre Hubuschman, MD, in Residence
Tetsuya Iwasaki, PhD
Y. Sungtaek Ju, PhD
Ann R. Karagozian, PhD (Collins Aerospace Term Professor of Innovation)
H. Pirouz Kavehpour, PhD
Chang-Jin (CJ) Kim, PhD (Volgenau Endowed Professor of Engineering)
Adrienne G. Lavine, PhD
Xiaochun Li, PhD (Raytheon Company Professor of Mechanical Engineering)
Jaime Marian, PhD
Robert T. M’Closkey, PhD
Ali Mosleh, PhD, NAE (Evalyn Knight Professor of Engineering)
Sriram Narasimhan, PhD
Laurent G. Pillon, PhD
Jacob Rosen, PhD
Veronica J. Santos, PhD
Jason L. Speyer, PhD (Ronald and Valerie Sugar Endowed Professor of Engineering)
Kunihiro (Sam) Taira, PhD
Tsuyoshi Tsuchiyama, PhD
Xiaolin Zhong, PhD

Professors Emeriti
Mohamed A. Abdou, PhD
Oddvar O. Bendiksen, PhD
Peretz P. Friedman, ScD
Nasr M. Gholien, PhD

Vice Chair
Chair
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 design, robotics, and manufacturing; fluid mechanics; micro- and nanotechnology; structural and solid mechanics; systems control; and thermal science and engineering. 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 BS degrees in Aerospace Engineering and in Mechanical Engineering. At the graduate level, the department offers programs leading to MS and PhD degrees in Mechanical Engineering and in Aerospace Engineering. An MS 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 Study

#### Aerospace Engineering BS

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.

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

#### Capstone Major

The Aerospace Engineering major is a designated capstone major. 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. Graduates 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.

### Educational Objectives

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.

### 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 M20 (or Computer Science 31), 82; 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 (16 units): aeronautics (150B, C150P, 154A, 154S) or space (C150R, 161A, 161B, 161C); three technical breadth courses (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 ma-

For information on UC, school, and general education requirements, see Requirements for BS Degrees on page 21 or the GE Requirement web page.

Mechanical Engineering BS

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.

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

Capstone Major

The Mechanical Engineering major is a designated capstone major. Within their capstone courses, Mechanical Engineering students work in teams to propose, design, analyze, and build a mechanical or electromechanical device. Graduates 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.

Educational Objectives

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.

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, C136, C137, C138, CM140, 150A, 150B, 150C, C150G, C150P, C150R, 154B, 154S, 155, C156B, 157A, 161A, 161B, 161C, C162A, C163B, 158, M168, 169A, 171B, 172, 174, C175A, 181A, 182B, 182C, 183A (unless taken as a required course), and M183B (unless taken as a required course), C183C, 185, C186, C187L.

For information on UC, school, and general education requirements, see Requirements for BS Degrees on page 21 or the GE Requirement web page.

Graduate Study

For admission information, see Graduate Programs Admission on page 27.

The following introductory information is based on 2022-23 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 (MS) degree in Manufacturing Engineering, Master of Science (MS) and Doctor of Philosophy (PhD) degrees in Aerospace Engineering, and Master of Science (MS) and Doctor of Philosophy (PhD) degrees in Mechanical Engineering. All new MS and PhD students who are pursuing an MS 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 MS degree requirements. Students should obtain an MS planning form from the department Student Affairs Office and return it with their advisers’ signature by the end of the first term.
Aerospace Engineering MS and Mechanical Engineering MS

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 BS 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, 109, Computer Science M152A, 152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, M133A, M171L, 199, Materials Science and Engineering 110, 120, 130, 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) 150A 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 MS committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the PhD 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 MS 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 MS degree is expected. There is no examination under the thesis plan.

Manufacturing Engineering MS

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 BS degree from an ABET-accredited aerospace program.

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, M133A, M171L, 199, Materials Science and Engineering 110, 120, 130, 131L, 132, 140A, 140B, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Upper-Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering M168, 174, 183A, 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 MS committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the PhD 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 MS 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 should normally start to plan the thesis at least one year before the award of the MS degree is expected. There is no examination under the thesis plan.

Aerospace Engineering PhD and Mechanical Engineering PhD

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.
PhD 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 PhD degree is built around major and minor fields. The established major fields are listed above, and a detailed syllabus describing each PhD major field can be obtained from the Student Affairs Office.

The program of study for the PhD 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 plasma physics and fusion engineering. Also, an ad hoc field can be used in exceptional circumstances, such as when certain knowledge is desirable for a program of study that is not available in established minor fields.

Grades of B– or better, with a grade-point average of at least 3.33 in all courses included in the minor field, and the three additional courses mentioned above are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only).

**Written and Oral Qualifying Examinations**

After mastering the body of knowledge defined in the major field, students take a written qualifying (preliminary) examination covering this knowledge. Students must have been formally admitted to the PhD program or admitted subject to completion of the MS degree by the end of the term following the term in which the examination is given. The examination must be taken within the first two calendar years from the time of admission into the PhD program. Students must be registered during the term in which the examination is given and be in good academic standing (minimum GPA of 3.25). The student’s major field proposal must be completed prior to taking the examination. Students may not take an examination more than twice. Students in an ad hoc major field must pass a written qualifying examination that is approximately equivalent in scope, length, and level to the written qualifying examination for an established major field.

After passing the written qualifying examination, students take the University Oral Qualifying Examination within four calendar years from the time of admission into the PhD 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, bio-fluid mechanics, chemically reactive flows, chemical reaction kinetics, numerical methods for computational fluid dynamics (CFD), and experimental methods. The educational program for graduate students provides a strong foundational background in classical incompressible and compressible flows, while providing elective breadth courses in advanced specialty topics such as computational fluid dynamics, microfluidics, 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 nanofabrication/microfabrication technologies, molecular fluidic phenomena, nanoscale/microscale material processing, biomolecular signatures, heat transfer at the nanoscale, and system integration. The program is highly interdisciplinary in nature.

**Structural and Solid Mechanics**

The solid mechanics program features theoretical, numerical, and experimental studies, including fracture mechanics and damage tolerance, micromechanics with emphasis on technical applications, wave propagation and nondestructive evaluation, mechanics of composite materials, mechanics of thin films and interfaces, analysis of coupled 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 aeroelasticity, fluid structure interaction, computational transonic aeroelasticity, 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.

Advanced Space Systems Laboratory
Artur Davoyan, Director
The laboratory is focused on nanoscale materials for space and energy applications. Research topics encompass space exploration, device physics, and sustainability.

Anatomical Engineering Group
Tyler R. Clites, Director
The group researches anatomy, the co-engineering of body and machine in pursuit of synergistic bionic performance. The research combines surgical and mechanical design to codevelop body and machine. The long-term goal of the work is to transform the field of human rehabilitation and augmentation by making anatomy 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.

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.

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).

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.

Collaborative Center for Aerospace Sciences (CCAS)
Ann R. Karagozian, Director
CCAS is a multi- and 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.

Computational Fluid Dynamics Laboratory
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.

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.

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. Karagözian, 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.

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, thermonuclear, 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 thermonuclears.

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.

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 Tsa, 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), electrowetting, droplets and bubbles, and superhydrophobic surfaces; and applications 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 instruments 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.

Multidisciplinary University Research Initiative (MURI)
Yong Chen, Director
The Multidisciplinary University Research Initiative (MURI)...(TBD)

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.

Nano Intelligent Systems Laboratory
Yong Chen, Director
The Nano Intelligent Systems Laboratory studies nanofabrication, nanoscale electronic materials and devices, micro-nano electronic/optical/bio/mechanical systems, and ultrascale spatial and temporal characterization.

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 fluidics devices; 3D micro- and nano-manufacturing technologies; and flexible mechanical, photonics, and electronics systems.

Pilon Research Group
Laurent G. Pilon, Director
The Pilon Research Group researches photobiological fuel production, mesoporous materials, electrochemical capacitors, waste heat energy harvesting, foams/microfoams, biomedical optics, and energy efficiency.

Plasma and Beam Assisted Manufacturing Laboratory
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.
Robotic and Mechanisms Laboratory (RoMeLa)
Dennis W. Hong, PhD, 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, PhD, 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 engineer breakthroughs in manufacturing. The laboratory links molecular, nano, and microscale 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.

Sensors and Instrumentation Laboratory
Robert T. M’Closkey, PhD, 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.

Simulations of Flow Physics and Acoustics Laboratory (SOFiA)
Jeffrey D. Eldredge, PhD, 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 viscus streaming; the fluid dynamics of biological and biologically-inspired locomotion; interactions of fluid flows with flexible surfaces; transitional and turbulent hypersonic boundary layer flows; vortex estimation techniques for autonomous control of formation flight; and new computational tools for simulation of biomedical flows.

Smart Grid Energy Research Center (SMERC)
Rajit Gadh, PhD, 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 (G2V and V2G), automated demand response (ADR), microgrids, distributed energy resources, renewable integration, battery energy storage integration, and autonomous vehicle infrastructure.

Thin Films, Interfaces, Composites, Characterization Laboratory
Vijay Gupta, PhD, Director

The Thin Films, Interfaces, Composites, Characterization Laboratory includes a Nd:YAG laser of 1 Joule capacity with 3 ns pulse widths; a state-of-the-art optical interferometer including an ultra-high-speed digitizer, sputter deposition chamber, 56 Kip-capacity servohydraulic biaxial test frame, and polishing and imaging equipment for microstructural characterization; for measurement and control study of thin film interface strength.

Faculty Areas of Thesis Guidance

Professors
Robert N. Candler, PhD (Stanford, 2006) MEMS/NEMS for compact free-electron lasers, miniature medical devices, nanoscale magnetic structures and devices, additive manufacturing, fundamental limits of micro- and nano-scale devices
Yong Chen, PhD (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
Eric Pei-Yu Chiou, PhD (UC Berkeley, 2005) BioMEMS, biophotonics, electromagnetics, optical manipulation, optoelectronic devices
Vijay K. Dhir, PhD (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
Jeffrey D. Eldredge, PhD (Caltech, 2002) 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 biomedical flows
Timothy S. Fisher, PhD (Cornell, 1998) Heat and mass transfer, interfacial transport, nanomaterial synthesis, nano-/micro-device fabrication, non-equilibrium thermodynamics, subcontinuum modeling and measurements of heat and charge transport, electrochemical and thermal energy storage, mechanics and transport in granular materials and porous media, plasma science and technology, aerospace thermal systems
Rajit Gadh, PhD (Carnegie Mellon, 1991) Smart grid, electric vehicle and grid integration, microgrid, distributed energy resource, solar- and renewable-grid integration, demand response, autonomous electric vehicle, machine learning from transportation data, radio frequency identification (RFID), Internet of Things

Vijay Gupta, PhD (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, PhD (Purdue, 2002) Analysis and visualization of contact force solution space for multilimbed mobile robots
Jonathan B. Hopkins, PhD (MIT, 2010) Design and manufacturing of microstructural architectures, flexure systems, and compliant mechanisms; screw theory kinematics; precision machine design; novel micro- and nano-fabrication processes; MEMS
Jean-Pierre Hubschman, MD
TBD

Tetsuya Iwasaki, PhD (Purdue, 1993) Dynamical systems, robust and optimal controls, nonlinear oscillators, resonance entrainment, modeling and analysis of neuronal control circuits, locomotion, central pattern generators, body-fluid interaction during undulatory and oscillatory swimming

Y. Sungtaek Ju, PhD (Stanford, 1999) Heat and mass transfer, energy, energy-water nexus, MEMS and nanotechnology

Ann R. Karagozian, PhD (Caltech, 1982) Fluid mechanics and combustion with applications to air breathing, rocket propulsion, and energy-generation systems, focusing on combustion processes improved efficiency, and reduced emissions

H. Pirouz Kavehpour, PhD (MIT, 2003) Microscale fluid mechanics, transport phenomena in biological systems, biofluids, coating flows and physical contact phenomena, complex fluids, non-isothermal flows, energy systems and energy storage

Chang-Jin (CJ) Kim, PhD (UC Berkeley, 1991) Microelectromechanical systems (MEMS), microfluidics and fabrication technologies, microfluidics especially involving surface tension and droplets

Adrienne Lavine, PhD (UC Berkeley, 1984) Heat transfer: thermomechanical behavior of shape memory alloys, thermal aspects of manufacturing processes, natural and mixed convection

Xiaochun Li, PhD (Stanford, 2001) Embedded sensor and layered manufacturing

Jaime Marian, PhD (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

Robert T. M’Closkey, PhD (Caltech, 1995) Nanofluidic and microfluidic design with application to mechanical and aerospace systems, real-time implementation

Ali Mosleh, PhD, NAE (UCLA, 1981) Reliability engineering, physics of failure modeling and analysis, life data analysis, inverse problems, analytics, reliability, and risk management

Sriram Narasimhan, PhD (Rice University, 2005) Fluid mechanics and combustion with applications to air breathing, rocket propulsion, and energy-generation systems, focusing on combustion processes improved efficiency, and reduced emissions

Kunihiko (Sam) Taira, PhD (Caltech, 2008) Development of computation fluid dynamics that incorporate unsteady aerodynamics, flow control, and network theory

Tsu-Chin Tsao, PhD (UC Berkeley, 1988) Mechatronics and control with applications in manufacturing systems, manufacturing, vehicles, medical robots, and energy

Xiaolin Zhong, PhD (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

Mohamed A. Abdou, PhD (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; blankets and first wall components; experiments, modeling and analysis

Peretz P. Friedmann, ScD (MIT, 1972) Aeroelasticity of helicopters and fixed-wing aircraft, structural dynamics of rotating systems, rotor dynamics, unsteady aerodynamics, active control of structural dynamics, structural optimization with aeroelastic constraints

Nasr M. Ghoniem, PhD (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 of mechanics and physics of material defects; fusion energy; materials for space propulsion

James S. Gibson, PhD (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, PhD (Johns Hopkins, 1974) Molecular fluidic phenomena, microelectromechanical systems (MEMS), bionano technologies, biomolecular sensor arrays, control of cellular complex systems, rapid search of combinatorial libraries

J. John Kim, PhD (Stanford, 1978) Numerical simulation of turbulent and transitional flows, physics and control of turbulent flows, application of modern control theories to flow control

Ajit K. Mai, PhD (Calcutta U., India, 1964) Mechanics of solids, composite materials, wave propagation, nondestructive evaluation, structural health monitoring

Anthony F. Mills, PhD (UC Berkeley, 1966) Convective heat and mass transfer, condensation heat transfer, turbulent flows, ablation and transpiration cooling, perforated plate heat exchangers

D. Lewis Mengori, PhD (Stanford, 1966) Dynamics and control, stability theory, non-linear methods, applications to space and ground vehicles

Peter A. Monkewitz, PhD (ETH Zürich, Switzerland, 1977) Fluid mechanics, internal acoustics and noise produced by turbulent jets

Philip F. O’Brien, MS (UCLA, 1949) Industrial engineering, environmental design, thermal and luminous engineering systems

Owen I. Smith, PhD (UC Berkeley, 1977) Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductors for chemical vapor deposition

Richard Stern, PhD (UCLA, 1964) Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics


Daniel C. H. Yang, PhD (Rutgers, 1982) Robotics and mechanisms; CAD/CAM systems, computer-controlled machines

Associate Professors

Elisa Franco, PhD (U. Trieste, Italy, 2007; Caltech, 2011) Convergence of structural biology, dynamics, and controls using specialized biomolecular frameworks

Yvone Hu, PhD (Harvard, 2011) Heat transfer and electron transport in nanostructures; interfaces and packaging; thermal, electronic, optoelectronic, and thermoelectric devices and systems; energy conversion, storage, and thermal management; ultrafast optical spectroscopy and high-frequency electronics; nanomaterials design, processing, and manufacturing

Raymond M. Searain, PhD (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

Assistant Professors

Tyler R. Clites, PhD (MIT, 2018); joint program certificate, Harvard Medical-MIT (2018) Bionic systems to rehabilitate and augment human function; movement biomechanics; neural interfacing and control; advancements in orthopaedic and plastic surgery

Arthur R. Davoyan, PhD (Australian National University, 2011) Mechatronics and control with applications in mechanical and aerospace systems; optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation

Eldon J. Weiss, PhD (UCLA, 1971) Convergence of structural biology, dynamics, and controls using specialized biomolecular frameworks

TBD

Lecturers

Ravneesh C. Amar, PhD (UCLA, 1974) Heat transfer and thermal science

Amiya K. Chattajee, PhD (UCLA, 1976) Elastic wave propagation and penetration dynamics

Robert J. Kinsey, PhD (UCLA, 1991) Modeling, simulation, and analysis of spacecraft dynamics and pointing control systems; nonlinear dynamics of spinning bodies; con-
Mechanical and Aerospace Engineering Courses

Lower-Division Courses

1. Undergraduate Seminar. (1) Seminar, one hour; outside study, six 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 interest; integral importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

2. Introduction to MATLAB. (4) Lecture, two hours; discussion, two hours; laboratory, two hours; outside study, six hours. Requisite: Mathematics 33A. Fundamentals of computer programming taught in context of MATLAB computing environment. Basic data types and control structures. Input/Output functions. Data visualization using MATLAB-based data structures. Development of efficient codes. Introduction to object-oriented programming. Examples and exercises from engineering, mathematics, and physical sciences. Letter grading.

Mr. Jawed (F,W,Sp)


Mr. Mal (F,W,Sp)

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. Gadh (F,W,Sp)

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

Upper-Division Courses


Mr. Mal (F,W,Sp)

102. Dynamics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 101, Mathematics 33A, Physics 1A. Fundamental concepts of Newtonian mechanics. Kinematics and kinetics of particles and rigid bodies in two and three dimensions. Impulse-momentum and work-energy relationships. Applications. Letter grading.

Ms. Santos (F,W,Sp)

103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 101, Mathematics 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading.

Mr. Kavehpour (F,W,Sp)

105A. Introduction to Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20B, Mathematics 32B. Phenomenological thermodynamics. Conservation of mass, energy, and entropy. First law and concept of energy; second law and concept of entropy. Equations of state and thermodynamic properties. Engineering applications of these principles used in design of closed and open systems. Letter grading.

Mr. Pilon (F,W,Sp)

105D. Transport Phenomena. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 82, 103, 105A. Transport phenomena; heat conduction, mass species diffusion, convective heat and mass transfer, radiation. Engineering applications in thermal and environmental control. Letter grading.

Mr. Ju, Ms. Lavine (F,W,Sp)

107. Introduction to Modeling and Analysis of Dynamic Systems. (4) Lecture, 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, root-locus and second-order system response analysis, and numerical solution. Nonlinear differential equation descriptions with discussion of equilibrium solutions, small signal linearization, large signal response. Block diagram representation and response of interconnections of systems. Hands-on experiments reinforce lecture material. Letter grading.

Mr. M’Closkey, Mr. Tsao (F,W,Sp)


Ms. Lavine (F)

C131G. Microscopic Energy Transport. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Exploration of basic principles of transporation of energy in natural and fabricated structures by three carriers: electrons, phonons, and molecules. Study of statistical properties of heat carriers, common Landauer framework for heat flow, scattering and propagation of heat carriers, derivation of classical laws from microscopic transport equations, and deviation from classical laws at small scale. Concurrently scheduled with course C231G. Letter grading.

Mr. Fisher (F)

133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. Applications of thermodynamic principles to engineering processes. Energy conversion systems. Rankine cycle and other cycles, refrigeration, psychrometry, reactive and non-reactive fluid flow systems. Elements of thermodynamic design. Letter grading.

Mr. Fisher (W,Sp)

135. Fundamentals of Nuclear Science and Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 82, Chemistry 20A. Review of nuclear physics, radioactive decay and radiation interaction with matter. Nuclear fission and fusion processes and mass defect, chain reactions, criticality, neutron diffusion and multiplication, heat transfer issues, and applications. Introduction to nuclear power plants for commercial electricity production, space power, spacecraft propulsion, nuclear fusion, and nuclear science for medical uses. Letter grading.

Mr. Abdou (Not offered 2022-23)

C136. Energy and Environment. (4) Formerly numbered 136) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 105A or equivalent. Global energy use and supply, electrical power generation, fossil fuel and nuclear power plants, renewable energy, such as hydro-power, biomass, geothermal, solar, wind, and ocean, fuel cells, transportation, energy conservation, air and water pollution, global warming. Concurrently scheduled with course C236. Letter grading.

Mr. Pilon (W)

C137. Design and Analysis of Smart Grids. (4) Lecture, four hours; outside study, eight hours. Description of key components of a smart power grid; demand response; transmission and distribution infrastructure; renewable energy in-
C150R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, two hours; laboratory, six hours. Enforced requisites: courses 103, 105A. Rocket propulsion concepts, including chemical rockets (liquid, gas, and solid propellants), hybrid rockets, air-breathing (turbo) rockets, nuclear rockets, and solar-powered vessels. Current issues in launch vehicle technologies. Concentratedly scheduled with course C250R. Letter grading.

Mr. Wirz (Sp)

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 154S. Classical preliminary design of aircraft, including weight estimation, center of gravity, flight control, and control consideration. Term assignment consists of preliminary design of low-speed aircraft. Letter grading.

Mr. Wirz (W)


Ms. Franco, Mr. Tsao (F)

156A. Advanced Strength of Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 82, 101. Not open to students with credit for course 166B. Concepts of stress, strain, and material behavior. Stresses in loaded beams with symmetric and asymmetric cross sections. Torsion of cylinders and thin-walled structures. Stress, strain, deflection, stresses in pressure vessels, misfit and shrink-fit problems, rotating shafts. Curved beams, Contact stresses. Strength and failure, plastic deformation, fatigue, elastic instability. Letter grading.

Mr. Mal (W,Sp)

C156B. Mechanical Design for Power Transmission. (4) Lecture, four hours; outside study, eight hours. Requisite: course 155A or 166A. Mechanical design for power transmission. Deflection and stiffness. Failure due to static loading. Fatigue failure. Design for safety factors and reliability. Applications of failure prevention in design of power transmission shafting. Design project involving design of gears, clutches, chains, splines, and drive elements. Letter grading.

Ms. Franco, Mr. Tsao (F)

161A. Introduction to Astronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 102. Recommended course 104. Spaceflight vehicle design — two-body and three-body problem, Kepler laws, and Keplerian orbits. Ground track and taxonomy of common orbits. Orbital and transfer maneuvers, patched conics, perturbation theory, low-earth-spacecraft pointing, and spacecraft attitude control. Space mission design, space environment, rendezvous, re-entry, and launch. Letter grading.

Mr. Wirz (F)

161B. Introduction to Space Technology. (4) Lecture, four hours; discussion, two hours; laboratory, 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. Wirz (W)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 161B. Preliminary design and analysis by students of Earth-orbiting or interplanetary space missions and spacecraft. Students work in groups of three or four, undergoing student-led research to design a subsystem and for integration with whole. Letter grading.

Mr. Wirz (Sp)


Mr. Hopkinson (F,Sp)


Mr. Hopkins (W)

162D. Mechanical Engineering Design I. (4) Lecture, two hours; laboratory, four 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. Lectures on engineering project management, design of thermal systems, mechatronics, mechanical systems, and mechanical components. Students work in teams to begin their two-term design project. Laboratory modules include CAD design, CAE 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. Limited to seniors. Second of two mechanical engineering capstone design courses. Students group continues design projects started in course 162D, making use of CAD design laboratory, CAD analysis laboratory, and mechatronics laboratory. Design theories, design tools, economics, marketing, manufacturability, quality, intellectual property, design for manufacture and assembly, design for safety and reliability, and engineering ethics. Students conduct hands-on design, fabrication, and testing. Cumnulating project demonstr-
M163A. Kinematics of Robotic Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: courses 155, 171. Five analytical models of serial and parallel robotic manipulators, including spatial descriptions and transformations (Euler angles, Denavit-Hartenberg/DH parameters, equivalent angle vector), frame assignment procedures, inverse dynamics, inverse kinematics, (geometric and algebraic approaches), mechanical design topics. Concurrently scheduled with course C263A. Letter grading. Mr. Tsao (Sp)

C163B. Dynamics of Robotic Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 163A. Dynamics models of serial and parallel robotic manipulators, including review of spatial descriptions and transformations along with direct and inverse kinematics, linear and angular velocities, Jacobian matrix (velocity and force), velocity propagation method, force propagation method, explicit formulation of Jacobian (Newton Euler formulation, Lagrangian formulation), trajectory generation, introduction to parallel manipulators. Concurrently scheduled with course C263A. Letter grading. Mr. Hong (F)

166A. Analysis of Aerospace Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses B2, 101. Enforced requisites: course 156A or 166A. An introduction to advanced topics in 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; preprocessing and postprocessing; structural analysis; term projects. Concurrently scheduled with course C263A. Letter grading. Mr. Mal (Sp)

163A. Introduction to Manufacturing Processes. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 156A or 166A or Civil Engineering 130. Introduction to basic dynamics (Newton/Euler formulation, Lagrangian formulation), trajectory generation, introduction to parallel manipulators. Concurrently scheduled with course C263A. Letter grading. Ms. Santos (Sp)

166C. Design of Composite Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 166A or 166A. A brief introduction to the design of composite materials and the mechanical properties of composites. Lecture grading. Mr. Carman (W)

M168. Introduction to Finite Element Methods. (4) (Same as Civil Engineering M135C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 156A or 166A or Civil Engineering 130. Introduction to basic dynamics (Newton/Euler formulation, Lagrangian formulation), trajectory generation, introduction to parallel manipulators. Concurrently scheduled with course C263A. Letter grading. Mr. O'Colley (W)

171A. Introduction to Feedback and Control Systems. (4) (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 107. Introduction to feedback principles, control systems design, and system stability. Modeling of physical systems in engineering and other fields; transform methods; controller design using Nyquist, Bode locus, and root locus methods; compensation; computer-aided analysis and design. Letter grading. Ms. Franco, Mr. Iwakawa (F/Sp)


172. Control System Design Laboratory. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 171A. Introduction to loop shaping controller design with application to laboratory electromechanical systems. Power spectrum, autocorrelation and disturbance, and performance trade-offs imposed by conflicting requirements. Constraints on sensitivity function and complementary sensitivity function imposed by nonminimum phase plants. Lecture grading. Mr. Mal (F)

174. Probability and Its Applications to Risk, Reliability, and Quality Control. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 33A. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength models, fault tree analysis, statistical quality control by variables and by attributes, acceptance sampling. Letter grading. Mr. M'Clokey (W)

C175A. Probability and Stochastic Processes in Manufacturing. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Enforced requisites: courses 82, 107. Probability spaces, random variables, stochastic processes and sequences, expectation, conditional expectation, separability of variables, eigenvalue problems, fault tree analysis and Kalman filter with applications. Concurrently scheduled with course C271A. Letter grading. Mr. Speyer (F)

181A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: course 82. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals; Laplace transform; Separation of variables, eigenvalue problems, Fourier transform: properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading.


Mr. Eldredge, Mr. Taira (Not offered 2022-23)


Mr. Zhong (F)


C183B. Introduction to Microscale and Nanoscale Manufacturing. (4) (Same as Bioengineering M153, Chemical Engineering M153, and Electrical and Computer Engineering M153) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4AL. Introduction to general manufacturing methods, mechanisms, constraints, and microfabrication techniques. Novel micro and nanofabrication concepts, tools, 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 chemical and physical etching methods. Hands-on experience for microfabrication and nanofabrication techniques. Letter grading. Mr. Chiou (W)

C183C. Rapid Prototyping and Manufacturing. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisites: course 183A. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as a popular manufacturing technology to accelerate product creation in last two decades. Machine for layered manufacturing builds parts directly from CAD models. Novel manufacturing technology enables building of parts that have traditionally been impossible to fabricate because of their complex shapes or of variety in materials. In analogy to speed and flexibility of desktop publishing, rapid prototyping is also called desktop manufacturing, with actual three-dimen- sional solid objects instead of mere two-dimensional images. Methodology of rapid prototyping has also been extended into microdot technology to produce microfabrication. Rapid prototyping (RP), microfabrication, or additive manufacturing technology. Rapid prototyping (RP), microfabrication, or additive manufacturing technology. Rapid prototyping (RP), microfabrication, or additive manufacturing technology. Rapid prototyping (RP), microfabrication, or additive manufacturing technology. Lecture 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 requisites: course 220 or Civil Engineering 220 or Computer Science 31. Manufacturing today requires as- sembling of individual components into assembled products, shipping of such products, and eventually use, maintenance, and recycling of such products. Radio frequency identification (RFID) is being utilized in manufacturing, with focus on automotive and aerospace. Letter grading. Mr. Mal (Sp)

C186. Applied Optics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 220 or Civil Engineering 220 or Computer Science 31. Manufacturing today requires as- sembling of individual components into assembled products, shipping of such products, and eventually use, maintenance, and recycling of such products. Radio frequency identification (RFID) is being utilized in manufacturing, with focus on automotive and aerospace. Letter grading. Mr. Mal (Sp)

C188. Applied Optics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 220 or Civil Engineering 220 or Computer Science 31. Manufacturing today requires as- sembling of individual components into assembled products, shipping of such products, and eventually use, maintenance, and recycling of such products. Radio frequency identification (RFID) is being utilized in manufacturing, with focus on automotive and aerospace. Letter grading. Mr. Mal (Sp)

Mr. Chiu (Sp)

218L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Multidisciplinary. Students will be introduced to laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles related to these techniques, top-down and bottom-up (self-assembly) fabrication, nanotechnology (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C228L. Letter grading.

Mr. Y. Chen (Sp)

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Special topics in mechanics and aerospace engineering for undergraduate students taught on experimental or theoretical basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. P/NP or letter grading.

188SA. Individual Studies for USIE Facilitators. (1) Tutorial, to be arranged. Enforced prerequisite: Honors Collegium 101E. Limited to junior/senior USIE facilitators. Individual study in regularly scheduled meetings with faculty mentor to discuss selected USIE seminar topic, conduct preparatory research, and begin preparation of syllabus. Individual contract with faculty mentor required. May not be repeated. Letter grading.


188SC. Individual Studies for USIE Facilitators. (2 to 4) Tutorial, to be arranged. Enforced prerequisite: course 188SB. Limited to junior/senior USIE facilitators. Individual study in regularly scheduled meetings with faculty mentor to complete capstone project. Individual contract with faculty mentor required. May not be repeated. Letter grading.

194. Research Group Seminars: Mechanical and Aerospace Engineering. (2 to 4) Seminar, two hours. Designed for undergraduate students to participate in research group. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated for credit. P/NP or letter grading. 

199. Directed Research in Mechanical and Aerospace Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Concurrently scheduled with research project. 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


Ms. Lavine (F)

213B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: course 105D. Radiative properties of materials and radiative energy transport. Emphasis on fundamental concepts, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiation transfer in absorbing, emitting, and scattering media. Proctor and Lebedev’s laser-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading.

Mr. Pilon (Sp)


Ms. Lavine (W)

231G. Microscopic Energy Transport. (4) For- merly numbered 231GL. Lecture, four hours; outside study, eight hours. Requisites: course 233. Provides students with a basic explanation of fundamental principles of transport of energy in natural and fabricated structures by three carriers: electrons, phonons, and molecules. Study of statistical properties of heat carriers, complementary framework for heat flow, scattering and propagation of heat carriers, derivation of classical laws from microscopic transport equations, and derivation from classical laws at small scale. Term project. Concurrently scheduled with course C131G. Letter grading.

Mr. Fisher (F)

233. Nanoscience for Energy Technologies. (4) Lecture, four hours; outside study, eight hours. Introductory principles of fundamental principles of energy transport, conversion, and storage at nanoscale, and recent development for these energy technologies involving nanotechnology. Focus on basics of thermal science, solid state, quantum mechanics, electronics, magnetic, and statistical physics. Topic discussions given for examples that connect technological application, fundamental challenge, and scientific-solution-based nanotechnology to improve device performance and energy efficiency. Letter grading.

Mr. Hu (Not offered 2022-23)

235A. Nuclear Reactor Theory. (4) Lecture, four hours; outside study, eight hours. Underlying physics and mathematics of nuclear reactors. Theoretical core design. Diffusion theory, reactor kinetics, slowing down and thermalization, multigroup methods, introduction to transport theory. Letter grading.

Mr. Abdou (Not offered 2022-23)

236. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: course 105A or equivalent. Global energy use and supply, electric power generation, energy conversion and transport, energy conservation, air and water pollution, global warming. Concurrently scheduled with course C136. Letter grading.

Mr. Abdou (Not offered 2022-23)

239C. Special Topics in Transport Phenomena. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lecture, discussions, student presentations, and project work in areas of current interest in transport phenomena. May be repeated for credit. S/U grading.

Mr. Ju (Not offered 2022-23)

239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in nuclear engineering, such as reactor safety, risk-benefit trade-offs, nuclear materials, and reactor design. May be repeated for credit with topic change. S/U grading.

C236. Introduction to Statistical Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 105A, 105D. Introduction to the fundamental statistical thermodynamics of matter. Abstract concepts of entropy, temperature, and chemical potential are explained by developing these concepts from ground up using only mechanistic and statistical principles. Statistical equilibrium properties of thermodynamic systems and associated distributions. Provides sound foundation for further studies in transport phenomena, plasma, chemical kinetics, micro/nanoscale science and technology, and other related subjects. Concurrently scheduled with course C138. Letter grading.

Mr. Abdou (Not offered 2022-23)

239B. Seminar: Current Topics in Transport Phenomena. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lecture, discussions, student presentations, and project work in areas of current interest in transport phenomena. May be repeated for credit. S/U grading.

C236A. Advanced Transport Processes. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate students in the areas of heat and mass transfer, such as turbulence, stability and transition, buoyancy effects, variational methods, and measure-range applications. May be repeated for credit with topic change. S/U grading.

C239B. Special Topics in Transport Phenomena. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in transport phenomena, such as combustion and thermal insulation. Letter grading. 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, four to eight hours. Requisites: courses 101, 102, and 156A or 166A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and control. Dynamics and kinematics of fluid mechanics applications. Heat and mass transfer, Power gener-
tion. 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, magnetic, and non-linear behavior with associated mechanisms such as spin reorientation. Presentation of analytical tools necessary to predict material response ranging from constitutive relations to governing equations. Basic crystallographic structure of multiferroics, as well as fundamental physics underling ferroelectricity and ferromagnetism. Material science description of these materials, with focus on linear and non-linear behavior with associated mechanisms such as spin reorientation. Solution of model partial differential equations, application to Navier-Stokes equations, boundary conditions. Letter grading. Mr. Eldredge (Sp)


2520. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: courses 105A, 150A. Thermodynamic properties of gaseous and fluid systems, jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Concurrently scheduled with course C150P. Letter grading.


2526. Spectroscopy and Molecular Gas Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Introduction to science that governs interaction between matter from physical sciences (quantum mechanics, statistical mechanics, thermodynamics and quantum chemistry). Introduction to modern techniques for measuring physical properties of gases and molecules. Letter grading. Ms. Karagozian, Mr. Wirz (Sp)


2528A. Linear Elasticity. (4) (Same as Civil Engineering B230A.) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear elastic problems; plane strain problems; plates, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Introduction to boundary integral equation method. Letter grading.

2528B. Nonlinear Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Kinematics of deformation, material and geometric nonlinearities, gradient formation tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stresses, Cauchy equations of motion, balance of energy and momentum, constitutive relations, elasticity, hyperelasticity, thermoelasticity; linearization of field equations; solution of selected problems. Letter grading. Mr. W. Ju, Mr. Mal (W)


2555. Elastodynamics. (4) (Same as Earth, Planetary, and Space Sciences M255A.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity, Cauchy equation of motion, constitutive relations, boundary and initial conditions, principle of energy. Sources
and waves in unbounded isotropic, anisotropic, and dissipative solids. Hydrodynamic problems of surface waves in layered media. Applications to dynamic fracture, nondestructive evaluation (NDE), and mechanics of earthquakes. Letter grading.

Mr. Mal (Not offered 2022-23)

258A. Nanomechanics and Micromechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Analytical and computational modeling methods to describe mechanics of materials at scales ranging from atomic through microstructure to continuum. Discussion of atomistic simulation methods (e.g., molecular dynamics, Langevin dynamics, and kinetic Monte Carlo) and continuum modeling methods. Development and applications of dislocation dynamics and statistical mechanics methods in areas of nanostructure and microstructure self-organization, heterogeneous plastic deformation, material instabilities, and failure phenomena. Presentation of technical applications of these emerging modeling techniques to surfaces and interfaces, grain boundaries, dislocations and defects, surface growth, quantum dots, nanotubes, nanocrystals, superlattices, and promiscuous materials. Letter grading.

Mr. Carman (Sp)

258B. Seminar: Advanced Topics in Fluid Mechanics. (2) Seminar, four hours; discussion, two hours; outside study, six hours. Requisite: course M258A. Kinematics of fluid flows, constitutive equations, and homogenization techniques as they apply to active materials. Active systems design, inch-worm, and biomim. Letter grading.

Mr. Carman (Sp)

C263A. Kinematics of Robotic Systems. (4) Formerly numbered 263B. Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: courses 155, 171A. Kinematical models of serial robotic manipulators, including spatial descriptions and transformations (Euclidean, Euler angles, Denavit-Hartenberg/DOH parameters, equivalent angle vector), frame assignment procedure, direct kinematics, inverse kinematics (geometric and algebraic approaches), mechanical design topics. Concurrently scheduled with course C163A. Letter grading.

Mr. Hong (F)

C263B. Dynamics of Robotic Systems. (4) Formerly numbered 263B. Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course C263A. Recommended: course 255B. Dynamics models of serial and parallel robotic manipulators, including review of spatial descriptions and transformations (Euclidean, Euler formula, Lagrangian formulation), trajectory generation, introduction to parallel manipulators. Concurrently scheduled with course C163B. Letter grading.

Mr. Rosen (W)

C263C. Control of Robotic Systems. (4) Formerly numbered 263C.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course C263B. Sensors, actuators, and control schemata for robotic systems, including computer torque control, linear feedback control, impedance and force feedback control, and advanced control topics from nonlinear and adaptive control, hybrid control, nonholonomic systems, vision-based control, and perception. Concurrently scheduled with course C163C. Letter grading.

Ms. Santos (Sp)

263D. Advanced Topics in Robotics and Control. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course C263C. Current and advanced topics in robotics and control, including kinematics, dynamics, control, mechanical design, advanced sensors and actuators, flexible links, manipulability, redundancy, and robot softening, teleoperation and haptic interaction, teleoperation, haptics. Letter grading.

Mr. Rosen (Not offered 2022-23)

263E. Bionic Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M216A, 201, or equivalent. Introduction to bionic systems engineering, principles of biomimetics, evolution, and design. Applications of bionic systems to real-world problems in robotics and biomechanics. Letter grading.

Mr. Rosen (Not offered 2022-23)

M269A. Dynamics of Structures. (4) (Same as Chemical Engineering M237A.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Civil Engineering 135A, C137, or equivalent. Principles of dynamics. Determination of normal modes and frequencies of vibration. Euler formulation, Lagrangian formulation, trajectory generation, introduction to parallel manipulators. Letter grading.

Mr. Speyer (Not offered 2022-23)


Mr. Mal (Not offered 2022-23)

269D. Aerelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course M269A. Presentation of field of aerelasticity from unified viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Determination of aerelastic contributions to governing variational principles. Flow induced instability and response of structural systems. Letter grading.

Mr. Mal (Not offered 2022-23)

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

Mr. Kennedy (F)

270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering M240A. Existence of optimal solutions, Kalman filtering, earliest optimal control problems for continuous-time and discrete-time systems, finite-time and infinite-time problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, stabilizability, observability, and detectability solutions. Letter grading.

Mr. Gibson (W)


Mr. Speyer (Not offered 2022-23)


Mr. Speyer (W)

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course M271A. Stochastic processes, filtering, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading.

Mr. Speyer (W)


Mr. Speyer (Not offered 2022-23)

271D. Seminar: Special Topics in Dynamic Systems Control. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, inference and aerospace applications. Letter grading.

Mr. Speyer (Not offered 2022-23)


Mr. Speyer (Not offered 2022-23)
time-varying nonlinear dynamic systems with emphasis on stability, Lyapunov theory (including inverse theorems), invariance, center manifold theory, input-to-state stability and small-gain theorem. Letter grading.


279A. System Identification. (4) Lecture, four hours; outside study, eight hours. Methods for identification of dynamical systems from input/output data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of conversion to continuous-time models. Models identified include transfer functions and state-space models. Discussion of applications in mechanical and aerospace systems. Letter grading. (Not offered 2022-23) 279B. Dynamics and Control of Biological Oscillations. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 107, M270A. Analysis and design of dynamical mechanisms underlying biological and developmental processes. Emphasis on bifurcations and pattern formation. Topics include neural information processing through action potential generation, central pattern generator, coupled nonlinear oscillators, optical gait patterns (periodic motion) for animal locomotion, and entrainment to natural oscillations via feedback control. Letter grading. Mr. Iwasaki (Sp) 279B. Dynamics and Feedback in Biological and Ecological Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 171A, 171B, M270A. Dynamics of non-equilibrium and self-organized systems. Topics include biological oscillators, spatial and temporal patterns, biological rhythms, and evolutionary stable strategies. Letter grading. Mr. Ghoniem (Not offered 2022-23) 280B. Microelectromechanical Systems (MEMS) Fabrication. (Same as Bioengineering M250B and Electrical and Computer Engineering M250B.) Lecture, four hours; outside study, eight hours. Enforced requisite: course M183B. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes used to construct MEMS. Many practical examples. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. C-J. Kim (W)

281. Microsciences. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 102, 103, 105D. Fundamental issues in imaging in microscopic world and mechanical engineering of microscopic devices. Topics include scanning, transmission, surface tension, superhydrophobic surfaces and applications, and electrowetting and applications. Letter grading. Mr. C-J. Kim (F)

M282. Microelectromechanical Systems (MEMS) Design. (Same as Bioengineering M252 and Electrical and Computer 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. Chiu (Not offered 2022-23) 284. Sensors, Actuators, and Signal Processing. (4) Lecture, four hours; outside study, eight hours. Principles and performance of micro transducers. Applications of using micro transducers for distributed and real-time control of engineering problems. Associated signal processing requirements for these applications. Letter grading. Mr. C-J. Kim (Not offered 2022-23) 285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 82, 103, 105A, 105D. Introduction to fundamental physical phenomena occurring at interfaces and application of their knowledge to engineering problems. Fundamental concepts of interfacial phenomena, including surface tension, surfactants, interfacial thermodynamics, interfacial forces, interfacial hydrodynamics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), forms and emulsions, microelectromechanical systems, and biological systems. Letter grading. Mr. Pilou (Not offered 2022-23) 296. Applied Optics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Physics 1C. Fundamental principles of optical systems and their design. Diffraction and interference. Fourier optics, beam optics, Propagation of light, Snell’s law, and Huygen’s principle. Refraction and reflection. Plane waves, spherical waves, plane and spherical waves, and multiple-beam interference and thin film coatings. Diffraction theory. Fraunhofer and Fresnel diffraction. Fresnel zone plate. Fiber optics, waveguides and modes, fiber coupling, types of fiber: single and multimode. Concurrently scheduled with course C186B. Letter grading. 291. Nanoscience and Technology. (4) Lecture, four hours; outside study, eight hours. Introduction to fundamentals of nanoscience and technology. Basic principles of quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanofabrication; nano-characterization; nanomaterials, nanoelectronics, and nanobiotechnology. Emphasis on introduction to new knowledge and techniques in nano areas to understand scientific principles behind nanotechnology and inspire students to create new paradigms in multidisciplinary nanoscale Letter grading. Mr. Y. Chen (F)

C294A. Compliant Mechanism Design. (4) Lecture, four hours; outside study, eight hours. Requisite: linear algebra. Advanced compliant mechanism synthesis approaches, modeling techniques, and optimization tools. Fundamentals of flexible continuum principles of constraint-based design, projective geometry, screw theory kinematics, and freedom and constraint topologies. Applications: precision motion stages, general purpose measure bearings, microstructural architectures, MEMS, optical mounts, and nanoscale positioning systems. Hands-on exercises include build-your-own flexure kits, CAD and FEA simulations, and term project. Concurrently scheduled with course C194A. Letter grading. Mr. Y. Chen (Sp)

294A. Radio Frequency Identification Systems: Analysis, Design, and Applications. (4) Lecture, four hours; outside study, eight hours. Designed for graduate engineering students. Examination of emerging discipline of radio frequency identification (RFID), including basics of RFID, how RFID systems function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading. Mr. Gadh (Not offered 2022-23) 296A. Mechanical Design for Power Transmission. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 156A. Mechanical design of power transmission systems. Emphasis on load and stress analysis. Deflection and stiffness. Fatigue due to static loading. Fatigue design. Design for safety factors 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 C156B. Letter grading. Mr. Chiu (Not offered 2022-23) 296B. High-Temperature Mechanical Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or equivalent. Review of elasticity and continuum thermodynamics, multiaxial plasticity, failure rules, creep, creep damage in cyclic loading. Damage mechanics: thermodynamics, ductile, creep, fatigue, and fatigue-creep interaction damage. Fracture mechanics: elastic and elastoplastic analysis, J-integral, brittle fracture, ductile fracture, fatigue and creep crack propagation. Applications in design of high-temperature components such as turbine blades, pressure vessels, heat exchangers, connecting rods. Design project involving CAD and FEM modeling. Letter grading. Mr. Ghoniem (Not offered 2022-23) 297A. Rapid Prototyping and Manufacturing. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Emphasis at the level of knowledge in manufacturing equivalent to course 183A and CAD capability. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as popular manufacturing technology to accelerate product creation in last two decades. Machine for layered manufacturing builds parts directly from CAD models. This novel manufacturing technique enables engineers who have traditionally been impossible to fabricate because of their complex shapes or of variety in materials. In analogy to speed and flexibility of desktop publishing, rapid prototyping is also computer-aided manufacturing, with actual three-dimensional solid objects instead of mere two-dimensional images. Methodology of rapid prototyping has also been extended into micro-/nano-scale to produce three-dimensional

Mr. Li (W)

**M297B. Material Processing in Manufacturing.** (4) (Same as Materials Science M297B) Lecture, four hours; outside study, eight hours. Enforced requisite: course 183A. Thermodynamics, principles of material processing: phase equilibria and transitions, transport mechanisms of heat and mass, nucleation and growth of microstructure. Applications in casting/solidification, welding, consolidation, chemical vapor deposition, infiltration, composites. Letter grading.

Mr. Li (Not offered 2022-23)

**M297C. Composites Manufacturing.** (4) (Same as Materials Science M297C) Lecture, four hours; outside study, eight hours. Requisites: course 186C. Materials Science 151. Matrix materials, fibers, fiber pre-forms, elements of processing, autoclave/compression molding, filament winding, pultrusion, resin transfer molding, automation, material removal and assembly, metal and ceramic matrix composites, quality assurance. Letter grading.

Mr. Ghoum (Not offered 2022-23)

**296. Seminar: Engineering.** (2 to 4) Seminar, to be arranged. Limited to graduate mechanical and aerospace engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading.

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

**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.

Mr. Eldredge (F,W,Sp)

**495. Teaching Assistant Training Seminar.** (2) Seminar, two hours; outside study, four hours. Preparation: appointment as teaching assistant in department. Seminar on communication of mechanical and aerospace engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of visual aids; grading, advising, and rapport with students. S/U grading. Mr. Eldredge (F)

**596. Directed Individual or Tutorial Studies.** (2 to 8) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Petition forms to be arranged. Request for 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 mechanical and aerospace engineering 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 mechanical and aerospace engineering students. S/U grading.

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

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**598. Research for and Preparation of MS Thesis.** (2 to 16) Tutorial, to be arranged. Limited to graduate mechanical and aerospace 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 mechanical and aerospace engineering students. Usually taken after students have advanced to candidacy. S/U grading.

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**Master of Engineering Program**

4732E Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
310-825-1759

Department e-mail
Department website

Jenn-Ming Yang, PhD, Associate Dean

**Overview**

The one-year Master of Engineering (MEng) is a self-supporting, professional degree designed to develop future engineering leaders. Tailored to those who wish to pursue technical management positions, the degree addresses the needs of both students and industry with high-tech skill set and management savvy. Students in the program develop technical mastery in emerging research areas, learning business and technology management skills while creating real-world projects with industry input.

**Graduate Study**

For admission information, see Graduate Programs Admission on page 27.

The following introductory information is based on 2022-23 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.

**Master of Engineering**

**Course Requirements**

Students must complete nine courses (36 units of graduate and upper-division undergraduate coursework) in or related to the major subject areas:

- five core engineering technology courses related to the concentration (20 units)
- three professional development electives (12 units)
- one capstone project (4 units)

Students take two technical courses and one engineering professional development course in fall (12 units), two technical courses in winter (8 units), one technical and one en-
engineering professional development course in spring (8 units), and one engineering professional development and one capstone project course in summer (8 units).

**Areas of Study**

### Artificial Intelligence (AI)

**Guy Van den Broeck**, PhD (Computer Science), Area Director

The artificial intelligence program integrates faculty expertise from the departments of Computational Medicine, Computer Science, and Electrical and Computer Engineering. Study focuses on building smart machines capable of reasoning, learning, and acting intelligently; and performing tasks that typically require human intelligence.

### Autonomous Systems

**Tsu-Chin Tsaao**, PhD (Mechanical and Aerospace Engineering), Area Director

The autonomous systems program integrates faculty expertise from the departments of Computer Science, Electrical and Computer Engineering, and Mechanical and Aerospace Engineering. Study focuses on recent advances including dynamic systems and controls, embedded and cyber-physical systems, machine learning, and optimization. It also explores important autonomous system technologies including autonomous electric vehicles, smart grids, robotics, transportation networks, and more.

### Data Science

**Guy Van den Broeck**, PhD (Computer Science), Interim Area Director

The data science program integrates faculty expertise from the departments of Computational Medicine, Computer Science, and Electrical and Computer Engineering. Study focuses on unifying data mining and analysis, distributed and parallel systems, machining learning, and statistics to understand and analyze large amounts of data.

### Digital Health Technology

**Eleazar Eskin**, PhD (Computer Science), Area Director

The digital health technology program integrates faculty expertise from the departments of Bioengineering, Computational Medicine, Computer Science, Electrical and Computer Engineering, and the David Geffen School of Medicine. Study focuses on digital health tools that have vast potential to improve the ability to accurately diagnose and treat disease, and to enhance health care delivery.

### Green Energy Systems

**Jenn-Ming Yang**, PhD (Materials Science and Engineering), Interim Area Director

The green energy systems program integrates faculty expertise from the departments of Chemical and Biomolecular Engineering, Electrical and Computer Engineering, Materials Science and Engineering, and Mechanical and Aerospace Engineering. Study focuses on renewable energy and energy storage, including energy generation (fuel cells, solar energy, and other renewables); smart grid systems and grid integration; and storage systems (batteries, supercapacitors, and large-scale storage).

### Internet of Things (IoT) Systems

**Mani B. Srivastava**, PhD (Computer Science, Electrical and Computer Engineering), Area Director

The Internet of Things program integrates faculty expertise from the departments of Computer Science and Electrical and Computer Engineering. Study focuses on the foundation needed to design, implement, and fabricate systems for the Internet of Things—where actuation, communication, computing, and sensing capabilities are embedded in and coupled with physical spaces and humans.

### Translational Medicine

**Song Li**, PhD (Bioengineering), Area Director

The translational medicine program integrates faculty expertise from the departments of Bioengineering, Chemical and Biomolecular Engineering, Computational Medicine, the School of Dentistry, and the David Geffen School of Medicine. Study focuses on improving human health and longevity by translating discoveries in biomedical sciences into disease therapies. Translational medicine facilitates the development of diagnostic tools and therapeutics, and the application of systems biology and data sciences to biomedical problems.

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**Master of Science in Engineering Online Programs**

4732 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
310-825-6542

**Department website**

Jenn-Ming Yang, PhD, Associate Dean

**Overview**

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 MS 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 MS programs are addressed to those highly qualified employed engineers who, for various reasons, do not attend the on-campus MS programs and who are keenly interested in developing up-to-date knowledge of cutting-edge engineering and technology.

**Graduate Study**

For admission information, see Graduate Programs Admission on page 27.

The following introductory information is based on 2022-23 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.

**MS 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**

Jungho (John) Cho, PhD (Computer Science), Area Director

Vwani P. Roychowdhury, PhD (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, PhD (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, PhD (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, PhD (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, PhD, 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, PhD (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.

**MS in Engineering – Aerospace**

Xiaolin Zhong, PhD (Mechanical and Aerospace Engineering), Area Director

The objective of this program is to provide students with a broad knowledge of major technical areas of aerospace engineering in order to fulfill the current and future needs of the aerospace industry. The major technical areas of this program include aerodynamics and computational fluid dynamics (CFD), propulsion, systems and control, and structures and dynamics. Undergraduate and graduate courses in the area of aerospace engineering cover a wide range of fundamental concepts of the science and engineering of aerodynamics, space technology, compressible flow, computational aerodynamics, aircraft and rocket propulsion systems, digital control of physical systems, linear dynamic systems, linear optimal control, design of aerospace structures, dynamics of structures, robust control system analysis and design, and probability and stochastic processes in dynamical systems.

**MS in Engineering – Computer Networking**

Songwu Lu, PhD (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.
MS in Engineering – Electrical
Izhak Rubin, PhD (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.

MS in Engineering – Electronic Materials
Ya-Hong Xie, PhD (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.

MS in Engineering – Integrated Circuits
Dejan Markovic, PhD (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.

MS in Engineering – Manufacturing and Design
Xiaochun Li, PhD (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.

MS in Engineering – Materials Science
Yinmin (Morris) Wang, PhD (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 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.

MS in Engineering – Mechanical
Ajit K. Mal, PhD (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.

MS in Engineering – Signal Processing and Communications
Izhak Rubin, PhD (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.


Schoolwide Programs and Courses

6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
310-825-9580

School website

Graduate Study

For information on admission to the schoolwide engineering programs, and requirements for the Engineer degree and certificate of specialization, see Graduate Programs Admission on page 27.

Engineering Courses

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 associated with technology. Drawing from historical and contemporary examples, consideration of some of ethical, policy, and legal questions spurred by rapid technological change. Development of perspective to take broad, contextualized view of operation of some of ethical, policy, and legal questions associated with technology. Drawing of broader societal opportunities, impacts, and challenges associated with technology. (Sp) 21. Computing Immersion Summer Experience. (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 understand about successfully publish first research project. P/NP grading. 22. Summer Bridge Review for Enhancing Engineering Majors. (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. Provides students for career-related social interactions. Development of skills and insights to successfully secure future opportunities, such as first industry internship. 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. Provides students for career-related social interactions. Development of skills and insights to successfully secure future opportunities, such as first industry internship. P/NP grading. 24. Finding Undergraduate Research Opportunity. (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 understand about successfully publish first research project. P/NP grading. 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 understand about successfully publish first research project. P/NP grading. 26. Finding Entry-Level Job. (2) Seminar, two hours; discussion, two hours; outside study, two hours. Designed to engage engineering students in process of getting ready to graduate and need help joining workforce. Focus on how to apply to entry-level positions in engineering field, and specifically industries that value engineering degree over technical experience. Offers suggestions to overcome typical barriers students encounter in securing entry-level position including students with no industry internships, lack of professional resume, lack of technical experience, low grade-point average, lack of student organization extracurricular activities, international students, Deferred Action for Childhood Arrivals (DACA) students, and other low-confidence candidates. Students learn about various components of job application, practice preparing relevant materials, and prepare for career-related social interactions. Students develop skills and insights to successfully secure entry-level position as soon as possible after graduation. P/NP grading. 87. Introduction to Engineering Disciplines. (4) Lecture, four hours; discussion, four hours; outside study, one hour. Intended for students who are interested in 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 workforce. Letter grading. Mr. Wesel (F,W,S). 96B. Introduction to Engineering Design: Digital Imaging. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Recommended for undergraduate Aerospace Engineering, Computer Science, Electrical Engineering, and Mechanical Engineering Majors. Introduction to engineering design while building teamwork and communication skills and examination of engineering majors offered at UCLA and of engineering careers. Hands-on experience with state-of-art solid-state imaging devices. How to focus, expose, record, and 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 report describing projects, and presentation of results. Letter grading. Mr. Stafsudd. 96C. Cybertech: Introduction to Robotic Control Systems. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Complete introduction to robotics control systems that are critical and rapidly growing engineering technology with expanding societal impact. Designed to support entry-level students with professional experience to modern control systems. Students are provided with background in fundamental principles. Includes breakthrough technology providing hands-on experience with physical robotics control systems. Extensive use of graphical and animation methods to support understanding of mathematical concepts. Hands-on systems are provided in laboratory sections for each student for system design and characterization. Students connect personal computers to robotic control system and have real-time access for configuration and control. Conventional computing tools are provided to support each design method, as well as real-time visualization and performance characterization. Letter grading. 96D. Introduction to Engineering Design: Electrocardiogram. (2) Lecture, one hour; laboratory, 90 minutes; outside study, three hours. Students learn and use concepts and techniques in electrical circuit design and analysis, cardiac electrophysiology, bio- physics, microcontrollers, and computer programming. Students work in teams to design, construct, and test circuit boards capable of measuring human electrocardiograms by capturing data with microcontrollers, writing computer algorithms, and testing circuits. Students present their designs orally and in writing. Letter grading. Mr. Reiher (F,W,S). 96E. Introduction to Engineering Design: Internet of Things. (2) Formerly numbered 96EC.) 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 skills and examination of engineering majors offered at UCLA and of engineering careers. Hands-on experience with state-of-art Internet of things (IoT) technology to offer students opportunity to rapidly develop innovative and inspiring systems that provide ideal introduction to concepts behind engineering majors specific to their major field. IoT technology has become one of the most important advances in technology history with applications ranging from wearable devices for healthcare to residential home automation, natural resource protection and management, intelligent vehicles and transportation systems, robotics systems, and energy conservation. Completion of hands-on
Upper-Division Courses

102. Synthetic Biosystems and Nanosystems Design. (4) Lecture; four hours; outside study; eight hours. Requisites: course M101, Life Sciences 3. Introduction to current progress in engineering to integrate biosciences and nanosciences into synthetic systems where biological components are reengineered and rewired to perform desired functions in both intracellular and cell-free environments. Discussion of basic technologies and systems analysis that deal with noise, nonlinearity, and uncertainty. Design project in which students are challenged to design novel biosystems and nanosystems for non-trivial task required. Letter grading. 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 requisite: course M101. Introduction to potential implications of environmental nanotechnology as well as potential application of nanotechnology to environmental protection. Technical contents include these multidisciplinary areas: (1) physical, chemical, and biological aspects 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. Mr. Hoek (Sp)

110. Introduction to Technology Management and Economics for Engineers. (4) Lecture; four hours; discussion; one hour; outside study; seven hours. Fundamentals of micro-level (individual, firm, and industry) and macro-level, (international) economics as they relate to technology management. How individuals, firms, and governments impact successful commercialization of high technology products and services. Letter grading. Mr. Monbouquette (FSp)

111. Introduction to Finance and Marketing for Engineers. (4) Lecture; four hours; discussion; one hour; outside study; seven hours. Fundamental concepts of finance and marketing research and practice as they impact management of technology commercialization, internal (within firm) and external (in markets/pace) marketing and financing of high-technology innovation. Concepts include present value, future value, discounted cash flow, internal rate of return, return on assets, return on equity, return on investment, interest rates, cost of capital, and product price, positioning, and promotion. Use of market research, segmentation, and forecasting in management of technological innovations. Letter grading. Mr. Monbouquette (F)

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture; four hours; discussion; one hour; outside study; seven hours. Critical components of the entrepreneurship process and enterprise-oriented learning by students in small teams. Rocketry from Mojave Desert launch site in class field trip. No prior experience or coursework needed. Letter grading. Mr. Monbouquette (W,Sp)

113. Product Strategy. (4) Lecture; four hours; discussion; one hour; outside study; seven hours. Designed for seniors/juniors. Introduction to current management concept of product development. Topics include product strategy, product platform, and product line; competitive strategy, vectors of differentiation, product pricing, first-to-market versus fast-follower; growth strategy, growth through acquisition, and new ventures; product portfolio management, design studies, class projects, group discussions, and guest lectures by speakers from industry. Letter grading. Mr. Pao

116. Statistics for Management Decisions. (4) Lecture; four hours; study; eight hours. Management as well as engineering decisions nearly always take place in environment characterized by uncertainty. Probability provides mathematical framework for understanding how to make rational decisions when outcomes of actions are uncertain. Application of probability to problem of reasoning from sample data, encompassing estimation, hypothesis testing, and regression analysis. Discussion of specific analytical techniques needed in various business applications. Letter grading. Mr. Dolecek

120. Entrepreneurship for Scientists and 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 course 160C. Focus on process and methodology for starting new venture. Introduction to entrepreneurship from perspective of entrepreneur. Examination of core concepts and frameworks on idea generation, market analysis, fundraising, corporate structures, and financial accounting for entrepreneurial endeavors. Focus on fundamentals of building business, and also emphasis on inherent experiential nature of entrepreneurship and need for constant learning on this subject. Letter grading. Mr. Wesel

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 understanding of innovations and innovative processes related to creating new products. Inquiry into why, what, and how products work; what products are essential to any business (start-up or well-established) and thriving economies. Making successful new products requires innovation. Availability of digital technologies and global outsource have accelerated pace of these innovations. Letter grading.

170. Project-Based Technology Bootstrap for Social Impact. (4) Lecture; four hours; off-campus; block, five hours; outside study; five hours. Study of design thinking covering various business, technology, and interpersonal topics such as data analysis, user interface, and user experience research and collaboration. Application of learned skills to define social-impact problem and build solution in student teams coached by industry professionals. P/NP or letter grading. (Sp)

180. Engineering of Complex Systems. (4) Lecture; four hours; discussion; two hours; outside study; six hours. Designed for junior/senior engineering majors. Holistic view of engineering discipline, covering lifecycle of engineering, processes and techniques used in industry today. Multidisciplinary systems engineering perspective in which aspects of electrical, mechanical, materials, and software engineering are integrated. Students work in small teams including this course). Individual contract required; may be repeated. P/NP grading. Mr. Wesel (Sp)

182EW. Technology and Society. (4) Lecture; five hours; discussion; three hours; outside study; four hours. Requisites: English Composition 3, 3D, 3DS, 3E, or 3SL. Not open for credit to students with credit for course 181EW, 183EW, or 185EW. Focuses on negotiation and complex ethical issues that emerge as result in areas such as biotechnology, information technology, nanotechnology, and energy technology. Discussion of nature of these issues, which are both ethical, legal, social, political, and cultural, and what society values in relation to these issues. Writing and revision of about 20 pages total, including two essays and one analysis of a negotiation from an ethical and practical perspective. Satisfies engineering writing requirement. Letter grading. Mr. Wesel

183EW. Engineering and Society. (4) Lecture; four hours; discussion; three hours; outside study; five hours. Requisites: English Composition 3, 3D, 3DS, 3E, or 3SL. Not open for credit to students with credit for course 181EW, 183EW, 185EW, or 188EW. 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 examination of ethical and legal frameworks generally and in relation to technology. Examination of key ethical, legal, social, political, and cultural concepts, and guest lectures by speakers from industry. Letter grading. Mr. Villasenor (F)

185EW. Art of Engineering Endeavors. (4) Lecture; four hours; discussion; five hours; outside study; six hours. Designed for junior/senior engineering students with credit for Management 160, 160C, or Management 163. Focuses on negotiation and complex ethical issues that emerge as result in areas such as biotechnology, information technology, nanotechnology, and energy technology. Discussion of nature of these issues, which are both ethical, legal, social, political, and cultural, and what society values in relation to these issues. Writing and revision of about 20 pages total, including two essays and one analysis of a negotiation from an ethical and practical perspective. Satisfies engineering writing requirement. Letter grading. Mr. Wesel (Sp)

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dents. Nontechnical skills and experiences necessary for engineering career success. Importance of gaining dynamics in engineering practice. Teamwork and ef-
ficent group skills in engineering environments. Or-
ganization and control of multidisciplinary complex engineering projects. Principles of leadership and qua-
tities and characteristics of effective leaders. How en-
gineering, computer sciences, and technology relate to
major ethical and social issues. Societal demands on
practice of engineering. Emphasis on research
and writing in engineering environments. Satisfies en-
gineering writing requirement. Letter grading.

Mr. Wesel (F, W, Sp)

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

188EW. Experimental Courses in Engineering Eth-
ics. (4) Lecture, four hours; discussion, three hours;
outside study, five hours. Enforced requisite: English
Composition 3, 3D, 3D+ or ESL. Not open to
credit to students with credit for course 181EW, 182EW,
183EW, or 185EW. Limited to junior/senior
engineering students. Professional and ethical con-
siderations in practice of engineering and computer
science. Emphasis on research and writing within en-
gineering 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 re-
quirement. Letter grading. (W, Sp)

201. Systems Engineering. (4) Lecture, four hours;
outside study, eight hours. Designed for graduate
students. Practical review of major elements of
system engineering process. Coverage of key ele-
ments: system requirements and flow down, product
development cycle, functional analysis, system syn-
thesis and trade studies, budget allocations, risk
management metrics, review and audit activities and
documentation. Letter grading. (W)

202. Reliability, Maintainability, and Supportability. (4)
Lecture, four hours; outside study, eight hours. Requisite:
course 201. Designed for graduate stu-
dents with one to two years work experience. Inte-
grated logistic support (ILS) is major driver of system
life-cycle cost and one key element of system engi-
nearing activities. Overview of engineering disciplines
critical to this function—reliability, maintainability, and
supportability—and their relationships, taught using
probability theory. Topics also include fault detections and
isolation and parts obsolescence. Discussion of
6-sigma process, one effective design and manufac-
turing methodology, to ensure system reliability,
maintainability, and supportability. Letter grading.

Mr. Lynch, Mr. Wesel (W)

203. System Architecture. (4) Lecture, four hours;
outside study, eight hours. Requisite: course 201.
Designed for graduate students with BS degrees in
engineering or science and one to two years work ex-
perience in selected domain. Art and science of ar-
chitecting. Introduction to architecting method-
ology—paradigm and tools. Principles of architecting
through analysis of architecture designs of major ex-
sisting systems. Discussion of selected elements of
architectural practices, such as representation
models, design progression, and architecture frame-
works. Examination of professionalization of system
architect. Letter grading. Mr. Lynch, Mr. Wesel.

204. Trusted Systems Engineering. (4) Lecture, four
hours; outside study, eight hours. Trust is placed in
information systems to behave properly, but cyber
threats and breaches have become routine, including
penetration of financial, medical, government, and
national security systems. To build systems that can
protect confidentiality, integrity, and availability in-
volve more than composing systems from network
security, computer security, data security, cryptog-
raphy, etc. One can use most secure components, and
resulting system could still be vulnerable. Skills
learned ensure that systems are architected, de-
sign, implemented, tested, and operated for spe-
cific levels of trust. Aspects include assessing vulner-
ability and risk for systems, establishing protection
principles, and using them as guide to formulate
architecture. Understanding application architecture
and system design and verifying correctness of design;
and constructing and following trusted development and
implementation process. Letter grading.

Mr. Lichtman, Mr. J-M. Yang (Sp)

211. Financial Management. (4) Lecture, four hours;
outside study, eight hours. Introduction to concepts
and tools of financial management. Material general
core and elective courses. Integration of both
theory—introduce essential conceptual building
blocks in accounting and finance—and empirical
practice—to emphasize how these theories are actu-
ally implemented in real world. Cases, comprehen-
sive problems, and recent events presented to pro-
vide students with as much hands-on experience in
applying material presented as is possible.

Mr. Vandenberghe (Sp)

212. Intellectual Property Law and Strategy. (4) Lecture,
four hours; outside study, eight hours. Prior knowl-
edge of legal doctrines or materials not re-
quired. Intellectual property law is not just topic for
lawyers. Engineers who have design responsibilities
must understand how legal system in some in-
stances 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 stra-
tegic partnerships. Examination of intellectual prop-
erty law, not only by learning fundamental rules asso-
ciated with patent, copyright, trademark, and trade
secret protection, but by studying business strate-
gies that these rules support. Examples and case
studies associated with patent, copyright, trademark,
and trade secret law, not only by learning fundamental
rules asso-
ciated with patent, copyright, trademark, and trade
secret protection, but by studying business strate-
gies that these rules support. Examples and case
studies
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 managerial situations 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: completion of minimum of four 200-level courses in online MS program. Project course that satisfies UCLA final comprehensive examination requirement of MS degree in Engineering. Project is completed under individual guidance from UCLA Engineering faculty member and incorporates advanced knowledge learned in MS program of study. Letter grading. Mr. Lynch (F, W, Sp)

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

470A-470D. Engineer in Technical Environment. (3 each) Lecture, three hours; outside study, six hours. Limited to Engineering Executive Program students. Theory and application of quantitative methods in analysis and synthesis of engineering systems for purpose of making management decisions. Optimization of outputs with respect to dollar costs, time, material, energy, information, and manpower. Case studies and individual projects. S/U or letter grading. 471A-471B-471C. Engineer in General Environment. (3–3–1.5) Lecture, three hours (courses 471A, 471B) and 90 minutes (course 471C). Limited to Engineering Executive Program students. Influences of human relations, laws, social sciences, humanities, and fine arts on development and utilization of natural and human resources. Interaction of technology and society past, present, and future. Change agents and resistance to change. S/U or letter (471A) grading; In Progress (471B) and S/U or letter (471C) grading.

472A-472B-472C-472D. Engineer in Business Environment. (3–3–3–1.5) Lecture, three hours (courses 472A, 472B, 472C) and 90 minutes (course 472D). Limited to Engineering Executive Program students. Language of business for engineering executive. Accounting, finance, business economics, business law, and marketing. Laboratory in organization and management problem solving. Analysis of actual business problems of firm, community, and nation, provided through cooperation and participation with California business corporations and government agencies. In Progress (472A, 472C) and S/U or letter grading (credit to be given on completion of courses 472B and 472D).

473A-473B. Analysis and Synthesis of Large-Scale System. (3–3) Lecture, two and one half hours; outside study, six hours. Limited to Engineering Executive Program students. Problem area of modern industry or government is selected as class project, and its solution is synthesized using quantitative tools and methods. Project also serves as laboratory in organization for goal-oriented technical group. In Progress (473A) and S/U (473B) grading.

495A. Teaching Assistant Training Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: appointment as teaching assistant. Limited to graduate engineering students. Seminar on communication of engineering principles, concepts, and methods, preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading. (F, W, Sp)

M495I. Teaching Preparation Seminar: Writing for Engineers. (4) (Same as English Composition M495I) Seminar, two and one half hours; outside study, nine and one half hours. Limited to graduate students. Required of all teaching assistants for Engineering writing courses not exempt by appropriate departmental or program training. Training and mentoring, with focus on composition pedagogy, assessment of student writing, guidance of revision process, and specialized writing problems that may occur in engineering writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F, W, Sp)

M495J. Supervised Teaching of Writing for Engineers. (2) (Same as English Composition M495J) Seminar, one hour; outside study, five hours. Enforced requisite: course M495I. Required of all teaching assistants in their initial term of teaching Engineering writing courses. Mentor students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F, W, Sp)

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of UCLA graduate 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.
Externally Funded Research Centers and Institutes

Center for Domain-Specific Computing (CDSC)

National Science Foundation (NSF) Expeditions in Computing Program and InTrans Program and industry partners
Jason (Jingsheng) Cong, PhD (Computer Science), Director

CDSC looks beyond parallelization and focuses on domain-specific customization as the next disruptive technology to bring orders-of-magnitude power-performance efficiency improvement. 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; and actively exploring the use of emerging computing technologies such as neuromorphic computing and quantum computing. It also develops highly automated compilation tools and runtime management software for customizable heterogeneous platforms including multicore CPUs, many-core GPUs, FPGAs, and quantum computers. By combining these capabilities, CDSC researchers are able to deliver a supercomputer-in-a-box or -in-a-cluster. This approach has been successfully applied to multiple application domains such as machine learning, big data analytics, medical imaging, and bioinformatics.

Center for Synthetic Control Across Length-scales for Advancing Rechargeables (SCALAR)

Department of Energy (DOE) Energy Frontier Research Center
Sarah Tolbert, PhD (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 capacity through multi-electron redox, improving power density by 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.

Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS)

National Science Foundation (NSF) Engineering Research Center
Gregory P. Carman, PhD (Mechanical and Aerospace Engineering), Director; Jane P. Chang, PhD (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 world’s best researchers from the five TANMS campuses (California State University, Northridge; 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 11 industrial partners to translate the advancements into applications such as ultra-efficient memory, electrically small antennas, and motors to manipulate individual T-cells. These research and translational efforts rely on a workforce of postgraduate, graduate, undergraduate, and K-12 students supporting the education mission of producing the next generation of engineering leaders. The TANMS program relies on an inclusive atmosphere where all are welcome in the center’s quest to change the world.

Center of Excellence for Green Nanotechnologies (CEGN)

Kang L. Wang, PhD (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.
The Internet has far exceeded expectations, 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, PhD (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 (VIG 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 vehicles 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.

### WIN Institute of Neurotronics (WINs)

**Nanoelectronics Research Initiative National Institute of Excellence**

Kang L. Wang, PhD (Electrical and Computer Engineering), Director

Successor to the Western Institute of Nanoelectronics, **WINs** focuses on cutting-edge research including nanostructures for high-efficiency solar cells, patterned nanostructures for integrated active opto-electronics on silicon, and carbon nanotube circuits.

Through the multidisciplinary research efforts of WINs, the National Institute of Standards and Technology (NIST) awarded UCLA $6 million to build the Western Institute of Nanotechnology−Green Engineering and Metrology (WIN-GEM) located within the Engineering building suite on campus.
# BS in Aerospace Engineering Curriculum

## Aeronautics Track

### FRESHMAN YEAR

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<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
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<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Mechanical and Aerospace Engineering 1 — Undergraduate Seminar</td>
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<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>Physics 1A — Mechanics</td>
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<td>3rd Quarter</td>
<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td>UCLA Samueli GE Elective</td>
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### SOPHOMORE YEAR

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<tr>
<td>1st Quarter</td>
<td>Mathematics 32B — Calculus of Several Variables</td>
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<td></td>
<td>Physics 1C/4BL — Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<tr>
<td>2nd Quarter</td>
<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials</td>
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<td>Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics</td>
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<tr>
<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering M20 (Intro to Computer Programming with MATLAB) or Computer Science 31 (Intro to Computer Science I)</td>
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<td>Mechanical and Aerospace Engineering 82 — Mathematics of Engineering</td>
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<td>Mechanical and Aerospace Engineering 102 — Dynamics of Particles and Rigid Bodies</td>
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<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics</td>
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### JUNIOR YEAR

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<td>Electrical and Computer Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Mechanical and Aerospace Engineering 105D — Transport Phenomena</td>
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<td>Mechanical and Aerospace Engineering 166A — Analysis of Aerospace Structures</td>
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<td>UCLA Samueli Ethics Course</td>
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<td>2nd Quarter</td>
<td>Mechanical and Aerospace Engineering 107 — Introduction to Modeling and Analysis of Dynamic Systems</td>
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<td>Mechanical and Aerospace Engineering 150A — Intermediate Fluid Mechanics</td>
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<td>UCLA Samueli GE Elective</td>
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<tr>
<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering 150B — Aerodynamics</td>
<td>4</td>
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<td>Mechanical and Aerospace Engineering 152R (Rocket Propulsion Systems) or 161A (Intro to Astronautics) or 161B (Intro to Space Technology)</td>
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<td>Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems</td>
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<td>UCLA Samueli GE Elective</td>
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### SENIOR YEAR

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<td>1st Quarter</td>
<td>Aerospace Engineering Elective</td>
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<td>Mechanical and Aerospace Engineering 150P — Aircraft Propulsion Systems</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 154S — Flight Mechanics, Stability, and Control of Aircraft</td>
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<td>Technical Breadth Course</td>
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<td>Mechanical and Aerospace Engineering 154A — Preliminary Design of Aircraft</td>
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<td>Mechanical and Aerospace Engineering 157A — Fluid Mechanics and Aerodynamics Laboratory</td>
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### TOTAL

180

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE; details on page 22.
4. See list of electives on page 113.
# BS in Aerospace Engineering Curriculum

## Space Track

### Freshman Year

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<td>Materials Science and Engineering 104—Science of Engineering Materials(^\d)</td>
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### Junior Year

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<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems(^\d)</td>
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<td>Mechanical and Aerospace Engineering 150A—Intermediate Fluid Mechanics(^\d)</td>
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### Senior Year

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### Total

180

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE; details on page 22.
4. See list of electives on page 113.
## BS in Bioengineering Curriculum

### FRESHMAN YEAR

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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>Chemistry and Biochemistry 30AL—General Chemistry Laboratory II</td>
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<td>Life Sciences 7A—Cell and Molecular Biology 4</td>
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<td>Mathematics 33A—Linear Algebra and Applications 1</td>
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<td>Computer Science 31 (Introduction to Computer Science I) or Mechanical and Aerospace Engineering M20 (Introduction to Computer Programming with MATLAB) 5</td>
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### JUNIOR YEAR

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<td>Bioengineering 120—Biomedical Transducers 4</td>
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<td>Bioengineering 175—Machine Learning and Data-Driven Modeling in Bioengineering 5</td>
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<td>Bioengineering 110—Biortransport and Bioreaction Processes 4</td>
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<td>Bioengineering 176—Principles of Biocompatibility 3</td>
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### SENIOR YEAR

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<td>Bioengineering 177B—Bioengineering Capstone Design II 7</td>
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<td>Bioengineering 180—System Integration in Biology, Engineering, and Medicine I 8</td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 74.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE; details on page 22.
4. Bioengineering electives include C101, C102, C104, C105, C106, C107, 121, C131, C139A, C139B, CM140, CM145, C147, C155, CM178, C179, 180L, M182, C183, C185, CM186, CM187, 198 (8 units maximum).
# BS in Chemical Engineering Curriculum

## Chemical Engineering Core Option

### FRESHMAN YEAR

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<td>Chemical Engineering 45 — Biomolecular Engineering Fundamentals</td>
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### JUNIOR YEAR

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<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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### 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; details on page 22.
## BS in Chemical Engineering Curriculum
### Biomedical Engineering Option

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<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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<td>Chemical Engineering C116 — Surface and Interface Engineering</td>
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<td><strong>TOTAL</strong></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; details on page 22.
### BS in Civil Engineering Curriculum

#### FRESHMAN YEAR

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<tr>
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<th>Units</th>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<tr>
<td>1st</td>
<td>Mathematics 31A—Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B—Integration and Infinite Series</td>
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<td>Physics 1A—Mechanics</td>
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<td>Mathematics 32A—Calculus of Several Variables</td>
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<tr>
<td>3rd</td>
<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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#### SOPHOMORE YEAR

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<tr>
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<td>Civil and Environmental Engineering 91 (Statics) or Mechanical and Aerospace Engineering 101 (Statics and Strength of Materials)</td>
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<td>Mathematics 32B—Calculus of Several Variables</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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<td>UCLA Samueli Ethics Course</td>
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<td>Civil and Environmental Engineering 102—Dynamics of Particles and Bodies</td>
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<td>Civil and Environmental Engineering 104 (Structure, Processing, and Properties of Civil Engineering Materials) or Materials Science and Engineering 104 (Science of Engineering Materials)</td>
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<td>Civil and Environmental Engineering 108—Introduction to Mechanics of Deformable Solids</td>
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<td>Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science)</td>
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<td>Mechanical and Aerospace Engineering 103—Elementary Fluid Mechanics</td>
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#### JUNIOR YEAR

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<th>Quarter</th>
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<td>Civil and Environmental Engineering 120—Principles of Soil Mechanics</td>
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<td>Civil and Environmental Engineering 135A—Elementary Structural Analysis</td>
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<td>Civil and Environmental Engineering 150—Introduction to Hydrology</td>
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<td>Civil and Environmental Engineering 153—Introduction to Environmental Engineering Science</td>
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<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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#### SENIOR YEAR

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<td>1st</td>
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<td>Major Field Electives</td>
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<td>Technical Breadth Course</td>
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<td>1st</td>
<td>UCLA Samueli GE Elective</td>
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<td>2nd</td>
<td>Major Field Electives</td>
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<td>Technical Breadth Course</td>
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<td>UCLA Samueli GE Elective</td>
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<td>Major Field Elective</td>
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<td>Technical Breadth Course</td>
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<td>3rd</td>
<td>UCLA Samueli GE Elective</td>
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**TOTAL**: 183

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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; details on page 22.
4. Must include required courses for two of the major field areas listed on page 51.
## BS in Computer Engineering Curriculum

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<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
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<td>Computer Science 1 (Freshman Computer Science Seminar) or Electrical and Computer Engineering 1 (Undergraduate Seminar)</td>
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<td>Computer Science 31 — Introduction to Computer Science I</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<td>Computer Science 32 — Introduction to Computer Science II</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<tr>
<td>Physics IA — Mechanics</td>
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<tr>
<td>UCLA Samueli GE Elective</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
<td></td>
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<tr>
<td>Computer Science 33 — Introduction to Computer Organization</td>
<td>5</td>
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<tr>
<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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| SOPHOMORE YEAR | |
| **1st Quarter** | |
| Electrical and Computer Engineering 3 — Introduction to Electrical Engineering | 4 |
| Engineering 96I — Introduction to Engineering Design: Internet of Things | 2 |
| Mathematics 32B — Calculus of Several Variables | 4 |
| Mathematics 33A — Linear Algebra and Applications | 4 |
| Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory) | 2 |
| **2nd Quarter** | |
| Computer Science 35L — Software Construction Laboratory | 4 |
| Computer Science M51A or Electrical and Computer Engineering M16 — Logic Design of Digital Systems | 4 |
| Electrical and Computer Engineering 100 — Electrical and Electronic Circuits | 4 |
| Mathematics 33B — Differential Equations | 4 |
| **3rd Quarter** | |
| Electrical and Computer Engineering 102 — Systems and Signals | 4 |
| Mathematics 61 — Introduction to Discrete Structures | 4 |
| Physics 1C — Electrodynamics, Optics, and Special Relativity | 5 |

| JUNIOR YEAR | |
| **1st Quarter** | |
| Computer Science 111 — Operating Systems Principles | 5 |
| Probability Elective | 4 |
| UCLA Samueli Ethics Course | 4 |
| **2nd Quarter** | |
| Computer Science 118 (Computer Network Fundamentals) or Electrical and Computer Engineering 132B (Data Communications and Telecommunication Networks) | 4 |
| Computer Science M152A or Electrical and Computer Engineering M116 — Introductory Digital Design Laboratory | 2 |
| Computer Science 180 — Introduction to Algorithms and Complexity | 4 |
| Electrical and Computer Engineering 115C — Digital Electronic Circuits | 4 |
| **3rd Quarter** | |
| Computer Science M151B or Electrical and Computer Engineering M116C — Computer Systems Architecture | 4 |
| Computer Science Elective | 4 |
| Electrical and Computer Engineering Elective | 4 |
| UCLA Samueli GE Elective | 4 |

| SENIOR YEAR | |
| **1st Quarter** | |
| Electrical and Computer Engineering 113 | 4 |
| Electrical and Computer Engineering Elective | 4 |
| Technical Breadth Course | 4 |
| UCLA Samueli GE Elective | 5 |
| **2nd Quarter** | |
| Computer Science Elective | 4 |
| Electrical and Computer Engineering Design Course | 4 |
| Technical Breadth Course | 4 |
| UCLA Samueli GE Elective | 5 |
| **3rd Quarter** | |
| Electrical and Computer Engineering Design Course | 4 |
| Technical Breadth Course | 4 |
| UCLA Samueli GE Elective | 5 |

**TOTAL** 181

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; details on page 22.
4. See the list of electives on page 66 or list of electives on page 88.
# BS in Computer Science Curriculum

## FRESHMAN YEAR

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<tr>
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<td>Computer Science 1 — Freshman Computer Science Seminar</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>2nd</td>
<td>Computer Science 32 — Introduction to Computer Science</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>Physics 1A — Mechanics</td>
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<tr>
<td>3rd</td>
<td>Computer Science 33 — Introduction to Computer Organization</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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## SOPHOMORE YEAR

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<tr>
<td>1st</td>
<td>Computer Science 35L — Software Construction Laboratory</td>
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<td>Computer Science M16A 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>UCLA Samueli Ethics Course</td>
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<td>2nd</td>
<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Mathematics 61 — Introduction to Discrete Structures</td>
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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)</td>
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<td>3rd</td>
<td>Computer Science 11I — Operating Systems Principles</td>
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<td>Computer Science M116A or Electrical and Computer Engineering M116 — Introductory Digital Design Laboratory</td>
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<td>Mathematics 33B — Differential Equations</td>
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<td>UCLA Samueli GE Elective</td>
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## JUNIOR YEAR

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<th>Quarter</th>
<th>Course</th>
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<tbody>
<tr>
<td>1st</td>
<td>Computer Science 118 — Computer Network Fundamentals</td>
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<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
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<td>UCLA Samueli GE Elective</td>
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<td>2nd</td>
<td>Computer Science 13I — Programming Languages</td>
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<td>Computer Science M116B or Electrical and Computer Engineering M116 — Computer Systems Architecture</td>
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<td>Probability Elective</td>
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<td>UCLA Samueli GE Elective</td>
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<td>Computer Science 181 — Introduction to Formal Languages and Automata Theory</td>
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## SENIOR YEAR

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<th>Quarter</th>
<th>Course</th>
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<td>Computer Science 130 (Software Engineering) or 152B (Digital Design Project Laboratory)</td>
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<td>Science and Technology Elective</td>
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**TOTAL** 180

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 49.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE; details on page 22.
4. See list of electives on page 65.
5. Any excess or available units not already applied to another degree requirement will satisfy this unit.
### BS in Computer Science and Engineering Curriculum

**FRESHMAN YEAR**

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<th>Quarter</th>
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<th>Course Title</th>
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<td>Computer Science 1 — Freshman Computer Science Seminar</td>
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<td>Computer Science 33 — Introduction to Computer Organization</td>
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<td>Physics 18 — Oscillations, Waves, Electric and Magnetic Fields</td>
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**SOPHOMORE YEAR**

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<th>Quarter</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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<tr>
<td>1st</td>
<td>Computer Science 35L — Software Construction Laboratory</td>
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<td>Computer Science M16 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 — Electrodynamics, Optics, and Special Relativity</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Mathematics 61 — Introduction to Discrete Structures</td>
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**JUNIOR YEAR**

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<th>Course Title</th>
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<td>Electrical and Computer Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Computer Science M16L — Introduction Digital Design Laboratory or Electrical and Computer Engineering M116L</td>
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**SENIOR YEAR**

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<tr>
<th>Quarter</th>
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<th>Course Title</th>
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<td>Computer Science 152B — Digital Design Project Laboratory</td>
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<tr>
<td></td>
<td>Computer Science 181 — Introduction to Formal Languages and Automata Theory</td>
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<td></td>
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<tr>
<td></td>
<td>UCLA Samueli GE Elective</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>Computer Science Elective</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrical and Computer Engineering Elective</td>
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<tr>
<td></td>
<td>Technical Breadth Course</td>
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<tr>
<td></td>
<td>UCLA Samueli GE Elective</td>
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<td>Computer Science Elective</td>
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<td></td>
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<tr>
<td></td>
<td>UCLA Samueli GE Elective</td>
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<td></td>
<td>Technical Breadth Course</td>
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<tr>
<td></td>
<td>Additional coursework to meet 180 unit requirement</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>180</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; details on page 24.
4. See list of electives on page 65.
5. Any excess or available units not already applied to another degree requirement will satisfy this unit.
## BS in Electrical Engineering Curriculum

### FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
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<tbody>
<tr>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A—Differential and Integral Calculus&lt;sup&gt;1&lt;/sup&gt;</td>
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<tr>
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<td>Chemistry and Biochemistry 20A—Chemical Structure&lt;sup&gt;1&lt;/sup&gt;</td>
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<td></td>
<td>Computer Science 32—Introduction to Computer Science II&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Mathematics 31B—Integration and Infinite Series&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Physics 1A—Mechanics&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>3rd</td>
<td>Electrical and Computer Engineering M16 (or Computer Science M51A)—Logic Design of Digital Systems&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Mathematics 32A—Calculus of Several Variables&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Physics 18/44AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory&lt;sup&gt;1&lt;/sup&gt;</td>
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### SOPHOMORE YEAR

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<td>Mathematics 32B—Calculus of Several Variables&lt;sup&gt;1&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>Mathematics 33A—Linear Algebra and Applications&lt;sup&gt;1&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>Physics 1C—Electrodynamics, Optics, and Special Relativity&lt;sup&gt;1&lt;/sup&gt;</td>
<td>5</td>
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<tr>
<td>2nd</td>
<td>Electrical and Computer Engineering 10 (Circuit Theory I) and 11L (Circuits Laboratory I)&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering 102—Systems and Signals&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Physics 4BL—Electricity and Magnetism Laboratory&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering 2—Physics for Electrical Engineers&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering 110 (Circuit Theory II) and 111L (Circuits Laboratory II)&lt;sup&gt;1&lt;/sup&gt;</td>
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### JUNIOR YEAR

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<tr>
<td>1st</td>
<td>Electrical and Computer Engineering 113—Digital Signal Processing&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering 131A—Probability and Statistics&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering 101A—Engineering Electromagnetics&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering Core Course&lt;sup&gt;1,4&lt;/sup&gt;</td>
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<td>UCLA Samuels GE Elective</td>
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<tr>
<td>3rd</td>
<td>Electrical and Computer Engineering Core Course&lt;sup&gt;1,4&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering Core Course&lt;sup&gt;1,4&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering Core Course or Computer Science 33 (Introduction to Computer Organization)&lt;sup&gt;1,4&lt;/sup&gt;</td>
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### SENIOR YEAR

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<td>Electrical and Computer Engineering Design Course&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>UCLA Samuels GE Elective</td>
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<td>3rd</td>
<td>Electrical and Computer Engineering or UCLA Samuels Elective&lt;sup&gt;1&lt;/sup&gt;</td>
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### TOTAL

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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; details on page 22.
4. See the list of electives on page 86.
# BS in Materials Engineering Curriculum

## Materials Engineering Option

### FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Description</th>
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<tbody>
<tr>
<td>1st</td>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<td>Materials Science and Engineering 10—Freshman Seminar: New Materials</td>
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<td>Mathematics 31A—Differential and Integral Calculus</td>
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### 2nd Quarter

<table>
<thead>
<tr>
<th>Course Description</th>
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<tbody>
<tr>
<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
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<tr>
<td>Mathematics 31B—Integration and Infinite Series</td>
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<td>Physics 1A—Mechanics</td>
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### 3rd Quarter

<table>
<thead>
<tr>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>Materials Science and Engineering 104—Science of Engineering Materials</td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables</td>
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<tr>
<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields</td>
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### SOPHOMORE YEAR

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<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Materials Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory</td>
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<tr>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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### 2nd Quarter

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<thead>
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<th>Course Description</th>
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<tbody>
<tr>
<td>Materials Science and Engineering 90L—Physical Measurement in Materials Engineering</td>
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<tr>
<td>Materials Science and Engineering 150—Introduction to Polymers</td>
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<tr>
<td>Mathematics 33A—Linear Algebra and Applications</td>
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<td>UCLA Samueli GE Elective</td>
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### 3rd Quarter

<table>
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<th>Course Description</th>
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<tbody>
<tr>
<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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<tr>
<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits</td>
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<tr>
<td>Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)</td>
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<td>Technical Breadth Course</td>
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### JUNIOR YEAR

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<th>Course Description</th>
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<tbody>
<tr>
<td>1st</td>
<td>Materials Engineering Laboratory Course</td>
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<tr>
<td></td>
<td>Materials Science and Engineering 130—Phase Relations in Solids</td>
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<tr>
<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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### 2nd Quarter

<table>
<thead>
<tr>
<th>Course Description</th>
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<tbody>
<tr>
<td>Materials Science and Engineering 131/131L—Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<td>Materials Science and Engineering 143A—Mechanical Behavior of Materials</td>
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### 3rd Quarter

<table>
<thead>
<tr>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>Civil and Environmental Engineering 108—Introduction to Mechanics of Deformable Solids</td>
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<td>Materials Science and Engineering 132—Structures and Properties of Metallic Alloys</td>
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</tr>
<tr>
<td>Materials Engineering Laboratory Course</td>
<td>2</td>
</tr>
<tr>
<td>UCLA Samueli GE Elective</td>
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### SENIOR YEAR

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<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Materials Engineering Elective</td>
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<tr>
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<td>Materials Science and Engineering 160—Introduction to Ceramics and Glasses</td>
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<td>UCLA Samueli Ethics Course</td>
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### 2nd Quarter

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<td>Materials Science and Engineering 120—Physics of Materials</td>
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<tr>
<td>Materials Science and Engineering 140A—Materials Selection and Engineering Design A</td>
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### 3rd Quarter

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<td>Materials Engineering Elective</td>
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<td>Technical Breadth Course</td>
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<td>UCLA Samueli GE Elective</td>
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### 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; details on page 22.
4. See counselor in 6426 Boelter Hall for details.
5. See the list of approved mathematics courses on page 105.
# BS in Materials Engineering Curriculum

## Electronic Materials Option

### FRESHMAN YEAR

<table>
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<th>Course and Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<tr>
<td></td>
<td>Materials Science and Engineering 10—Freshman Seminar: New Materials</td>
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<tr>
<td></td>
<td>Mathematics 31A—Differential and Integral Calculus</td>
<td>4</td>
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<tr>
<td>2nd</td>
<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B—Integration and Infinite Series</td>
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<tr>
<td></td>
<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields</td>
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### SOPHOMORE YEAR

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<tr>
<th>Quarter</th>
<th>Course and Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Materials Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory</td>
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<td>Mathematics 32B—Calculus of Several Variables</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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<td>2nd</td>
<td>Electrical and Computer Engineering 101A—Engineering Electromagnetics</td>
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<tr>
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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 33A—Linear Algebra and Applications</td>
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### JUNIOR YEAR

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<th>Quarter</th>
<th>Course and Description</th>
<th>Units</th>
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<tbody>
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<td>1st</td>
<td>Electronic Materials Laboratory Course</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials</td>
<td>4</td>
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<tr>
<td></td>
<td>Technical Breadth Course</td>
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</tr>
<tr>
<td>2nd</td>
<td>Materials Science and Engineering 120 (Physics of Materials)</td>
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<tr>
<td></td>
<td>Materials Science and Engineering 131/131L—Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
<td>6</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>
<td>6</td>
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<td>Materials Science and Engineering 132—Structures and Properties of Metallic Alloys</td>
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### SENIOR YEAR

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<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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<td></td>
<td>UCLA Samueli GE Elective</td>
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<td>Upper-Division Mathematics Course</td>
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<td>2nd</td>
<td>Electronic Materials Elective (Materials Science and Engineering 150—Introduction to Polymers or 160—Introduction to Ceramics and Glasses)</td>
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<td>Materials Science and Engineering 140A—Materials Selection and Engineering Design A</td>
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<tr>
<td></td>
<td>UCLA Samueli Ethics Course</td>
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<tr>
<td>3rd</td>
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**TOTAL 182**

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; details on page 22.
4. See counselor in 6426 Boelter Hall for details.
5. See the list of approved mathematics courses on page 105.
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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; details on page 22.
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