UCLA Samueli School of Engineering

2019 - 2020

ANNOUNCEMENT
UNIVERSITY OF CALIFORNIA, LOS ANGELES

October 1, 2019

Bioengineering
Chemical & Biomolecular
Civil & Environmental
Computer Science
Electrical & Computer
Materials Science
Mechanical & Aerospace
Master of Science in Engineering Online
ANNOUNCEMENT 2019-20

HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE

UNIVERSITY OF CALIFORNIA, LOS ANGELES
OCTOBER 1, 2019
DISCLOSURE OF STUDENT RECORDS

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

UCLA, in accordance with federal and state laws and University policies, has designated the following categories of personally identifiable information as public information that UCLA may release and publish without the student’s prior consent: name, e-mail address, telephone numbers, major field of study, dates of attendance, number of course units in which enrolled, degrees and honors received, the most recent previous educational institution attended, participation in officially recognized activities (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 electronic directory unless released by the student. The term public information in this policy is synonymous with the term directory information in FERPA.

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

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

A copy of the federal and state laws, University policies, and the print UCLA Telephone Directory may be inspected in the office of the Information Practices Coordinator, 500 UCLA Wilshire Center. Information concerning students’ hearing rights may be obtained from that office and from the Office of Student Conduct, 1104 Murphy Hall.

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

Cover: Students create, build, discover, fly, connect, and develop inventions of all kinds in seven engineering departments and an online Master’s degree program. They epitomize the growth and contributions of UCLA as it celebrates its centennial anniversary in 2019-20.
The UCLA Henry Samueli School of Engineering has a long legacy of excellence in education and research.

In the twenty-first century this includes designing sustainable and resilient communities, developing personalized medicine, advancing artificial intelligence, and unearthing insights from an unprecedented volume of data. We welcome a new generation of engineers to join us as we tackle these and many more compelling issues.

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

The school offers a rigorous curriculum that pairs strong fundamentals with practical, hands-on experience. For our prospective students, let me offer three points beyond the curriculum that this dynamic school offers.

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

Second, in addition to paving the way into industry, we offer unique research opportunities for our undergraduate students. Our faculty members are distinguished leaders in their fields and students have an active role in their research labs, with some research even earning course credit. Our students also often collaborate with the UCLA medical school, and other disciplines, as they pursue new approaches and breakthroughs.

Third, you will meet some extraordinary people in your fellow students. The talent, smarts, outside-the-box thinking, and collaborative can-do energy at UCLA are unparalleled. If you are interested in exploring fields outside your major, we have more than 44 engineering clubs focused on a wide range of activities. We also recently opened a 9,000-square-foot makerspace where you can work on personal projects, and hold group activities such as hack-a-thons.

UCLA Samueli is entering an extraordinary period of growth, with significant expansion in the number of research labs, faculty, and students. The school already is world-renowned, but we are reaching for new heights. This growth will offer extraordinary new opportunities for you to make a significant impact on our society and the world, and I invite you to be part of it.

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

Officers of Administration

Jayathi Y. Murthy, Ph.D., Professor and Dean, Henry Samueli School of Engineering and Applied Science
Scott J. Brandenberg, Ph.D., Professor and Associate Dean, Research and Physical Resources
Jia-Ming Liu, Ph.D., Professor and Associate Dean, Academic and Student Affairs
Harold G. Monbouquette, Ph.D., Professor and Associate Dean, Academic and Student Affairs
Richard D. Wesel, Ph.D., Professor and Associate Dean, Academic and Student Affairs
Jenn-Ming Yang, Ph.D., Professor and Associate Dean, International Initiatives and Online Education
Panagiotis D. Christofides, Ph.D., Professor and Chair, Chemical and Biomolecular Engineering Department
Bruce S. Dunn, Ph.D., Professor and Chair, Materials Science and Engineering Department
Timothy S. Fisher, Ph.D., Professor and Chair, Mechanical and Aerospace Engineering Department
Richard E. Korf, Ph.D., Professor and Interim Chair, Computer Science Department
Song Li, Ph.D., Professor and Chair, Bioengineering Department
Gregory J. Pottie, Ph.D., Professor and Chair, Electrical and Computer Engineering Department
Ertugrul Taciroglu, Ph.D., Professor and Chair, Civil and Environmental 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 into the far reaches of the globe. Students come from around the world to receive a UCLA education, and our alumni go on to become leaders in their fields, from 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 300,000 patients from around the world come to the Ronald Reagan UCLA Medical Center for treatment. The University’s 419-acre campus houses the College of Letters and Science and 12 professional schools. There are more than 46,000 students enrolled in 138 undergraduate programs, and more than 250 graduate degree programs.

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

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

The School

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

Counted among the faculty are scores of National Academy of Engineering members, three Turing award winners, one National Medal of Science recipient, and one Nobel laureate. While no ranking can fully capture the mission as a leading public research university, the school is consistently ranked in the top 10 among U.S. public engineering schools, and the online master’s program has consistently been ranked first or second nationally.

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

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

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

The school offers 40 academic and professional degree programs. The Bachelor of Science degree is offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Engineering, Computer Science, Computer Science and Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering. The undergraduate curricula leading to these degrees offer students with a solid foundation in engineering and applied science and prepare graduates for immediate practice of the profession as well as advanced studies. In addition to engineering courses, students complete about one year of study in the humanities, social sciences, and/or fine arts.

Master of Science and Doctor of Philosophy degrees are offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Computer Science and Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering. The schoolwide online Master of Science in Engineering degree program includes 11 individual degrees. The Engineering degree is more advanced than the master’s, but does not require the research effort and orientation involved in a doctoral dissertation. For information on the Engineer degree, see Graduate Programs on page 26. A one-year program leading to a Certificate of Specialization is offered in various fields of engineering and applied science.

Endowed Chairs

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

L.M.K. Boelter Chair in Engineering
Vijay K. Dhir Chair in Engineering
Englekirk Presidential Endowed Chair in Structural Engineering
Traugott and Dorothea Frederking Endowed Chair in Cryogenics
Norman E. Friedmann Chair in Knowledge Sciences
Armond and Elena Hairapetian Chair in Engineering and Medicine
Leonard Kleinrock Chair in Computer Science
Evelyn Knight Chair in Engineering
Levi James Knight, Jr., Chair in Engineering
Richard G. Newman AECOM Endowed Chair in Civil Engineering
Nippon Sheet Glass Company Chair in Materials Science
Northrop Grumman Chair in Electrical Engineering
Northrop Grumman Chair in Electrical Engineering/Electromagnetics
Northrop Grumman Opto-Electronic Chair in Electrical Engineering
Ralph M. Parsons Foundation Chair in Chemical Engineering
Jonathan B. Postel Chair in Computer Systems
Jonathan B. Postel Chair in Networking
Raytheon Company Chair in Electrical Engineering
Raytheon Company Chair in Mechanical Engineering
Charles P. Reames Endowed Chair in Electrical Engineering
Ben Rich Lockheed Martin Chair in Aeronautics
Rockwell Collins Chair in Engineering
John P. and Claudia H. Schauerman Endowed Chair in Engineering
William Frederick Seyer Chair in Materials Electrochemistry
Ronald and Valerie Sugar Endowed Chair in Engineering
Syntech 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 B.S. program in Aerospace Engineering emphasizes fundamental disciplines and therefore provides a solid base for professional career development in industry and graduate study in aerospace engineering. Graduate education prepares students for careers at the forefront of aerospace technology. The Ph.D. degree provides a strong background for employment by government laboratories, such as NASA, and industrial research laboratories supported by the major aerospace companies. It also provides the appropriate background for academic careers.

Bioengineering

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

Chemical and Biomolecular Engineering

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

Major areas of fundamental interest within chemical engineering are

1. Applied chemical kinetics, which involves the design of chemical and biochemical reactors and processes and the creation of catalysts that accelerate reaction kinetics and modeling,
2. Transport phenomena, which involves the exchange of momentum, heat, and mass in physical and biological systems and has applications to the separation of valuable materials from mixtures, or of pollutants from gas and liquid streams,

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

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

Civil and Environmental Engineering

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

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

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

Computer Science and Engineering

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

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

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

Materials Engineering

Materials engineering is concerned with the structure and properties of materials used in modern technology. Advances in technology are often limited by available materials. Solutions to energy problems depend largely on new materials, such as solar cells or materials for batteries for electric cars.

Two programs within materials engineering are available at UCLA:

1. In the materials engineering program, students become acquainted with metals, ceramics, polymers, and composites. Such expertise is highly sought by the aerospace and manufacturing industries.

2. In the electronic materials option of the materials engineering program, students learn the basics of materials engineering with a concentration in electronic materials and processing. The optional program requires additional coursework which includes five to eight electrical and computer engineering courses.

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

Mechanical Engineering

Mechanical engineering is a broad discipline finding application in virtually all industries and manufactured products. The mechanical engineer applies principles of mechanics, dynamics, and energy transfer to the design, analysis, testing, and manufacture of consumer and industrial products. A mechanical engineer usually has specialized knowledge in areas such as design, materials, fluid dynamics, solid mechanics, heat transfer, thermodynamics, dynamics, control systems, manufacturing methods, and human factors. Applications of mechanical engineering include design of machines used in the manufacturing and processing industries, mechanical components of electronic and data processing.
equipment, engines and power-generating equipment, components and vehicles for land, sea, air, and space, and artificial components for the human body. Mechanical engineers are employed throughout the engineering community as individual consultants in small firms providing specialized products or services, as designers and managers in large corporations, and as public officials in government agencies. Mechanical engineers apply their knowledge to a wealth of systems, products, and processes, including energy generation, utilization and conservation, power and propulsion systems (power plants, engines), and commercial products found in the automotive, aerospace, chemical, or electronics industries. The B.S. program in Mechanical Engineering at UCLA provides excellent preparation for a career in mechanical engineering and a foundation for advanced graduate studies. Graduate studies in one of the specialized fields of mechanical engineering prepare students for a career at the forefront of technology. The Ph.D. degree provides a strong background for employment by government laboratories, industrial research laboratories, and academia.

Correspondence Directory

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

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

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

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

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

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

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

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

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

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

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

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

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University of California, Los Angeles
Los Angeles, California 90095
http://www.ucla.edu

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

Graduate Diversity, Inclusion, and Admissions
1248 Murphy Hall
https://grad.ucla.edu/gasaa/admissions/

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

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

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

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

University of California Systemwide Admissions
http://admission.universityofcalifornia.edu
## Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2019</th>
<th>Winter 2020</th>
<th>Spring 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>First day for continuing students to check MyUCLA at <a href="http://my.ucla.edu">http://my.ucla.edu</a> for assigned enrollment appointments</td>
<td>May 28</td>
<td>October 28</td>
<td>January 27</td>
</tr>
<tr>
<td>MyUCLA enrollment appointments begin</td>
<td>June 17</td>
<td>November 1</td>
<td>February 1</td>
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<tr>
<td>Registration fee payment deadline</td>
<td>September 20</td>
<td>December 20</td>
<td>March 20</td>
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<tr>
<td>Quarter begins</td>
<td>September 23</td>
<td>January 2, 2020</td>
<td>March 25</td>
</tr>
<tr>
<td>Instruction begins</td>
<td>September 26</td>
<td>January 6</td>
<td>March 30</td>
</tr>
<tr>
<td>Last day for undergraduates to add courses with per-course fee through MyUCLA</td>
<td>October 18</td>
<td>January 24</td>
<td>April 17</td>
</tr>
<tr>
<td>Last day for undergraduates to drop nonimpacted courses without a transcript notation (with per-transaction fee through MyUCLA)</td>
<td>October 25</td>
<td>January 31</td>
<td>April 24</td>
</tr>
<tr>
<td>Last day for undergraduates to change grading basis (optional P/NP) with per-transaction fee through MyUCLA</td>
<td>November 8</td>
<td>February 14</td>
<td>May 8</td>
</tr>
<tr>
<td>Instruction ends</td>
<td>December 6</td>
<td>March 13</td>
<td>June 5</td>
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<tr>
<td>Final examinations</td>
<td>December 9–13</td>
<td>March 16–20</td>
<td>June 8–12</td>
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<tr>
<td>Quarter ends</td>
<td>December 13</td>
<td>March 20</td>
<td>June 12</td>
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<tr>
<td>Engineering Commencement</td>
<td>—</td>
<td>—</td>
<td>June 13</td>
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<tr>
<td>Academic and administrative holidays</td>
<td>November 11</td>
<td>January 20</td>
<td>March 27</td>
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<td>November 28-29</td>
<td>February 17</td>
<td>May 25</td>
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<td>December 24-25</td>
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<td></td>
<td>January 1</td>
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<tr>
<td>Winter campus closure (tentative)</td>
<td>December TBD</td>
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</tbody>
</table>

*Dates subject to change; see UCLA Registrar’s Office website for most current information.*

## Admission Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2019</th>
<th>Winter 2020</th>
<th>Spring 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filing period for undergraduate applications (file online at <a href="http://admission.universityofcalifornia.edu/how-to-apply">http://admission.universityofcalifornia.edu/how-to-apply</a> /apply-online/index.html)</td>
<td>November 1–30, 2018</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Last day to file Application for Graduate Admission or readmission with complete credentials and application fee, online at <a href="https://app.applyyourself.com/AY">https://app.applyyourself.com/AY</a> ApplicantLogin/ fl_ApplicantConnectLogin.asp?id=ucla-grad or with Graduate Diversity, Inclusion, and Admissions (DIA), 1248 Murphy Hall, UCLA, Los Angeles, CA 90024-1419</td>
<td>Consult department</td>
<td>Consult department</td>
<td>Consult department</td>
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<tr>
<td>Last day to file Undergraduate Readmission Application at 1113 Murphy Hall (late applicants pay a late fee)</td>
<td>August 15</td>
<td>November 25</td>
<td>February 25</td>
</tr>
</tbody>
</table>
General Information

Facilities and Services
Teaching and research facilities at UCLA Samueli are in Boelter Hall, Engineering IV, Engineering V, and Engineering VI, located in the southern part of the UCLA campus. Boelter Hall houses classrooms and laboratories for undergraduate and graduate instruction, the Office of Academic and Student Affairs (http://www.seasoas.ucla.edu), the SEASnet computer facility (https://www.seasnet.ucla.edu), specialized libraries, offices of faculty and administration, Shop Services Center, and the Student and Faculty Shop. The California Nano-Systems Institute (CNSI) building hosts additional school collaborative research activities.

Library Facilities

University Library System
The UCLA Library, a campuswide network of libraries serving programs of study and research in many fields, is among the top 10 ranked research libraries in the U.S. Total collections number more than 12 million volumes, and over 112,000 serial titles are received regularly. Nearly 53,000 serials and databases are electronically available through the UCLA Library Catalog, which is linked to the library homepage at http://www.library.ucla.edu

Science and Engineering Library
The combined Science and Engineering Library (SEL) collections contain more than half a million print volumes; subscriptions to nearly 5,400 print or electronic journals, many with full archival access; a large collection of online technical reports; and tens of thousands of e-books. The library offers access to online databases covering each discipline.

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

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

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

Services
Computing Resources
Nicodemus Wibowo, SEASnet Director
UCLA Samueli maintains an advanced computing facility and local-area network to support its education, research, and administrative activities. A total of 16 full-time positions and 10 lab consultants support the school’s computing needs.

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

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

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

A high-speed network that links the entire infrastructure ensures latency-free operation for users from UCLA and around the world. It consists of dual fiber uplinks to a Cisco core router, which feeds and routes 20 networks and over 100 switches. The network serves over 8,000 users across four buildings.

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

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

Students and faculty have access to retail Microsoft software, through the Microsoft Azure Dev Tools for Teaching program; MathType software; and Abaqus, through a download service at no charge. Faculty and staff have access to Microsoft Office software at no charge through the same service and the Microsoft Consolidated Campus Agreement (CCCA). Adobe software is also available to tenure-track faculty and staff. Microsoft Azure Dev Tools for Teaching, Autodesk, and Ansys programs offer additional software at no charge to all UCLA engineering students.

The school’s manufacturing engineering program operates a group of workstations dedicated to CAD/CAM instruction; and the Computer Science Department operates a network of SUN, Windows, and Macintosh workstations. The school is connected to the Internet through high-speed networks. Computing resources at the national supercomputer centers are also available.

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

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

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

Department of Digital Technology
Bruce Huang, Ph.D., Director

The UCLA Extension Engineering and Digital Technology departments offer one of the nation’s largest selections of continuing education education programs. A short-course program of 150 annual offerings draws participants from around the world for two- to four-day intensive programs. Many of these short courses are also offered on-site at companies and government agencies. The acclaimed Technical
Management Program has been offered for more than 60 years.

The Information Systems program offers over 200 courses annually in applications programming, database management, information systems security, Linux/Unix, operating systems, systems analysis, data science, and Web technology.

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

**Career Services**

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

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

Services include individual career counseling, career assessments, workshops, industry-specific programming, employer information sessions, career fairs, and targeted networking opportunities. Annual engineering and technical fairs, held in fall and winter quarters, feature more than 100 top national and local employers. Using a Handshake account (https://ucla.joinhandshake.com/login), 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 with résumés, cover letters, and the job/internship search process. The center is open Monday through Friday from 9 a.m. to 5 p.m. An engineering-specific pop-up event is held once per quarter in 6288 Boelter Hall.

**Health Services**

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

The Ashe Student Health and Wellness Center is a full-service medical clinic available to all registered UCLA students. Most services are subsidized by registration fees, and a current BruinCard is required for service. Its clinical staff of physicians, nurse practitioners, and nurses is board certified. It offers primary care, specialty clinics, and physical therapy. The center has its own 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 UCLA-sponsored UCHIP or other plans that provide adequate coverage. Adequate medical insurance is a condition of registration. Students who waive UCHIP must ensure that they are enrolled in a plan qualified to cover expenses incurred outside of the Ashe Center, and are responsible for knowing the benefits of and local providers for their medical plan.

Contact the Ashe Center for specific information on its primary care, women's health, immunization, health clearance, optometry, travel medicine, and mind-body clinics, as well as dental care available to students at discounted rates. UCHIP benefits tier structure 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 opens on Monday through Friday during the academic year.

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

**Services for Students with Disabilities**

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

The Center for Accessible Education (CAE) offers academic support services to regularly enrolled students with documented permanent or temporary disabilities in compliance with Section 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA) of 1990, and UC and UCLA policies. Services include campus orientation and accessibility, notetakers, reader service, sign-language interpreters, registration assistance, test-taking facilitation, special parking assistance, real-time captioning, assistive listening devices, on-campus transportation, adaptive equipment, support groups and workshops, tutorial referral, special materials, housing appeals, referral to the Disabilities and Computing Program, and processing of California Department of Rehabilitation authorizations.

There is no fee for any of these services. All contacts and assistance are handled confidentially.

**Disabilities and Computing Program**
4909 Math Sciences
voice 310-206-7133
https://dcp.ucla.edu

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 Hall
https://www.internationalcenter.ucla.edu

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

Fees and Expenses

Annual UCLA student fees shown for 2019-20 are current as of publication. See the Registrar’s Office fees web page for fees breakdown by term at https://sa.ucla.edu/RO/Fees/Public/public-fees.

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

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

Living Accommodations

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

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

Information about campus residence halls and suites, 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
https://www.financialaid.ucla.edu

Undergraduate Students

Financial aid at UCLA includes scholarships, grants, loans, and work-study programs. With the exception of certain scholarships, awards are based on need as determined by national financial aid criteria. California residents must file the Free Application for Federal Student Aid (FAFSA). Students who are not citizens or permanent residents but who are eligible for Assembly Bill 540 nonresident fee waivers may be eligible to qualify for scholarships, UCLA grant aid, and additional state aid if they complete a California Dream Act application. International students in their first year are ineligible for aid. Continuing undergraduate international students are asked to submit a separate Financial Aid Application for International Students.

Applications for each academic year are available in January. The priority application deadline for financial aid for the 2020-21 academic year is March 2, 2020.

Scholarships

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

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

UCLA Samueli Scholarships are awarded to entering and continuing undergraduate students based on criteria including financial need, academic excellence, community service, extracurricular activities, and research achievement. The school works with alumni, industry, and individual donors to establish scholarships to benefit engineering students. In 2018-19, the school awarded 143 undergraduate scholarship awards totaling more than $883,500. The majority of these scholarships are publicized in fall, with additional scholarships promoted throughout the academic year as applicable. For more information on all available scholarships, see http://www.seasoasa.ucla.edu/scholarships-for-undergraduates.

Grants

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

Federal Pell Grants are federal aid awards designed to provide financial assistance to U.S. citizens or eligible noncitizen undergraduates in exceptional need of funds to attend post-high school educational institutions. Students who file a FAFSA are automatically considered for a Pell Grant. Detailed information on other grants for students with demonstrated need is available from Financial Aid and Scholarships.

Federal Family Education Loan Program

Student Loan Services and Collections
A227 Murphy Hall
310-825-9864
https://www.loans.ucla.edu

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

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

Work-Study Programs

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

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

Community Service is a component of the Federal Work-Study program. Students who secure a community service position are eligible to petition for an increase in work-study funds up to a total of $5,000.
while at the same time reducing their Perkins and/or Stafford loan by the amount of the increase. Most community service positions are located off campus.

**Graduate Students**

A high percentage of UCLA Samueli graduate students receive departmental financial support.

**Merit-Based Support**

Three major types of merit-based support are available in the school:

1. Fellowships from University, private, or corporate funds
2. Employment as a teaching assistant
3. Employment as a graduate student researcher

**Fellowships** usually supply stipends competitive with those of other major universities, plus tuition and nonresident 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 (CSR) appointments are awarded to students on the basis of scholastic achievement and promise as creative scholars. Appointees perform research under the supervision of a faculty member in research work. Full-time employment in summer and interterm breaks is possible, depending on the availability of research funds from contracts or grants.

Since a graduate student researcher appointment constitutes employment in the service of a particular faculty member who has a grant, students must take the initiative in obtaining desired positions.

CSR appointments are generally awarded after one year of study at UCLA.

Applicants for departmental financial support must be accepted for admission at UCLA before applying for financial aid.

Applicants should check the deadline for submitting the UCLA Application for Graduate Admission and the Fellowship Application for Entering Graduate Students with their preferred department.

**Need-Based Aid**

Unlike the awards above, which are based solely on merit and administered by the school, the University also offers work-study and low-interest loans based on financial need exclusively.

Need-based awards are administered by Financial Aid and Scholarships, AI29J Murphy Hall. Financial aid applicants must file the Free Application for Federal Student Aid (FAFSA).

Continuing graduate students should contact Financial Aid and Scholarships in December 2019 for information on 2020-21 application procedures.

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

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### 2019-20 ANNUAL UCLA UNDERGRADUATE AND GRADUATE STUDENT FEES

*Fees are subject to revision without notice.*

<table>
<thead>
<tr>
<th></th>
<th>Undergraduate Students</th>
<th>Academic Master's Students</th>
<th>Academic Doctoral Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resident</td>
<td>Nonresident</td>
<td>Resident</td>
</tr>
<tr>
<td>Tuition</td>
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<td>Nonresident Supplemental Tuition (NRST)*</td>
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<td>Course Materials and Services Fee</td>
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</table>

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

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

- Atlantic Richfield Company (ARCO) Fellowship. Chemical and Biomolecular Engineering Department; supports study in chemical engineering
- Balu and Mohini Balakrishnan Endowed Fellowship. Supports doctoral study in any engineering department
- William and Mary Beedle Fellowship. Chemical and Biomolecular Engineering Department; supports study in chemical engineering
- Boeing Fellowship. Supports graduate study in mechanical and aerospace engineering
- John J. and Clara C. Boelter Fellowship. Supports study in engineering
- Broadcom Fellowship. Electrical and Computer Engineering Department; supports doctoral students who have passed the preliminary examination and are doing research that explores new possibilities in state-of-the-art 22-nm CMOS technology
- Broadcom Foundation First Year Fellowship. Supports first-year doctoral students in electrical engineering
- Leon and 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
- Texaco Scholarship. Civil and Environmental Engineering Department; supports research in environmental engineering
- Dr. Robert K. Williamson Graduate Fellowship. Supports graduate study in mechanical and aerospace engineering

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

Special Programs, Activities, and Awards

Center for Excellence in Engineering and Diversity (CEED)

The UCLA Samueli Center for Excellence in Engineering and Diversity (CEED) seeks to create a community of collaborative and sustainable partnerships that increase academic opportunities for urban, disadvantaged, and underrepresented students. CEED supports precollege students in science, engineering, mathematics, and technology curricula, and focuses on engineering and computer science at the undergraduate and graduate levels.

Precollege Outreach Programs

Summer Math and Science Honors Academy (SMASH). A rigorous and innovative education program, SMASH increases opportunities for educationally and financially disadvantaged urban school students to excel in the fields of science, technology, engineering, and math (STEM) at the college level for five weeks each summer. SMASH scholars also receive year-round academic support including SAT preparation, college counseling, financial aid workshops, and other activities to ensure continued academic success. Thirty new SMASH scholars are selected each year to attend the residential program each of three summers (after their 9th, 10th, and 11th grade years). A total of 103 students participated in SMASH during summer 2019.

MESA Schools Program (MSP). Through CEED, UCLA Samueli partners with middle
and high school principals to implement MSP services, which focus on outreach and student development in engineering, mathematics, science, and technology. At individual school sites, four mathematics and science teachers serve as MSP advisers and coordinate the activities and instruction for 1000 students. Advisers work as a team to deliver services that include SAT preparation. MSP prepares students for regional engineering and science competitions and provides an individual academic planning program, academic excellence workshops, CEED undergraduate mentors, field trips, and exposure to high-tech careers. The MSP goal is to increase the numbers of urban and educationally underserved students who are competitively eligible for UC admission, particularly in engineering and computer science.

Students are provided academic planning, SAT preparation, career exploration, and other services starting at the elementary school level through college. UCLA Samueli CEED currently serves 18 schools in the Los Angeles Unified School District and four schools in the Inglewood Unified School District.

**Undergraduate Programs**

CEED currently supports some 330 underrepresented and educationally disadvantaged engineering students. Components of the undergraduate program include

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

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

**Academic Excellence Workshops (AEW).** Providing an intensive mathematics/science approach to achieving mastery through collaborative learning and facilitated study groups, workshops meet twice a week for two hours and are facilitated by a Ph.D. student.

**Bridge Review for Enhancing Engineering Students (BREES).** Sponsored by the National Science Foundation (NSF). A 14-day intensive summer program designed to provide CEED students with the skills and knowledge to gain sufficient mastery, understanding, and problem solving skills in the core engineering courses. Current CEED students and incoming CEED transfer students take part in lectures and collaborative, problem-solving workshops facilitated by UCLA graduate students.

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

**Academic Advising and Counseling.** A CEED counselor assists in the selection of course combinations, professors, and course loads and meets regularly with students to assess progress and discuss individual concerns.

**Tutoring.** Review sessions and tutoring are provided for several upper division engineering courses.

**Career Development.** Presentations by corporate representatives and field trips to major company locations are offered. Other services include summer and full-time job placement and assistance.

**Cluster Systems.** Common class sections that team students, Cluster Systems facilitate group study and successful academic excellence workshops.

**Student Study Center:** A complex with a study area open 24 hours a day, the Student Study Center also houses a computer room and is used for tutoring, presentations, and engineering student organizations.

**Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS).** The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) brings together critical expertise in physics, chemistry, materials science, and engineering to enable rapid advancement and application of multiferroic technologies to next-generation electromagnetic (EM) devices. Its goal is to create a synergistic environment that fosters fundamental studies on magnitism control through application of an electric field while providing a pathway to commercial endeavors. Its unique needs include diverse participant characteristics that encompass how we think, how we do things, and our humanity— including but not limited to age, color, culture, disability, diversity of thought, ethnicity, gender, geographic and national origin, language, life experience, perspective, race, religion, sexual identity, socio-economic status, and technical expertise—aimed to increase creativity and innovation.

The center workforce is composed of researchers who span a wide range of disciplines from chemical to mechanical engineering, and an educational spectrum from K-12 and undergraduate students to post-doctoral scholars, including those who work with industries and national laboratories focused on multiferroic systems.

The TANMS vision is to move from diversity and inclusion advocate to active leader in the ERC community, and provide an educational pathway from cradle to career for the nation’s best and brightest, fully representative and inclusive of the talents of every community. TANMS recognizes diversity as a national imperative to take specific actions by its leadership to source and include a complete talent pool, especially those critically underrepresented populations, and all its population segments and characteristics, in the TANMS academic leadership, technical workforce, and efforts to develop the next generation of engineers, scientists, and entrepreneurs in multiferroics systems.
TANMS is a multi-university partnership between lead institution UCLA and partners California State University Northridge, Cornell University, UC Berkeley, and the Edgenossische Technische Hochschule in Switzerland. CEED directs the TANMS program component, supports undergraduates placed in research laboratories, and coordinates recruitment of undergraduates from other universities. CEED brings teacher-student teams to UCLA to conduct summer research and gain exposure to entrepreneurship.

Scholarships/Financial Aid

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

Student Organizations

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)

http://nsbebruins.wixsite.com/nsbe/home
Chartered in 1980 to respond to the shortage of blacks in science and engineering fields and to promote academic excellence among black students in these disciplines, NSBE provides academic assistance, tutoring, and study groups while sponsoring ongoing activities such as guest speakers, company tours, and participation in UCLA events such as Career Day and Engineers Week. NSBE also assists students with employment. Through the various activities sponsored by NSBE, students develop leadership and interpersonal skills while enjoying the college experience. UCLA NSBE was recently named national chapter of the year for small chapters by the national organization.

Society of Latino Engineers and Scientists (SOLES)

http://www.uclasoles.com
Recognized as the national chapter of the years 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 25 percent of the UCLA Samueli undergraduate enrollment and 22 percent of the graduate enrollment. Today’s opportunities for women in engineering are excellent, as both employers and educators try to change the image of engineering as a males-only field. Women engineers are in great demand in all fields of engineering.

Society of Women Engineers (SWE)

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

Student and Honorary Societies

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

AAAEA Arab American Association of Engineers and Architects
ACM Association for Computing Machinery
ACM-W Association for Computing Machinery—Women
AIAA American Institute of Aeronautics and Astronautics
AIChe American Institute of Chemical Engineers
AISES American Indian Science and Engineering Society
ASCE American Society of Civil Engineers
ASME American Society of Mechanical Engineers
AWWA American Water Works Association
BEAM Building Engineers and Mentors
BMES Biomedical Engineering Society
— Blockchain at UCLA
— Bruin Amateur Radio Club
— Bruin Home Solutions
BruinKSEA Korean-American Scientists and Engineers Association
— Bruin Space Group
CalGeo California Geotechnical Engineers Association
Chi Epsilon Civil Engineering Honor Society
DBF Design/Build/Fly at UCLA
— Engineering Ambassador Program
EGSA Engineering Graduate Students Association
ESUC Engineering Society, University of California. Umbrella organization for all engineering and technical societies at UCLA
Eta Kappa Nu Electrical engineering/computer science and engineering honor society
EWB Engineers Without Borders
IEEE Institute of Electrical and Electronic Engineers
ISPE International Society for Pharmaceutical Engineering
ITE Institute of Transportation Engineers
LUG Linux Users Group
MRS Materials Research Society
— Mentor SEAS
NSBE National Society of Black Engineers
Phi Sigma Engineering social sorority
PIE Pilipinos in Engineering
QSTEM Queen’s in STEM at UCLA
REA Renewable Energy Association at UCLA
— Robotics Club
— Rocket/Space Project at UCLA
SAE Society of Automotive Engineers
SASE Society of Asian Scientists and Engineers
SMV Supermileage Vehicle SAE
SOLES Society of Latino Engineers and Scientists
SWE Society of Women Engineers
Tau Beta Pi Engineering honor society
Theta Tau Triangle Social fraternity of engineers
— UCLA 3D4E
— UCLA DevX
Upsilon Pi Epsilon International honor society for the computing and information disciplines
WATT IEEE Women Advancing Technology through Teamwork

Student Representation

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

Prizes and Awards

Each year, outstanding students are recognized for their academic achievement and exemplary record of contributions to the school. Recipients are acknowledged in the UCLA Samueli annual commencement program as well as by campuswide announcement.

The Russell R. O’Neill Distinguished Service Award is presented annually to an upper-division student in good academic standing who has made outstanding contributions through service to the undergraduate student body, student organizations, the school, and to the advancement of the undergraduate engineering program, through service and participation in extracurricular activities.

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

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

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

Departmental Scholar Program

The school may nominate exceptionally promising juniors and seniors as Departmental Scholars to pursue engineering bachelor’s and master’s degrees simultaneously.

Minimum qualifications include the completion of 24 courses (96 quarter units) at UCLA, or the equivalent at a similar institution, a minimum 3.7 grade-point average (GPA) in the major field upper-division courses and a minimum 3.7 cumulative GPA, and the requirements in preparation for the major. To obtain both the bachelor’s and master’s degrees, Departmental Scholars fulfill the requirements for each program. Students may not use any one course to fulfill requirements for both degrees.

For details, contact the Office of Academic and Student Affairs, 6426 Boelter Hall.

Exceptional Student Admissions Program

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

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

Official Publications

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

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

Grades

Grading Policy

Instructors should announce their complete grading policy in writing at the beginning of the term, along with the syllabus and other course information, and make that policy available on the course website. Once the policy is announced, it should be applied consistently for the entire term.

Grade Disputes

A student who believes that a grade has been given unfairly should first discuss the issue with the instructor of the course. If the dispute cannot be resolved between the student and the instructor, the student may refer the issue to the Associate Dean for Academic and Student Affairs, 6426 Boelter Hall.

The associate dean may form an ad hoc committee to review the complaint. The ad hoc committee members are recommended by the appropriate department chair and the associate dean. The student receives a copy of the ad hoc committee report as well as a copy of the associate dean’s recommendation. The student file will contain no reference to the dispute. The associate dean informs the students of their rights with respect to complaints and appeals at UCLA.

Nondiscrimination

The University of California, in accordance with applicable federal and state laws and University policies, does not discriminate on the basis of race, color, national origin, religion, sex, gender identity, pregnancy (including pregnancy, childbirth, and medical conditions related to pregnancy and
Disability. Disability-based harassment is conduct which is sufficiently severe, pervasive, or persistent so as to interfere with or limit an individual’s ability to participate in or benefit from the services, activities, or opportunities offered by the University.

UCLA has issued Procedure 230.2: Student Grievances Regarding Violations of Anti-Discrimination Laws or University Policies on Discrimination on Basis of Disability. See http://www.adminpolicies.ucla.edu/APP/Number/230.2. 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 at dean@saonet.ucla.edu, or in person at 1104 Murphy Hall. Refer to procedure 230.2 for more information and procedures.

Title IX prohibits sex discrimination, including sexual harassment and sexual violence, in any education program or activity receiving federal financial assistance. Inquiries regarding the application of Title IX may be directed to the Title IX Director, 2255 Murphy Hall, 310-206-3417, titleix@conet.ucla.edu, or the U.S. Department of Education Office for Civil Rights at ocr@ed.gov.

Harassment

Sexual Harassment

The University of California is committed to creating and maintaining a community where all persons who participate in University programs and activities can work and learn together in an atmosphere free from all forms of harassment, exploitation, or intimidation. Every member of the University community should be aware that the University is strongly opposed to sexual harassment and that such behavior is prohibited both by law and by the UC Policy on Sexual Violence and Sexual Harassment (hereafter referred to as the SVSH Policy) at https://policy.ucop.edu/doc/4000385/SVSH(PDF). The University will respond promptly and effectively to reports of sexual harassment and will take appropriate action to prevent, correct and, if necessary, discipline behavior that violates the SVSH Policy. See the Title IX Office website at https://wwwsexualharassment.ucla.edu.

Definitions

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

Complaint Resolution

An individual who believes that they have been sexually harassed may contact the Title IX Director Mohammed Cato, 2255 Murphy Hall, 310-206-3417, titleix@conet.ucla.edu. If a student reports sexual harassment or sexual violence to a responsible employee, as defined under the SVSH Policy, the responsible employee must report it to the Title IX Director. Responsible employees include academic personnel, faculty members, and most other employees who are not defined as a confidential resource under the SVSH Policy.

Title IX prohibits sex discrimination, including sexual harassment and sexual violence, in any education program or activity receiving federal financial assistance. Inquiries regarding Title IX may be directed to the Title IX Director, 2255 Murphy Hall, 310-206-3417, titleix@conet.ucla.edu, or the U.S. Department of Education Office for Civil Rights at ocr@ed.gov.

Other Forms of Harassment

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

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

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.
Undergraduate Programs

The Henry Samueli School of Engineering and Applied Science offers 10 four-year curricula listed below (see the departmental listings for complete descriptions of the programs), in addition to undergraduate minors in Bioinformatics and in Environmental Engineering:

1. Bachelor of Science in Aerospace Engineering
2. Bachelor of Science in Bioengineering
3. Bachelor of Science in Chemical Engineering
4. Bachelor of Science in Civil Engineering
5. Bachelor of Science in Computer Engineering
6. Bachelor of Science in Computer Science
7. Bachelor of Science in Computer Science and Engineering
8. Bachelor of Science in Electrical Engineering
9. Bachelor of Science in Materials Engineering
10. Bachelor of Science in Mechanical Engineering

The aerospace engineering, bioengineering, chemical engineering, civil engineering, computer science and engineering, electrical engineering, materials engineering, and mechanical engineering programs are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The computer science and computer science and engineering curricula are accredited by the Computing Accreditation Commission of ABET, http://www.computingAccreditation.org. The undergraduate program in computer engineering, established in fall 2017, will be submitted to ABET for accreditation during the next ABET visit in 2024.

Admission

Applicants to UCLA Samueli must satisfy the general UC admission requirements. See the Undergraduate Admission website at http://www.admission.ucla.edu for details. Applicants must apply directly to the school by selecting one of the majors within the school or the undeclared engineering option. In the selection process many elements are considered, including grades, test scores, and academic preparation.

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

Applicants must submit scores from an approved core test of mathematics, language arts, and writing. This requirement may be satisfied by taking either the ACT with Writing tests, the SAT Reasoning Test (last administered January 2016), or the SAT with Essay test. Applicants to the school are strongly encouraged to also take the following SAT Subject Tests: Mathematics Level 2 and a laboratory science test (Biology E/M, Chemistry, or Physics) that is closely related to the intended major.

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

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

Admission as a Freshman

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

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

Credit for Advanced Placement Examinations

Students may fulfill part of the school requirements with credit allowed at the time of admission for College Board Advanced Placement (AP) Examinations with scores of 3, 4, or 5. Students with AP Examination credit may exceed the 213-unit maximum by the amount of this credit. AP Examination credit for freshmen entering fall quarter 2019 fulfills UCLA Samueli requirements as indicated on the AP credit table.

Students who have completed 36 quarter units after high school graduation at the time of the examination receive no AP Examination credit.

Admission as a Transfer Student

Admission as a junior-level transfer student is competitive. The University of California requires applicants to have completed a minimum of 60 transferable semester units (90 quarter units) and two transferable English courses prior to enrolling at UCLA. In addition, to be considered all applicants to UCLA Samueli majors must have at least a 3.4 grade-point average in their college work. Many of the majors in the school are impacted. Excellent grades, especially for courses in preparation for the major, are expected.

Completion of the required courses in preparation for the major is critical for admission. Articulation agreements between California community colleges and UCLA Samueli include college-specific course numbers for these requirements and can be found at http://www.assist.org. Applicants who are lacking two or more of the courses are unlikely to be admitted.

Required preparation for UCLA Samueli majors:

1. Mathematics, including calculus I and II, calculus III (multivariable), differential equations, and linear algebra. The Aerospace Engineering and Mechanical Engineering majors do not require differential equations, but it is recommended.
2. Calculus-based physics courses in mechanics, electricity and magnetism, and waves, sound, heat, optics, and modern physics.
3. Chemistry, including two terms of general chemistry. Bioengineering and Chemical Engineering majors are also required to complete two terms of organic chemistry. The Computer Science and Computer Engineering majors do not require chemistry. Electrical Engineering majors must complete only one term of chemistry.
4. Computer programming: applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors may take any C++, C, or Java course to meet the admission requirement, but to be competitive the applicant must take a C++ course equivalent to UCLA Computer Science 31. Applicants to Chemical Engineering may take any C++, C, Java, or MATLAB course to satisfy the admission requirement, but lack of a MATLAB course...
Henry Samueli School of Engineering and Applied Science
Advanced Placement (AP) Examination Credit

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

<table>
<thead>
<tr>
<th>AP EXAMINATION</th>
<th>SCORE</th>
<th>UCLA LOWER-DIVISION UNITS AND COURSE EQUIVALENTS</th>
<th>CREDIT ALLOWED FOR UNIVERSITY AND GE REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art History</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Art, Studio</td>
<td></td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>Drawing Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Biology</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may be applied toward Chemistry 20A) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Science A Test</td>
<td>3, 4, or 5</td>
<td>2 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science AB Test</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science Principles</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macroeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Economics 2 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Economics 1 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing requirement</td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing requirement</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparative</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>Satisfies American History and Institutions requirement</td>
</tr>
<tr>
<td>History</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>Satisfies American History and Institutions requirement</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Languages and Literatures</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>--------------------------------------------------------------</td>
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<td>----------------</td>
</tr>
<tr>
<td>Chinese Language and Culture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>German Language</td>
<td>3</td>
<td>German 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>German 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Japanese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Latin</td>
<td></td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Latin Literature</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Vergil</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Language</td>
<td>3</td>
<td>Spanish 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics</td>
<td></td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Mathematics AB Test: Calculus</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 units May be applied toward Mathematics 31A</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics BC Test: Calculus</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units plus 4 units 4 units may be applied toward Mathematics 31A</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8 units Mathematics 31A plus 4 units that may be applied toward Mathematics 31B</td>
<td>No application</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>Physics 1</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics 2</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics B Test</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics C Test: Mechanics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may be applied toward Physics 1A)</td>
<td>No application</td>
</tr>
<tr>
<td>Physics C Test: Electricity and Magnetism</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Psychology 10 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Statistics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
</tbody>
</table>
equivalent to UCLA Mechanical and Aerospace Engineering M20 or Civil and Environmental Engineering M20 will delay time to graduation. Applicants to all other engineering majors may take any C++, C, Java, or MATLAB course to satisfy the admission requirement, but the MATLAB course equivalent to Mechanical and Aerospace Engineering M20 or Civil and Environmental Engineering M20 is preferred.

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

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

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

Lower-Division Courses in Other Departments

Chemistry and Biochemistry 20A. Chemical Structure (4 units)
Chemistry and Biochemistry 20B. Chemical Energetics and Change (4 units)
Chemistry and Biochemistry 20L. General Chemistry Laboratory (3 units)
English Composition 3. English Composition, Rhetoric, and Language (5 units)
Mathematics 31A. Differential and Integral Calculus (4 units)
Mathematics 31B. Integration and Infinite Series (4 units)
Mathematics 32A, 32B. Calculus of Several Variables (4 units each)
Mathematics 33A. Linear Algebra and Applications (4 units)
Mathematics 33B. Differential Equations (4 units)
Physics 1A. Physics for Scientists and Engineers: Mechanics (5 units)
Physics 1B. Physics for Scientists and Engineers: Oscillations, Waves, Electric and Magnetic Fields (5 units)
Physics 1C. Physics for Scientists and Engineers: Electrodynamics, Optics, and Special Relativity (5 units)
Physics 4AL. Physics Laboratory for Scientists and Engineers: Mechanics (2 units)
Physics 4BL. Physics Laboratory for Scientists and Engineers: Electricity and Magnetism (2 units)
The courses in chemistry, mathematics, and physics are those required as preparation for majors in these subjects. Transfer students should select equivalent courses required for engineering or physical sciences majors.

Requirements for B.S. Degrees

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

University Requirements

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

School Requirements

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

Unit Requirement

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

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

Scholarship Requirement

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

Academic Residence Requirement

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

Writing Requirement

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

Writing I

The Writing I requirement may also be satisfied by completing English Composition 3, 3D, 3DS, 3E, or 3SL with a grade of C or better (a C– or Passed grade is not acceptable) by the end of the second year of enrollment.

Students admitted to the school are required to complete a two-term writing requirement—Writing I and engineering writing. Both courses must be taken for letter grades, and students must receive a grade of C or better in each (a C– grade is not acceptable).

Writing II

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

Students whose native language is not English may need to take English Composition 1A, 1B, and 2I before enrolling in a Writing I course. All courses in the sequence must be passed with a grade of C or better (a C– or Passed grade is not acceptable).
the relevant general education foundational area.

Technical Breadth Requirement

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

Ethics Requirement

The ethics and professionalism requirement is satisfied by completing one course from Engineering 181EW, 182EW, 183EW, or 185EW with a grade of C or better (a C– or Passed grade is not acceptable). The course may be applied toward the engineering writing requirement.

General Education Requirements

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

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

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

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

Foundations of Knowledge

General education courses are grouped into three foundational areas: Foundations of the Arts and Humanities, Foundations of Society and Culture, and Foundations of Scientific Inquiry.

Five courses (24 units minimum) are required. Engineering writing requirement courses also approved for GE credit may be applied toward the relevant GE foundational areas.

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

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

Foundations of the Arts and Humanities

Two 5-unit courses selected from two different subgroups:

- Literary and Cultural Analysis
- Philosophical and Linguistic Analysis
- Visual and Performance Arts Analysis and Practice

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

Intersegmental General Education Transfer Curriculum

Transfer students from California community colleges have the option to fulfill UCLA lower-division GE requirements by completing the Intersegmental General Education Transfer Curriculum (IGETC) prior to transfer. The curriculum consists of a series of subject areas and types of courses which have been agreed on by the University of California and the California community colleges. Although GE or transfer core courses are degree requirements rather than admission requirements, students are advised to fulfill them prior to transfer. The IGETC significantly eases the transfer process, as all UCLA GE requirements are fulfilled when students complete the IGETC courses. Students who select the IGETC
must complete it entirely before enrolling at UCLA. Otherwise, they must fulfill UCLA 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 average of at least a 2.0 (C) in all courses in order to remain in the major. Each course in the major department must be taken for a letter grade. 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 after, completing 105 lower-division quarter units toward the degree in all institutions attended, students are allowed no further unit credit for courses completed at a community college or for lower-division courses completed at any institution outside of the University of California. The University of California does not grant transfer credit for community college or lower-division courses beyond 105 quarter units, but students may still receive subject credit for this coursework to satisfy lower-division requirements. Units earned through Advanced Placement (AP), International Baccalaureate (IB), and/or A-Level examinations are not included in the limitation. To convert semester units to quarter units, multiply the semester units by 1.5; for example, 12 semester units x 1.5 = 18 quarter units. To convert quarter units into semester units, multiply the quarter units by .666; for example, 12 quarter units x .666 = 7.99 or 8 semester units.

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

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

1. To improve the GPA, students may repeat only those courses in which they receive a grade of C– or lower; NP or U grades may be repeated to gain unit credit. Courses in which a letter grade is received may not be repeated on a P/NP or S/U basis. Courses originally taken on a P/NP or S/U basis may be repeated on the same basis or for a letter grade.
2. Repetition of a course more than once requires the approval of the College or school or the dean of the Graduate Division and is granted only under extraordinary circumstances.
3. Degree credit for a course is given only once, but the grade assigned each time the course is taken is permanently recorded on the transcript.
4. There is no guarantee that in a later term a course can be repeated (such as in cases when a course is deleted or no longer offered). In these cases, students should consult with their academic counselor to determine if there is an alternate course that can be taken to satisfy a requirement. The alternate course would not count as a repeat of the original course.

Minors and Double Majors
UCLA Samueli students in good academic standing may be permitted to have a minor or double major. The minor or second major must be outside the school (e.g., Electrical Engineering major and Economics major). UCLA Samueli students are not per-
mitted to have a double major with two school majors (e.g., Chemical Engineering and Civil Engineering). Students may file an Undergraduate Request to Double Major or Add Minor form at the Office of Academic and Student Affairs. The school determines final approval of a minor or double major request; review is done on a case-by-case basis, and filing the request does not guarantee approval. Students interested in a minor or double major should meet with their counselor in 6426 Boelter Hall. While the school considers minor or double major requests, specializations are not considered.

Advising
It is mandatory for all students entering undergraduate programs to have their course of study approved by an academic counselor. After the first term, curricular and career advising is accomplished on a formal basis. Freshman students are assigned a faculty adviser in their particular specialization.

In addition, all undergraduate students are assigned, by major, to an academic counselor in the Office of Academic and Student Affairs who provides them with advice regarding general requirements for degrees, and UC, UCLA, and school regulations and procedures. It is the student’s responsibility to periodically meet with the academic counselor, as well as with the faculty adviser, to discuss curriculum requirements, programs of study, and any other academic matters of concern.

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

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

UCLA Samueli undergraduate students following a Catalog year prior to fall quarter 2012 should schedule an appointment with their academic counselor in 6426 Boelter Hall, or by calling 310-825-9580, to review course credit and degree requirements and for program planning.

The student’s regular faculty adviser is available to assist in planning electives and for discussions regarding career objectives.

Students should discuss their elective plan with the adviser and obtain the adviser’s approval.

Students should also see any member or members of the faculty specially qualified in their major for advice in working out a program of major courses.

Students are assigned to advisers by majors and major fields of interest. A specific adviser, or an adviser in a particular engineering department, may be requested by logging in to MyEngineering (https://my.engineering.ucla.edu) and clicking on the My Advisors link.

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

Honors

Dean’s Honors List

Students following the engineering curriculum 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 2019-20 honors at graduation must have completed 90 or more units for a letter grade at the University of California and must have attained a cumulative grade-point average at graduation that places them in the top five percent of the school (GPA of 3.899 or better) for summa cum laude, next five percent (GPA of 3.839 or better) for magna cum laude, and the next 10 percent (GPA of 3.715 or better) for cum laude. The minimum GPAs required are subject to change on an annual basis. Required GPAs in effect in the graduating year determine student eligibility.

Based on grades achieved in upper-division courses applied to a specific UCLA Samueli degree requirement, engineering students must also have a GPA of 3.899 grade-point average for summa cum laude, a 3.839 for magna cum laude, and a 3.715 for cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field upper-division courses. Upper-division courses that are not applied to a specific school BS degree requirement are excluded from these upper-division averages.
Graduate Programs

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

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

Master of Science Degrees

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

Concurrent Degree Program

A concurrent degree program between UCLA Samueli and the Anderson Graduate School of Management allows students to earn two master’s degrees simultaneously: the M.B.A. and the M.S. in Computer Science. Contact the Office of Academic and Student Affairs for details.

Ph.D. Degrees

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

Established Fields of Study for the Ph.D.

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

Bioengineering Department

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

Chemical and Biomolecular Engineering Department

- Chemical engineering

Civil and Environmental Engineering Department

- Civil engineering materials
- Environmental engineering
- Geotechnical engineering
- Hydrology and water resources engineering
- Structures (structural mechanics and structural/earthquake engineering)

Computer Science Department

- Artificial intelligence
- Computational systems biology
- Computer network systems
- Computer science theory
- Computer system architecture
- Data science computing
Admission

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

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

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

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

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

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

Graduate Record Examination

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

Applicants to UCLA Samueli graduate programs are required to take the General Test of the Graduate Record Examination (GRE). Specific information about the GRE may be obtained from the department of interest. Obtain applications for the GRE by contacting Educational Testing Service.
Departments and Programs of the School

Bioengineering

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

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

Professors
Denise R. Aberle, M.D.
Pei-Yu Chiou, Ph.D.
Mark S. Cohen, Ph.D., in Residence
Linda L. Demer, M.D., Ph.D.
Timothy J. Deming, Ph.D.
Dino Di Carlo, Ph.D.
Robin L. Garrell, Ph.D.
Zheng Gu, Ph.D.
Daniel W. Hescheler, Ph.D.
H. Pirouz Kavehpour, Ph.D.
Andrea M. Kasko, Ph.D.
Wentai Liu, Ph.D.
Linda L. Demer, M.D., Ph.D.

AFFILIATED FACULTY

Professors
Peyman Benharash, M.D. (Cardiothoracic Surgery)
Marvin Bergsneider, M.D., in Residence
Douglas L. Black, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Alex A.T. Bui, Ph.D. (Radiological Sciences)
Gregory P. Carman, Ph.D. (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Yong Chen, Ph.D. (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Thomas Chou, Ph.D. (Biomechanics, Mathematics)
Samson A. Chow, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Jeffrey D. Eldredge, Ph.D. (Mechanical and Aerospace Engineering)
Alan Garfinkel, Ph.D. (Cardiology, Integrative Biology and Physiology)
Christopher C. Giza, Ph.D. (Neurosurgery, Surgery)
Thomas G. Greaser, Ph.D. (Molecular and Medical Pharmacology)
Robert P. Gunsalus, Ph.D. (Chemistry and Biological Chemistry, Biophysics, and Astronomy)
Vijay Gupta, Ph.D. (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Y. Sungtaek Ju, Ph.D. (Mechanical and Aerospace Engineering)
H. Phillip Koefler, M.D., in Residence (Medicine)
Jody E. Kreiman, Ph.D., in Residence (Surgery)
Elliot M. Landaw, M.D., Ph.D. (Biometrics)
Mfn Lee, Ph.D., in Residence (Surgery)
Karen M. Lyons, Ph.D. (Molecular, Cell, and Developmental Biology, Orthopaedic Surgery)
Dejan Markovic, Ph.D. (Electrical and Computer Engineering)
Thomas G. Mason, Ph.D. (Chemistry and Biochemistry, Physics and Astronomy)
Heather D. Maynard, Ph.D. (Chemistry and Biochemistry)
Istvan Mody, Ph.D. (Neurology, Physiology)
Harold G. Monbouquette, Ph.D. (Chemical and Biomolecular Engineering)
Samuel S. Murray, M.D., Ph.D., in Residence (Medicine)
Peter M. Narins, Ph.D. (Ecology and Evolutionary Biology, Integrative Biology and Physiology)
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)
Matteo Pellegrini, Ph.D. (Human Genetics, Molecular, Cell, and Developmental Biology)
Laurent Pilon, Ph.D. (Mechanical and Aerospace Engineering)
Zhinli Qu, Ph.D., in Residence (Cardiology, Medicine)
Dario L. Ringach, Ph.D. (Neurobiology, Psychology)
Ke Sheng, Ph.D. (Radiation Oncology)
Desmond Smith, Ph.D. (Molecular and Medical Pharmacology)
Michael V. Sofroniew, M.D., Ph.D. (Neurobiology)
Chia B. Soo, M.D. (Plastic Surgery)
Igor Spigelman, Ph.D. (Dentistry)
Ricky Taira, Ph.D., in Residence (Radiological Sciences)
Albert Thomas, Ph.D., in Residence (Radiological Sciences)
James G. Tidball, Ph.D. (Integrative Biology and Physiology, Pathology and Laboratory Medicine)
Kang Ting, D.M.D., D.M.Sc. (Dentistry)
Hsin-Rong Tseng, Ph.D. (Molecular and Medical Pharmacology)
Jack Van Horn, Ph.D. (Neurology)
David Wong, Ph.D. (Dentistry)
Lily Wu, Ph.D., M.D. (Molecular and Medical Pharmacology, Urology)
Xinzheng Yang, Ph.D. (Integrative Biology and Physiology)
Z. Hong Zhou, Ph.D. (Microbiology, Immunology, and Molecular Genetics)

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

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

Assistant Professors
Sam Emaninejad, Ph.D. (Electrical and Computer Engineering)
Zhaoyang Fan, Ph.D. (Medicine)
Neema Jamshidi, Ph.D. (Radiological Sciences)
Shantanu Joshi, Ph.D. (Neurology)
Sotiris C. Masmanidis, Ph.D. (Neurobiology)
Behzad Sharif, Ph.D. (Medicine)
Scope and Objectives
The faculty members in the Department of Bioengineering have created state-of-the-art facilities for cutting-edge research and developed an innovative curriculum for the education of the next generation of bioengineers.

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

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

Undergraduate Program Educational Objectives
The bioengineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

The goal of the bioengineering curriculum is to train future leaders by providing students with the fundamental scientific knowledge and engineering tools necessary for graduate study in engineering or scientific disciplines, continued education in professional schools, or employment in industry. There are five main program educational objectives: graduates (1) participate in graduate, professional, and continuing educational activities that demonstrate an appreciation for lifelong learning, (2) demonstrate professional, ethical, societal, environmental, and economic responsibility (e.g., by active membership in professional organizations), (3) demonstrate the ability to identify, analyze, and solve complex, open-ended problems by creating and implementing appropriate designs, (4) work effectively in teams consisting of people of diverse disciplines and cultures, and (5) be effective written and oral communicators in their professions or graduate/professional schools.

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

Bioengineering B.S.
Capstone Major
Learning Outcomes
The Bioengineering major has the following learning outcomes:

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

Preparation for the Major
Required: Bioengineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Civil and Environmental Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20; Life Sciences 2 (satisfies GE life sciences requirement) and 3, or 7A (satisfies GE life sciences requirement) and 7C; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4A.

The Major
Students must complete the following courses:

1. Bioengineering 100, 110, 120, 167L, 176, 180, Electrical and Computer Engineering 100, Engineering 183EW or 185EW; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Bioengineering 177A, 177B)

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

3. Five additional major field elective courses (20 units) from Bioengineering C101 (unless taken under item 2), CM102, CM103, C104, C105, C106 (unless taken under item 2), C131 (unless taken under item 2), CM140, CM145, C147, M153, C155 (unless taken under item 2), C170, C171, CM178, C179, 180L, C183, C185, CM186, CM187, 199 (8 units maximum)

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

Bioengineering undergraduates seed cells to make 3D tissue constructs.
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, M153, C172, 199 (8 units maximum), Electrical and Computer Engineering 102, Mechanical and Aerospace Engineering C187L. The electrical and computer engineering or mechanical and aerospace engineering courses listed above may be used to satisfy the technical breadth requirement.

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

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or [https://www.registrar.ucla.edu/Academics/GE-Requirement](https://www.registrar.ucla.edu/Academics/GE-Requirement).

**Graduate Study**

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

The following introductory information is based on 2019-20 program requirements for UCLA graduate degrees. Complete program requirements are available at [https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/](https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/). Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

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

**Bioengineering M.S.**

**Course Requirements**

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

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

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

To remain in good academic standing, M.S. students must maintain an overall grade-point average of 3.0 and a grade-point average of 3.0 in graduate courses.

**Comprehensive Examination**

**Plan**

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

**Thesis Plan**

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

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

**Bioengineering Ph.D.**

**Course Requirements**

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

**Written and Oral Qualifying Examinations**

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

To remain in good standing in the program, Ph.D. students are expected to take the University Oral Qualifying Examination within six academic quarters and two summer quarters (i.e., two years) following matriculation. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation, the written component of the qualifying examination, prior to the oral qualifying examination.

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

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

**Fields of Study**

**Biomedical Instrumentation**

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

**Course Requirements**

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

**Group I: Core Bioengineering Courses.** At least three courses selected from Bioengineering C201, C202, CM203, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, CM278, C283, C285, CM286, an approved topic of 298.
**Course Requirements**

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


**Biomedical Signal and Image Processing**

The biomedical signal and image processing (BSIP) field prepares students for careers in the acquisition and analysis of biomedical signals and enables students to apply feature extraction. Career opportunities for BSIP trainees include medical instrumentation, engineering positions in medical imaging, and research in the application of advanced engineering skills to the study of anatomy and function.


**Biosystems Science and Engineering**

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

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

**Course Requirements**

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


**Biosystems Science and Engineering**

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**Course Requirements**

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


**Biosystems Science and Engineering**

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

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

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

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

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


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


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


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

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

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

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

Group I: Core Bioengineering Courses. At least three courses selected from Bioengineering C201, CM202, CM203, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C278B, C283, C285, C286, an approved topic of 298.


**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 neuro-science-based, 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 the science and engineering. The goal is for new scientific insights and dramatic technological progress in the twenty-first century, 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.

**Course Requirements**

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

**Group I: Core Bioengineering Courses.** At least three courses selected from Bioengineering C201, CM202, CM203, C204 C205, 206, 207, M219, M229, C239A, C239B, CM245, CM255, M260, C275, CM278, CM283, CM285, CM286, an approved topic of 298.

**Group II: Elective Courses.** At least three courses selected from Bioengineering C201, CM202, CM203, C204, C205, 206, 207, M219, M229, C239A, C239B, CM245, CM255, M260, C275, CM278, CM283, CM285, CM286, an approved topic of 298.

**Faculty Areas of Thesis Guidance**

**Professors**

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

Pei-Yu Chiu, Ph.D. (UC Berkeley, 2005)
Optofluidics systems

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

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

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

Dino Di Carlo, Ph.D. (UC Berkeley, 2006)
Microfluidics, biomimetic microdevices, cellular diagnostics, cell analysis and engineering

Robin L. Garrell, Ph.D. (U. Michigan, 1990), Ph.D. (UCLA, 1999)
Mechanisms of cardiac arrhythmias in humans, complex catheter ablation, medical technology for cardiovascular therapeutics

Maie St. John, M.D., Ph.D. (Yale, 1999)
Novel diagnostic and treatment modalities for head and neck cancer

Ren Sun, Ph.D. (Yale, 1993)
Integration of biology and nanotechnology to define underlying mechanism and develop new diagnostic and therapeutic approaches, with murine gammaherpesvirus 68 (MHV-68) as an in vivo model

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

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

H. Pirouz Kavehpour, Ph.D., M.D. (MIT, 2003)
Microfluidic flow mechanics, transport phenomena in biological systems, physics of contact line phenomena, complex fluids, non-isothermal flows, micro- and nano-heat guides, microfluidics

Ali Rezae Khademhosseini, Ph.D. (MIT, 2005)
Biomaterials, tissue engineering, organ-on-a-chip, stem cell engineering, biofabrication, micro- and nano-technology, biomedical devices

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

Debiao Li, Ph.D. (U. Virginia, 1992)
Development and clinical application of fast MR imaging techniques for the evaluation of the cardiovascular system

Song Li, Ph.D. (UC San Diego, 1997)
Stem cell engineering, tissue engineering and vascular remodeling, mechanobiology/mechanotransduction

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

Arash Naeini, M.D. (UCLA, 1995), Ph.D. (RAND Graduate School, 2002)
Remote monitoring, wearable sensors, big data analytics, clinical informatics, health care analytics

Aydogan Ozcan, Ph.D. (Stanford, 2005)
Photonics, nano- and bio-technology

Jacob Rosen, Ph.D. (Tel Aviv U., Israel, 1997)
Natural integration of a human arm/powered exoskeleton system

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

Mobile health, biosensors, salivary diagnostics, value-based care

Kalyanam Shivkumar, M.D. (U. Madras, India, 1990), Ph.D. (UCLA, 1999)
Mechanisms of cardiac arrhythmias in humans, complex catheter ablation, medical technology for cardiovascular therapeutics

Immune system development and cancer; regulation of gene expression in development and malignancy; linking RNA processing with mitochondrial homeostasis, metabolism and proliferation; nanoscale evaluation of malignant transformation

Immune system development and cancer; regulation of gene expression in development and malignancy; linking RNA processing with mitochondrial homeostasis, metabolism and proliferation; nanoscale evaluation of malignant transformation

Professor Pei-Yu Chiu (UC Berkeley, 2005)
Optofluidics systems
Paul S. Weiss, Ph.D. (UC Berkeley, 1986)
Atomic-scale surface chemistry and physics, molecular devices, nanolithography, bio-physics and nanobiophysics, functionalized nanometer-scale electronics and storage, surface interactions, surface motion, dynamics, and direct manipulation, extending capabilities of scanning tunneling microscope, molecular-scale control and measurement of composition and properties in membranes.

Gerald C.L. Wong, Ph.D. (UC Berkeley, 1994)
Antimicrobials and antibiotic-resistant pathogens, bacterial communities, cystic fibrosis, apoptosis proteins and cancer therapeutics, infection and water purification, self-assembly in biology and biotechnology, physical chemistry of solvation, soft condensed matter physics, biophysics

Biomaterials, cell-material interactions, materials processing, tissue engineering, prosthesis and regenerative dentistry

Yang Yang, Ph.D. (U. Massachusetts Lowell, 1992)
Conjugated polymers and applications in optoelectronic devices such as light-emitting diodes, photodiodes, and field-effect transistors

Professors Emeriti
Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular fluidic phenomena, microelectromechanical systems (MEMS), bionano technologies, biomolecular sensor arrays, control of cellular complex systems, rapid search of combinatorial medicine

Stem cell identification, regenerative medicine, systems biology

Associate Professors
Corey W. Arnold, Ph.D. (UCLA, 2009)
Machine learning, deep learning, medical imaging, radiology, pathology, electronic health records, mHealth

Elsa Freese, Ph.D. (U. Trieste, Italy, 2007)
Convergence of structural biology, dynamics and controls using specialized biomolecular frameworks

William Hsu, Ph.D. (UCLA, 2009)
Deep and reinforcement learning, data integration, clinical data science, imaging informatics

Dan Ruan, Ph.D. (U. Michigan Ann Arbor, 2008)
Signal and image processing, system modeling and optimization, time series, data science and informatics

Holden H. Wu, Ph.D. (Stanford, 2009)
Signal and image processing, magnetic resonance imaging, MRI-guided interventions, nanotheranostics

Assistant Professors
Jun Chen, Ph.D. (Georgia Tech, 2016)
Biomaterials, biomedical devices, wearable bioelectronics, smart textiles, nanogenerators, body area network

Liang Gao, Ph.D. (Rice, 2011)
Biomedical optics, tissue imaging, ultra-fast optics, hyperspectral imaging

Aaron S. Meyer, Ph.D. (MIT, 2014)
Cellular bioengineering, systems-level cellular signaling analysis, model-driven analysis and design, cancer and innate immune signaling

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

Adjoint Associate Professors
Micro- and nano-scale sensors and systems, biomolecular devices, tissue engineering, implantable sensors

Sophia N. Sangiorgio, Ph.D. (UCLA, 2006)
Orthopedic biomechanics

Bill J. Tawill, M.B.A (California Lutheran, 2006), Ph.D. (McGill, 1992)
Skin tissue engineering, bone tissue engineering, vascular tissue engineering, wound healing

Adjoint Assistant Professor
Chase Linsky, Ph.D. (UCLA, 2015)
Biomaterials, tissue engineering, drug delivery, additive manufacturing

Affiliated Faculty
For areas of thesis guidance, see http://www.bioeng.ucla.edu/about-your-faculty-adviser.

Lower-Division Courses
10. Introduction to Bioengineering. (2) Lecture, two hours; discussion, one hour; outside study, three hours. Preparation: high school biology, chemistry, mathematics, physics. Introduction to scientific and technological bases for established and emerging subfields in bioengineering, including sensors, bioinstrumentation, and bioengineering, processing, biomechanics, biomaterials, tissue engineering, biotechnology, biological imaging, biomedical optics and lasers, neuroengineering, and biomaterials. Lett grading. Mr. Deming (F)

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

99. Student Research Program. (1 to 2) Letter grading. Ms. Seidlits (Not offered 2019-20)

Upper-Division Courses
100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 32A, Physics 1A. Fundamental basis for analysis and design of biological and biomedical devices and systems. Classical and statistical thermodynamic analysis of biological systems. Material, energy, charge, and force balances. Introduction to network analysis. Lett grading. Mr. Kamei (F)


CM102. Human Physiological Systems for Bioengineering I. (4) (Same as Physiological Science CM102). 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) to system (organ system). Emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM202. Lett grading. Ms. Seidlits (Sp)

CM103. Human Physiological Systems for Bioengineering II. (4) (Same as Physiological Science CM103.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Broad overview of basic biological activities and organization of human body in system (organ/tissue) to system (organ system). 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 CM203. Lett grading. Ms. Seidlits (Not offered 2019-20)

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

C105. Engineering of Bioconjugates. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry is science of coupling biomolecules for range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of bioconjugates are used in delivery of pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including choice and design of conjugate linkers depending on 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 C205. Lett grading. Mr. Deming (F)

C106. Topics in Bioelectricity for Bioengineers. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced: Requisites: Chemistry 20B, Life Sciences 2, 3, Mathematics 33B, Physics 10. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrical activity of electric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Flanck and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course C206. Letter grading. Mr. Schmidt (F)
C107. Polymer Chemistry for Bioengineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Bioengineering 100 or 120. 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 microstructure, and chain-end functionality. Polymerization, crosslinking, chain copolymerization, and stereochemistry in polymerizations. Presentation of applications of use of different synthesis techniques and their underlying principles. Study of how biological and biotechnological 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. Emphasis on the design principles and engineering concepts used in fabricating microstructures and nanostructures. Helps students become sufficiently fluent with fluid mechanics vocabulary and techniques, design and manufacture micro- and nano-fluidic systems, instruments, and devices, and develop strong intuition for how fluid and particles behave in arbitrarily structured microchannels over a range of Reynolds numbers. Concurrently scheduled with course C239B. Letter grading. Mr. Wong (Sp)

CM140A. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM140A.) Lecture, four hours; discussion, one hour; outside study, six hours. Enforced requisites: Mechanical and Aerospace Engineering 101, 102, and 156A or 166A. Introduction to the mechanical functions of human body, skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading. Mr. Gupta (W)

CM145. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course CM102, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical and chemical properties. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neonate tissue engineering, and liver, kidney, and other organ-like tissues. May be taken independently for credit. Concurrently scheduled with course CM245. Letter grading.

C147. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM102, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical and chemical properties. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neonate tissue engineering, and liver, kidney, and other organ-like tissues. May be taken independently for credit. Concurrently scheduled with course CM247. Letter grading. Mr. Wu (Sp)

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) (Same as Chemical Engineering M153, Electrical and Computer Engineering M183B.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4A, 4B, Introduction to general mathematics and physics for scientists and engineers, and Fundamentals of tissue engineering. Manufacturing constraints, limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course C270. Letter grading. Mr. Wu (Sp)

C172. Design of Minimally Invasive Surgical Tools. (4) Lecture, two hours; laboratory, four hours; discussion, three hours. Concurrently scheduled with course C270. Letter grading. (Not offered 2019-20)

C170L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) Laboratory, four hours; discussion, two hours. Corequisite: course C170. Introduction to simulation and experimental techniques in studying laser-tissue interactions. Topics include computer simulations of light propagation in tissue, measuring absorption spectra of tissues, laser safety, and diagnostic and therapy devices in medical and dental applications, with emphasis on understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C271. Letter grading.


C172. Design of Minimally Invasive Surgical Tools. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, Mathematics 32A. Introduction to design principles and engineering concepts used in

C175. Machine Learning and Data-Driven Modeling in Bioengineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Required prerequisites: Civil Engineering M20 or Mechanical and Aerospace Engineering M20, Computer Science 31, Mathematics 32B, 33A. Overview of foundational data analysis and machine-learning methods in bioengineering, focusing on how these techniques can be applied to interpret experimental observations. Topics include 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, gain hands-on experience of these methods, and work on experimental data from bioengineering studies. Students become sufficiently familiar with these techniques to design studies incorporating such analyses, and are prepared to work in teams using similar approaches, and ensure correctness of their results. Concurrently scheduled with course CM275. Letter grading. Mr. Meyer (Sp)

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

177A. Bioengineering Capstone Design I. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced prerequisites: courses 167L, 176. Lectures, seminars, and discussions on aspects of biomedical device and therapeutic design, including topics such as need finding, intellectual property, entrepreneurship, regulation, and project management. Working in teams, students develop innovative solutions to problems in medicine and biology. Sourcing and ordering of materials and supplies relevant to student projects. Exploration of different experimental and computational methods. Scientific presentation of progress. Letter grading. Mr. Di Carlo (F)

177B. Bioengineering Capstone Design II. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced prerequisite: course 177A. Lectures, seminars, and discussions on aspects of biomedical device and therapeutic design, including meetings with scientific/clinical advisers and guest lecturers from scientists in industry. Working in teams, students develop innovative solutions to problems in medicine and biology. Sourcing and ordering of materials and supplies relevant to student projects. Exploration of different experimental and computational methods. Scientific presentation of progress. Letter grading. Mr. Di Carlo (W)

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

C179. Biomaterials–Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Required prerequisites: course 179A. The progression of host cell responses, including cytokine production, cell–cell contact, and cell adhesion, to biomaterials: vascular response, interface, and clotting, biocompatibility, animal models, inflammation, infection, extracellular matrix, cell adhesion, and role of mechanical forces. Concurrently scheduled with course CM279. Letter grading. Mr. Wu (Not offered 2019–20)

180. System Integration in Biology, Engineering, and Medicine I. (4) Lecture, three hours; discussion, two hours; outside study, six hours. Required prerequisites: courses 100, 110, 120, Life Sciences 3, Physics 1C. Corequisite: course 180L. Part I of two-part series. Molecular basis of normal physiology and pathology of cells, tissues, and organ systems. Design principles of cardiovascular and pulmonary systems. Fundamental engineering principles of selected medical therapeutic devices. Letter grading. Mr. Dunn, Ms. Wu (W)

180L. System Integration in Biology, Engineering, and Medicine I Laboratory. (4) Lecture, one hour; laboratory, four hours; clinical visits, four hours; outside study, three hours. Corequisite: course 180. Hands-on experimentation and clinical visits to cardiovascular and pulmonary systems. Letter grading. Mr. Dunn, Ms. Wu (Sp)

M182. Systems Biomodeling and Control Basics. (4) (Same as Computer Science M182.) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. Required prerequisite: Mathematics 3B, 31B, or Life Sciences 3CA. Recommended corequisite: Mathematics 3C, 32A, or Life Sciences 3CB. Designed for undergraduate students in life sciences and engineering. Introduction to explicit modeling and simulation of biological systems. Presentation of how biology, biochemistry, and physiology underlying dynamic systems biomodeling are transformed into system diagrams and graphs. Students gain understanding of their form and function. Structural models, formulated from basic conservation and mass action laws and feedback concepts, are further transformed into first-order differential equations, and implemented in simulation diagrams for quantifying and exploring biosystem properties. Examples show how to use these explicit models to gain clarity on nature of biosystem phenomena, and frame questions to explore new ideas for research. Letter grading. (F)

C183. Targeted Drug Delivery and Controlled Drug Release. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Required prerequisites: Chemistry 20B, 20C. Hands-on experiments require comprehensive understanding of modern biology, physical science, biochemistry, and engineering. Targeted delivery of genes and drugs and their controlled release are important in treatments of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug pharmacodynamics and clinical pharmacokinetics. Application of engineering principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of novel drug delivery systems that can provide spatial and temporal control of drug release. Applications of new systems to specialized structural and interfacial properties. Exploration of both chemistry of materials and physical presentation of devices and compounds used in delivery and regulatory agency evaluation. Letter grading. Ms. Kasko (Sp)

M184. Introduction to Computational and Systems Biology. (2) (Same as Computational and Systems Biology M184 and Computer Science M184.) Lecture, two hours; laboratory, one hour. Enforced prerequisites: one course from Civil Engineering M20, Computer Science 31, Mechanical and Aerospace Engineering M20, or Physics. Corequisite: Physics 104A or 104B or 104C. Survey course designed to introduce students to computational and systems modeling and computation in biology and medicine, providing motivation, flavor, culture, and cutting-edge contributions in computational biosciences and aiming for more informed basis for focused studies by students with computational and systems biology interests. Presentations by individual UCLA researchers discuss their research at the computational and systems biology research. P/NP grading. Mr. DiStefano (Not offered 2019-20)

C185. Introduction to Tissue Engineering. (4) Lecture, three hours; discussion, one hour; outside study, seven hours. Required prerequisites: Chemistry 202, Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences with engineering approach to regenerate tissues and organs. Guiding principles for proper selection of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently scheduled with course C285. Letter grading. Mr. Fahim (W)

CM186. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Computational and Systems Biology M186, Computer Science CM186, and Ecology and Evolutionary Biology M187.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes at different scales and under different experimental and computational conditions. Control system, multiparameter, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular and cellular pathways/networks, organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and computer laboratory assignments. Concurrently scheduled with course CM286. Letter grading. Mr. DiStefano (W)

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

188. Special Courses in Bioengineering. (4) Lecture; discussion; tutorial, to be arranged. Limited to juniors/seniors. Special topics in bioengineering 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. (F,W,Sp)

194. Research Group Seminars: Bioengineering. (4) Seminar, three hours. Limited to bioengineering undergraduate students who are part of research group. Study and analysis of current topics in bioengineering. Discussion of current research literature in research specialty of faculty member teaching course. Students attend presentations by visiting faculty members. May be repeated for credit. Letter grading. (F,W,Sp)

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

Graduate Courses

C201. Engineering Principles for Drug Delivery. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced prerequisites: Mathematics 33B, Physics 1B. Application of engineering principles.
CM202. Human Physiological Systems for Bioengineering I. (4) (Same as Physiological Science CM202.) 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 activity of human body systems (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 CM102. Letter grading. Mr. Kamei (F)

CM203. Human Physiological Systems for Bioengineering II. (4) (Same as Physiological Science CM203.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Broad overview of basic biological activity of human body systems (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 CM102. Letter grading. Ms. Seidlls (F)

C204. Physical Chemistry of Biomacromolecules. (4) Lecture, three hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20B, 30A, Life Sciences 2, 3. To understand biological materials and design synthetic replacements, it is imperative to understand their physical chemistry. Biomacromolecules such as protein or DNA can be analyzed and characterized by applying fundamentals of polymer physical chemistry. Investigation of polymer structure and conformation, solution and solution thermodynamics and phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as protein, conformation, variables 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 discussing 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 enhance its stability in serum. Wide variety of new applications in delivery of phospho- cestins, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including choice and design of conjugate linkers dependent on type of molecule and desired application, such as degradable versus nondegradable linkers. Presentation and discussion of design and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C105. Letter grading. Mr. Deming (F)

C206. Topics in Bioelectricity for Bioengineers. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20B, Life Sciences 2, 3, 33B, Physics 1C. An introduc- ence in depth of physical processes associated with biological membranes and channel proteins, with special emphasis on electrophysiology. Basic physical principles governing electrophysics in dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Poisson/Boltz- mann equations, Nerst potential, Donnan equilib- rium, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integrations. Concurrently scheduled with course C106. Letter grading. Mr. Schmidt (F)

C207. Polymer Chemistry for Bioengineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course C202 or C205. Fundamental concepts of polymer synthesis, in- cluding step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on fact that can be used to control chain length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in po- lymerizations. Presentation of applications of use of different polymerization techniques. Concepts of step-growth, chain-growth, ring-opening, and coordi- nation polymerization, and effects of synthesis route on polymer properties. Lectures include both theory and practical issues demonstrated through exam- ples. Concurrently scheduled with course C107. Letter grading. Mr. Deming (W)


M215. Biochemical Reaction Engineering. (4) (Same as Chemical Engineering CM215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Chemical Engi- neering 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. Requisite: Electrical and Computer Engi- neering 114 or 211A. Optical imaging modalities in biomedicine. Other nonoptical imaging modalities discussed briefly for comparison purposes. Letter grading.

M219. Principles and Applications of Magnetic Resonance Imaging. (4) (Same as Physics and Bi- ology in Medicine M219.) Lecture, three hours; dis- cussion, one hour. Basic principles of magnetic reso- nance (MRI), physics, and image formation. Emphasis on hardware, Bloch equations, analytic expressions, image contrast mechanisms, spin and gradient echoes. Fourier transform imaging methods, struc- ture of pulse sequences, and various scanning pa- rameters. Introduction to advanced techniques in rapid imaging, quantitative imaging, and spectros- copy. Letter grading.

220. Introduction to Medical Informatics. (2) Lect- ture, 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 applications such as in rehabilitation system architectures, data and process modeling, in- formation extraction and representations, information retrieval and visualization, health services research, telemedicine. Emphasis on current research en- devors and applications. S/U grading.

Mr. Kangaroo (F)

221. Human Anatomy and Physiology for Medical and Imaging Informatics. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on understand- ing and visualization of anatomy and physiology through medical images. Topics relevant to acquisi- tion, representation, and dissemination of anatomi- cal knowledge in computerized clinical applications. Topics include chest, cardiac, neurology, gastrointesti- nal, urology, endocrinology, and musculoskeletal. Introduction to basic imaging physics (magni- netic resonance, computed tomography, ultrasound, computed radiography) to provide context for im- aging modalities predominantly used to view human anatomy. Geared toward nonphysicians who require more formal understanding of human anatomy/physi- ology. Letter grading. Mr. El-Saden (F)

223A-223B-223C. Programming Laboratories for Medical and Image Informatics I, II, III. (4–4–4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Programming laboratories to support coursework in other medical imaging and anatomy core curric- ulum courses. Exposure to programming concepts for medical applications, with focus on basic abstrac- tion techniques used in image processing and med- ical information systems. Letter grading.

M223A. Requisites: Computer Science 31, 32, Program in Computing 20A, 20B. Course 223A is requisite to 223B, which is requisite to 223C. Integ- rated with topics presented in course M211A to rein- force concepts presented with practical experience. Projects focus on understanding medical networking issues and implementation of basic protocols for healthcare environment, with emphasis on use of DICOM. Introduction to basic tools and methods used within informatics.

M223B. Requisite: course 223A. Integrated with topics presented in courses 223A, 223B, and disease specific concepts presented with practical experience. Projects focus on medical image manipulation and decision support systems. M223C. Requisite: course 223B. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used to ex- tract meaningful features from medical text and im- aging data and visualize results. Integrated with topics presented in courses 2224B and M226 to rein- force concepts presented with practical experience. Projects focus on medical information retrieval, knowledge representation, and visualization.

Mr. M. Kurihara (FW,Sp)

224A. Physics and Informatics of Medical Imaging. (4) Lecture, four hours; laboratory, eight hours. Requisites: Mathematics 33A, 33B. Designed for graduate students. Introduction to principles of med- ical imaging and imaging informatics. Overview of core imaging modalities: X ray, computed tomography (CT), and magnetic reso- nance (MR). Topics include signal generation, locali- zation, and quantization. Image representation and analysis techniques such as Markov random fields, spatial characterization (atlases), denoising, energy representations, and clinical imaging workstations. Topics include basic understanding of medical image acquisition and analysis. Current research efforts focus on clinical applica- tions and new types of information made available through these modalities. Letter grading.

Mr. Moroka (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 other research concepts in imaging informatics, reviewing seminal papers on evaluating IR systems and their use in medicine (e.g., teaching files, case-based retrieval, etc.). Examination of specific techniques for image feature extraction, image feature rep- resentation, indexing and querying, and classification
(machine/deep learning). Survey of clinical applications of these techniques and ongoing challenges. **Letter grading.** Mr. Monbouquette (W)

**M225. Bioseparations and Bioprocess Engineering.** (4) (Same as Chemical Engineering CM225.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: Chemical Engineering 101C. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Letter grading. Mr. Monbouquette (W)

**M226. Medical Knowledge Representation.** (4) (Same as Information Studies M253.) Seminar, four hours; outside study, eight hours. Designed for graduate students in medical knowledge representation and its application in healthcare processes. Topics include data structures used for representing knowledge (conceptual graphs, frame-based models), different data models for representing spatio-temporal information, rule-based implementations, current statistical methods for discovery of knowledge (data mining, statistical classifiers, and hierarchical classification), and basic information retrieval. Review of work in constructing ontologies, with focus on problems in implementation and definition. Common medical ontologies, coding schemes, and standard code sets (terminology, SNOMED, UMLS). Letter grading. Mr. Taira (Sp)

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

**M228. Medical Decision Making.** (4) (Same as Information Studies M255.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concept of evidence-based medicine and decision processes related to process of care (evaluation of diagnostic and therapeutic options) to understand treatment results and evaluations, and algorithmic methods for decision-making processes (Bayes theorem, decision trees). Study design, hypothesis testing, and estimation. Focus on technical advances in medical decision support systems and expert systems, with review of classical and current research. Introduction to common statistical and decision-making software packages to familiarize students with current tools. Letter grading. Mr. Kangaroo (W)

**M229. Advanced Topics in Magnetic Resonance Imaging.** (4) (Same as Physics and Biology in Medicine CM229.) Lecture, four hours; discussion, one hour; outside study, seven hours. Designed for students interested in pursuing research related to development or translation of new magnetic resonance imaging (MRI) techniques, tools and protocols. Recent MRI developments that have had high impact on field, involve novel pulse sequence design or image reconstructions, and enable imaging of anatomy or function in way that sometimes were not previously possible. Understanding of role of biological imaging in modern biology and medicine. Illustration of these ideas using examples from bioengineering and biomedical engineering. Students should be able to make simple calculations and estimates that allow them to engage broad spectrum of biological Imaging and medicine, such as choice of drug and gene delivery and tissue engineering. May be taken for independent credit. Concurrently scheduled with course C139A. Letter grading. Mr. Wong (W)

**C231. Nanopore Sensing.** (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 5, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of fluctuating ionic conductance through artificial or protein nanopores. Physics of pore conductance. Applications to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of measurements in electrolytes, nanopore fabrication, ionic conductance 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 Opportunities.** (4) (Same as Management M271A.) Lecture, three hours; outside study, nine hours. Designed for graduate and professional students in engineering, dentistry, design, law, management, and computer science. Introduction of how to identify unmet clinical needs, properly filtering through these needs using various acceptance criteria, and selecting promising needs for which potential medtech solutions. Students work in groups to expedite traditional research and development processes to invent and implement new medical devices that increase quality of clinical care and result in improvement in patient health. 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 Management M271B.) Lecture, three hours; outside study, nine hours. Requisite: course M233A. Designed for graduate and professional students in engineering, dentistry, design, law, management, and computer science. Development of medtech solutions for unmet clinical needs previously identified in course M233A. Steps necessary to commercialize viable medtech solutions. Exploration of concept selection, business plan development, intellectual property filing, financing strategies, and device prototyping. Letter grading. Mr. Liu, Mr. 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 of biology, cell biology, and bioengineering. Understanding of different types of interactions that exist between biomolecules, such as van der Waals interactions, ionic interactions, hydrogen bonding, hydrophobic interactions, hydration and solvation interactions, polymer-mediated interactions, deple- tion interactions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Students should be able to make simple calculations and estimates that allow them to engage broad spectrum of biological Imaging and medicine. May be taken for independent credit. Concurrently scheduled with course C139A. Letter grading. Mr. Wong (W)

**C239B. Biomolecular Materials Science II.** (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Course C239A is not requisite to C239B. Overview of chemical and physical foundations of biomolecular materials science that concern materials of 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 their functional properties via self-assembly and how these structures impact biological function. Illustration of these ideas using examples from bioengineering and biomaterials structure and function. Topics include drug delivery, gene therapy, cancer therapeutics, emerging pathways, and role of self-assembly to disease states. May be taken independently for credit. Concurrently scheduled with course C139B. Letter grading. Mr. Cudner (Sp)

**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, 107. Introduction to biomechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics, applications, fluid transfer, 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 industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading. Mr. Liu, Mr. Shivkumar (W)

**C247. Applied Tissue Engineering: Clinical and Industrial Perspective.** (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisite: course CM202, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological testing. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, heart, and various other organs. Clinical and industrial perspectives of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course C147. Letter grading. Mr. Wu (Sp)

**M248. Introduction to Biological Imaging.** (4) (Same as Pharmacology M248 and Physics and Biological Engineering M248.) Lecture, three hours; discussion, one hour; outside study, eight hours. Designed for graduate students in engineering, dentistry, design, law, management, and computer science. Overview of role of biological imaging in modern biology and medicine, including imaging physics, instrumentation, imaging applications, and imaging for range of modalities. Practical experience provided through series of imaging laboratories. Letter grading.

**M250B. Microelectromechanical Systems (MEMS) Fabrication.** (4) (Same as Electrical and Computer Engineering M250B and Mechanical and Aerospace Engineering M280B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, silicon micromachining techniques, and physical/mechanical systems. Coverage of many lithographic, deposition, and etching processes, as well as their combination in photolithographic processes. Topics include chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. A. Cudner (Sp)

**M252. Microelectromechanical Systems (MEMS) Design and Fabrication.** (4) (Same as Electrical and Computer Engineering M252 and Mechanical and Aerospace Engineering M282.) 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 conventional and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. Wu (Sp)
C255. Fluid-Particle and Fluid-Structure Interactions in Microflows. (4) Lecture, four hours; laboratory, one hour; outside study, seven hours. Enforced requisites: course 110. Introduction to Navier-Stokes equations, assumptions, and simplifications. Analytical framework for calculating simple flows and numerical methods to solve and gain insight for complex flows. Forces on particles in Stokes flow and finite-inertia flows. Flows induced around particles with and without finite inertia and implications for particle trajectories. Second-order flows induced by structures and particles in confined flows. Particle separations by fluid dynamic forces: field-flow fractionation, inertial focusing, structure-induced separations. Application concepts in internal biological flows and separations for biotechnology. Helps students become sufficiently fluent with fluid mechanics vocabulary and techniques, design and model microfluidic systems to manipulate fluids, cells, and particles, and develop strong intuition for how fluid and particles behave in arbitrarily structured microchannels over range of Reynolds numbers. Concurrently scheduled with course C155. Letter grading.

Mr. Di Carlo (Sp)

M260. Neuroengineering. (4) (Same as Electrical and Computer Engineering M255 and Neuroscience M206.) Lecture, four hours; laboratory, three hours; outside study, five hours. Enforced requisites: Mathematics 32A, Physics 1B or 5C. Introduction to principles and technologies of bioelectricity and neural signal recording, processing, and stimulation. Topics include bioelectricity and neurotechnology (action potentials, local field potentials, EEG, ECOG), intracellular and extracellular recording, microelectrode technology, neural signal processing (neural signal frequency bands, filtering, spike detection, spike sorting, stimulation artifact removal), brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading.

Mr. Liu (F)


M263. Anatomy of Central Nervous System. (4) (Same as Neuroscience M203.) Lecture, 75 minutes; discussion/laboratory, one hour; outside study, eight hours. Prior to the first laboratory meeting, students must complete Bloodborne Pathogens training course through UCLA Environment, Health and Safety. Study of anatomical locations of the central nervous system (CNS), efferent and afferent axons involved in the CNS and its subdivisions, and the descending and ascending sensory and motor systems from spinal cord to cerebral cortex. Covers cranial nerves and brainstem anatomy along with anatomy of ventricular and vascular systems that support CNS function. Areas covered in detail. Integrated anatomy laboratory includes brain dissections and overview of tools for MRI analysis. Letter grading.


F

C270E. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) Laboratory, four hours; outside study, eight hours. Corequisite: course C270. Introduction to simulation and experimental techniques used in studying laser-tissue interactions. Topics include laser tissue interaction, spatial resolution, and light propagation in tissue, measuring absorption spectra of tissue/tissue phantoms, making tissue phantoms, determination of optical properties of different tissues, techniques of temperature distribution measurements. Concurrently scheduled with course C170L. Letter grading.


W

C272. Design of Minimally Invasive Surgical Tools. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Introduction to minimally invasive techniques and tools used in minimally invasive surgery. Focus on surgical techniques and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, biopsy devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instrumentation, and integration of devices with therapy. Examination of complex process of tool design, fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel devices. Concurrently scheduled with course C172. Letter grading.

Sp

C275. Machine Learning and Data-Driven Modeling in Bioengineering. (4) Lecture, four hours; laboratory, three hours; outside study, six hours. Requisites: Mathematics 32B, 33A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive procedures and surgical methods. Examines biological systems theory with applications to computer-aided surgery and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, biopsy devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instrumentation, and integration of devices with therapy. Examination of complex process of tool design, fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel devices. Concurrently scheduled with course C175. Letter grading.

C276. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Computer Science CM286.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Requisites: courses CM102 or CM104, and either Chemistry 20A, 20B, or Chemistry 20L, or Materials Science CM287. Computationally oriented introduction to computer-aided modeling and simulation of biological systems. Topics include fundamental system biology theory and methods relevant to bioengineering. Application of these methods to experimental data from bioengineering studies. Students become sufficiently familiar with these techniques to design studies incorporating such analyses, execute analysis, and work in teams using familiar approaches, and ensure correctness of their results. Concurrently scheduled with course CM175. Letter grading.

Ms. Kasko (F)

C278. Introduction to Biomaterials. (4) (Same as Materials Science CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Mathematics 20A, 20B, and 20L. Introduction to biomaterials. Historical and current biomaterials development milestones and applications. Focus on biomaterials in tissue engineering, wound healing, and drug delivery applications. Letter grading.


Mr. Wu (Not offered 2019-20)

282. Biomaterials Interface. (4) Lecture, four hours; laboratory, eight hours. Requisites: course CM178 or CM278. Function, utility, and biocompatibility of biomaterials depend critically on their surface and interfacial properties. Discussion of surface morphology and composition of biomaterials and nanoscale, macroscale, and macromolecular, techniques for characterizing structure and properties of biomaterial interfaces, and methods for designing and fabricating biomaterials with desired properties in vitro and in vivo. Letter grading.

Ms. Maynard (W)

C283. 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 comprehensive understanding of modern biology, physiology, biotechnology, and engineering. Targeted delivery of genes and drugs are hence front areas of research and development. Development and delivery of novel drug delivery systems that can achieve spatial and temporal control implies strong understanding of treatment. New drug formulation and delivery to establish rationale for design and development of novel drug delivery systems that can achieve spatial and temporal control of drug release. Introduction to biomaterials with specialized structural and interfacial properties. Exploration of both chemistry of materials and physical presentation of devices and compounds used in delivery and release. Concurrently scheduled with course C183. Letter grading.

Ms. Kasko (Sp)

M284. Functional Neuroimaging: Techniques and Applications. (3) (Same as Neuroscience M235.) Lecture, three hours. In-depth examination of activation imaging, including fMRI and electrophysiological methods, data acquisition and analysis, experimental design, and results obtained thus far in human systems. Strong focus on understanding technologies, how to design activation imaging paradigms, and how to interpret results. Laboratory involves and demonstration of functional MRI experiment. S/U or letter grading.


C286. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Computer Science CM286.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multicompartamental, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Focus on modeling in vivo therapeutic approaches that involve designing small molecules that focus on translating biomodeling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, mathematical techniques, and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading.

Mr. DiStefano (F)

C287. Research Communication in Computational and Systems Biology. (4) (Same as Computer Science CM287.) Lecture, four hours; outside study, eight hours. Requisite: course CM286. Closely directed, interactive, and real research experience in active computational and systems biology labs. Introduction. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Criticals of oral presentations and written papers entail 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.

Sp

295A-295Z. 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 research topics. Exploration and literature in research specialty of faculty member teaching course. Student presentation of projects in research specialty. May be repeated for credit. S/U grading.

295A. Biomedical Research. (295B. Biomaterials and Tissue Engineering Re-

M296A. Advanced Modeling Methodology for Dynamic Biomedical Systems. (4) (Same as Computer Science M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biometrics 220. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano (F)

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

M296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) (Same as Biometrics 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. Mr. DiStefano (Sp)

M296D. Introduction to Computational Cardiology. (4) (Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM180. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological processes. Ionic models of action potential (AP). Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading. Mr. Kogan (F,Sp)

298. Special Studies in Bioengineering. (4) Lecture, four hours; outside study, eight hours. Study of selected topics in bioengineering taught by resident and visiting faculty members. May be repeated for credit. Letter grading.

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

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

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

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

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

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

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

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

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

Chemical and Biomolecular Engineering

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

Professors Emeriti
Robert F. Hicks, Ph.D.
Kendall N. Houk, Ph.D. (Saul Winstein Professor Emeritus of Organic Chemistry)
Louis J. Ignarro, Ph.D. (Vorst Professor Emeritus of Chemical Engineering)
Selim M. Senkan, Ph.D.
Vincent L. Vilker, Ph.D.
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Associate Professors
Irene A. Chen, Ph.D.
Yvonne Y. Chen, Ph.D.

Assistant Professors
Nasim Annabi, Ph.D.
Carissa N. Eisler, Ph.D.
Carlos G. Morales-Guijo, Ph.D.
Junyoung O. Park, Ph.D.
Dante A. Simonetti, Ph.D.
Vijay K. Dhir, Ph.D.

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

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

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

Undergraduate Program Educational Objectives

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

The mission of the undergraduate program is to educate future leaders in chemical and biomolecular engineering who effectively combine their broad knowledge of physics, chemistry, biology, and mathematics with their engineering analysis and design skills for the creative solution of problems in chemical and biological technology and for the synthesis of innovative (bio)chemical processes and products. This goal is achieved by producing chemical and biomolecular engineering alumni who (1) draw readily on a rigorous education in mathematics, physics, chemistry, and biology in addition to the fundamentals of chemical engineering to creatively solve problems in chemical and biological technology, (2) incorporate social, ethical, environmental, and economical considerations, including the concept of sustainable development, into chemical and biomolecular engineering practice, (3) lead or participate successfully on multidisciplinary teams assembled to tackle complex multifaceted problems that may require implementation of both experimental and computational approaches and a broad array of analytical tools, and (4) pursue graduate study and achieve an M.S. or Ph.D. degree in the sciences and engineering and/or achieve success as professionals in chemical and biomolecular engineering as well as related fields, including business, medicine, and environmental protection.

Undergraduate Study

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

Chemical Engineering B.S.

Capstone Major

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

Learning Outcomes

The Chemical Engineering major has the following learning outcomes:

- Application of knowledge of mathematics, physics, chemistry, biology, and chemical and biological engineering, especially to integration of molecular- 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 one biomolecular elective course (4 units) from Bioengineering C105, C183, Chemical Engineering C112, Chemistry and Biochemistry C105, C15A, or C159 (another chemical engineering elective may be substituted with approval of the faculty adviser).

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Biomedical Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109, CM145; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one biomolecular elective course (4 units) from Bioengineering C105, C183, Chemical Engineering C112, Chemistry and Biochemistry C105, C15A, or C159 (another chemical engineering elective may be substituted with approval of the faculty adviser).

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Environmental Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and two elective courses (8 units) from Chemical Engineering 113, C118, C119, C121, C128, C135, C140 (another chemical engineering elective may be substituted with approval of the faculty adviser).

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Semiconductor Manufacturing Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 104C, 104CL, 106, 107, 109, C116; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one elective course (4 units) from chemical engineering or from Materials Science and Engineering 104, 120, 121, 122, or 150.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Graduate Study

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

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

The following introductory information is based on 2019-20 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

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

Chemical Engineering M.S.

Areas of Study

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

Course Requirements

The requirements for the MS degree are a thesis, nine courses (36 units), and a minimum 3.0 grade-point average in the graduate courses. Chemical Engineering 200, 210, and 220 are required. Two other courses must be taken from regular offerings in the department, while two Chemical Engineering 598 courses involving work on the thesis may also be selected. The remaining two courses may be taken from those offered by the department or any other field in life sciences, physical sciences, mathematics, or engineering. At least 24 units must be in letter-graded 200-level courses. All M.S. degree candidates are required to enroll in Chemical Engineering 299 during each term in residence.

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-

Semiconductor Manufacturing Specialization

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

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

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

Comprehensive Examination Plan

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

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

Thesis Plan

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

Chemical Engineering Ph.D.

Major Fields or Subdisciplines

Consult the department.

Course Requirements

All Ph.D. students are required to take six letter graded, 200-level courses (24 units). They can select three chemical engineering core courses from 200, 210, 220, CM245, and a graduate engineering mathematics course. Two additional courses must be taken from those offered by the department. The final course can be selected from offerings in life sciences, physical sciences, mathematics, or engineering. Students are encouraged to take more courses in their field of specialization. The minor field courses should be selected in consultation with the research adviser. A minimum 3.33 grade-point average in graduate courses is required. A program of study to fulfill the course requirements must be submitted for approval to the departmental Student Affairs Office no later than one term after successful completion of the preliminary oral examination.

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

Written and Oral Qualifying Examinations

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

All Ph.D. students are required to pass the preliminary written examination (PWE) to demonstrate proficiency in at least three of the five core areas as follows. Students must select the transport phenomena core area and either the thermodynamics core area or reaction engineering core area or both. If they select only one of thermodynamics or reaction engineering, they must also select either the biomolecular engineering or engineering mathematics core area. The PWE is offered at the end of winter quarter of each academic year and is graded by a faculty committee. Students must take the PWE in their first year. If they fail the PWE on the first attempt, they can retake it for a second term the following spring quarter. Students who fail both attempts are not allowed to continue in the Ph.D. program.

After completion of the required courses for the degree and passing of the PWE, students must pass the written and oral qualifying examinations. These examinations focus on the dissertation research and are conducted by a doctoral committee consisting of at least four faculty members nominated by the department in accordance with University regulations. Three members, including the chair, are inside members and must hold faculty appointments in the department. The outside member must be a UCLA faculty member in another department. Students are required to have a minimum 3.33 grade-point average in graduate coursework to be eligible to take these examinations.

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

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

Facilities

Biomolecular Engineering Laboratories

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

Chemical Kinetics, Catalysis, and Reaction Engineering Laboratory

The laboratory is equipped with advanced research tools for experimental and computational studies of chemical kinetics, reaction engineering, and catalytic and absorptive 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. Original simulation methods, developed by the researchers, are available for the modeling of electrocatalysis. A high-performance cluster is available for research and teaching. Campuswide computers are also available to laboratory researchers.

Electrochemical Engineering and Catalysis Laboratories

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

Electronic Materials Processing Laboratory

The 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 Microelectronics 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-volume flow rate impactor suitable for collecting particulate matter for chemical analysis. Several types of specially designed aerosol generators are also available, including a laser ablation chamber, tube furnaces, and a specially designed aerosol microreactor.

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

Polymer and Separations Research Laboratory

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

Process Systems Engineering Laboratory

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

Faculty Areas of Thesis Guidance

Professors

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

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

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

Intelligent systems in process, control operations and design, decision support, management of abnormal situations, data interpretation, knowledge databases, pattern recognition

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

Ali Reza Khademhosseini, Ph.D. (MIT, 2005)
Biomaterials, tissue engineering, organ-on-a-chip, stem cell engineering, biofabrication, micro- and nano-technology, biomedical devices

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

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

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

Computational science, image processing, information science

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

Professors Emeriti

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

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

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

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

Metabolic engineering, synthetic biology, bioenergy

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

A.R. Frank Wazzan, Ph.D. (UC Berkeley, 1963)
Fast reactors, nuclear fuel element modeling, stability and transition of boundary layers, heat transfer
Associate Professors
Irene A. Chen, Ph.D. (Harvard, 2007) Synthetic living systems, in vitro evolution, molecular biophysics, phage nanotechnology, microbial
Yvonne Y. Chen, Ph.D. (Caltech, 2011) Synthetic biology, gene-circuit engineering, cell-based therapy, T-cell engineering

Assistant Professors
Nasim Amnabi, Ph.D. (U. Sydney, Australia, 2010) Biomaterials, tissue engineering, 3D bioprinting, microfabrication, nanocomposite hydrogels for drug/gene delivery; surgical sealants/ adhesives/glues, conductive hydrogels for heart tissue regeneration
Carissa N. Eisler, Ph.D. (Caltech, 2016) Light and energy transport in nanomaterials, nanophotonics, renewable energy
Carlos G. Morales-Guió, Ph.D. (Ècole Polytechnique Fédérale de Lausanne [EPFL], Switzerland, 2016) Electrochemistry, renewable energy storage, nanotechnology, advanced energy, energy materials catalysis, CO₂ utilization, process design, mass transport coupled to chemical transformations
Junyoung O. Park, Ph.D. (Princeton, 2016) Cancer metamaterial engineering, bioenergy, systems biology, metabolomics
Dante A. Simonetti, Ph.D. (U. Wisconsin-Madison, 2008) Heterogeneous catalysis and adsorption, catalytic reaction engineering and kinetics, design of reactive materials, materials characterization
Samravaya Srivastava, Ph.D. (Cornell, 2014) Soft materials, self-assembly, polymer chemistry and polymer physics, scattering rheology and experimental methods, with strong emphasis on applications in medicine, industry, and bioenergy.
Letter grading. Mr. Tang (F)

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

Upper-Division Courses
100. Fundamentals of Chemical and Biomolecular Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20B, 20L (not enforced), Mathematics 328B (may be taken concurrently), Physics 1A. Introduction to analysis and design of industrial chemical processes. Material and energy balances. Introduction to programming in MATLAB. Letter grading. Mr. Rahardianto (F)


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

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


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

104A. Chemical and Biomolecular Engineering Laboratory I. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisite: course 100. Enforced corequisite: course 101B. Recommended: course 102B. Investigation of basic transport phenomena in 10 predetermined experiments, collection of data for statistical analysis and interpretation. Written and oral technical reports and group presentations. Design and performance of one original experimental study involving transport, separation, or another aspect of chemical and biomolecular engineering. Basic statistics: mean, standard deviation, confidence limits, comparison of two means of multiple means, single and multiple variable linear regression, and brief introduction to factorial design of experiments. Oral and presentation of technical writing sections of technical reports and their contents; writing clearly, concisely, and consistently; importance of word choices and punctuation in multidisciplinary engineering environment and following required formatting. Letter grading. Ms. Eisler, Mr. Lu, Mr. Simonetti (W)

104B. Chemical and Biomolecular Engineering Laboratory II. (4) Lecture, four hours; laboratory, eight hours; outside study, four hours; other, two hours. Enforced requisites: courses 101C, 103, 104A. Course consists of four experiments in chemical engineering unit operations, experimental design, data collection, and data analysis. Students present their results both written and orally. Written report includes sections on theory, experimental procedures, scaleup and process design, and error analysis. Letter grading. Ms. Chang (Sp)

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

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

104D. Molecular Biotechnology Laboratory: From Gene to Product. (6) Lecture, two hours; laboratory, eight hours; outside study, eight hours. Enforced requisites: courses 101C, 121, 125. Integration of molecular and engineering techniques in modern biotechnology. Cloning of protein-coding gene into plasmid, transformation of constructed plasmid into bacterial culture, production of gene product in bioreactor, downstream processing of bioreactor broth to purify recombinant protein, and characterization of purified protein. Letter grading. Mr. Park, Mr. Tang (W)

105. Chemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 100, 101C, 102B. Fundamentals of chemical kinetics and catalytic reaction engineering. Kinetic analysis of homogeneous and heterogeneous chemical reactions. Letter grading. Mr. Lu (F)

107. Process Dynamics and Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101C, 103 (or 121C), 106 (or 1C11), Principles of dynamics modeling and start-up behavior of chemical engineering processes. Chemical process control ele-
108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 104A, 106 (or C115), 108A, Civil and Environmental Engineering M20 (or Mechanical and Aerospace Engineering M20). Introduction to application of some mathematical and computing methods to chemical engineering design problems; use of simulation programs as automated method of performing steady state material and energy balance calculations. Letter grading.

Mr. Morales Guo (W)

108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 106 (or C115), 108A, Chemical and Environmental Engineering M20 (or Mechanical and Aerospace Engineering M20). Introduction to application of some mathematical and computing methods to chemical engineering design problems; use of simulation programs as automated method of performing steady state material and energy balance calculations. Letter grading.

Mr. Morales Guo (Sp)

109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 106 (or C115), 108A, Chemical and Environmental Engineering M20 (or Mechanical and Aerospace Engineering M20). Enforced corequisite: course 102B. Fundamentals and numerical methods to solve various problems arising from various fields/applications, including bioengineering. Use of MATLAB as platform (programming environment) to write programs based on numerical methods to solve various problems arising in chemical engineering. Letter grading.

Mr. Christofides (F)

110. Intermediate Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 102B. Principles and engineering applications of 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)

C111. Cryogenic and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 102A, 102B (or Materials Science 130), Fundamentals of cryogenics and cryogenic engineering 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 C221. Letter grading.

Mr. Cohen (W)

(Coursera 2019-20)

C112. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A, Chemistry 30A, Formation of polymers, selecting reaction-scheme, polymerization techniques, polymer characterization, Mechanical properties. Rheology of macromolecules, polymer process engineering. Diffusion in polymeric systems. Polymer physical and application as 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 requisites: courses 101C, 102B, integrated approach to air pollution, including concentrations 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 2019-20)

CM114. Electrochemical Processes. (4) (Formerly numbered C114.) (Same as Materials Science CM163.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 102B, Mechanical and Aerospace Engineering 105A or Materials Science 130). Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes. Use of electrochemical approach to study of basic phenomena, thermodynamics, transport phenomena, and reaction engineering and simple economic principles for purpose of designing chemical processes and evaluating alternatives. Letter grading.

Ms. Chang (Not offered 2019-20)

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.

Ms. Annabi (F)

C116. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to surfaces and interfaces of engineering importance. Use of electrochemical surface and thin films for solid-state electronic devices. Topics include classification of crystals and surfaces, analysis of structure and composition of crystals and their surfaces and the determination of engineering applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C216. Letter grading.

Mr. Cohen (Not offered 2019-20)


Mr. Cohen (Not offered 2019-20)


Mr. Manousiouthakis (Not offered 2019-20)

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 and transport behavior of membranes and their application as separations. Use of technology for design of selective membranes and models of membrane transport (flux and selectivity). Examples provided from various fields/applications, including bio-technology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C221. Letter grading.

Mr. Manousiouthakis (Not offered 2019-20)

C122. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 2, 3, 23L. Introduction to design of biomaterials for regenerative medicine, in vitro cell culture, and drug delivery. Biological principles of cellular microenvironment and design of extracellular matrix analogs using biological and engineering principles. Biomaterials for growth factor, and DNA and siRNA delivery as therapies and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C224. Letter grading.

Ms. Annabi (F)

C125. Bioseparations and Bioprocess Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101C. Use of separation technologies and economic factors used to design processes for isolating and purifying materials like whole cells, en- zymes, food additives, or pharmaceuticals that are products of biological reactions. May be concurrently scheduled with course CM225. Letter grading.

Ms. Annabi (Sp)

CM127. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM127.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 153A. Engineering microorganisms for complex phenotype is common goal of metabolic en- gineering and synthetic biology. Production of ad- vanced biofuels involves designing and constructing novel metabolic networks in cells. Such efforts re- quire profound understanding of biochemistry, pro- tein structure, and biological regulations and are aided by tools in bioinformatics, systems biology, and molecular biology. Fundamentals of metabolic bio- chemistry, protein structure and function, and bioin- formatics. Use of systems modeling for metabolic networks to design microorganisms for energy appli- cations. Concurrently scheduled with course CM227. Letter grading. (Not offered 2019-20)

C128. Hydrogen. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101C. Introduction to advanced-process control. Topics include (1) Lya- punov stability for autonomous nonlinear systems in- cluding converse theorems, (2) input to state stability, interconnected systems, and small gain theorems, (3) design of nonlinear and linear 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) in- troduction to control of distributed parameter sys- tems. Concurrently scheduled with course C235. Letter grading. (Not offered 2019-20)


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 mo- lecular biology that form foundation of biotechnology and biomedical industry today. Topics include recom- binant DNA technology, molecular research tools, manipulation of gene expression, directed mutagen- esis and protein engineering, DNA and protein analysis, biopolymer and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engi- neering. Concurrently scheduled with course CM245. Letter grading. (Not offered 2019-20)

Mr. Park (F)
M153. Introduction to Microscale and Nanoscale Manufacturing. (4) Same as Bioengineering M153, Electrical Engineering M153, and Mechanical and Aerospace Engineering M183B. Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4A, 4L. Introduction to general manufacturing concepts, mechanisms, and microfabrication and nanofabrication. Focus on concepts, physics, and instruments of various microfabrication techniques, computer-aided design, and fabrication processes. Techniques that have been broadly applied in industry and academia, including various photolithography technologies, physical and chemical deposition methods, and physical and chemical etching methods. Hands-on experience for fabrication of microstructures and nanoparticles in modern cleanroom environment. Letter grading. Mr. Chiu (F,Sp)

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.


200. Advanced Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: course 102B, Physical Chemistry 223A. 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. Park (F)

201. Methods of Molecular Simulation. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: course 200 or Chemistry C223A or Physics 215A. Modern methods for classical and molecular systems. Monte Carlo and molecular dynamics in various ensembles. Applications to liquids, solids, and polymers. Letter grading. Mr. Sautet (W)

210. Advanced Chemical Reaction Engineering. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 101C, 106. Principles of chemical reactor analysis and design. Specific 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)

211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101A, Chemistry 30A. Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymer process engineering. Diffusion in polymeric systems. Computer-aided design, physical, and chemical reaction schemes, and microelectronics. Concurrently scheduled with course C111. Letter grading. Mr. Cohen (W)

CM214. Electrochemical Processes. (4) Formerly numbered C214. (Same as Materials Science C263B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 102B, Mechanical and Aerospace Engineering 105A or Materials Science 130. Fundamentals of electromechanics and engineering. Industrial electrochemical processes. Primary emphasis on fundamental approach to analyze electrochemical processes. Specific topics include electrochemical reaction on solid and solution surfaces, electropolymerization, electretosis, deposition, electrosynthesis, electrolysing, fuel cells, aqueous and non-aqueous batteries, solid-state electrochemistry. May be concurrently scheduled with course CM114. Letter grading. Ms. Annabi (F)

C215. Biocatalytic Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 101C. Use of previously learned concepts of biological chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and modern bioengineering. May be concurrently scheduled with course C115. Letter grading. Mr. Manousiouthakis (Not offered 2019-20)

C216. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for selecting reaction scheme, mechanisms of reactions, atomic and molecular spectra and intermolecular forces in modern cleanroom environment. Letter grading. Ms. Annabi (F)

217. Electrochemical Engineering. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisites: course C114. Transport phenomena in electrochemical systems; relationships between molecular transport, convection, and electrode kinetics, with applications to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading. Mr. Lu (Sp)


C221. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology, with emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/mor- phology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective membranes and models of mem- brane transport (flux, selectivity) are provided from various fields/applications, including bio- technology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C121. Letter grading. Mr. Cohen (W)


223. Design for Environment. (4) Lecture, four hours; outside study, eight hours. Limited to graduate chemical engineering, mechanical engineering, or Master of Engineering program students. Design of products for meeting environmental object- ives; lifecycle inventories; lifecycle impact assessment; design for energy efficiency; design for waste minimization, computer-aided design tools, mate- rials selection methods. Letter grading. (Not offered 2019-20)

C224. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Life Sciences 2, 3, 23L. Introduc- tion to design and synthesis of biomaterials for re- generative medicine, in vitro cell culture, and drug delivery. Biological principles of cell-cell, cell-environ- ment and design of extracellular matrix analogs using biological and engineering principles. Biomaterials for growth factor, and DNA and siRNA delivery as thera- peutics and to facilitate tissue regeneration. Use of bioengineered tissue in tissue engineering. Concurrently sched- uled with course C124. Letter grading. Ms. Annabi (W)

CM225. Bioprocessing and Bioprocess Engineering. (4) Same as Bioengineering M225.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: course 101A. Separation strategies, unit operations, and economic factors unique to bioprocess design. Processing of biologically active materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reac- tors. Concurrently scheduled with course C125. Letter grading. Ms. Annabi (Sp)

CM227. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM227.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: course 101A. Separation strategies, unit operations, and economic factors unique to bioprocess design. Processing of biologically active materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reac- tors. Concurrently scheduled with course C125. Letter grading. Ms. Annabi (Sp)
bioinformatics. Use of systems modeling for meta-
biological networks to design microorganisms for energy
applications. Concurrently scheduled with course
CM127. S/U or letter grading. (Not offered 2019-20)
C228. Hydrogen. (4) Lecture, four hours; discus-
sion, one hour; outside study, seven hours. Enforced
requirement: Chemistry 20A. Electronic, physical,
and chemical properties of hydrogen. Various methods
of hydrogen production, including production through
methane steam reforming, electrolysis, and thermo-
catalytic cycles. Description in depth of several uses of
hydrogen, including hydrogen combustion and the
hydrogen fuel cells. Concurrently scheduled with
course CM128. Letter grading.
Mr. Manousiouthakis (Sp)
230. Reaction Kinetics. (4) Lecture, four hours;
outside study, eight hours. Requisites: courses 106, 200.
Macroscopic descriptions: reaction rates, relaxation
times, thermodynamic correlations of reaction rate
constants. Molecular descriptions: kinetic theory of
gases, models of elementary processes. Applica-
tions: absorption and dispersion measurements, uni-
molecular reactions, photochemical reactions, hydro-
carbon pyrolysis and oxidation, explosions, polymer-
ization. (Not offered 2019-20)
231. Molecular Dynamics. (4) Lecture, four hours;
outside study, eight hours. Requisite: course 106 or
110. Analysis and design of molecular-beam sys-
tems, examples of reaction dynamics in combustion
combustion of engines or gasjets. Molecular-beam
studies of gas-surface interactions, including energy
accommodations and heterogeneous reactions. Ap-
plications to air pollution control and to catalysts.
Letter grading. (Not offered 2019-20)
232. Combustion Processes. (4) Lecture, four
hours; outside study, eight hours. Requisite: course
106, 200, or Mechanical and Aerospace Engineering
C130A. Fundamentals: change equations for multi-
component reactive mixtures, rate laws. Applications:
combustion, including burning of (1) premixed gases
or (2) condensed fuels. Detonation, Sound absorption
and dispersion. Letter grading. (Not offered 2019-20)
233. Frontiers in Biotechnology. (2) Lecture,
one hour. Requisite: Life Sciences 3. Integration of sci-
ence and business in biotechnology. Academic re-
search leading to licensing and founding of compa-
ties that turn research breakthroughs into marketable
products. Invited lecturers from academia and indus-
tustry cover emerging areas of biotechnology from
biocatalysis, biofuels, and business points of view, S/U or letter grading. (Not offered 2019-20)
234. Plasma Chemistry and Engineering. (4) Lec-
ture, four hours; outside study, eight hours. Requisites:
course 108B. Application of principles to design and
operation of plasma and ion-
beam reactors used in etching, deposition, oxidation,
and cleaning of materials. Examination of atomic,
molecular, and ionic phenomena involved in plasma
and ion-beam processing of semiconductors, etc.
Letter grading. Ms. Chang (Not offered 2019-20)
C235. Advanced Process Control. (4) Lecture, four
hours; discussion, one hour; outside study, seven
hours. Enforced requisite: course 107. Introduction to
advanced process control. Topics include (1) Lya-
punov stability for autonomous nonlinear systems in
cluding converse theorems, (2) input to state stability,
interconnected systems, and small gain theorems, (3)
design of nonlinear and robust controllers for various
classical systems, (4) model predictive control of linear
and nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) in-
troduction to control of distributed parameter sys-
tems. Concurrently scheduled with course CM154.
Letter grading.
236. Chemical Vapor Deposition. (4) Lecture,
four hours; outside study, eight hours. Requisites:
courses 210, C216. Chemical vapor deposition is widely
used to deposit thin films that comprise microelectronic
devices. Topics include reactor design, transport
phenomena, gas and surface chemical kinetics,
structure and composition of deposited films, and re-
lationship between process conditions and film prop-
erties. Letter grading. (Not offered 2019-20)
C240. Fundamentals of Aerosol Technology. (4)
Lecture, four hours; outside study, eight hours. En-
forced requisite: course 101C. Technology of particle/
gas systems with applications to gas cleaning, com-
mercial biotechnology, and air pollution analysis.
Particle transport and deposition, optical properties,
experimental methods, dynamics and control of par-
ticle formation processes. Concurrently scheduled
with course C140. Letter grading. (Not offered 2019-20)
CM245. Molecular Biotechnology for Engineers. (4)
(Same as Bioengineering CM245.) Lecture, four
hours; discussion, one hour; outside study, seven
hours. Selected topics in molecular biology that form
foundation of biotechnology and biomedical industry
today. Topics include recombinant DNA technology,
molecular research tools, manipulation of gene ex-
pression, directed mutagenesis and protein engi-
neering, DNA-based diagnostics and DNA microar-
rays, antibody and protein-based diagnostics, ge-
omics and bioinformatics, isolation of human genes,
genome therapy, and biotechnology. Letter grading.
(Not offered 2019-20)
CM246. Systems Biology: Intracellular Network Iden-
tification and Analysis. (4) Lecture, four hours;
outside study, eight hours. Requisites: course CM245,
Life Sciences 1, 2, 3, 4, 23L. Mathematics 31A, 31B,
32A, 32B. Systems approach to intracellular network
identification and analysis. Transcriptional regulatory
networks, protein networks, and metabolic networks.
Data from genome sequencing, large-scale expres-
sion analysis, and other high-throughput techniques
provide bases for systems identification and analysis.
Discussion of gene-metabolic network synthesis
Letter grading. (Not offered 2019-20)
Lecture, four hours; outside study, eight hours. Requisite:
course 108B. Application of optimization
methods in chemical process design; computer aids
in process engineering; process modeling; system-
atic flowsheet invention; process synthesis; optimal
design and operation of large-scale chemical pro-
cessing systems. Letter grading.
Mr. Manousiouthakis (Not offered 2019-20)
259. Theory of Applied Mathematics for Chemical
Engineers. (4) Lecture, four hours; discussion,
one hour; outside study, seven hours. Requisites:
course 108B. Application of optimization
methods in chemical process design; computer aids
in process engineering; process modeling; system-
atic flowsheet invention; process synthesis; optimal
design and operation of large-scale chemical pro-
cessing systems. Letter grading.
Mr. Manousiouthakis (Not offered 2019-20)
270R. Advanced Research in Semiconductor
Manufacturing. (6) Laboratory, nine hours; outside
study, eight hours. Requisites: life sciences, elec-
tronic, and mechanical engineering students in MS semicon-
ductor manufacturing. Supervised research in processing
semiconductor materials and devices. Letter grading.
M280A. Linear Dynamic Systems. (4) (Same as
Electrical and Computer Engineering M240A and
Mechanical and Aerospace Engineering M270A.) Lec-
ture, four hours; outside study, eight hours. Requisite:
Electrical and Computer Engineering 141 or Mechani-
cal and Aerospace Engineering 141A. 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 value decomposition, Hamil-
tonian theory, 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: Elec-
trical and Computer Engineering 240B or Mechanical
and Aerospace Engineering 270B. Applications of
variational methods, Pontryagin maximum principle,
Hammerstein (Boltzmann/Beltrami/functional pro-
gression) to optimal control of dynamic systems
modeled by nonlinear ordinary differential equations.
Letter grading.
M282A. Nonlinear Dynamic Systems. (4) (Same as
Electrical and Computer Engineering M222A and
Mechanical and Aerospace Engineering M272A.) Lec-
ture, four hours; outside study, eight hours. Requisite:
course M280A or Electrical and Computer Engi-
neering M240A or Mechanical and Aerospace Engi-
neering M270A. State-space techniques for studying
solutions of time-invariant and time-varying nonlinear
dynamic systems with stability, Lyapunov theory
(including converse theorems), invari-
ance, center manifold theorem, input-to-state sta-
bility and small-gain theorem. 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 dy-
amical and controller synthesis methods for nonlinear infinite dimensional systems. Topics include
(1) linear operator and stability theory (basic results
on Banach and Hilbert spaces, semigroup theory,
convergence theory in function spaces), (2) nonlinear modal reduction (linear and nonlinear Galerkin
method, proper orthogonal decomposition), (3) non-
linear and robust control of nonlinear hyperbolic and
parabolic partial differential equations (PDEs), (4)
aplications to transport-reaction processes. Letter
grading. Mr. Christofides (Not offered 2019-20)
284A. Optimization in Vector Spaces. (4) Lecture,
four hours; outside study, eight hours. Requisites:
Electrical engineering 236A, 236B. Review of func-
tional analysis concepts. Convexity, convergence,
continuity. Minimum distance problems for Hilbert and
grading. Mr. Manousiouthakis (Not offered 2019-20)
290. Special Topics. (2 to 4) Seminar, four hours.
Requires for each offering announced in advance
by department. Advanced and current study of one or
two aspects of chemical process design and analysis such as chemical process dynamics and control, fuel cells
and batteries, membrane transport, advanced chem-
ical engineering analysis, polymers, optimization in
chemical process design. May be repeated for credit
with topic change. Letter grading.
M297. Seminar: Systems, Dynamics, and Control
Topics. (2) (Same as Electrical and Computer Engi-
neering M248S and Mechanical and Aerospace Engi-
neering M248A.) Seminar, four hours; discussion,
six hours. Limited to graduate engineering students.
Presentations of research topics by leading academic
Chemical and Biomolecular Engineering / 49
Civil and Environmental Engineering

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J.R. DeShazo, Ph.D.
Eric M.V. Hoek, Ph.D.
Jennifer A. Jay, Ph.D.
Dennis P. Lettenmaier, Ph.D., NAE
Shaily Mahendra, Ph.D. (Henry Samueli Fellow)
Steven A. Margulis, Ph.D.
Ali Mosleh, Ph.D., NAE (Evelyn Knight Professor of Engineering)
Gaurav N. Sant, Ph.D. (Henry Samueli Fellow)
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Associate Professors
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Sanjay Mohanty, Ph.D.

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

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

Scope and Objectives
The Department of Civil and Environmental Engineering programs at UCLA include civil engineering materials, earthquake engineering, environmental engineering, geotechnical engineering, hydrology and water resources engineering, structural engineering, and structural mechanics. The civil engineering undergraduate curriculum leads to a B.S. in Civil Engineering, a broad-based education in environmental engineering, geotechnical engineering, hydrology and water resources engineering, and structural engineering and mechanics. This program is an excellent foundation for entry into professional practice in civil engineering or for more advanced study. The department also offers the undergraduate Environmental Engineering minor. At the graduate level, M.S. and Ph.D. degree programs are offered in the areas of civil engineering materials, environmental engineering, geotechnical engineering, hydrology and water resources engineering, and structures (including structural/earthquake engineering and structural mechanics). In these areas, research is being done on a variety of problems ranging from basic physics and mechanics problems to critical problems in earthquake engineering and in the development of new technologies for pollution control and water distribution and treatment.

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

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

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

Civil Engineering B.S.
Capstone Major

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

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

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 1, M20 (or Computer Science 31); Mathematics 31A, 31B, 32A, 32B, 33A, 33B (or Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C, 4AL; one natural science course selected from Civil and Environmental Engineering 58SL, Earth, Planetary, and Space Sciences 3, 15, 16, 17, 20, Environment 12, Life Sciences 1, 2, 7A, Microbiology, Immunology, and Molecular Genetics 5, 6, or Neuroscience 10.

The Major

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

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

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

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

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

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

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Environmental Engineering Minor

The Environmental Engineering minor is designed for students who wish to augment their major program of study with courses addressing issues central to the application of environmental engineering to important environmental problems facing modern society in developed and developing countries. The minor provides students with a greater depth of experience and understanding of the role that environmental engineering can play in dealing with environmental issues.

To enter the minor, students must be in good academic standing (2.0 grade-point average or better) and file a petition in the Office of Academic and Student Affairs, 6426 Boelter Hall.

Required Lower-Division Course (4 units): Mathematics 3C or 32A.
Required Upper-Division Courses (24 units minimum): Civil and Environmental Engineering 153 and five courses from 154, 155, 156A, M165, M166, Chemical Engineering C118, Environment 159, 166, Environmental Health Sciences C125, C164.

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

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

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

The following introductory information is based on 2019-20 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

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

Civil Engineering M.S.
Course Requirements
There are two plans of study that lead to the M.S. degree: the capstone plan (also known as comprehensive examination) and the thesis plan. At least nine courses (26 units) are required, a majority of which must be in the Civil and Environmental Engineering Department. At least five of the courses must be at the 200 level. In the thesis plan, seven of the nine must be formal 100- or 200-series courses. The remaining two may be 598 courses involving work on the thesis. In the capstone (comprehensive examination) plan, 500-series courses may not be applied toward the nine-course requirement. Courses completed outside of the department must be equal in rigor and related to the civil and environmental engineering program of study and are recommended to be quantitative in nature. In addition, M.S. students must attend the Civil and Environmental Engineering 200 seminar each quarter. Graduate students must meet two grade-point average requirements to graduate—a minimum 3.0 GPA in all coursework and a minimum 3.0 GPA in all 200-level coursework applied toward the degree. All courses counting toward the nine-course requirement, except for 598, must be taken for a letter grade.

Each major field has a set of required preparatory courses which are normally completed during undergraduate studies. Equivalent courses taken at other institutions can satisfy the preparatory course requirements. The preparatory courses cannot be used to satisfy course requirements for the M.S. degree; courses must be selected in accordance with the lists of required graduate and elective courses for each major field. Courses not listed below may be completed toward the course requirement if pre-approved by the faculty adviser and student affairs officer.

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

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

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

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

Other Elective Courses. Remaining courses (at least two) must be selected from Chemical Engineering 102A, 102B, 200, C219, 223, 230, 270, Chemistry and Biochemistry 103, 110A, 110B, 113A, C213B, C215A, C215B, C215C, C223A, C223B, C226A, C275, 276B, 277, Civil and Environmental Engineering 110, M135C, 153, 154, 155, 157B, 157C, 157L, M165, 226, 250A through 250D, 251C, 251D, 252, 253, 254A, 255A, 255B, 258A, 260, 261B, M262A, 263A, 263B, 266, or other elective courses approved by the academic adviser and graduate adviser. Electives in the fields of biostatistics/statistics, chemical engineering, chemistry and biochemistry, computer science, Earth and space sciences, electrical and computer engineering, and environmental health sciences are commonly approved to satisfy course requirements. No more than two courses may be applied outside of Civil and Environmental Engineering unless pre-approved for exceptional circumstances. No more than two undergraduate courses may be applied toward the nine-course requirement unless pre-approved for exceptional circumstances.

Geotechnical Engineering
Required Preparatory Courses. Civil and Environmental Engineering 108, 120, 121.
Required Graduate Courses. Civil and Environmental Engineering 220, 221, 223, 224.
Major Field Elective Courses. Civil and Environmental Engineering 225, 226, 227, 228, C239, 245.
Other Elective Courses. Other elective courses may be taken with prior approval from the faculty adviser.

Structural/Earthquake Engineering

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

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

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

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

Structural Mechanics

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


Elective Courses. Undergraduate—maximum of two courses from Civil and Environmental Engineering M135C, C137, 137L; graduate—Civil and Environmental Engineering M230B, M230C, 232, 235C, 238, 244, 246, 247; Mechanical and Aerospace Engineering 269B.

Structures and Civil Engineering Materials

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

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

Elective Courses. At least one course from civil engineering materials (Civil and Environmental Engineering 226, 253, 258A, 261B, M262A, 266, or 267) and if M230A is

Civil Engineering Ph.D.

Major Fields or Subdisciplines

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

Course Requirements

There is no formal course requirement for the Ph.D. degree, and students may theoretically substitute coursework by examinations. However, students normally take courses to acquire the knowledge needed for the required written preliminary examination. The basic program of study for the Ph.D. degree is built around one major field and one super-minor field or two minor fields. A super-minor field is comprised of a body of knowledge equivalent to five courses, at least three of which are at the graduate level. When two minor fields are selected, each minor field normally embraces a body of knowledge equivalent to three courses from the selected field, at least two of which are graduate courses. The minimum acceptable grade-point average for the minor field is 3.25. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor fields are selected to support the major field and are usually subsets of other major fields. A minimum 3.25 grade-point average is required in all coursework. In addition, Ph.D. students must attend the Civil and Environmental Engineering 200 seminar each quarter until they advance to candidacy.

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

Written and Oral Qualifying Examinations

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

After completing the written preliminary examination and/or starting the second year of the Ph.D. program, all Ph.D. students are required to make a public presentation once per year (summer through spring) each year of the program. The pre-
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 Ph.D. program, after completing a M.S. degree, is 12 quarters. The maximum time allowed for completing the Ph.D. degree, after completing the M.S. degree, is 24 quarters. Each quarter, students must maintain satisfactory academic progress toward their degree. Quarters taken on an approved leave of absence do not count toward the time limit.

Fields of Study

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

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

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

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

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

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

Teaching and research areas in structural/earthquake engineering involve assessing the performance of new and existing structures subjected to earthquake ground motions. Specific interests include assessing the behavior of reinforced concrete buildings and bridges, as well as structural steel, masonry, and timber structures. Integration of analytical studies with laboratory and field experiments is emphasized to assist in the development of robust analysis and design tools, as well as design recommendations. Reliability-based design and performance assessment methodologies are also an important field of study.

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

Instructional Laboratories

Engineering Geomatics Laboratory
This field laboratory teaches basic and advanced geomatics techniques including light detection and range (LIDAR) imaging, geo-referencing using total station and differential global positioning system (GPS)
equipment, and integration of measurements with LIDAR mapping software and Google Earth. Experiments are conducted on campus.

**Environmental Engineering Laboratories**

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

**Experimental Fracture Mechanics Laboratory**

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

**Hydrology Laboratory**

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

**Mechanical Vibrations Laboratory**

The laboratory is used for conducting free and forced vibration and earthquake response experiments on small model structures such as a three-story building, a portal frame, and a water intake/outlet tower for a reservoir. Two electromagnetic exciters, each with a 30-pound dynamic force rating, are available for generating steady state forced vibrations. A number of accelerometers, LVDTs (displacement transducers), and potentiometers are available for measuring the motions of the structure. A laboratory view-based computer-controlled dynamic data acquisition system, an oscilloscope, and a spectrum analyzer are used to visualize and record the motion of the model structures. Two small electromagnetic and servohydraulic shaking tables (1.5 ft. x 1.5 ft. and 2 ft. x 4 ft.) are available to simulate the dynamic response of structures to base excitation such as earthquake ground motions.

**Reinforced Concrete Laboratory**

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

**Soil Mechanics Laboratory**

The laboratory is used for performing experiments to establish data required for soil classification, soil compaction, shear strength of soils, soil settlement, and consolidation characteristics of soils. Students enrolled in the Advanced Soil Mechanics Laboratory course see demonstrations of cyclic soil testing techniques including triaxial and direct simple shear, and advanced data acquisition and processing.

**Structural Design and Testing Laboratory**

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

**Research Laboratories**

**Building Earthquake Instrumentation Network**

The network consists of more than 100 earthquake strong motion instruments in two campus buildings to measure the response of actual buildings during earthquakes. When combined with over 50 instruments placed in Century City high-rises and other nearby buildings, this network, which is maintained by the U.S. Geological Survey (USGS) and the California Geological Survey’s Strong Instrumentation Motion Program, represents one of the most detailed building instrumentation networks in the world. The goal of the research conducted using the response of these buildings is to improve computer modeling methods and the ability of structural engineers to predict the performance of buildings during earthquakes.

**Environmental Engineering Laboratories**

The laboratories are used for conducting water and waste-water analysis, including instrumental techniques such as 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 techniques, allowing direct interfacing with computer-based systems such as computer-aided testing or robotic manufacturing.

The Experimental Fracture Mechanics Laboratory is currently involved in computer-aided testing (CAT) of the fatigue fracture mechanics of ductile material. An online dedicated computer controls the experiment as well as records and manipulates data.

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

Laboratory research efforts are directed toward development and design of sustainable, low-carbon-dioxide-footprint materials for infrastructure construction applications. To this end, its research group develops fundamental constituent chemistry-microstructure-engineering performance descriptors of cementitious materials to correlate and unify the fundamental variables that describe the overall response of the material. These efforts are directed toward addressing the practical needs of the wider construction community and developing “new concretes” for the next generation of infrastructure construction applications. The overall research theme aims to rationalize use of natural resources in construction, promote environmental protection, and advance the cause of ecological responsibility in the concrete construction industry.
Laboratory for the Physics of Amorphous and Inorganic Soils (PARISlab)

PARISlab research focuses on improving materials of engineering and industrial relevance. Its goal is to understand composition-nano- and 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.

Large-Scale Structure Test Facility

The facility allows investigation of the behavior of large-scale structural components and systems subjected to gravity and earthquake loadings. The facility consists of a high-bay area with a 20 ft. x 50 ft. strong floor with anchor points at 3 ft. on center. Actuators with servohydraulic controllers are used to apply monotonic or cyclic loads. The area is serviced by two cranes.

The facilities are capable of testing large-scale structural components under a variety of axial and lateral loadings. Associated with the laboratory is an electrohydraulic universal testing machine with force capacity of 100 tons. The machine is used mainly to apply tensile and compressive loads to specimens so that the properties of the materials from which the specimens are made can be determined. It can also be used in fatigue testing of small components.

Soil Mechanics Laboratory

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

Faculty Areas of Thesis Guidance

Professors

Yousef Bozorgnia, Ph.D., P.E. (UC Berkeley, 1981)
Structural engineering, earthquake engineering, engineering seismology

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

J.R. DeShazo, Ph.D. (Harvard, 1997)
Regulatory policy, institutional design, environmental economics, energy economics, electric vehicles

Eric M.V. Hoek, Ph.D. (Yale, 2001)
Physical and chemical environmental processes, colloidal and interfacial phenomena, environmental membrane separations, bio-adhesion and bio-fouling

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

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

Dennis P. Lettenmaier, Ph.D., NAE (U. Washington, 1975)
Hydrologic modeling and prediction, hydrology-climate interactions, hydrologic change

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

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

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

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

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

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

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

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

William W-G. Yeh, Ph.D., NAE (Stanford, 1967)
Hydrology and optimization of water resource systems

Professors Emeriti

Stanley B. Dong, Ph.D., P.E. (UC Berkeley, 1962)
Structural mechanics, structural dynamics, finite element methods, numerical methods and mechanics of composite materials

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

Michael E. Fourny, Ph.D., P.E. (Caltech, 1963)
Experimental mechanics, special emphasis on application of modern optical techniques

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

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

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

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

Kevin D. Stolzenburg, Ph.D., P.E. (MIT, 1971)
Environmental fluid mechanics, fate and transport of pollutants, dynamics of particles

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

Associate Professors

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

David Jussey, Ph.D. (U. Colorado Boulder, 2011)
Water treatment and desalination, membrane separation processes, membrane material fabrication, electrochemistry, environmental applications of nanotechnology

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

Assistant Professors

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

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

Timu W. Gallien, Ph.D. (UC Irvine, 2012)
Urban coastal flood prediction, wave runup and overtopping, coastal hazards, sea level rise, flood control infrastructure and mitigation methods, nearshore remote sensing and observation

Sanjay Mohanty, Ph.D. (U. Colorado Boulder, 2011)
Effect of water change on water quality and quantity; sustainable urban development at the water-energy nexus; transport of contaminants and colloids in the subsurface and groundwater; stormwater capture, treatment, and re-use; bioremediation
Adjunct Professors
Michael Ayd, Ph.D. (Wright State U., NAE (Drexel, 1977)) Control of trace organics in water treatment including activated carbon
George Mylonakis, Ph.D., P.E. (SUNY Buffalo, 2005) Soil mechanics and dynamics, earthquake engineering, geomechanics, stress wave propagation, foundation engineering
Thomas Sabol, Ph.D., S.E. (UCLA, 1985) Seismic performance and structural design issues for steel and concrete seismic frame resisting systems; application of probabilistic methods to earthquake damage quantification

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

Lower-Division Courses

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

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

Upper-Division Courses

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

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


C105. Structure and Properties of Amorphous Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Req- uisites: course 101, Chemistry 20A, 20B, Mathemat- ics 31A, 31B, 32B, Physics 1A, 1B, 1C. Corequi- site: course 108. Nature and properties of amorphous civil engineering materials in fields of infrastructure and technology. Special attention to composition-structure-properties relationships and design and se- lection with respect to targeted civil engineering appli- cations. Concurrently scheduled with course C205. Letter grade only. Mr. Sant (W)

108. Introduction to Mechanics of Deformable Solids. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 91, Mathematics 32B, Physics 1A. Review of equilib-rium principles and forces transmitted by slender members. Concepts of stress and strain. Stress-strain relations with focus on linear elasticity. Transformation of stress and strain. Deformations and stresses caused by linear-elastic compression, bending, shear, and torsion of slender members. Structural applications to trusses, beams, shafts, and columns. Introduction to virtual work principle. Letter grade only. Mr. Stewart (Sp)

108L. Experimental Structural Mechanics. (4) (For- merly numbered 130L.) Lecture, two hours; labora- tory, six hours; outside study, four hours. Requisite or corequisite: course 108. Laboratories and laboratory ex- periments to be performed by students to obtain soil parameters required for foundation and bridge design. Soil classification, grain size distribution, Atterberg limits, specific gravity, compaction, expansion index, consolidation, shear strength determination. Design problems, laboratory report writing, letter grading. Ms. Zhang (W,Sp)

128L. Soil Mechanics Laboratory. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisite or corequisite: course 128. Laboratory ex- periments to be performed by students to obtain soil parameters required for foundation and bridge design. 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)
140L. Structural Components and Systems Testing Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: course 140. 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 structures, columns, and slabs; design and systems (slab-column, beam-column) and dynamic tests of simple building systems. Quasi-static tests focus on assessment of axial load, shear, deflection, torsional rigidity, strength, and 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. Requisite: course 135A. Analysis of truss and frame structures using matrix methods; matrix force method; introduction to displacement method and energy concepts. Letter grading.

Mr. Ju (F)

135B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Analysis of truss and frame structures using matrix methods; matrix force methods; matrix displacement method; 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 and Aerospace Engineering M168B.) Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; convergence of finite elements; applications to multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postprocessing of results; term projects with computational aspects. Letter grading.

Mr. Taciroglu (F)

135L. Structural Design and Testing Laboratory. (4) Lecture, two hours; laboratory, five hours; outside study, five hours. Requisites: courses M20, 135A. Laboratory design, construction, instrumentation, and test of small-scale model structure. Use of computer-based data acquisition and interpretation systems for comparison of experimental and theoretically predicted behavior. Letter grading. Mr. Burton, Mr. Wallace (F,Sp)

C137. Elementary Dynamic Structures. (4) Formerly numbered 137.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics course for civil engineering students. Elastic free and forced vibrations of single degree of freedom systems, intro-duction to response to random and deterministic inputs; frequency response and damping analysis approaches for single and multidegree of freedom systems. Axial, bending, and torsional vibration of beams. Concurrently scheduled with course C239B. Lecture, four hours; discussion, two hours. Mr. Moore (F)

137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 137. Calibration of instrumentation for dynamic measurements. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Dynamic similarity. Letter grading.

Mr. Wallace (Not offered 2019-20)

140L. Structural Components and Systems Testing Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: course 140. 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 structures, columns, and slabs; design and systems (slab-column, beam-column) and dynamic tests of simple building systems. Quasi-static tests focus on assessment of axial load, shear, deflection, torsional rigidity, strength, and 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. Requisite: course 135A. Analysis of truss and frame structures using matrix methods; matrix force method; introduction to displacement method and energy concepts. Letter grading.

Mr. Ju (F)

135B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Analysis of truss and frame structures using matrix methods; matrix force methods; matrix displacement method; 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 and Aerospace Engineering M168B.) Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; convergence of finite elements; applications to multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postprocessing of results; term projects with computational aspects. Letter grading.

Mr. Taciroglu (F)

135L. Structural Design and Testing Laboratory. (4) Lecture, two hours; laboratory, five hours; outside study, five hours. Requisites: courses M20, 135A. Laboratory design, construction, instrumentation, and test of small-scale model structure. Use of computer-based data acquisition and interpretation systems for comparison of experimental and theoretically predicted behavior. Letter grading. Mr. Burton, Mr. Wallace (F,Sp)

C137. Elementary Dynamic Structures. (4) Formerly numbered 137.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics course for civil engineering students. Elastic free and forced vibrations of single degree of freedom systems, intro-duction to response to random and deterministic inputs; frequency response and damping analysis approaches for single and multidegree of freedom systems. Axial, bending, and torsional vibration of beams. Concurrently scheduled with course C239B. Lecture, four hours; discussion, two hours. Mr. Moore (F)

137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 137. Calibra-tion of instrumentation for dynamic measure-ments. Determination of natural frequencies, mode shapes, and damping factors from free vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Dynamic similarity. Letter grading.

Mr. Wallace (Not offered 2019-20)

150. Introduction to Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course M20 (or Computer Science 31), Mechanical and Aerospace Engineering 103. Study of hydrologic cycle and relevant atmo-spheric processes, water and energy balance, radia-tion, precipitation formation, infiltration, evaporation, vegetation transpiration, groundwater flow, storm runoff, and flood processes. Letter grading.

Mr. Arbogast (W)

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 hy-draulics, 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. Gallow (W)

152. Hydraulic and Hydrologic Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 150. Design of open channel and surface water systems, including stormwater management systems, potable and recycled water distribution systems, wastewater collection systems, and constructed wetlands. Emphasis on practical design components, including reading/interpreting professional drawings and docu-ments, environmental impact reports, permitting, agency coordination, and engineering. Project-based course includes analysis of alternative de-signs, use of engineering economics, and prepara-tion of written engineering reports. Letter grading.

Ms. Hall (F)

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, disposal, air pollution, global environmental problems. Field trips. Letter grading.

Mr. Mohanty (F)

154. Chemical Fate and Transport in Aquatic Envi-ronments. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 153. Fundamentals of chemical and biological principles governing movement and fate of chemicals in surface waters and groundwater. Topics include physical transport in various aquatic environments, air-water exchange, acid-base equi-libria, oxidation-reduction chemistry, chemical sorp-tion, biodegradation, and bioaccumulation. Practical quantitative problems solved considering both reac-tion and transport of chemicals in environment. Letter grading.

Ms. Jay (W)

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

Mr. Hoek (F)

156A. Environmental Chemistry Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: course 153 (may be taken concurrently). Chemist laboratory techniques in analytical chemistry related to water and wastewater analysis. Selected experi-ments include gravimetric analysis, titrimey spectro-photometry, redox systems, pH and electrical con-ductivity. Concepts to be applied to analysis of real water samples in course 156B. Letter grading.

Mr. Stenstrom (F,Sp)
156B. Environmental Engineering Unit Operations and Processes Laboratory. (4) Lecture, two hours; laboratory, two hours; outside study, four hours. Requisite: Chemistry 20A, 20B. Characterization and analysis of typical natural waters and wastewaters for inorganic and organic constituents. Selected experiments include analysis of solids, nitrogen species, oxygen demand, and chloride residual, that are used in unit operation experiments that include reactor dynamics, aeration, gas stripping, coagulation/floculation, and membrane separation. Letter grading. Ms. Stenstrom (W)

157A. Hydrologic Modeling. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 150 or 151. Introduction to hydrologic modeling techniques 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. Ms. Gallien (Not offered 2019-20)

157B. Design of Water Treatment Plants. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 155. Water quality standards and regulations, overview of water treatment plants, water quality standards and testing of water treatment plants, hydraulics of plants, process control, and cost estimation. Letter grading. Mr. Stenstrom (W)

157C. Design of Wastewater Treatment Plants. (4) Lecture, four hours; outside study, eight hours. Requisite: course 155. Process design of wastewater treatment plants, including primary and secondary treatment, detailed design review of existing plants, process control, and economics. Letter grading. Mr. Stenstrom (Sp)

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

159. Green Infrastructure. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 150, 153. Overview of fundamental science, engineering, and ecological principles to designing green infrastructure for stormwater management, water quality improvements, and integration infrastructure based on 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 C259, Letter grading.


M165. Environmental Nanotechnology: Implications and Applications. (4) (Same as Engineering 103.) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: Engineering M101. Introduction to potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental protection. Technical contents include three multidisciplinary areas: (1) physical, chemical, and biological properties of nanomaterials, (2) transport, reactivity, and toxicity of nanoscale materials in natural environmental systems, and (3) use of nanotechnology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading. Ms. Mahendra (Sp)

M166. Environmental Microbiology. (4) (Same as Environmental Health Sciences M166.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: Microbiology 101. Microbial cell and its metabolic capabilities, microbial genomics and its potentials, growth of microbes and kinetics of growth, microbial ecology and diversity, microbiology of wastewater treatment, probing of microbes, public health microbiology, pathogen control. Letter grading. Ms. Mahendra (W)

M166L. Environmental Microbiology and Biotechnology Laboratory. (1) (Same as Environmental Health Sciences M166L.) Laboratory, two hours; outside study, two hours. Corequisite: course M166. General laboratory practice within environmental microbiology, sampling of environmental samples, classical and modern molecular methods for enumeration of microbes from environmental samples, techniques for determination of microbial activity in environmental samples; laboratory setups for studying environmental biotechnology. Letter grading. Ms. Mahendra (Not offered 2019-20)

170. Introduction to Construction Management. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/senior Civil Engineering students and Public Affairs graduate students. Course consists of an introduction to construction engineering, management, and techniques. Implementation of exercises from academic texts and real project case studies. Discussion of building systems, building components, project delivery methods, construction project critical path method scheduling, labor management, quality management, estimating, sustainability, and cost controls. Letter grading. Mr. Brandenberg (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. Applications of traffic safety improvements, highway capacity analyses, signal design and timing, Intelligent Transportation Systems, and traffic management and control for urban roadways, rural transit, bicycle, and pedestrian. Students analyze local roadway and present recommended improvements to public agency officials. Letter grading. Mr. Brandenberg (Sp)

181. Traffic Engineering Systems: Operations and Control. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: courses C104, 108, 120, Materials Science 104. Correlation, analysis, and metrification of aspects of pavement design, including materials selection and traffic loading and volume. Special attention given to 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 C105, Letter grading. Mr. Sant (W)

C182. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: courses C104, 108, 120, Materials Science 104. Correlation, analysis, and metrification of aspects of pavement design, including materials selection and traffic loading and volume. Special attention given to 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 C105, Letter grading. Mr. Sant (Not offered 2019-20)

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. (Sp)

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

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

Graduate Courses

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

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

C205. Structure and Properties of Amorphous Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: Chemistry 20A. Fundamental principles of structure and properties of materials of civil engineering materials such as concrete, cement, steel, and asphalt. Concurrently scheduled with course C104. Letter grading. Mr. Sant (W)


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

221. Advanced Foundation Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 121, 220. Stress distribution. Bearing capacity and settlement of shallow foundations, including spread footings and mats. Performance of
driven pile and drilled shaft foundations under vertical and lateral loading. Construction considerations.

Letter grading. Mr. Stewart (Sp)

222. Introduction to Soil Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Review of engineering problems involving soil dynamics. Fundamentals of theoretical soil dynamics. Dynamic behavior including blocking of cyclic earthquake loads, application of theories of single degree-of-freedom (DOF) system, multiple DOF system and one-dimensional wave propagation. Fundamentals of soil behavior: stresses, pore pressures, pore water pressure behavior, shear moduli and damping, cyclic settlement and concept of volumetric cyclic threshold shear strain. Introduction to modeling of soil behavior. Letter grading.

Mr. Brandenberg (Not offered 2019-20)

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

Mr. Brandenberg (W)

224. Advanced Cyclic and Monotonic Soil Behavior. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. In-depth study of soil behavior under cyclic and monotonic loads. Relationships between stress, strain, pore water pressure, and volume change in range of very small and large strains. Concept of normalized static and cyclic soil behavior. Cyclic degradation and liquefaction of saturated soils, cyclic settlement of partially saturated and dry soils. Concept of volumetric cyclic threshold shear strain. Factors affecting shear moduli and damping during cyclic loading. Postcyclic behavior under monotonic loads. Critical review of laboratory field, and modeling testing techniques. Letter grading.

Mr. Vuicic (W)

225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 223, 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 ground response effects on earthquake ground motions. Soil-structure interaction, including inertial and kinematic interaction and foundation deformations under seismic loading. Letter grading.

Mr. Brandenberg (W)

226. Geoenvironmental Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Field of geoenvironmental engineering involves application of geotechnical principles to environmental problems. Topics include environmental regulations, waste characterization, geosynthetics, solid waste landfills, subsurface barrier walls, and disposal of high water content materials. Letter grading.

227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of finite element modeling of soils using the finite element method, and to constitutive modeling based on elasticity and plasticity theories. Special emphasis on numerical applications and identification of modeling concepts such as nonlinearity, bifurcation, celerity, existence, and uniqueness of solutions. Letter grading.

Mr. Stewart (Not offered 2019-20)

228. Engineering Geology: Geologic Principles for Engineers. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Engineering geology involves interpretation, evaluation, analysis, and application of geologic information and data to civil works. Topics include geologic characterization and classification of soil and rock units. Relationships developed between landforms, active, past, and ancient geologic processes, ground and surface water, and properties of soil and rock. Landform changes occur in response to dynamic processes, including changes in climate, slope formation, fluvial (river) dynamics, and sedimentary processes like volcanism, seismicity, and tectonics. Evaluation and analysis of effects of geologic processes to predict their potential effect on land use, development, public health, and public safety. Letter grading.

Mr. Stewart (F)

230A. Linear Elasticity. (4) (Same as Mechanical and Aerospace Engineering M258A.) Lecture, four hours; outside study, eight hours. Requisite: Mechan- ical and Aerospace Engineering 156A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastostatic problems, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Introduction to boundary integral solution method. Letter grading.

Mr. Ju, Mr. Mal (F)

230B. Nonlinear Elasticity. (4) (Same as Mechanical and Aerospace Engineering M256B.) Lecture, four hours; outside study, eight hours. Requisite: course M230A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor, nonlinear deformation, finite displace- ment relations; balance laws, Cauchy and Piola stresses, Cauchy equations of motion, balance of energy, stored energy; constitutive relations, elasticity, hypoplasticity, thermoplasticity, thermoviscoplasticity; constitutive equations for constrained problems. Letter grading.

Mr. Ju, Mr. Mal (W)

230C. Plasticity. (4) (Same as Mechanical and Aerospace Engineering M256C.) Lecture, four hours; outside study, eight hours. Requisites: courses M230A, M230B. Classical rate-independent plasticity theory, yield functions, flow rules and thermody- 

amic functions; classical rate-independent viscoplasticity; Perzyna and Duvant/Lions types of viscoplasticity. Thermoplasticity and creep. Return mapping algo- rithms for plasticity and viscoplasticity. Finite element implementation. Letter grading. Mr. Ju, Mr. Mal (W)

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

Ms. Zhang (F)


Mr. Tacioglu (F)


Mr. Sabot, Mr. Wallace (Sp)

243A. Behavior and Design of Reinforced Con- crete Structural Elements. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 142. Advanced topics on design of re- inforced concrete structures, including stress-strain relationships for plain and confined concrete, mo- ment-curvature analysis of sections, and design for shear. Design of slender and low-rise walls, as well as design of beam-column joints. Introduction to dis- placement-based design and applications of strut- and-tie models. Letter grading.

Mr. Wallace (F)


Mr. Wallace (S)

244. Structural Reliability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Intro- duction to concepts and applications of structural re- liability analysis. Topics include first-order and second-order estimates of failure probabilities of engineered systems, computing sensitivities of failure probabil-
ties to assumed parameter values, measuring relative importance of random variables associated with sys-
tem, for processes, to discuss applications and implica-
tions of various analytical reliability methods, using
reliability tools to calibrate simplified building codes, and
performing reliability calculations related to per-
formance-based engineering. Letter grading.

Mr. Burton (W)

245. Earthquake Ground Motion Characteriza-
tion. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Corequisite: course C137 or 246. Earthquake fundamentals, including plate tec-
tonics, fault types, seismic waves, and magnitude scales. Characterization of earthquake source, in-
cluding magnitude range and rate of future earth-
quake occurrence and prediction. Letter grading.

Mr. Bozorgnia (W)

246. Structural Response to Ground Motions. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses C137, 180, 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 de-
sign standards. Limitations due to idealization of structures. Letter grading. Mr. Tacioglu, Mr. Wallace (W)

247. Earthquake Hazard Mitigation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 130, and M247A or 246. Concept of seismic isolation, linear theory of base isolation, visco-elastic and hysteretic behavior, elas-
tomeric bearings under compression and bending, bucking of bearings, sliding bearings, passive energy dissipation devices, response of structures with iso-
lation and passive energy dissipation devices, static and dynamic analysis procedures, code provisions and engineering for isolated or semi-isolated struc-
tures. Letter grading. Ms. Zheng (Sp)

250A. Surface Water Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 150. In-depth study of surface-
face water hydrology, including discussion and inter-
relationship of major topics such as rainfall and run-
evaporation, soils and infiltration properties, runoff and snowmelt processes. Introduction to rainfall-runoff models and issues involved in water resource engineering and management. Letter grading. Mr. Gebremichael (F)


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

250D. Water Resources Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 151. Application of mathematical pro-
gramming techniques to water resources systems. Topics include reservoir management and operation; optimal timing, sequencing and sizing of water re-
source projects; and multifield planning and conjunctive use of surface water and groundwater. Emphasis on management of water quantity. Letter grading. Mr. Yeh (Sp)

251A. Rainfall-Runoff Modeling. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 251B. Introduction to hydrologic models and sim-
ulation concepts, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analy-
sis, and application of models for flood forecasting and prediction. Six hours in water resource ap-
lications. Letter grading. Mr. Margulis (Not offered 2019-20)

251B. Contaminant Transport in Groundwater. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250B, 253. Phenomena and mecha-
nisms of hydrodynamic dispersion, governing equa-
tions of mass transport in porous media, various ana-
litical and numerical methods of dispersion parameter estimation, and field experi-
ments, biological and reactive transport in multiphase flow, remediation design, software packages and ap-
lications. Letter grading. Mr. Yeh (Not offered 2019-20)

251C. Remote Sensing with Hydrologic Applica-
tions. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250C. Introduction to basic concepts of classical and Bayesian estimation theory for purposes of hydrologic data assimilation. Applications geared toward assimilating disparate observations into dynamic models of hydrologic systems. Letter grading. Mr. Gebremichael (Sp)

251D. Hydrologic Data Assimilation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250C. Introduction to basic con-
cepts of classical and Bayesian estimation theory for purposes of hydrologic data assimilation. Applications geared toward assimilating disparate observations into dynamic models of hydrologic systems. Letter grading. Mr. Margulis (Sp)

252. Engineering Economic Analysis of Water and Environmental Planning. (4) Lecture, four hours; discussion, two hours; outside study, six hours. En-
forced requisites: Engineering 110, or one or more courses from Economics 1, 2, 11, 101. Economic theory and applications in analysis and management of water and environmental problems; application of price theory to water resource management and re-
newable resources; benefit-cost analysis with appli-
cations to water resources and environmental plan-
ing. Field experiences. Three hours in environmental planning, letter grading. Mr. Stenstrom (F)

254A. Environmental Aquatic Inorganic Chemistry. (4) Lecture, four hours; discussion, two hours; out-
side study, six hours. Requisites: Chemistry 20B, Mathematics 31A, 31B, Physics 1A, 1B. Equilibrium and kinetic descriptions of chemical behavior of metals and inorganic ions in natural fresh/saline surface waters and in water treatment processes. Processes include acid-base chemistry and alkalinity (carbonate system), precipitation and dissolution, adsorp-
tion oxidation/reduction, and photochemistry. Letter grading. Ms. Fay (J)

255A. Physical and Chemical Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Re-
quises: courses 155, 254A. Review of momentum and mass transfer, chemical reaction engineering, co-
agulation and flocculation, granular filtrations, sedi-
mementation, biological processes, idealkinetics, in-
sorption oxidation/reduction, and photochemistry. Letter grading. Ms. Fay (J)

255B. Biological Processes for Water and Waste-
water Treatment. (4) Lecture, four hours; discus-
sion, two hours; outside study, six hours. Requisites: courses 254A, 255A. Fundamentals of environmental microbial growth and biochemical oxidation; applications for activ-
ated sludge, gas transfer, fixed-film processes, aer-
obic 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. Requisites: course 254A. Membrane separations to desalination, water reclamation, brine disposal, and ultrapure water systems. Discussion of reverse osmosis, ultrafiltration, electrolydosis, and ion exchange technologies from both practical and theoretical standpoints. Letter grading. Mr. Jassby (Sp)

259. Green Infrastructure. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Req-
uisites: courses 150, 153. Overview of fundamental science, engineering, and ecological principles to de-
signing green infrastructure for stormwater manage-
ment. Students design green infrastructure based on current practices, perform engineering calculations to calculate its performance, and develop critical thinking skills needed to design innovative or futur-
istic green infrastructures that would not only mitigate adverse effects of climate change but remain resil-
ient under extreme weather conditions expected during climate change. Concurrently scheduled with course C159. Letter grading.

260. Advanced Topics in Hydrology and Water Re-
sources. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250B, 250D. Cur-
rent research topics in inverse problem of parameter estimation, experimental design, conjunctive use of surface and groundwater, multiobjective water re-
sources planning, and optimization of water resource systems. Topics may vary from term to term. Letter grading. Mr. Hoek (Not offered 2019-20)

261. Colloidal Phenomena in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requ-
uisites: courses 254A, 255A. Colloidal interactions, colloid stability, colloidal hydrodynamics, surface charge, adsorption, colloidal surf-
fases, transport of colloids in porous media, coagula-
tion, and particle deposition. Consideration of applica-
tions to colloidal processes in aquatic environ-
ments. Letter grading. Mr. Yeh (Not offered 2019-20)

261B. Advanced Biological Processes for Water and Wastewater Treatment. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255B. In-
depth treatment of standard and emerging environmental problems. Emphasis on treatment of bench scale efflu-
ciates: courses 150, 153. Overview of fundamental science, engineering, and ecological principles to de-
signing green infrastructure for stormwater manage-
ment. Students design green infrastructure based on current practices, perform engineering calculations to calculate its performance, and develop critical thinking skills needed to design innovative or futur-
istic green infrastructures that would not only mitigate adverse effects of climate change but remain resil-
ient under extreme weather conditions expected during climate change. Concurrently scheduled with course C159. Letter grading.

262. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric and Oceanic Sciences M262A.) Lecture, three hours. Requisite for under-
graduates: Chemistry 20B. Principles of chemical ki-
netics, thermochromy, spectroscopy, and photo-
chemistry; chemical composition and history of Earth’s atmosphere; biogeochemical cycles of key at-
mospheric constituents; basic photochemistry of tro-
pomorphic processes and stratosphere ozone; tropo-
chemical processes; air pollution; chemistry and cli-
mate. S/U or letter grading. (F)

M224B.) Lecture, three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban com-
plicates; meteorological aspects of air pollution. S/U or letter grading. (F)

262B. 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 com-
plicates; meteorological aspects of air pollution. S/U or letter grading. (F)

263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, eight hours. De-
signated for graduate students. Transport processes in surface and ground water, meteorological and sot-
pological effects on exchanges across phase boundaries: sedi-
mant/water interface; air/water gas exchange; parti-
cies, droplets, and bubbles; small-scale dispersion and mixing; effect of reactions on transport; linkages between physical, chemical, and biological processes. Letter grading.

Mr. Mohanty (Not offered 2019-20)

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

Ms. Jay (Not offered 2019-20)


Ms. Mahendra (F)

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

Ms. Jay (Not offered 2019-20)

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

Mr. Sant (Not offered 2019-20)

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. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading. (F,W,Sp)

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

495. Teaching Assistant Training Seminar. (2) Seminar, two hours. Preparation: appointment as teaching assistant in Civil and Environmental Engineering Department. Seminar on communication of civil engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of visual aids; grading, advising, and rapport with students. S/U grading. (F)
In addition, UCLA Samueli offers M.S. and Ph.D. degrees in Computer Science, as well as minor fields for graduate students seeking engineering degrees. In cooperation with the John E. Anderson Graduate School of Management, the Computer Science Department offers a concurrent degree program that enables students to obtain the M.S. in Computer Science and the M.B.A. (Master of Business Administration).

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

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

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

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

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

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

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

The Computer Engineering major is a designated capstone major that is jointly administered by the Computer Science and Electrical and Computer Engineering departments. Undergraduate students complete a design course in which they integrate their knowledge of the discipline and engage in creative design within realistic and professional constraints. Students apply their knowledge and expertise gained...
in previous mathematics, science, and engineering coursework. Students identify, formulate, and solve engineering problems and present their projects to the class.

Computer Science and Engineering B.S.

Capstone Major

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

Learning Outcomes

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

- 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, 6I; Physics 1A, 1B, 1C, and 4AL or 4BL.

The Major

Required: Computer Science 111, 118, 131, M151B, M152A, 180, 181, Electrical and Computer Engineering 100, 102, 115C; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone design course (Computer Science 152B); a minimum of 4 units of at least one elective course selected from Electrical and Computer Engineering 101A through M188S; a minimum of 12 units of at least three elective courses selected from Computer Science 111 through CM187; and 12 units of technical breadth courses selected from an approved list available in the Office of Academic and Student Affairs. Students who want to deepen their knowledge of electrical engineering are encouraged to select that discipline as their technical breadth area.

Computer Science B.S.

Capstone Major

The computer science curriculum is designed to accommodate students who want professional preparation in computer science but do not necessarily have a strong interest in computer systems hardware. The curriculum consists of components in computer science, a minor or technical support area, and a core of courses from the social sciences, life sciences, and humanities. Within the curriculum, students study subject matter in software engineering, principles of programming languages, data structures, computer architecture, theory of computation, and formal languages, operating systems, distributed systems, computer modeling, computer networks, compiler construction, and artificial intelligence. Majors are prepared for employment in a wide range of industrial and business environments.

Learning Outcomes

The Computer Science major has the following learning outcomes:

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

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

### The Major

**Required:** Computer Science 111, 118, 131, M151B, M152A, 180, 181; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone software engineering or design course from Computer Science 130 or 132B; a minimum of 20 units of at least five elective courses selected from Computer Science 111 through CM187; a minimum of 12 units of at least 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.

Students must take at least one course from Computer Science 130 or 132. Computer Science 130 or 132B may be applied as an elective only if it is not taken as the capstone course. Credit is not allowed for both Computer Science 170A and Electrical 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 M116B). Credit is applied automatically.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or [https://www.registrar.ucla.edu/Academics/GE-Requirement](https://www.registrar.ucla.edu/Academics/GE-Requirement).

### Computer Engineering B.S.

#### Capstone Major

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

### Learning Outcomes

The Computer Engineering major has the following learning outcomes:

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

### Preparation for the Major

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

### Suggested Tracks

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

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

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

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

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

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

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or [https://www.registrar.ucla.edu/Academics/GE-Requirement](https://www.registrar.ucla.edu/Academics/GE-Requirement).
Students are also free to design ad hoc tracks. The technical breadth area requirement provides an opportunity to combine elective courses in electrical and computer engineering and computer science with those from another UCLA Samueli major to produce a specialization in an interdisciplinary domain. As noted above, students can also select a technical breadth area in either Electrical and Computer Engineering or Computer Science to deepen their knowledge in either discipline.

Bioinformatics Minor

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

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

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

Required Lower-Division Courses (17 units minimum): Computer Science 32 or Program in Computing 10C, Life Sciences 3 or 7A, Mathematics 33A, 61.

Required Upper-Division Courses (18 units minimum): Computer Science 180 (or Mathematics 182), M184, two courses selected from Computer Science CM121, CM122, and CM124, and one course selected from Chemistry and Biochemistry C100, 153B, Civil and Environmental Engineering 110, Computer Science CM121, CM122, CM124, 170A, CM186, CM187, Ecology and Evolutionary Biology C125, Electrical and Computer Engineering 102, 131A, 141, Human Genetics C144, Mathematics 170A, Microbiology, Immunology, and Molecular Genetics 132, Molecular, Cell, and Developmental Biology 144, 187AL, Physiological Science 125, Statistics 100A, 100B. Eight units of either Bioinformatics 199 or Computer Science 194 or 199 may be applied as an elective by petition. Students are strongly encouraged to take Computer Science M184 as early as possible to obtain an overview of computational biology.

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

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

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

Graduate Study

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

The following introductory information is based on 2019-20 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

The Department of Computer Science offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Computer Science and participates in a concurrent degree program (Computer Science M.S./Management M.B.A.) with the John E. Anderson Graduate School of Management.

Computer Science M.S.

Course Requirements

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

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, M152B, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

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

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

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

Comprehensive Examination Plan

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

Thesis Plan

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

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

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

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

**Computer Science Ph.D.**

**Major Fields or Subdisciplines**

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

**Course Requirements**

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

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

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

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

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

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

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

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

For requirements for the Graduate Certificate of Specialization, see Engineering Schoolwide Programs.

**Written and Oral Qualifying Examinations**

The written qualifying examination consists of a high-quality paper, solely authored by the student. The paper can be either a research paper containing an original contribution or a focused critical survey paper. The paper should demonstrate that the student understands and can integrate and communicate ideas clearly and concisely. It should be approximately 10 pages single-spaced, and the style should be suitable for submission to a first-rate technical conference or journal. The paper must represent work that the student did as a graduate student at UCLA. Any contributions that are not the student’s own, including those of the student’s advisor, must be explicitly acknowledged in detail. Prior to submission, the paper must be reviewed by the student’s adviser on a cover page with the adviser’s signature indicating review. After submission, the paper must be reviewed and approved by at least two other members of the faculty. There are two deadlines a year for submission of papers. After passing the preliminary examination and coursework for the major and minor fields, the student should form a doctoral committee and prepare to take the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, must hold appointments in the department. The remaining member must be a UCLA faculty member in another department. The nature and content of the oral qualifying examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

**Fields of Study**

**Artificial Intelligence**

Artificial intelligence (AI) is the study of intelligent behavior. While other fields such as philosophy, psychology, neuroscience, and linguistics are also concerned with the study of intelligence, the distinguishing feature of AI is that it deals primarily with information processing models. Thus the central scientific question of artificial intelligence is how intelligent behavior can be reduced to information processing. Since even the simplest computer is a completely general information processing device, the test of whether some behavior can be explained by information processing mechanisms is whether a computer can be programmed to produce the same behavior. Just as human intelligence involves gathering sensory input and producing physical action in the world, in addition to purely mental activity, the computer for AI purposes is extended to include sense organs such as cameras and microphones, and output devices such as wheels, robotic arms, and speakers. The predominant research paradigm in artificial intelligence is to select some behavior that seems to require intelligence on the part of humans, to theorize about how the behavior might be accounted for, and to implement the theory in a computer program to produce the same behavior. If successful, such an experiment lends support to the claim that the selected behavior is reducible to information processing terms, and may suggest the program’s architecture as a candidate explanation of the corresponding human process. The UCLA Computer Science Department has active research in the following major subfields of artificial intelligence:

1. **Problem Solving.** Analysis of tasks, such as playing chess or proving theorems, that require reasoning about relatively long sequences of primitive actions, deduc-
tions, or inferences.

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

3. Expert systems. Study of large amounts of specialized or highly technical knowledge that is often probabilistic in nature. Typical domains include medical diagnosis and engineering design.

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

5. Computer vision. Processing of images, as from a TV camera, to infer spatial properties of the objects in the scene (three-dimensional shape), their dynamics (motion), their photometry (material and light), and their identity (recognition).

6. Robotics. Translation of a high-level command, such as picking up a particular object, into a sequence of low-level control signals that might move the joints of a robotic arm/hand combination to accomplish the task; often this involves using a computer vision system to locate objects and provide feedback.

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

8. Parallel architecture. Design and programming of a machine with thousands or even millions of simple processing elements to produce intelligent behavior; the human brain is an example of such a machine.

Computational Systems Biology

The computational systems biology (CSB) field can be selected as a major or minor field for the M.S. degree in Computer Science.

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

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

Typical research areas with a systems focus include molecular and cellular systems biology, organ systems physiology, medical, pharmacological, pharmacokinetic (PK), pharmacodynamic (PD), toxicokinetic (TK), physiologically based PBPK-PD, PBTK, and pharmacogenomic system studies; neuro-systems, imaging and remote sensing systems, robotics, learning and knowledge-based systems, visualization, and virtual clinical environments. Typical research areas with 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, queuing theory, distributed systems theory, mathematical programming, control theory, operating systems design, simulation methods, measurement tools, and heuristic design procedures. The outcome of these studies provides the following:

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

Resource Allocation

A central problem in the design and evaluation of computer networks deals with the allocation of resources among competing demands (e.g., wireless channel bandwidth allocation to backlogged stations). In fact, resource allocation is a significant element in most of the technical (and 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 internationally to a certain body of knowledge emphasizing the interweaving themes of computability and algorithms, interpreted in the broadest sense. Under computability, one includes questions concerning which tasks can and cannot be performed by information systems of different types restricted in various ways, as well as the mathematical analysis of such systems, their computations, and the languages for communication with them. Under algorithms, one includes questions concerning (1) how a task can be performed efficiently under reasonable assumptions on available resources (e.g., time, storage, type of processor), (2) how efficiently a proposed system performs a task in terms of resources used, and (3) the limits on how efficiently a task can be performed. These questions are often addressed by first developing models of the relevant parts of an information processing system (e.g., the processors, their interconnections, their rules of operation,
the means by which instructions are conveyed to the system, or the way the data is handled) or of the input/output behavior of the system as a whole. The properties of such models are studied both for their own interest and as tools for understanding the system and improving its performance or applications.

**Emphasis of Computer Science**

**Theory**

Computer science theory emphasizes:

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

**Computer System Architecture**

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

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

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

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

1. **Novel architectures** encompass the study of computations that are performed in ways that are quite different than those used by conventional machines. Examples include various domain-specific architectures characterized by high computational rates, low power, and reconfigurable hardware used in a wide range of computing devices from smart phones to data centers.

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

3. The study of **computational algorithms and structures** deals with the relationship between computational algorithms and the physical structures that can be employed to carry them out. It includes the study of interconnection networks, and the way that algorithms can be formulated for efficient implementation where regularity of structure and simplicity of interconnections are required.

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

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

**Data Science Computing**

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

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

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

**Graphics and Vision**

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

**Software Systems**

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

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

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

Facilities

Departmental laboratories and centers for instruction and research include:

**Artificial Intelligence Laboratories**

**Automated Reasoning Group**
Adnan Y. Darwiche, Director
http://reasoning.cs.ucla.edu

The 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
http://singapore.cs.ucla.edu/cogsys.html

The laboratory targets research areas concerned with evidential reasoning, the distributed interpretation of multisource data in networks of partial beliefs; learning, the structuring and parameterizing of links in belief networks to form a representation consistent with a stream of observations; constraint processing, including intelligent backtracking, learning while searching, temporal reasoning, etc.; 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.

**Statistical and Relational Artificial Intelligence Laboratory (StarAI)**
Guy Van den Broeck, Director
http://starai.cs.ucla.edu

The 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
http://web.cs.ucla.edu/~qgu/uclaml

The 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**

**Big Data and Genomics Laboratory**
Eran Halperin, Director
https://www.eranhalperingenomics.com

The laboratory aims to understand and treat 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
http://biocyb.cs.ucla.edu/wp/

This interdisciplinary research typically involves integration of theory with real laboratory data, using biomodeling, computational, and biosystems approaches.

Problem domains are physiological systems, disease processes, pharmacology, and some post-genomic bioinformatics. Laboratory pedagogy involves development and exploitation of the synergistic and methodologic interface between structural and computational biomodeling with laboratory data, or computational systems biology, with a focus on integrated approaches for solving complex biosystem problems from sparse biodata e.g., in physiology, medicine, and pharmacology, as well as voluminous biodata (e.g., from genomic libraries and DNA array data).

**Computational Genetics Laboratory**
Eleazar Eskin, Director
http://zarlab.cs.ucla.edu/about/

The laboratory is comprised of a computational genetics group affiliated with both the Computer Science and Human Genetics departments. Research interests are in 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
https://sriramlab.dgsom.ucla.edu/pages/

This interdisciplinary research group is affiliated with UCLA departments of Computer Science, Human Genetics, and Biomathematics. The laboratory 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
http://web.cs.ucla.edu/~tjn/01-research/

The 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 codesign of ISAs, architecture, execution models, and compilers.

**Concurrent Systems Laboratory**
Yuval Tamir, Director
http://web.cs.ucla.edu/cscl/

The 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 both software and hardware, and often focus on parallel and distributed systems in the context of general-purpose as well as embedded applications.

**Digital Arithmetic and Reconfigurable Architecture Laboratory**
Milos D. Ercegovac, Director
http://arith.cs.ucla.edu

The laboratory is used for fast digital arithmetic (theory, algorithms, and design) and numerically intensive computing on reconfigurable hardware. Research includes floating-point arithmetic, online arithmetic, application-specific architectures, and design tools.

**eHealth Research Laboratory (ER Lab)**
Majid Sarrafzadeh, Director
http://er.cs.ucla.edu

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

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

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

**Graphics and Vision Laboratories**
Song-Chun Zhu, Director
http://vcla.stat.ucla.edu

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

**Computer Graphics and Vision Laboratory (GraViLab)**
Demetri Terzopoulos, Director
http://grafilab.cs.ucla.edu

The 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 applications in medicine and health care.

**UCLA Collective on Vision and Image Sciences**
http://visciences.ucla.edu

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

**UCLA Vision Laboratory**
Stefano Soatto, Director
http://vision.ucla.edu

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

**Information and Data Management Laboratories**

**Information and Data Management Group**
(Multiple Faculty)
http://www.cs.ucla.edu/idm/

The group is a collaboration of all UCLA faculty from the information and data management field. It is interested in multiple research areas including big data, archival information systems, knowledge discovery and data mining, Earth Science Partners’ private network, genomics graph database development, multimedia information stream system technology, Smart Space middleware architecture, and technologically based assessment of language and literacy, to name just a few.

**Natural Language Processing Group**
Kai-Wei Chang, Director

The 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.

**Web Information Systems Laboratory**

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

This research group investigates Web-based information systems and seeks to develop enabling technology for such systems by integrating the Web with database systems. Current research efforts include the DeAL system, a next-generation data log system; SemScape, an NLP-based framework for mining unstructured or free text; EARL (Early Accurate Result Library) for Hadoop; Panta Rei, a study of support for schema evolution in the context of snapshot databases and transaction-time databases; Stream Mill, a complete data stream management system; and ArchiS, a powerful archival information system.

**Network Systems Laboratories**

**Internet Research Laboratory (IRL)**

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

The laboratory 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 to 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
http://nda.cs.ucla.edu

The laboratory focuses on research in network design automation, 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
http://www.connectionlab.cs.ucla.edu

The 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
http://metro.cs.ucla.edu

The laboratory's research areas include wireless networking, mobile systems, and cloud computing. Its focus is on design, implementation, and experimentation of protocols, algorithms, and systems for wireless data networks. The goal is to build high-performance and dependable networking solutions for the wireless Internet.

**Software Systems Laboratories**

**Compilers Laboratory**

http://compilers.cs.ucla.edu

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

**Large-Scale Systems Group**

Harry Xu, Director
http://systems.cs.ucla.edu

The 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
http://web.cs.ucla.edu/~miryung/research.html

The 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 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)
http://compilers.cs.ucla.edu/ss/

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

**Computer Science Centers**

**Center for Autonomous Intelligent Networked Systems (CAINS)**

http://www.cains.cs.ucla.edu

The center was established in 2001 with researchers from several laboratories in the Computer Science, and Electrical and
Center for Domain-Specific Computing (CDSC)

Jason Cong, Director
http://www.cdsc.ucla.edu

The center looks beyond parallelization and focuses on domain-specific customization as a disruptive technology to bring orders-of-magnitude power-performance efficiency improvement to application domains. CDSC develops a general methodology for creating novel, customizable computing platforms, and associated compilation tools and runtime management environment to support domain-specific computing. Its recent focus is on design and implementation of accelerator-rich architectures, from single chips to data centers. It also includes highly automated compilation tools and runtime management software for customizable heterogeneous platforms, including multi-core CPUs, many-core GPUs, and FPGAs; and a general, reusable methodology for customizable computing applicable across domains. By combining these capabilities, the goal is to deliver a supercomputer-in-a-box or -in-a-cluster, customizable to an application domain to enable disruptive innovations therein. This approach has been successful in medical image processing, precision medicine, and machine learning. Originally funded by a $10 million National Science Foundation (NSF) Expeditions in Computing award, in 2014 CDSC received $3 million from Intel Corporation with matching NSF InTrans program support. CDSC research is also supported by SRC JUMP and several industrial partners.

Center for Encrypted Functionalities

Amit Sahai, Director
http://web.cs.ucla.edu/cef/

The center 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
http://www.cs.ucla.edu/security/

CICS 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 institute was established in 2013 with a focus on the continuing growth of data and demand for smart analytics to mine that data. Such analytics are creating major transformative opportunities in science and industry. To fully capitalize on these opportunities, computing technology must solve the three-pronged challenge created by the exploding size of big data, the growing complexity of that data, and the increased sophistication of analytics that can be used to extract patterns and trends from the data.

Wireless Health Institute (WHI)

Benjamin M. Wu, D.D.S., Ph.D. (Bioengineering), Director; Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical and Computer Engineering), Gregory J. Pottie, Ph.D. (Electrical and Computer Engineering), Co-Directors

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

WHI technology always serves the clinician community through 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 facility (DCF) or school network (SEASNet).

The departmental research network includes Oracle servers and shared workstations, on the school ethernet TCP/IP local network. A wide variety of peripheral equipment is also part of the facility, and many more research-group workstations share the network; the total number of machines exceeds 1000, the majority running the Linux operating system. The network consists of switched 10/100/1000 ethernet to the desktop with a gigabit backbone. The department LAN is connected to the campus gigabit backbone. An 802.11 wireless network is also available to faculty, staff, and graduate students.

Administrative Structure

The central facilities and wide-area networking are operated by the campuswide Information Technology Services. Access to the departmental and SEASNet machines is controlled so as to maximize the usefulness of these computers for education and research, but no direct charges are involved.

Technical Support Staff

The support staff consists of hardware and software specialists. The hardware laboratory supports network connections, configurations, routers, switches, and network monitoring tools. The software group administers the department UNIX servers, providing storage space and backup for department users.

Faculty Areas of Thesis Guidance

Professors

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

Databases, web technologies, information discovery and integration

Jason (Jingsheng) Cong, Ph.D. (U. Illinois, 1990)

Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, computer architecture, reconfigurable computing, design for nanotechnologies

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

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

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

Biocybernetics; computational systems biology; dynamic systems modeling, simulation, clinical therapy and experiment design optimization methodologies; pharmacokinetic (PK), pharmacodynamic (PD), and physiologically-based PK/PD (PBPK/PD) models.

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

Computer engineering, embedded systems, VLSI/CAD algorithms

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

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

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

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

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

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

Mihaela van der Schaar, Ph.D. (Eindhoven University of Technology, Netherlands, 2001)

Multimedia processing and compression, multimedia networking, multimedia communications, multimedia architectures, enterprise multimedia streaming, mobile and ubiquitous computing

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

Computer networks

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

Data mining, bioinformatics and computational biology, databases

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

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

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

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

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

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

Professors Emeriti

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

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

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

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

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

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

Jack W. Carlyle, Ph.D. (UC Berkeley, 1961)

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

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

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

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

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

*Also Professor of Medicine
†Also Professor of Mathematics
Theoretical computer science, computational complexity, program schemes and semantics, formal languages, computability

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

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

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

Pattern recognition, picture processing, biomedical applications, mathematical modeling

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

Computer graphics, discrete simulation, digital filtering, computer-aided design, LSI fabrication techniques, printed circuit board design


Multimedia systems, database systems, data mining

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

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

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

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

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

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

Associate Professors

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

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

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

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

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

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

Yuval Tamir, Ph.D. (UC Berkeley, 1985)

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

Guoging (Harry) Xu (Ohio State, 2011)

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

Assistant Professors

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

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

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

Computational biology, bioinformatics, machine learning

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

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

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

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

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

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

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

Computer systems, computer networks, distributed systems, cloud computing


Hardware/software co-design, modeling, and optimization

Sriram Sankararaman, Ph.D. (UC Berkeley, 2010)

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

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

Stroke and traumatic brain injuries (TBI) using brain mapping of imaging and biosignals (MR, 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

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

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

Senior Lecturers S.O.E.

Paul R. Eggert, Ph.D. (UCLA, 1980)

Programming languages, operating systems principles, compilers, Internet

David A. Smallberg, M.S. (UCLA, 1978)

Programming languages, software development

Adjunct Professors

David E. Heckerman, Ph.D. (UCLA, 1979)

Models and methods used for statistics and data analysis, machine learning, probability theory, decision theory, design of HIV vaccines, and genome-wide association studies

Van Jacobson, M.S. (U. Arizona, 1972)

Named data network (NDN), content-centric networking

Alan Kay, Ph.D. (U. Utah, 1969)

Object-oriented programming, personal computing, graphical user interfaces

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

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

Adjunct Associate Professor

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

Anti-virus and intrusion detection technology

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

Protocols design, implementation and evaluation for QOS support in wired/wireless network and vertical handover protocols and architectures

Adjunct Assistant Professors

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

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


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

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

Statistical machine learning, scalable data analytics, computational genomics

Bioinformatics

Lower-Division Courses

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

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

Upper-Division Course

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

Computer Science

Lower-Division Courses

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

Mr. Darwiche (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.

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 tools 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 conditions and loops; and functional decomposition. Letter grading.

Mr. Millstein (F)


Mr. Patsberg, Mr. Smallberg (FW,SP)
32. Introduction to Computer Science II. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisites: course 31. Engineering and computer science. Abstract data types, data structures, stacks, queues, lists, algorithm analysis, trees, graphs, sorting, searching, and basic sorting. Case studies and exercises from computer science applications. Letter grading.

Mr. N. Smalberg (W,Sp)

33. Introduction to Computer Organization. (5) Lecture, four hours; discussion, two hours; outside study, nine hours. Enforced prerequisite: course 32. Introductory course on computer architecture, assembly language, and operating systems fundamentals. Number systems, machine language, and assembly language. Procedure calls, stacks, interrupts, and traps. Assemblers, linkers, and loaders. Operating systems concepts: processes and process management, input/output (I/O) programming, memory management, file systems. Letter grading.

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

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

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

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

Mr. C. Ercogevic, Mr. Potkonjak (F, W, Sp)

97. Variable Topics in Computer Science. (1 to 4) Lecture, one hour; discussion, zero to two hours; outside study. Enforced prerequisite: course 31. Object-oriented programming designed for freshmen/sophomores. Variable topics in computer science not covered in regular computer science courses. May be repeated once for credit with topic or instructor change. Letter grading.

Mr. Kurf

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


Mr. Kame, Mr. Reiser (F, W, Sp)

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

Mr. Sanadidi, Mr. Soatto (Not offered 2019-20)

117. Computer Organization Layer 4. (Formerly numbered M117.) Lecture, two hours; discussion, two hours; laboratory, two hours; outside study, six hours. Not open to students with credit for course M117U. Introduction to computer communication concepts underlying and supporting modern networks, with focus on wireless communications and media access layers of network protocol stack. Systems include wireless (802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth, ZigBee). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for personal applications such as wireless health, positioning, and environmental awareness, and experimental laboratory sessions included. Letter grading.

Mr. Dzhyanin (Not offered 2019-20)

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

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

M119. Fundamentals of Embedded Networked Systems. (4) (Same as Electrical and Computer Engineering M119.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Civil and Environmental Engineering 131A or Electrical and Computer Engineering 131A or Mathematics 170A or Statistics 100A, course 118 or Electrical and Computer Engineering 132B, course 33. Design trade-offs and implementation of cyberphysical systems such as devices and systems constituting Internet of Things. Topics include signal propagation and modeling, sensing, node architecture and operation, and applications. Letter grading.

Mr. Srivastava (F, Sp)

CM121. Introduction to Bioinformatics. (4) (Same as Chemistry CM160A.) Lecture, four hours; discussion, two hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Statistics 100A, course 118 or Electrical and Computer Engineering 132B, course 33. Design trade-offs and implementation of cyberphysical systems such as devices and systems constituting Internet of Things. Topics include signal propagation and modeling, sensing, node architecture and operation, and applications. Letter grading.

Mr. Lee (F)

CM122. Algorithms in Bioinformatics. (4) (Same as Chemistry CM160B.) Lecture, four hours; discussion, two hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Statistics 100A, Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Prior knowledge of biology not required. Designed for engineering students as well as students from biological sciences and medical school. Introduction to bioinformatics and methodologies, with emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM221. P/NP or letter grading.

Mr. Reifer (F)

C137A. Prototyping Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: course 131. How different programming languages provide and view different and often dramatically different ways of thinking about computing and offer trade-offs on many dimensions, such as modularity, expressiveness, expressiveness, and safety. Study in detail of paradigmatic and non paradigmatic—functional, object-oriented, and logic—programming languages and implementations of new extensions. Letter grading.

Mr. Neukart (Not offered 2019-20)
C137B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced requisites: course C137A. Study of various programming language designs, from computing history and research literature, that attempt to address problems of software systems that are bloated, buggy, and difficult to maintain and extend despite trend in computing toward ever higher levels of abstraction. Exploration of various programming languages. Hands-on experience designing, prototyping, and evaluating new languages, language abstract syntax, and languages in programming environments. Concurrently scheduled with course C237B. Letter grading. Mr. Milstein (Not offered 2019-20)


144. Web Applications. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 143. Introduction to programming in modern web languages (HTML, CSS, and JavaScript); client-side/scripting languages and frameworks (like React or Angular); server-side languages and frameworks (like Node.js or Ruby); and new paradigms for building applications from the ground up. Emphasis on teamwork through projects and assignments. Core concepts include building APIs, web services and distributed transactions. Letter grading. Mr. Cho (Sp)

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

M146. Introduction to Machine Learning. (4) (Same as Electrical and Computer Engineering M146.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A or Mathematics 170A or Statistics 100A. Introduction to breadth of data science. Foundations for modeling data sources, selection of data mining algorithms, choosing measures: time, space, upper, lower bounds, asymptotic complexity; selection of prototypical algorithms; choice of data structures and representations; complexity measures: time, space, upper, lower bounds, asymptotic complexity; NP-completeness. Letter grading. Mr. Gafni, Mr. Ostrovsky, Mr. Sarrafzadeh (F,W,Sp)

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 131A or Mathematics 170A or Statistics 100A, course 33. Introduction to computer architecture. Instruction set design, memory hierarchy (caches, main memory), virtual memory (organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading. Mr. Reinman, Mr. Tamir (F,W,Sp)

M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical and Computer Engineering M152A.) Laboratory, four hours; outside study, two hours. Enforced requisite: course M51A or Electrical and Computer Engineering M16. Hands-on design implementation, and debugging of digital logic circuits, use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits using programmed array logic, design of VLSI test strategies, introduction to verification of VLSI circuits using computer-aided design tools. Letter grading. Mr. Gerla (Not offered 2019-20)

152B. Digital Design Project Laboratory. (4) Laboratory, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M151B or Electrical Engineering 151C. Recommended: Engineering 130A or Electrical and Computer Engineering 131A or Mathematics 170A. Students and teams to design and implement digital systems and to document and give oral presentations of their work. Letter grading. Mr. Samatadzeh (F,W,Sp)

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

168. Computational Methods for Medical Imaging. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 92 or Programming C in Computer C or better, Mathematics 33A, one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A or Mathematics 170A, or Statistics 100A. Theory and practice of image acquisition including angiography, computed tomography (CT), and magnetic resonance (MR). Project-based course cov ering image processing techniques, including image processing, attaining, predic tive modeling, personalized medicine, data driven and machine learning methods. Letter grading. Mr. Scalo (Sp)

170A. Mathematical Modeling and Methods for Computer Science. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 180, Mathematics 33B. Introduction to methods for modeling and simulation using theoretical and computer tools. Optimization techniques, data and models, and application of tools and models to data gathering and analysis. Topics include statistical foundations, regression, classification, kernel methods, clustering, expectation maximization, principal component analysis, decision theory, reinforcement learning and deep learning. Letter grading. Mr. Chang, Mr. Sankaranaram (F,W,Sp)

171L. Data Communication Systems Laboratory. (2 to 4) (Same as Electrical and Computer Engineering M171L.) Laboratory, four to eight hours; outside study, two to four hours. Recommended preparation: course M152A. Limited to seniors. Not open to students with credit for course M171. Interpretation of analog-signaling aspects of digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, base band and electrical communication computer terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modern and terminal characteristics, and interfaces. Letter grading. Mr. Gafni, Mr. Ostrovsky, Mr. Sarrafzadeh (F,W,Sp)

171TL. Data Communication Systems Laboratory. (2 to 4) (Same as Electrical and Computer Engineering M171TL.) Laboratory, four to eight hours; outside study, two to four hours. Recommended preparation: course M152A. Limited to seniors. Not open to students with credit for course M171. Interpretation of analog-signaling aspects of digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, base band and electrical communication computer terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modern and terminal characteristics, and interfaces. Letter grading. Mr. Gafni, Mr. Ostrovsky, Mr. Sarrafzadeh (F,W,Sp)

172. Real-Time Three-Dimensional Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 180. Designed for junior/senior Computer Science majors. Introduction to real-time three-dimensional animation, enabling them to refine their interactions to create professional animation and to concepts in artificial intelligence. Emphasis on teamwork through projects and assignments. Core concepts include building APIs, web services and distributed transactions. Letter grading. Ms. Ford (Not offered 2019-20)

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

174B. Introduction to Computer Graphics: Three-Dimensional Photography and Rendering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. State of art in three-dimensional photography and image-based rendering. How to use cameras and light to capture shape and appearance of real objects and scenes. Process provides simple way to acquire threedimensional models of detailed detail and realism. Applications of techniques from entertainment (reverse engineering and post-processing of movies, generation of realistic synthetic objects and characters to medicine (from 3D medical scans of virtual structures from imaging data), mixed reality (augmented and virtual reality)), and security (visual surveillance). Fundamental analytical tools for modeling and inferring geometric (shape) and photometric (reflectance, illumination) properties of objects and scenes, and for rendering and manipulating novel view. Letter grading. Mr. Soatto (Not offered 2019-20)

C174C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. Designed for juniors/seniors. 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 motion control. Concurrently scheduled with course C274C. Lecture grading. Mr. Terzopoulos (Sp)

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

181. Introduction to Formal Languages and Automata Theory. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 180. Designed for junior/senior Computer Science majors. Grammars, automata, and languages. Finite-state languages and finite-state automata. Context-free languages and pushdown stack automata. Unrestricted rewriting systems, recursively enumerable languages and Turing machines. Closure properties, pumping lemmas, and decision algorithms. Introduction to computability. Letter grading. Mr. Sahai, Mr. Shostov (F,W,Sp)
corequisite: Mathematics 3C, 32A, or 32T. For under-graduate students in life, computational, engineering, and mathematical sciences. Active learning ap-proach, Introduction to explicit modeling and simula-tion of dynamic biological systems. Basic method-o-logy for transforming biology, biochemistry, and physiology into system diagrams, graphs, and mathemat-ical expressions for studying their behavior. Structural models, formulated from basic conserva-tion and mass action laws and feedback concepts, are further developed in computer tools. Introduction to simula-tion, with emphasis on interpretation and translation of model results to biology. Concurrently scheduled with course CM187. Research Communication in Computa-tional and Systems Biology. (4) (Same as Bioengi-neering CM187 and Computational and Systems Bi-oogy M187.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Close-by directed, in-teractive, and real research experience in active qua ntitative systems biology research laboratory. Di-rection on how to focus on topics of current interest in scientific community, appropriate to student inter-ests and capabilities. Capabilities of oral presentations and written progress reports explain how to proceed with search for research results. Major emphasis on effec-ctive research reporting, both oral and written. Concurrently scheduled with course CM287. Letter grading.

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 those taught by resident and visiting faculty members. May be repeated for credit with topic or instructor change. Letter grading. (F,W,Sp)

192. Methods and Application of Collaborative Learning Theory in Life Sciences. (2) Seminar, four hours; outside study, eight hours. Seminar to further prepare students who are selected for learning assistants (LA) program. Exploration of current topics in pedagogy and education research focused on methods of learning and their practical application in small-group settings. Students practice communication skills with constant assessment of and feedback on progress. Letter grading. (F,W,Sp)

192A. Introduction to Collaborative Learning The-ory and Practice. (1) Seminar, one hour; outside study, two hours. Training seminar for undergraduate students who are selected for learning assistants (LA) program. Exploration of current topics in pedagogy and education research focused on methods of learning and their practical application in small-group settings. Students practice communication skills with constant assessment of and feedback on progress. Letter grading. (F,Sp)

194. Research Group Seminars: Computer Sci-ence. (4) Seminar, four hours; outside study, eight hours. Designed for graduate students who are part of research group. Discussion of research methods and current literature in field of research of faculty member or student. May be repeated for credit. Letter grading. (F,W,Sp)

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

Graduate Courses

201. Computer Science Seminar. (2) Seminar, four hours; outside study, two hours. Designed for grad-uate computer science seminars on current research topics in computer science. May be re-peated for credit. S/U grading. (F,W,Sp)

202. Advanced Computer Science Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: completion of major field examination in computer science. Current computer science re-search into theory of, analysis and synthesis of, and applications of information processing systems. Each member completes one tutorial and one or more original pieces of work in one specialized area. May be repeated for credit. Letter grading.
Introduction to algorithms for routers and servers. Models of network devices and hardware design. Principles for efficient network architecture design. Focus on mastering existing core set of Internet protocols, including IP, core transport protocols, routing protocols, DNS, NTP, and security protocols such as DSNSEC, to understand principles of these protocols and associate their design tradeoffs, and learn lessons from their operations. Letter grading. Ms. Zhang (Not offered 2019-20)

217B. Advanced Topics in Internet Research. (4) Lecture, four hours; outside study, eight hours. Enforced requirement: course 118. Focus on mastering existing core set of Internet protocols, including IP, core transport protocols, network measurements, network security protocols, and clean-slate approach to network architecture design. Fundamental issues in network protocol design and implementations. Letter grading. Ms. Zhang (Not offered 2019-20)

218. Advanced Computer Networks. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 112.116, Review of seven-layer ISO-OSI model. High-speed networks: LANs, MANs, ATM. Flow and congestion control; bandwidth allocation. Internetworking. Letter grading. Mr. Gerla (F)

219. Current Topics in Computer System Modeling and Analysis. (4) Lecture, four hours; outside study, four hours. Review of current literature in area of computer system modeling analysis in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading. CM221. Introduction to Bioinformatics. (4) (Same as Bioinformatics M221, Chemistry CM260A, and Human Genetics M268A.) Lecture, four hours: discussion, two hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Prior knowledge of biology not required. Designed for engineering students as well as students from biological sciences and medical school. Introduction to bioinformatics and methodologies, with emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM121, S/U or letter grading. Mr. Lee (F)

CM222. Algorithms in Bioinformatics. (4) (Same as Bioinformatics M222 and Chemistry CM260B.) Lecture, four hours: discussion, two hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Course CM221. Letter grading. Mr. Lee (F)

CM224. Computational Genetics. (4) (Same as Bioinformatics M224 and Human Genetics CM224.) Lecture, four hours; discussion; two hours; outside study, six hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, Mathematics 33A, 34A, Civil Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational techniques and methods in genetics. Topics include introduction to genetics, identification of genes involved in disease, inferring human population history, from modern applications of type systems. Specification and implementation of variety of type systems. Letter grading. Mr. Cong (F)

230. Software Engineering. (4) Lecture, four hours; discussion, two hours. Recommended preparation for undergraduate students: prior software engineering course. Required preparation for graduate students: understanding of computational techniques and data structures and object-oriented program languages. As software systems become increasingly large and complex, automated software engineering technology and development tools play important role in various elements of software engineering tasks, such as design, construction, evolution, and testing and debugging of software systems. Introduction to foundations, techniques, tools, and applications of automated software engineering technology. Development, extension, and evaluation of mini automated software engineering analysis tool and assessment of how tool fits into software development process. Introduction to current research topics in automated software engineering and software reliability. Letter grading. Mr. Kim (S)

231. Types and Programming Languages. (4) Lecture, four hours; outside study, eight hours. Requisite: course 132. Introduction to static analysis of object-oriented programs and its use for optimization and bug finding. Class hierarchy analysis, rapid type analysis, equality-checked analysis, flow-insensitive and flow-sensitive analysis, context-insensitive and context-sensitive analysis. Soundness proofs for static analyses. Efficient data structures for static analysis information such as directed graphs and binary decision diagrams. Flow-directed method inlining, type-safe method inlining, synchronization optimization, deadlock detection, security vulnerability detection. Formal specification and implementation of a variety of type systems, as well as readings from recent research literature on modern applications of static analysis. Letter grading. Mr. Palsberg (F)

232. Static Program Analysis. (4) Lecture, four hours; outside study, eight hours. Requisite: course 132. Introduction to static analysis of object-oriented programs and its use for optimization and bug finding. Class hierarchy analysis, rapid type analysis, equality-checked analysis, flow-insensitive and flow-sensitive analysis, context-insensitive and context-sensitive analysis. Soundness proofs for static analyses. Efficient data structures for static analysis information such as directed graphs and binary decision diagrams. Flow-directed method inlining, type-safe method inlining, synchronization optimization, deadlock detection, security vulnerability detection. Formal specification and implementation of a variety of type systems, as well as readings from recent research literature on modern applications of static analysis. Letter grading. Mr. Palsberg (F)

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

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

235. Advanced Operating Systems. (4) Lecture, four hours. Preparation: C or C++ programming experience. Requisite: course 111. In-depth investigation of operating systems issues through guided student research. Topics include operating system philosophy, virtual memory, file systems, programming, research operating systems. Series of laboratory projects, including extra challenge work. Letter grading. Mr. Eggert (F)
236. Computer Security. (4) Lecture; four hours; outside study, eight hours. Requisites: courses 111, 118. Basic security software and networking. Topics include cryptography, network security, and Internet security. Letter grading. (F,W,Sp)

244A. Distributed Database Systems. (4) Lecture; four hours; outside study, eight hours. File allocation, intelligent directory design, transaction management, deadlock, strong and weak concurrency control, compensation, semantics, query answering, multiple database systems, fault recovery techniques, network partitioning, examples, tradeoffs, and design experiences. Letter grading.

245. Big Data Analytics. (4) Lecture; four hours; outside study, eight hours. Analysis and storage of colossal datasets in the form of text, multimedia, and social media; advanced machine learning and statistical techniques; exploratory and predictive analytics. Letter grading.

246. Web Information Management. (4) Lecture; four hours; outside study, eight hours. Requisites: courses 112, 143, 180, 181. Designed for graduate students. Scale of Web data requires novel algorithms and principles for their management and retrieval. Study of Web characteristics and new management techniques needed to build computer systems suitable for Web environment. Topics include Web measuring techniques, large-scale data mining algorithms, efficient page refresh techniques, Web searching algorithms, and query processing techniques on independent data sources. Letter grading.

247. Advanced Data Mining. (4) Lecture; four hours; outside study, eight hours. Requisite: course 145 or M146 or equivalent. Introduction of concepts, algorithms, and techniques of data mining on different types of datasets, covering basic data mining algorithms, advanced topics on text mining, recommender systems, and graph/network mining. Team-based project work. Discussion of many useful knowledge from large data sets required. Letter grading.

249. Current Topics in Data Structures. (2 to 12) Lecture; four hours; outside study, eight hours. Requisites: courses 143, 145A. Recent developments in data structures and algorithms. Letter grading.


251A. Advanced Computer Architecture. (4) Lecture; four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 111. Design and implementation of high-performance systems, advanced memory hierarchy techniques, static and dynamic pipelining, superscalar and VLIW processors, branch prediction, speculative execution, vector processors, number systems. Discussion of many important optimization techniques, such as network flows, Steiner trees, simulated annealing, and generic algorithms. Letter grading.


252A. Advanced Scalable Architectures. (4) Lecture; four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 251A. Study of state-of-art scalable multiprocessors. Interdependency among implementation technologies, chip microarchitecture, and system architecture. High-performance building blocks, such as chip multiprocessors (CMPs). On-chip and off-chip communication. Mechanisms for exploiting parallelism at multiple levels. Current research areas. Examples of chips and systems. Letter grading. Mr. Tamir (Not offered 2019-20)

252CA. Design of VLSI Circuits and Systems. (4) (Same as Electrical and Computer Engineering M216A.) Lecture; four hours; discussion; two hours; laboratory; four hours; outside study, two hours. Requisite: course M151B. Study of VLSI design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on chips. Letter grading.

252CC. LSI in Computer System Design. (4) (Same as Electrical and Computer Engineering M216C.) Lecture; four hours; laboratory; four hours; outside study, four hours. Requisite: course M252A. LSI/VLSI design and application in computer systems. Fundamentals of state-of-art design techniques. Letter grading.

258F. Physical Design Automation of VLSI Systems. (4) Lecture; four hours; outside study, eight hours. Detailed study of various physical design automation problems of VLSI circuits, including logic partitioning, floorplanning, placement, global routing, channel and switchbox routing, planar routing and via minimization, compaction and performance-driven layout, and the use of local and global optimization techniques. Letter grading.

258G. Logic Synthesis of Digital Systems. (4) Lecture; four hours; outside study, eight hours. Requisite: courses M51A, 180. Detailed study of various problems in logic-level synthesis of VLSI digital systems, including two-level Boolean network optimization, multilevel Boolean network optimization, technology mapping for standard cells and field-programmable gate array (FPGA) designs; retiming for sequential circuits; and algorithms of binary decision diagrams (BDDs). Letter grading. Mr. Cong

258H. Analysis and Design of High-Speed VLSI Interconnects. (4) Lecture; four hours; outside study, eight hours. Requisites: courses M51A, 180. Detailed study of various problems in logic-level synthesis of VLSI digital systems, including two-level Boolean network optimization, multilevel Boolean network optimization, technology mapping for standard cells and field-programmable gate array (FPGA) designs; retiming for sequential circuits; and algorithms of binary decision diagrams (BDDs). Letter grading. Mr. Cong

259. Current Topics in Computer Science: System Design and Architecture. (2 to 12) Lecture; four hours; outside study, eight hours. Review of current literature in area of computer science system design and architecture. Letter grading. Mr. Cong

260. Pictorial and Multimedia Database Management. (4) Lecture; one half hour; discussion; 30 minutes; laboratory; one hour; outside study; seven hours. Requisite: course 143. Multimedia data: alphanumeric, long text, images/pictures, video, and voice. Multimedia systems requirements. Data models. Searching and accessing databases and across Internet by alphanumeric, image, video, and audio content, query, visual languages, and communication. Database design and organization, logical and physical. Indexing methods. Internet multimedia streaming. Other topics at discretion of instructor. Letter grading. Mr. Parker, Mr. Zaniolo (Not offered 2019-20)

265. Design of High-Performance Digital Systems. (2) Lecture; one half hour; discussion; three hours; laboratory; one hour. Requisite: course M151A, 180. Advanced topics on parallel systems, interconnection networks, and parallel algorithms. Letter grading. Mr. Ercegovac, Mr. Tamir (Not offered 2019-20)
260. Machine Learning Algorithms. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Prerequisite: course 181 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. Sha (F)

261A. Problem Solving and Search. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 180 or Electrical Engineering 131A. In-depth treatment of systematic problemsolving 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. Mr. Korf (Not offered 2019-20)

262A. Learning and Reasoning with Bayesian Networks. (4) Lecture, four hours; outside study, eight hours. Prerequisite: 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. Sha (F)

262B. Computational Thinking. (4) Lecture, four hours; outside study, eight hours. Letter grading. Mr. Pearl

262C. Current Topics in Causal Inference. (4) Lecture, four hours; outside study, eight hours. Prerequisite: one graduate probability or statistics course such as course 262A, Statistics 2008, or 202B. Review of Bayesian networks, causal Bayesian networks, and structural equations. Learning causal structures from data. Identifying causal effects. Covariate selection and instrumental variables in linear and nonparametric models. Simpson paradox and confounding control. Logic and algorithmization of counterfactuals. Analysis of counterfactuals using direct and indirect effects. Probabilities of causation. Identifying causes of events. Letter grading. Mr. Pearl

262Z. Current Topics in Cognitive Systems. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 262A. Additional requisites for each offering announced in advance by department. Theory and implementation of systems that emulate or support human reasoning. Current literature and individual studies in artificial intelligence, focusing on development of systems that emulate or support human reasoning. Computer science and psychology techniques useful. Letter grading. Mr. Korf

263A. Language and Thought. (4) Lecture, four hours; outside study, eight hours. Prerequisite: 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. Mr. Dyer (Not offered 2019-20)

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

264A. Automated Reasoning: Theory and Applications. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Prerequisite: course 161. Introduction to theory and practice of automated reasoning using propositional and first-order logic. Topics include syntax and semantics of formal logic; algorithms for logical reasoning, including satis-

274C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Prerequisite: 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, collision and contact systems, and potential fields. Students will build complex animation scenes, which may include importing and incorporating into sophisticated, self-animating graphical entities. Specific topics include modeling plants using L-systems, biomechanical simulation and control of bipedal and quadrupedal robots, and neural-net learning of locomotion, cognitive modeling, artificial animals and humans, human facial animation, and artificial evolution. Letter grading. Mr. Terzopoulos (Not offered 2019-20)

276A. Pattern Recognition and Machine Learning. (4) Same as Statistics M231A. Lecture, three hours; discussion, one hour. Designed for graduate students. Fundamental concepts, theories, and algorithms for pattern recognition and machine learning. Topics include in computer vision, image processing, speech recognition, data mining, statistics, and computational biology. Topics include Bayesian decision theory, parametric and nonparametric learning, clustering and dimensionality reduction, neural networks and backpropagation, probabilistic graphical models, hidden Markov models, mixture models, and Markov chain Monte Carlo methods.

276B. Statistical Computing and Inference. (4) Same as Statistics M232B. Lecture, three hours. Prerequisite: basic statistics, linear algebra (matrix analysis), computer vision. Introduction to broad range of algorithms for statistical inference and learning that could be used in vision, pattern recognition, speech, bioinformatics, and data mining. Topics include Markov chain Monte Carlo computing, sequential Monte Carlo methods, belief propagation, partial differential equations. S/U or letter grading.

276A. Probabilistic Programming and Relational Learning. (4) Lecture, four hours; outside study, six hours. Introduction to computational models of probability and statistical models of relational data. Study of relational representations such as probabilistic databases, relational graphical models, and Markov logic networks, as well as various probabilistic programming languages. Covers their syntax and semantics, probabilistic inference problems, parametric, and structure learning algorithms, and theoretical properties of representation and inference. Expressed in probability theory, this course aims to form a precise and deep understanding of the field of artificial intelligence and self-learning, with particular emphasis on the role of probability and deep learning in the field of artificial intelligence. Letter grading.

276B. Machine Perception. (4) Same as Electrical and Computer Engineering M206B. Lecture, four hours; discussion, two hours; outside study, six hours. Designed for graduate students. Computational aspects of processing visual and other sensory information. Unification of early vision in man and machine. Integration of symbolic and iconic representations in process of image segmentation. Computation of multimodal sensory information by neural-net architectures. Letter grading. Mr. Soatto (F)

268S. Seminar: Computational Neuroscience. (2) Seminar, four hours. Taught only if enrollment warrants. Letter grading. Mr. Pearl

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

291A. Computability and Complexity. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 181 or compatible background. Concepts fundamental to study of discrete information systems and theory of computing, with emphasis on regular sets of strings, Turing-recognizable (recursively enumerable) sets, closure properties, machine characterizations, nondeterminism, decidability, complexity classes, “easy” and “hard” problems, PTIME/NPTIME. Letter grading. Mr. Ostrovsky (Not offered 2019-20)

262A. Cryptography. (4) Same as Mathematics M220A. Lecture, four hours; outside study, eight hours. Introduction to theory of cryptography, stressing rigorous definitions and proofs of security. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permu-
tions, semantic security, public-key and private-key encryption, secret-sharing, message authentication, digital signature, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, key-agreement, contract signing, and two-party secure computation with static security.

Letter grading.

Mr. DiStefano (Not offered 2019-20)


Mr. Ostrovsky (Sp)

M283A-M283B. Topics in Applied Number Theory. (4-4) (Same as Mathematics M208A-M208B.) Lecture, three hours; outside study, eight hours. Topics include congruences and prime numbers, cryptography, public-key and discrete log cryptosystems. Attacks on cryptosystems. Primality testing and factorization methods. Topics from coding theory: Hamming codes, cyclic codes, Gilbert-Varshamov bounds, Shannon theorem. S/U or letter grading.

Letter grading.

Mr. Sahai (Not offered 2019-20)

CM286. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Bioengineering CM286.) Lecture, four hours; laboratory, one hour; outside study, eight hours. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control of cellular systems, systems-level feedback, signal transduction, transport mechanisms, and cellular processes and systems at multiple levels of organization. Treatment of networks of interacting biological and chemical processes. Model building and analysis in the life and physical sciences. Workshop on the computational biology of integrative physiology. Review of current literature in area of computational biology. Letter graded.

Mr. Sahai (Not offered 2019-20)

CM287. Research Communication in Computational and Systems Biology. (4) (Same as Bioengineering CM287.) Lecture, four hours; outside study, eight hours. Requisite: course CM286. Closest directed research 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 abilities. Opening and closing critiques of oral presentations and written work progress reports explain how to proceed with search for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM187. Letter grading.

Mr. DiStefano (Not offered 2019-20)

288S. Seminar: Theoretical Computer Science. (2) Seminar, two hours; outside study, six hours. Requisite: consent of instructor. Seminar for students undertaking research. Discussion of advanced topics and current research in such areas as algorithms and complexity models for parallel and concurrent computation, and formal language and automata theory. May be repeated for credit. Letter grading.

Mr. Ostrovsky

289A-289ZZ. Current Topics in Computer Theory. (2 to 12) Lecture, four hours; outside study, eight hours. Requisite: consent of instructor. 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.

289C. Complexity Theory. (4). Lecture, four hours; outside study, eight hours. Diagonalization, polynomial-time hierarchy, NPC theorem, randomness and de-randomization, circuit complexity, attempts and limitations to proving P does not equal NP, average-case complexity, one-way functions, hardness amplification. Problem sets and presentation of original and current research related to course topics. Letter grading.

Mr. Sahai (F)


Mr. Sahai

289A. Randomized Algorithms. (4). Lecture, four hours; outside study, eight hours. Basic concepts and design techniques applied to algorithms, such as probability theory, Markov chains, random walks, and probabilistic method. Applications to randomization algorithms in data structures, graph theory, computational geometry, number theory, and parallel and distributed systems. Letter grading.

CM296A. Advanced Modeling Methodology for Dynamic Biomedical Systems. (4) (Same as Bioengineering M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biomedical Engineering M270. 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 adaptive software architecture and optimal experiment design via applications in physiology and pharmacology. Letter grading.

Mr. DiStefano

CM296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Same as Bioengineering M296B, Biomedical Engineering M270, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course CM296A or M296A or Biomedical Engineering M220. 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 adaptive software architecture and optimal experiment design via applications in physiology and pharmacology. Letter grading.

Mr. DiStefano

CM296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) (Same as Bioengineering M296C and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course M296B. Research techniques and experience on special topics involving models, modeling methodology, and model validation in biologic 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.

Mr. DiStefano

CM296D. Introduction to Computational Cardiology. (4) (Same as Bioengineering M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological process. Ionic models of action potential generation and propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading.

Mr. DiStefano

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 current 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.

Mr. DiStefano

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

(F,W,Sp)

495. Teaching Assistant Training Seminar. (2) Seminar, four hours; outside study, two hours. Limited to graduate Computer Science students. Seminar on being effective teaching assistant, including preparation, classroom presentation, engagement, assessment, portfolio development, office hours, review sessions, making up and grading assignments and exam questions, proctoring exams, and grading. S/U grading.

Mr. Korf (F)

495B. Teaching with Technology. (2) Seminar, two hours; outside study, four hours. Limited to graduate Computer Science Department teaching assistants. Seminar for teaching assistants covering how technology can be used to aid instruction in and out of classroom. S/U grading.

Mr. Korf (Not offered 2019-20)

497D-497E. Field Projects in Computer Science. (4–4) Fieldwork, to be arranged. Students are divided into teams led by instructor; each team is assigned one external company or organization that they investigate as candidate for possible computerization, submitting team report of findings and recommendations. In Progress (497D) and S/U or letter (497E) grading.

596. Directed Individual or Tutorial Studies. (1 to 8) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for MS comprehensive exam. S/U grading.

597A. Preparation for MS Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for MS comprehensive examination. S/U grading.

597B. Preparation for PhD Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for PhD preliminary examinations. S/U grading.

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

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

Electrical and Computer Engineering

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Professors
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Scope and Objectives
Electrical and computer engineers are responsible for inventions that have revolutionized our society, such as the electrical grid, telecommunications, and automated computing and control. The profession continues to make vital contributions in many domains, such as the infusion of information technology into all aspects of daily life. To further these ends, the Department of Electrical and Computer Engineering fosters a dynamic academic environment that is committed to a tradition of excellence in teaching, research, and service and has state-of-the-art research programs and facilities in a variety of fields. Departmental faculty members are engaged in research efforts across several disciplines in order to serve the needs of industry, government, society, and the scientific community. Interactions with other disciplines are strong. Faculty members regularly conduct collaborative research projects with colleagues in the Geffen School of Medicine; Graduate School of Education and Information Studies; School of Theater, Film, and Television; and College of Letters and Science.

There are three primary research areas in the department: circuits and embedded systems, physical and wave electronics, and signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecom-

Professor Mona Jarrahi and her group work on a terahertz spectroscopy setup.
communications, control systems, signal processing, data science, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, and solid-state electronics.

The program grants two undergraduate degrees (Bachelor of Science in Electrical Engineering and Bachelor of Science in Computer Engineering) and two graduate degrees (Master of Science and Doctor of Philosophy in Electrical and Computer Engineering). The graduate program provides students with an opportunity to pursue advanced coursework, in-depth training, and research investigations in several fields.

**Department Mission**
The education and research activities in the Electrical and Computer Engineering Department are aligned with its mission statement. In partnership with its constituents, consisting of students, alumni, industry, and faculty members, the mission of the department is to (1) produce highly qualified, well-rounded, and motivated students with fundamental knowledge of electrical engineering who can provide leadership and service to California, the nation, and the world, (2) pursue creative research and new technologies in electrical engineering and across disciplines in order to serve the needs of industry, government, society, and the scientific community, (3) develop partnerships with industrial and government agencies, (4) achieve visibility by active participation in conferences and technical and community activities, and (5) publish enduring scientific articles and books.

**Electrical Engineering Undergraduate Program Educational Objectives**
The electrical engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The electrical engineering curriculum provides an excellent background for either graduate study or employment. Undergraduate education in the department provides students with (1) fundamental knowledge in mathematics, physical sciences, and electrical engineering, (2) the opportunity to specialize in specific areas of interest or career aspiration, (3) intensive training in problem solving, laboratory skills, and design skills, and (4) a well-rounded education that includes communication skills, the ability to function well on a team, an appreciation for ethical behavior, and the ability to engage in lifelong learning.

This education is meant to prepare students to thrive and to lead. It also prepares them to achieve the following two program educational objectives: (1) that graduates of the program have successful technical or professional careers and (2) that graduates of the program continue to learn and to adapt in a world of constantly evolving technology.

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

**Undergraduate Study**
The Electrical Engineering major is a designated capstone major. Undergraduate students complete a design course in which they integrate their knowledge of the discipline and engage in creative design within realistic and professional constraints. Students apply their knowledge and expertise gained in previous mathematics, science, and engineering coursework. Within a multidisciplinary team structure, students identify, formulate, and solve engineering problems and present their projects to the class.

The Computer Engineering major is a designated capstone major that is jointly administered by the Computer Science and Electrical and Computer Engineering departments. Undergraduate students complete a design course in which they integrate their knowledge of the discipline and engage in creative design within realistic and professional constraints. Students apply their knowledge and expertise gained in previous mathematics, science, and engineering coursework. Students identify, formulate, and solve engineering problems and present their projects to the class.

**Electrical Engineering B.S. Capstone Major**
The undergraduate curriculum provides all Electrical Engineering majors with preparation in the mathematical and scientific disciplines that lead to a set of courses that span the fundamentals of the three major departmental areas of signals and systems, circuits and embedded systems, and physical wave electronics. These collectively provide an understanding of inventions of importance to society, such as integrated circuits, embedded systems, photonic devices, automatic computation and control, and telecommunication devices and systems. Students are encouraged to make use of their electrical and computer engineering electives and a two-term capstone design course to pursue deeper knowledge within one of these areas according to their interests, whether for graduate study or preparation for employment. See the elective examples and suggested tracks below.

**Learning Outcomes**
The Electrical Engineering major has the following learning outcomes:

- Application of knowledge of mathematics, science, and engineering
- Design of a system, component, or process to meet desired needs within realistic constraints
- Function as a productive member of a multidisciplinary team
- Effective communication
- Identification, formulation, and solution of electrical engineering problems

**Preparation for the Major**
**Required:** Chemistry and Biochemistry 20A; Computer Science 31, 32; Electrical and Computer Engineering 2, 3, 10, 11L, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4A, 4B.

**The Major**
**Required:** Electrical and Computer Engineering 101A, 102, 110, 111L, 113, 131A; six core courses selected from Computer Science 33, Electrical and Computer Engineering 101B, 115A, 121B, 132A, 133A, 141, 170A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 12 units of major field elective courses, at least 8 of which must be upper-division electrical and computer engineering courses or from another UCLA Samueli department; and one two-term electrical and computer engineering capstone design course (8 units).

Electrical and Computer Engineering 100 and CM182 may not satisfy elective credit. For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.
Elective Examples

Communications Systems: Studies range from basic wave propagation to point-to-point links up to large-scale networks for both wired and wireless applications. Students might take 12 units selected from Electrical and Computer Engineering 112A, 112B, 113A, 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, and 142 and 8 capstone design units from 113DA/113DB or 184DA/184DB.

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

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

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

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

Signal Processing: The study of how to derive meaningful inferences from measured data, such as speech, images, or other data, after conversion from analog to digital form. Students might take 12 units selected from Electrical and Computer Engineering 114, 133A, 133B, 134, and M146 and 8 capstone design units from 113DA/113DB.

Simulation and Data Analysis: Studies focus on applications related to the processing of big data for both analog/multimedia and digital sources. Students might take 12 units selected from Electrical and Computer Engineering 114, 132A, 133A, 133B, 134, and M146 and 8 capstone design units from 113DA/113DB or 180DA/180DB.

Solid-State and Microelectromechanical Systems (MEMS) Devices: The study of the nanoscale and microscale devices that are the base of modern computation and sensing systems. Students might take 12 units selected from Electrical and Computer Engineering 121B, 123A, 123B, 128, and M153 and 8 capstone design units from 121DA/121DB.

Suggested Tracks

The technical breadth area requirement provides an opportunity to combine elective courses in the Electrical Engineering major with those from another UCLA Samueli major to produce a specialization in an interdisciplinary domain. Students are free to design a specialization in consultation with a faculty adviser.

Bioengineering and Informatics (BI) refers to the design of biomedical devices and the analysis of data derived from such devices and instruments. Students might take Chemistry and Biochemistry 208 and two courses from Bioengineering 100, C101, CM102, and 110 and/or 12 units from Computer Science CM121, Electrical and Computer Engineering 114, 133B, 134, and 176 and 8 capstone design units from 180DA/180DB.

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

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

Computer Engineering B.S.

Capstone Major

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

Learning Outcomes

The Computer Engineering major has the following learning outcomes:

• Application of mathematical, scientific, and engineering knowledge

• Design of a software or hardware system, component, or process to meet desired needs within realistic economic, environmental, social, ethical, health, safety, security, reliability, manufacturability, and sustainability constraints

• Function productively on a team with others

• Identification, formulation, and solution of computer engineering problems

• Effective communication

Preparation for the Major

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

The Major

Required: Computer Science 111, 118 (or Electrical and Computer Engineering 132B), M151B (or Electrical and Computer Engineering M16C), M152A (or Electrical and Computer Engineering M16L), 180; Electrical and Computer Engineering 100, 111, 113, 115C; one course from Civil and Environ-
mental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, Statistics 100A; 8 units of computer science and 8 units of electrical and computer engineering upper-division electives; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 8 units capstone design from either Electrical and Computer Engineering 180DA/180DB or 183DA/183DB.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Suggested Tracks

Networked Embedded Systems: This track targets two related trends that have been a significant driver of computing, namely stand-alone embedded devices becoming networked and coupled to physical systems, and the Internet evolving toward a network of things (the IoT). These may broadly be classified as cyber physical systems, and includes a broad category of systems such as smart buildings, autonomous vehicles, and robots, which interact with each other and other systems. This trend in turn is driving innovation both in the network technologies (new low-power wireless networks for connecting things, and new high-speed networks and computing infrastructure to accommodate the transport and processing needs of the deluge of data resulting from continual sensing), and in embedded computing (new hardware and software stack catering to requirements such as ultra-low power operation, and embedded machine learning). Students pursuing this track are strongly encouraged to take Electrical and Computer Engineering M119 or Computer Science M119 in junior year, and to choose three electives from courses such as Computer Science 117, 130, 131, 132, 133, 136, 181, 188, Electrical and Computer Engineering 2, 115A, 115B, 132A, 133A, 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.

Graduate Study

For information on graduate admission see Graduate Programs on page 26. The following introductory information is based on 2019-20 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees. Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

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

Electrical Engineering M.S.

Areas of Study

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

Course Requirements

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

The minimum requirements for the M.S. degree are as follows:

1. Requisite. B.S. degree in Electrical Engineering or a related field.
2. All M.S. program requirements should be completed within two academic years from admission into the M.S. graduate program in the Henry Samueli School of Engineering and Applied Science.
3. Students must maintain a minimum cumulative grade-point average of 3.0 every term and 3.0 in all graduate courses.
4. Thesis Option. Students selecting the thesis option must complete at least the following requirements: (a) five formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical and Computer Engineering 297, (d) two Electrical and Computer Engineering 598 courses involving work on the M.S. thesis, (e) no other 500-level courses, other seminar courses, nor Electrical and Computer Engineering 296 or 375 may be applied toward the course requirements, and (f) an M.S. thesis completed under the direction of the faculty adviser to a standard that is approved by a committee comprised of three faculty members. The thesis research must be conducted concurrently with the coursework.
5. Non-Thesis Option. Students selecting the non-thesis option must complete at least the following requirements: (a) six formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical and Computer Engineering 297, (d) Electrical and Computer Engineering 299 to serve as the M.S. comprehensive examination, which is evaluated by a committee of three faculty members appointed by the department. In case of failure, students may be re-examined only once with consent of the departmental graduate adviser, and (e) no 500-level courses, other seminar courses, nor Electrical and Computer Engineering
296 or 375 may be applied toward the course requirements
6. Students must select a number of formal graduate courses to serve as their major and minor fields of study according to the requirements listed above for the thesis (seven courses) and non-thesis (eight courses) options. The selection of the major and minor sequences of courses must be from different established tracks, or approved ad hoc tracks, or combinations thereof. The selected courses must be approved by the faculty adviser
7. For the thesis option at least four, and for the non-thesis option five, of the formal graduate courses used to satisfy the M.S. program requirements listed above must be in the Electrical and Computer Engineering Department
8. A formal graduate course is defined as any 200-level course, excluding seminar or tutorial courses
9. At most one upper-division undergraduate course is allowed to replace one of the formal graduate courses covering the major and minor fields of study provided that (a) the undergraduate course is not required of undergraduate students in the Electrical and Computer Engineering Department and (b) the undergraduate course is approved by the faculty adviser
10. A track is a coherent set of courses in some general field of study. The department suggests lists of established tracks as a means to assist students in selecting their courses. Students are not required to adhere to the suggested courses in any specific track

Circuits and Embedded Systems Area Tracks
1. Embedded Computing Track. Courses deal with the engineering of computer systems as may be applied to embedded devices used for communications, multimedia, or other such restricted purposes. Courses include Computer Science 251A, Electrical and Computer Engineering 201A, 201C, M202A, M202B, M216A
2. Integrated Circuits Track. Courses deal with the analysis and design of analog and digital integrated circuits; architecture and integrated circuit implementations of large-scale digital processors for communications and signal processing; hardware/software codesign; and computer-aided design methodologies. Courses include Computer Science 251A, 252A, Electrical and Computer Engineering 215A through 215E, M216A, 221A, 221B

Physical and Wave Electronics Area Tracks
1. Electromagnetics Track. Courses deal with electromagnetic theory; propagation and scattering; antenna theory and design; microwave and millimeter wave circuits; printed circuit antennas; integrated and fiber optics; microwave-optical interaction, antenna measurement, and diagnostics; numerical and asymptotic techniques; satellite and personal communication antennas; periodic structures; genetic algorithms; and optimization techniques. Courses include Electrical and Computer Engineering 221C, 260A, 260B, 261, 262, 263, 266, 270
2. Photonics and Plasma Electronics Track. Courses deal with laser physics, optical amplification, electro-optics, acoustooptics, magneto-optics, nonlinear optics, photonic switching and modulation; ultrafast phenomena, optical fibers, integrated waveguides, photodetection, optoelectronic integrated circuits, optical microelectromechanical systems (MEMS), analog and digital signal transmission, photonics sensors, lasers in biomedicine, fundamental plasma waves and instability; interaction of microwaves and laser radiation with plasmas; plasma diagnostics; and controlled nuclear fusion. Courses include Electrical and Computer Engineering 270, 271, 272, 273, 274, 285A, 285B, M287
3. Solid-State and Microelectromechanical Systems (MEMS) Devices Track. Courses deal with solid-state physical electronics, semiconductor device physics and design, and microelectromechanical systems (MEMS) design and fabrication. Courses include Electrical and Computer Engineering 221A, 221B, 221C, 222, 223, 225, M250B, Mechanical and Aerospace Engineering 281, 284, C287L

Signals and Systems Area Tracks
1. Communications Systems Track. Courses deal with communication and telecommunication principles and engineering applications; channel and source coding; spectrum analysis; communications; 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, queueing system, communication networks, local-area, metropolitan-area, and wide-area computer communication networks. Courses include Electrical and Computer Engineering 205A, 210A, 230A through 230D, 231A, 231E, 232A through 232E, 238, 241A
2. Control Systems and Optimization Track. Courses deal with state-space theory of linear systems; optimal control of deterministic linear and nonlinear systems; stochastic control; Kalman filtering; stability theory of linear and nonlinear feedback control systems; computer-aided design of control systems; optimization theory, including linear and nonlinear programming; convex optimization and engineering applications; numerical methods; nonconvex programming; associated network flow and graph problems; renewal theory; Markov chains; stochastic dynamic programming; and queuing theory. Courses include Electrical and Computer Engineering 205A, M208B, M208C, 210B, 236A, 236B, 236C, M237, M240A, M240C, 241A, M242A

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

Comprehensive Examination Plan
The M.S. comprehensive examination requirement is satisfied either (1) by solving a comprehensive examination problem in the final project, or equivalent, of every formal graduate electrical and computer engineering course taken. A grade-point average of at least 3.0 in the comprehensive examination problems is required for graduation. The M.S. individual study program is administered by the academic adviser, the director of the area to which the students belong, and the vice chair of Graduate Affairs or (2) through completion of an individual study course (Electrical and Computer Engineering 299) under the direction of a faculty member. Students are assigned a topic of individual study by the faculty member. The study culminates with a written report and an oral presentation. The M.S. individual study program is administered by the faculty member directing the course, the director of the area to which the students belong, and the vice chair of Graduate Affairs. Students who fail
the examination may be reexamined once with consent of the vice chair of Graduate Affairs.

Electrical Engineering Ph.D. Areas of Study

Students may pursue specialization across three major areas of study: (1) circuits and embedded systems, (2) physical and wave electronics, and (3) signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

Course Requirements

The selection of courses for the Ph.D. program is tailored to the professional objectives of the students and must meet the requirements stated below. The courses should be selected and approved in consultation with the faculty adviser. Departures from the stated requirements are considered only in exceptional cases and must be approved by the departmental graduate adviser. Normally, students take additional courses to acquire deeper and broader knowledge in preparation for the dissertation research.

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

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

2. All Ph.D. program requirements should be completed within five academic years from admission into the Ph.D. graduate program in the Henry Samueli School of Engineering and Applied Science

3. Students must maintain a cumulative grade-point average of 3.5 in the Ph.D. program

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

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

6. At least two of the formal graduate courses must be in electrical and computer engineering

7. Within two academic years from admission into the Ph.D. program, all courses should be completed and the Ph.D. preliminary examination should be passed. It is strongly recommended that students take the Ph.D. preliminary examination during their first academic year in the program

8. The University Oral Qualifying Examination must be taken when all required courses are complete, and within one year after passing the Ph.D. preliminary examination

9. Students admitted originally to the M.S. program in the Electrical and Computer Engineering Department must complete all M.S. program requirements with a grade-point average of at least 3.5 to be considered for admission into the Ph.D. program. Only after admission into the program can students take the Ph.D. preliminary examination

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

Written and Oral Qualifying Examinations

The written qualifying examination is known as the Ph.D. preliminary examination in the department. The purpose of the examination is to assess student competency in the discipline, knowledge of the fundamentals, and potential for independent research. Students admitted originally to the M.S. program in the Electrical and Computer Engineering Department must complete all M.S. program requirements with a grade-point average of at least 3.5 to be considered for admission into the Ph.D. program. Only after admission into the program can students take the Ph.D. preliminary examination, which is held once every year. Students are examined independently by a group of faculty members in their general area of study. The examination by each faculty member typically includes both oral and written components, and students pass the entire Ph.D. preliminary examination and not in parts. Students who fail the examination may repeat it once only with consent of the departmental graduate adviser. The preliminary examination, together with the course requirements for the Ph.D. program, should be completed within two years from admission into the program.

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

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

Facilities and Programs

Computing Resources

The department maintains a server room with several racks of computer and storage servers in addition to computing resources within individual faculty labs. The network infrastructure supports a variety of Windows, UNIX, and Linux servers, workstations, and laptops. The school also offers access to a computing cluster primarily used for undergraduate and graduate teaching purposes. The campus supplies free access to a large-scale computing cluster (Hoffman2) with over 13,000 computing cores on over 1200 server nodes. Archival-class backup storage is also available through the campus.
Research Centers and Laboratories

Center for Development of Emerging Storage Systems (CoDESS)

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

Center for Engineering Economics, Learning, and Networks

The center 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)

CHIPS addresses emerging technologies, design, and architectures to achieve a more holistic Moore’s Law for the overall system. The center’s core activities include advanced heterogeneous hardware integration technologies; methodologies and tools relying on fine-pitch interconnects on both rigid and flexible substrates; wafer-scale integration; active and passive components for advanced systems; and large-scale systems especially for cognitive, memory, and medical engineering applications.

CHIPS is multidisciplinary, integrating specialties and students in diverse areas including electrical engineering, materials science and engineering, mechanical engineering, computer science and engineering, and biosciences, with strong industry participation. The center has extensive fabrication facilities to support these activities.

Center for High-Frequency Electronics

The center was established with support from several governmental agencies and contributions from local industries, beginning with a $10 million grant from Hewlett-Packard. The first major goal of the center is to combine, in a synergistic manner, five areas of research. These include (1) solid-state millimeter wave devices, (2) millimeter systems for imaging and communications, (3) millimeter wave high-power sources (gyrotrons), (4) GaAs gigabit logic systems, and (5) VLSI and LSI based on new materials and structures. The center supports work in these areas by providing the necessary advanced equipment and facilities and allows the University to play a major role in initiating and generating investigations into new electronic devices. Students, both graduate and undergraduate, receive training and instruction in a unique facility.

The second major goal of the center is to bring together the manpower and skills necessary to synthesize new areas of activity by stimulating interactions between different interdependent fields. The Electrical and Computer Engineering Department, other departments within UCLA, and local universities (such as Caltech and USC) have begun to coordinate 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 aid in 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)
http://www.nanolab.ucla.edu
Nanolab is a state-of-the-art, 20,000-square-foot, class 10/100/1000 clean-room facility that supports graduate research and teaching. The space includes the Microlab, an undergraduate teaching laboratory for device fabrication (CMOS, MEMS, and optoelectronics). With a full complement of utilities (high-purity deionized water, high-purity nitrogen, exhaust scrubbers) and the latest technologies in vibration isolation and electromagnetic shielding, the Nanolab offers advanced processing equipment for fabrication and analysis. In BSL2-capable biosuits, researchers can leverage standard semiconductor process techniques with evolving biomedical, nanometer-scale fabrication to study fundamental quantum size effects; and explore novel nanometer-scale device concepts. Nanolab staff has deep knowledge of fabrication techniques and process development to support both academic and commercial research and development projects.

Photonics and Optoelectronics Laboratories
Students in the Laser Laboratory study the properties of lasers and gain an understanding of the application of this modern technology to optics, communication, and holography. The photonics and optoelectronics laboratories include facilities for research in all of the basic areas of quantum electronics. Specific areas of experimental investigation include high-powered lasers, nonlinear optical processes, ultrafast lasers, parametric frequency conversion, electro-optics, infrared detection, and semiconductor lasers and detectors. Operating lasers include mode-locked and Q-switched Nd:YAG and Nd:YLF lasers, Ti:Al2O3 lasers, ultraviolet and visible wavelength argon lasers, wavelength-tunable dye lasers, as well as gallium arsenide, helium-neon, excimer, and high-powered continuous and pulsed carbon dioxide laser systems. Also available are equipment and facilities for research on semiconductor lasers, fiber optics, nonlinear optics, and ultrashort laser pulses. These laboratories are open to 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, table-top terawatt (T3) 400fs laser system that can be operated in either a single or dual frequency mode for laser-plasma interaction studies. Diagnostic equipment includes a ruby laser scattering system, a streak camera, and optical spectrophotographs and multichannel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing. The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, focusable to 1016 W/cm2. The laser is used for testing new ideas for laser-driven particle accelerators and free-electron lasers. Several high-pressure, short-pulse drivers can be used on the MARS; other equipment includes a theta-pinch plasma generator, an electron linac injector, and electron detectors and analyzers.

A second group of laboratories is dedicated to basic research in plasma sources for basic experiments, plasma processing, and plasma heating. There is also a large computing cluster called DAWSON 2 that is dedicated to the study of plasma-based acceleration, inertial fusion energy, and high energy density plasma science. DAWSON 2 consists of 96 HP L390 nodes each with 12 Intel X5660 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 non-blocking QDR Infiniband network with 160TB of parallel storage from Panasas. Peak system performance is approximately 300TF/150TF (single/double precision) with a measured Linpack performance of 68.1TF (double precision). DAWSON 2 is housed within the UCLA Institute for Digital Research Engineering data center.

Solid-State Electronics Facilities
Solid-state electronics equipment and facilities include a modern integrated semiconductor device processing laboratory, complete new Si and III-V compound molecular beam epitaxy systems, CAD and mask-making facilities, lasers for beam crystallization study, thin film and characterization equipment, deep-level transient spectroscopy instruments, computerized capacitance-voltage and other characterization equipment, including doping density profiling systems, low-temperature facilities for material and device physics studies in cryogenic temperatures, optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices, and characterization equipment for high-speed devices, including high magnetic field facilities for magnetotransport measurement of heterostructures. The laboratory facilities are available to faculty, staff, and graduate students for their research.

Wireless Health Institute (WHI)
Benjamin M. Wu, D.D.S, Ph.D. (Bioengineering), Director; Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical and Computer Engineering), Gregory J. Pottie, Ph.D. (Electrical and Computer Engineering), Co-Directors
WHI is leading initiatives in health care solutions in the fields of disease diagnosis, neurological rehabilitation, optimization of clinical outcomes for multiple disease conditions, geriatric care, and many others. WHI also promotes this new field in the international community through the founding and organization of the leading Wireless Health conference series.

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

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

Multidisciplinary Research Facilities
The department is also associated with several multidisciplinary research centers including...
Faculty Groups and Laboratories

Department faculty members also lead a broad range of research groups and laboratories that cover a wide spectrum of specialties, including:

- Actuated Sensing and Coordinated Embedded Networked Technologies (ASCENT) Laboratory (Kaiser)
- Adaptive Systems Laboratory (Sayed)
- Algorithmic Research in Network Information Laboratory (Fragouli)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
- Autonomous Intelligent Networked Systems (Rubin)
- BioPhotonics Laboratory (Ozcan)
- CAD for VLSI Design and Manufacturing, Machine Learning Systems in Emerging Technologies (Gupta)
- CMOS Research Laboratory (Woo)
- Communication Circuits Laboratory (Razavi)
- Complex Networks Group (Roychowdhury)
- Cyber-Physical Systems Laboratory (Tabuada)
- Device Research Laboratory (K. Wang)
- Digital Microwave Laboratory (E. Wang)
- Energy and Electronic Design Automation Laboratory (He)
- High-Performance Mixed Mode Circuit Design Group (Yang)
- High-Speed Electronics Laboratory (Chang)
- Image Communications Laboratory (Villasenor)
- Information Theory and Systems Laboratory (Diggavi)
- Integrated Circuits and Systems Laboratory (Abidi)
- Interconnected and Integrated Bioelectronics Laboratory (12BL) (Emaminejad)
- Laboratory for Embedded Machines and Ubiquitous Robotics (Mehta)
- Laser-Plasma Group (Joshi)
- MedAdvance: Machine Learning and Artificial Intelligence for Medicine (van der Schaar)
- Mesoscopic Optics and Quantum Electronics Laboratory (Wong)
- Microwave Electronics Laboratory (Itoh)
- Nanoelectronics Research Center (Candler)
- Nanostructure Devices and Technology Laboratory (Chui)
- Networked and Embedded Systems Laboratory (Srivastava)
- Neural Computation and Engineering Laboratory (Kao)
- Neuroengineering Group (Markovic)
- Optoelectronics Circuits and Systems Laboratory (Jalali)
- Optoelectronics Group (Yablonovitch)
- Public Safety Network Systems Laboratory (Yao, Rubin)
- Quantum Biology Tech (QuBiT) (Aiello)
- Quantum Electronics Laboratory (Stafusdd)
- Robust Information Systems Laboratory (Dolecek)
- Sensors and Technology Laboratory (Candler)
- Signal Processing and Circuit Electronics Group (Pamarti)
- Speech Processing and Auditory Perception Laboratory (Alwan)
- Terahertz Devices and Intersubband Nanostructures Group (Williams)
- Terahertz Electronics Laboratory (Jarrahi)
- Visual Machines Group (Kadambi)
- Wireless Integrated Systems Research Group (Daneshrad)

Faculty Areas of Thesis Guidance

Professors

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

Abeer A.H. Alwan, Ph.D. (MIT, 1992)
Speech processing, acoustic properties of speech sounds with applications to speech synthesis, recognition by machine and coding, hearing-aid design, and digital signal processing

Katsushi Arisaka, Ph.D. (U. Tokyo, Japan, 1985)
High energy and astroparticle experiments

Daniela Cabric, Ph.D. (UC Berkeley, 2007)
Wireless communications system design, cognitive radio networks, VLSI architectures

of signal processing and digital communication algorithms, performance analysis and experiments on embedded system platforms

Robert N. Candler, Ph.D. (Stanford, 2006)
MEMS/NEMS for compact free-electron lasers, miniature medical devices, nanoscale magnetic structures and devices, additive manufacturing, fundamental limits of micro- and nanoscale devices

M.-C. Frank Chang, Ph.D. (National Chiao-Tung U., Taiwan, 1979)
High-speed semiconductor (GaAs, InP, and Si) devices and integrated circuits for digital, analog, microwave, and optoelectronic integrated circuit applications

Panagiotis D. Christofides, Ph.D. (U. Minnesota, 1998)
Process modeling, dynamics and control, computational and applied mathematics

Jason (Jingsheng) Cong, Ph.D. (U. Illinois, 1990)
Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, super architecture, reconfigurable computing, design for nanotechnologies

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

Suhas Diggavi, Ph.D. (Stanford, 1999)
Wireless communication, information theory, wireless networks, data compression, signal processing

Lara Dolecek, Ph.D. (UC Berkeley, 2007)
Information and coding theory, graphical models, statistical algorithms and computational methods with applications to large-scale and complex systems for data processing, communication and storage

Christina Fragouli, Ph.D. (UCLA, 2000)
Network coding, algorithms for networking, wireless networks, data compression, signal processing

Warren S. Grundfest, M.D., FACS (Columbia, 1980)
Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopy, spectroscopy, photodynamic therapy (PDT), optical technology, biologic feedback control mechanisms

Puneet Gupta, Ph.D. (UC San Diego, 2007)
CAD for VLSI design and manufacturing, physical design, manufacturing-aware circuits and layouts, design-aware manufacturing

Lei He, Ph.D. (UCLA, 1999)
Artificial intelligence (AI) and Internet of things (IoT) for education, health, transportation, and power and water sustainability; programmable logic (FPGA), re-configurable computing, AI-on-a-chip, neuromorphic computing, and quantum computing; modeling, simulation-end validation, and computer-aided design of VLSI circuits, software, and IoT systems

Tatsuo Itoh, Ph.D. (U. Illinois Urbana, 1969)
Microwave and millimeter wave electronics; guided wave structures; low-power wireless electronics; integrated passive components and antennas; photonic bandgap structures and meta materials applications; active integrated antennas, smart antennas; RF technologies for reconfigurable front-ends; sensors and transponders

Heterogeneous system integration and scaling, advanced packaging and 3D integration, technologies and techniques for memory sub-system integration and neuromorphic computing

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

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

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

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

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

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

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

Nhan N. Levan, Ph.D. (Monash U., Australia, 1966)
Control systems, stability and stabilizability, errors in dynamic systems, signal analysis, crossovers, flutter, throning

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

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

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

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

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

Chand R. Viswanathan, Ph.D. (UCLA, 1964)
Semiconductor electronics and technology, thin oxides; reliability and failure physics of MOS devices; process-induced damage, low-frequency noise

*Also Professor Emeritus of Anesthesiology

Associate Professor

Aydin Babakhani, Ph.D. (Caltech, 2008)
Millimeter-wave/terahertz integrated circuits, wirelessly powered single-chip circuits

Mona Jarrahi, Ph.D. (Stanford, 2007)
Radio frequency (RF), microwave, millimeter-wave, and terahertz circuits, high-frequency devices and circuits, integrated photonics and optoelectronics

Laser fusion, laser acceleration of particles, nonlinear optics, high-power lasers, plasma physics

William J. Kaiser, Ph.D. (Wayne State, 1982)

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

Kuo-Nan Liou, Ph.D. (New York U., 1971)
Radiative transfer, remote sensing of clouds and aerosols and climate/clouds-aerosols research

Jia-Ming Liu, Ph.D. (Harvard, 1982)

Nonlinear optics, ultrafast optics, laser chaos, semiconductor lasers, optoelectronics, photonics, nonlinear and ultrafast processes

Dejan Markovic, Ph.D. (UC Berkeley, 2006)
Implantable microsystem devices, domain-specific hardware accelerators, embedded systems, design methodologies

Warren B. Mori, Ph.D. (UCLA, 1987)
Laser and charged particle beam-plasma interactions, advanced accelerator concepts, advanced light sources, laser-fusion, high-energy density science, high-performance computing, plasma physics

Scientific computing, applied mathematics

Aydogan Ozcan, Ph.D. (Stanford, 2005)
Bioimaging, nanophotonics, nonlinear optics

Sudhakar Pamarti, Ph.D. (UC San Diego, 2003)
Analog, mixed-signal, and RF-integrated circuit design; signal processing techniques to improve circuit design

Gregory J. Pottie, Ph.D. (McMaster U., Canada, 1988)
Communication systems and theory with applications to wireless sensor networks

Yahya Rahmat-Samii, Ph.D. (U. Illinois, 1975)
Satellite communications antennas, personal communication antennas including human interactions, antenna remote sensing and radio astronomy applications, advanced numerical and genetic optimization techniques in electromagnetics, frequency selective surfaces and photonic band gap structures, novel integrated and fractal antennas, near-field antenna measurements and diagnostic techniques, electromagnetic theory

Behzad Razavi, Ph.D. (Stanford, 1992)
Analog, RF, and mixed-signal integrated circuit design, dual-standard RF transceivers, phase-locked systems and frequency synthesizers, A/D and D/A converters, high-speed data communication circuits

Vwani P. Roychowdhury, Ph.D. (Stanford, 1989)
Models of computation including parallel and distributed processing systems, quantum computation and information processing, circuits and computing paradigms for nanoelectronics and molecular electronics, adaptive and learning algorithms, nonparametric methods and algorithms for large-scale information processing, combinatorics and complexity, and information theory

Henry Samuell, Ph.D. (UCLA, 1980)
VLSI implementation of signal processing and digital communication systems, high-speed digital integrated circuits, digital filter design

Ali H. Sayed, Ph.D. (Stanford, 1992)
Adaptive systems, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplays between signal processing and control methodologies, fast algorithms for large-scale problems

Stefano Soatto, Ph.D. (Caltech, 1996)
Computer vision, systems and control theory, detection and estimation, robotics, system identification, shape analysis, motion analysis, image processing, video processing, autonomous systems

Jason L. Speyer, Ph.D. (Harvard, 1968)
Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics

Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)
Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems

Paulo Tabuada, Ph.D. (Technical U. Lisbon, Portugal, 2002)
Real-time, networked, embedded control systems; mathematical systems theory including discrete-event, timed, and hybrid systems; geometric nonlinear control; algebraic/rewritable methods

Lieven Vandenberghe, Ph.D. (Katholieke U. Leuven, Belgium, 1992)
Optimization in engineering and applications in systems and control, circuit design, and signal processing

Mihnea van der Schaar, Ph.D. (Eindhoven U. Technology, Netherlands, 2001)
Multimedia processing and compression, multimedia networking, multimedia communications, multimedia architectures, enterprise multimedia streaming, mobile and ubiquitous computing

John D. Villasenor, Ph.D. (Stanford, 1989)
Communications, signal and image processing, configurable computing systems, and design environments

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoelectronics and optoelectronics, nano and molecular devices, MBE and superlattices, microwave and millimeter electronics, quantum information

Yuanxin Ethan Wang, Ph.D. (U. Texas Austin, 1999)
Smart antennas, RF and microwave power amplifiers, numerical techniques, DSP techniques for microwave systems, phased arrays, wireless and radar systems, microwave integrated circuits

Richard D. Wesel, Ph.D. (Stanford, 1996)
Communication theory and signal processing with particular interests in channel coding, including turbo codes and trellis codes, joint algorithms for distributed communication and detection

Benjamin Williams, Ph.D. (MIT, 2003)
Development of terahertz quantum cascade lasers

Ultrafast and nonlinear optics, quantum communications and computing, chip-scale optoelectronics, precision measurements and sensing

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

C.-K. Ken Yang, Ph.D. (Stanford, 1998)
High-performance VLSI design, digital and mixed-signal circuit design
Assistant Professors
Clarice D. Aiello, Ph.D. (MIT, 2018) 
Computational imaging, computer vision, robotics, medical devices
Jonathan C. Kao, Ph.D. (Stanford, 2016) 
Computational neuroscience, neural engineering, machine learning
Ankur Mehta, Ph.D. (UC Berkeley, 2012) 
Robotics and electromechanical systems design, fabrication, and control; wireless sensor networks hardware and applications; systems integration
Lin F. Yang, Ph.D. (Johns Hopkins, 2017) 
Foundations for AI, machine learning theories and applications, reinforcement learning, statistical learning, big data algorithms, optimization control

Adjunct Professors
Ezio Biglieri, Dr. Ing. (Politecnico di Torino, Italy, 1967) 
Digital communication, wireless channels, modulation, error-control coding, signal processing in telecommunications
Danish Divsalar, Ph.D. (UCLA, 1978) 
Information theory, communication theory, bandwidth-efficient combined coding modulation techniques, spread spectrum systems and mutual user interference cancellation for CDMA, turbo codes, binary and nonbinary LDPC codes
Dan M. Goebel, Ph.D. (UCLA, 1981) 
Electric propulsion, high-efficiency ion and Hall thrusters, cathodes, high-voltage engineering, microwave devices and microwave communication, patrol and power
Diana L. Huffaker, Ph.D. (U. Texas Austin, 1995) 
Solid-state nanotechnology, MWIR optoelectronic devices, solar cells, Si photonics, novel materials
Asad M. Madni, Ph.D. (California Coast U., 1987) 
Development and commercialization of intelligent sensors and systems, RF and microwave instrumentation, signal processing
Yi-Chi Shih, Ph.D. (U. Texas Austin, 1982) 
Microwave/millimeter-wave active and passive devices, characterization and modeling, integrated circuits, components and subsystems for sensors and communications applications
Ingrid M. Verbauwhede, Ph.D. (Katholieke U. Leuven, Belgium, 1991) 
Embedded systems, VLSI, architecture and circuit design and design methodologies for applications in avionics; wireless communications and signal processing
Eli Yablonovitch, Ph.D. (Harvard, 1972) 
Optoelectronics, high-speed optical communication, photonic integrated circuits, photonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication

Adjunct Associate Professor
Chi On Chui, Ph.D. (Stanford, 2004) 
Nanoelectronics and optoelectronic devices and technology, heterostructure semiconductor devices, memristive integration of heterogeneous technology, exploratory nanotechnology

Adjunct Assistant Professors
Shervin Moloudi, Ph.D. (UC Santa Barbara, 2009) 
Biomedical optics, imaging system design, novel contrast-generation mechanisms
Zachary Taylor, Ph.D. (UC Santa Barbara, 2009) 
Telecommunication analog and high-frequency circuit design

Lower-Division Courses
1. Undergraduate Seminar. (1) (Formerly numbered Electrical Engineering 1.) Seminar, one hour; outside study, two hours. Introduction by faculty members and industry lecturers to electrical engineering disciplines through current and emerging applications of autonomous systems and vehicles, biomedical devices, aerodynamics, consumer products, data science, and entertainment products (amusement rides, etc.), as well as energy generation, storage, and transmission. P/NP grading.

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

3. Introduction to Electrical Engineering. (4) (Formerly numbered Electrical Engineering 3.) Lecture, two hours; laboratory, two hours; outside study, eight hours. Introduction to field of electrical engineering. Basic circuits techniques with application to explanation of electrical engineering inventions such as telecommunication and computation, amplifiers, computing and control, and enabling device technology. Research frontiers of electrical engineering. Introduction to measurement and design of electrical circuits. Letter grading. Mr. Potte (F,Sp)

10. Circuit Theory I. (4) (Formerly numbered Electrical Engineering 10.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 or (Computer Science 1 or Materials Science 10). Mathematics 33A, Physics 1B. Corequisites: course 11L (enforced only for Computer Science 1 or Materials Science 10), Mathematics 33B, Physics 1B. Corequisites: course 11L (enforced only for Computer Science 1 or Materials Science 10), Mathematics 33A, 33B. Honors course parallel to course 10. Letter grading. Mr. Pamarti (W)

10H. Circuit Theory I (Honors). (4) (Formerly numbered Electrical Engineering 10H.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 10L. Corequisites: or Computer Science 1 or Materials Science 10, Mathematics 33A, Physics 1B. Corequisites: course 11L (enforced only for Computer Science 1 or Materials Science 10), Mathematics 33A, 33B. Honors course parallel to course 10. Letter grading. Mr. Abdii (F)

11L. Circuits Laboratory I. (1) (Formerly numbered Electrical Engineering 11L.) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced corequisite: course 10. Experiments with basic circuits containing resistors, capacitors, inductors, and transformers. Ohm’s law and voltage current division, Thévenin and Norton equivalent circuits, superposition, transient and steady-state analysis. Letter grading. Mr. Abdii, Mr. Pamarti (F,W)

M16. Logic Design of Digital Systems. (4) (Formerly numbered Electrical Engineering M16.) (Same as Computer Science M51A) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and design of algorithmic systems: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading. Mr. Srivastava (F,W,Sp)

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

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

Upper-Division Courses
100. Electrical and Electronic Circuits. (4) (Formerly numbered Electrical Engineering 100.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Mathematics 33A, 33B or Mechanical and Aerospace Engineering 82, Physics 1C. Not open for credit to students with credit for course 110. Electrical quantities, linear circuit elements, circuit principles, signal waveforms, transient and steady state circuit behavior, semiconductor diodes and transistors, small signal models, and operational amplifiers. Letter grading. Mr. Padovani (F)

101A. Engineering Electromagnetics. (4) (Formerly numbered Electrical Engineering 101A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Mathematics 32A and 32B, or 33A and 33B. Principles of transformation of field concepts, waves and phasors, transmission lines and Smith chart, transient responses, vector analysis, introduction to Maxwell equations, static and quasi-static electric and magnetic fields. Letter grading. Mr. Joshi, Mr. Williams (F,W)

101B. Electromagnetic Waves. (4) (Formerly numbered Electrical Engineering 101B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Linear systems, frequency- and time-varying 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 antennas. Letter grading. Mr. Y.E. Wang (W,Sp)

M115L. Introductory Digital Design Laboratory. (2) (Formerly numbered Electrical Engineering 1116L.) Same as Computer Science M152A.) Laboratory, four hours; outside study, two hours. Enforced requisite: course M16 or Computer Science M51A. Hands-on design, implementation, and debugging of digital logic circuits, use of computer-aided design tools, schematic capture, simulation, and implementation of complex circuits using programmed array logic, design projects. Letter grading.

Mr. He (F, W)

M119. Fundamentals of Embedded Networked Systems. (4) (Formerly numbered Electrical Engineering M1119.) Same as Computer Science M1119.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requires: Physics 2 or Physics 1C. Introduction to computer system, microcontrollers, microprocessors, and digital logic circuits, internal and external structures and design methodologies in the context of mobile devices and computer networks. Letter grading.

Mr. Srivastava (Sp)

121B. Principles of Semiconductor Device Design. (4) (Formerly numbered Electrical Engineering 121B.) Lecture, three hours; discussion, one hour; outside study, two hours. Requires: Mathematics M152A, Computer Science M151B. Design and analysis of diffused and implanted p-n junction devices. Performance of solid-state devices and systems such as analysis of dynamics, variability, and controllability. Instruction set design, memory hierarchy, task parallelism, and caching in computer systems. Letter grading.

Mr. M. Woo (FW)

121DA-121DB. Semiconductor Processing and Device Design. (4-4) (Formerly numbered Electrical Engineering 121DA-121DB.) Design fabrication and characterization of p-n junction and epitaxial devices. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Introduction to CAD tools used in microelectronic circuit design and layout. Device structure optimization tool based on MEDICI; process integration tool based on SUPREM. Course familiarizes students with tools used in the design of MOS transistors, circuits, and systems. Letter grading.

Mr. F. Chen (Not offered 2019-20)

123A. Fundamentals of Solid-State I. (4) (Formerly numbered Electrical Engineering 123A.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requires: course 2 or Physics 1C. Limited to junior/senior engineering majors. Fundamentals of solid-state, introduction to quantum mechanics and quantum statistics applied to solid-state. Crystal structure, energy levels in solids, and band theory and semiconductor properties. Letter grading.

Mr. K.L. Wang (F)

123B. Fundamentals of Solid-State II. (4) (Formerly numbered Electrical Engineering 123B.) Lecture, four hours; outside study, eight hours. Enforced requisites: course 123A. Discussed solid-state devices, properties, lattice vibrations, thermal properties, dielectric, magnetic, and superconducting properties. Letter grading.

Mr. K.L. Wang (Not offered 2019-20)

128. Principles of Nanoelectronics. (4) (Formerly numbered Electrical Engineering 128.) Lecture, four hours; discussion, four hours; outside study, four hours. Requires: Physics 1C. Introduction to fundamentals of nanoscience for electronics nanosystems. Principles of fundamental quantities: electron charge, effective mass, Bohr magneton, and spin, as well as theoretical approaches. From these nanoscale concepts, the design of basic subunits of electronic systems such as analysis of dynamics, variability, and noise, contrasted with those of scaled CMOS. Incorporation of design project in which students are challenged to design electronics nanosystems. Letter grading.

Mr. K.L. Wang (W)
131A. Probability and Statistics. (4) Formerly numbered Electrical Engineering 131A. Lecture, four hours; discussion, one hour; outside study, six hours. Requisites: course 102 (enforced), Mathematics 32B, 33B. Introduction to basic concepts of probability, including random variables and vectors, distributions and densities, moments, characteristic functions, and limit theorems. Applications to communication systems, control, and signal processing. Introduction to computer simulation and generation of random events. Letter grading. Mr. R. Froychov (FW)

132A. Introduction to Communication Systems. (4) Formerly numbered Electrical Engineering 132A) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 102, 113, and 140. Overview of probability, basic principles of hypothesis testing, sufficient statistics and waveform communication, signal-design tradeoffs for digital communications, basics of error control coding, interference channel and orthogonal frequency-division multiplexing (OFDM), basics of wireless communications. Letter grading. Mr. Diggavi (WSp)

132B. Data Communications and Telecommunication Networks. (4) Formerly numbered Electrical Engineering 132B) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A. Layered communications architectures. Introduction to network modeling and analysis. Error control, flow and congestion control. Packet switching, circuit switching, and routing. Network performance analysis and design. Multiple-access communications and CDMA, polling, random access. Local, metropolitan, wide area, integrated services networks. Letter grading. Mr. Rubin (F)


134. Graph Theory in Engineering. (4) Formerly numbered Electrical Engineering 134) Lecture, four hours; discussion, one hour; outside study, seven hours. Basics of graph theory, including trees, bipartite graphs and matching, vertex and edge coloring, planar graphs, Euler and Hamiltonian paths, and applications to real-world engineering problems to graph theory formulations. Letter grading. Ms. Fragouli (W)


142. Linear Systems: State-Space Approach. (4) Formerly numbered Electrical Engineering 142) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A. State-space methods of linear system analysis and synthesis, with application to problems in networks, control, and system modeling. Letter grading. Mr. Tabuada (Not offered 2019-20)

143A. Neural Signal Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 131A, Mathematics 33A. Topics include fundamental properties of electrically active cells, computations in nervous systems, spike timing, system modeling of neural activity; spiking statistics and Poisson processes; generative models and classification; regression and Kalman filtering; principal components analysis, factor analysis, and expectation maximization. Concurrently scheduled with course C243A. Letter grading. Mr. Kao (Sp)

M146. Introduction to Machine Learning. (4) Formerly numbered Electrical Engineering M146) (Same as Computer Science M146) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 131A or 133A or 205A, or 205B, and M146, or equivalent. Review of machine learning concepts; maximum likelihood classification; neural network architectures; backpropagation; regularization for training neural networks; optimization for training neural networks; convolutional neural networks; practical CNN architectures; deep learning libraries in Python; recurrent neural networks. Hands-on experience in applying mathematical foundations, regression, classification, kernel methods, clustering, expectation maximization, principal component analysis, dimensionality reduction, reinforcement learning and deep learning. Letter grading. Mr. Doleck (F,W,Sp)

C147. Neural Networks and Deep Learning. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 131A, 133A or 205A, or 205B, and M146, or equivalent. Review of machine learning concepts; maximum likelihood; supervised classification; neural network architectures; backpropagation; regularization for training neural networks; optimization for training neural networks; convolutional neural networks; practical CNN architectures; deep learning libraries in Python; recurrent neural networks. Hands-on experience in applying mathematical foundations, regression, classification, kernel methods, clustering, expectation maximization, principal component analysis, dimensionality reduction, reinforcement learning and deep learning. Letter grading. Mr. Doleck (F,W,Sp)

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) Formerly numbered Electrical Engineering M153) (Same as Bioengineering M153, Mechanical Engineering M153, and Aerospace Engineering M183B) Lecture, three hours; laboratory; four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to general manufacturing methods, mechanisms, constraints, and micromanufacturing. Overview of historical and modern processes and their applications to manufacturing and fabrication methods, mechanisms, constrains, and micromanufacturing. Focus on controlling transport phenomena, micromachining, and nanofabrication. Focus on the design of manufac

163A. Introductory Microwave Circuits. (4) Formerly numbered Electrical Engineering 163A) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101B. Theory and design of microwave components for communication systems, radar systems, wireless sensors, and biological applications of microwaves. Letter grading. Mr. Itoh, Mr. Jalali (W)

163DA. Microwave and Wireless Design I. (4) Formerly numbered Electrical Engineering 163DA) Lecture, one hour; laboratory; three hours; outside study, eight hours. Enforced requisites: courses 101A, 101B, 163DA is enforced requisite to 163DB. Limitations to senior Electrical Engineering majors. Design of radio frequency transceivers and their building blocks according to given specifications or in form of open-ended problems. Introduction to advanced topics related to projects through lecture and laboratories. Creation by students of end-to-end systems in application context, managing trade-offs across subsystems while meeting constraints and optimizing metrics related to cost, performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations of project results required. Letter grading. Mr. Y.E. Wang (Sp)

163DB. Microwave and Wireless Design II. (4) Formerly numbered Electrical Engineering 163DB) Lecture, one hour; laboratory; three hours; outside study, eight hours. Enforced requisites: courses 101A, 101B, 163DA is enforced requisite to 163DB. Limitations to senior Electrical Engineering majors. Design of radio frequency circuits and systems, with emphasis on both theoretical foundations and hands-on experience. Design of radio frequency transceivers and their building blocks according to given specifications or in form of open-ended problems. Introduction to advanced topics related to projects through lecture and laboratories. Creation by students of end-to-end systems in application context, managing trade-offs across subsystems while meeting constraints and optimizing metrics related to cost, performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations of project results required. Letter grading. Mr. Y.E. Wang (Sp)

164DA-164DB. Radio Frequency Design Project I, II. (4-4) Formerly numbered Electrical Engineering 164DA-164DB) Lecture, one hour; laboratory; three hours; outside study, six 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, managing trade-offs across subsystems while meeting constraints and optimizing metrics related to cost, performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations of project results required. Letter grading. Mr. Y.E. Wang (Sp)

Electrical and Computer Engineering / 95
of materials, optical wave propagation and modes, optical interferometers and resonators, optical couplings and absorption, principles of lasers and light-emitting diodes, and optical detection. Letter grading. Mr. Liu (FW)

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

170C. Photonic Sensors and Solar Cells. (4) (Formerly numbered Electrical Engineering 170C.) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: course 170A. Recommended: courses 2, 170A. Fundamentals of detection of light. Mr. Stafuddi (173DA in F; 173DB in W)

173DA-173DB. Photonics and Communication Design. (4-4) (Formerly numbered Electrical Engineering 173DA-173DB.) Lecture, one hour; laboratory, four hours; outside study, two to four hours. Recommended preparation: course M116L. Limited to seniors. Not open to students with credit for course M117. Interpretation of analog-signaling aspects in digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, where students have their own, design, and terminal characteristics, and interfaces. Letter grading. Mr. Jalali (Not offered 2019-20)

173DA. Photonics in Biomedical Applications. (4) (Formerly numbered Electrical Engineering 173.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course M11A. Study of different types of optical systems and their physics background. Examination of their roles in current and projected biomedical applications. Specific capabilities of photonics to be related to each example. Letter grading. Mr. Ozcan (Sp)

180DA-180DB. Systems Design. (4-4) (Formerly numbered Electrical Engineering 180DA-180DB.) Limited to senior Electrical Engineering majors. Advanced systematic communication, control, and signal processing subsystems. Introduction to advanced topics related to projects through lecture and laboratories. Open-ended projects vary each offering. Student teams create high-performance designs that manage trade-offs among subsystem components, including cost, performance, ease of use, and other real-world constraints. Oral and written presentation of project results. 180DA. Lecture, two hours; laboratory, four hours; outside study, six hours. In Progress grading (credit to be given only on completion of course 180BD). 180DB. Laboratory, four hours; outside study, eight hours. Enforced requisite: course 180DA. Completion of projects begun in course 180BD. Letter grading. Mr. Kaiser, Mr. Pottie (180DA in F; 180BD in W)

CM182. Science, Technology, and Public Policy. (4) (Formerly numbered Electrical Engineering M182.) (Same as Public Affairs M164 and Public Policy CM182.) Lecture, three hours. Recent and continuing advances in science and technology are raised in terms of their societal impact and public issues. Consideration of selection of critical policy issues, each of which has substantial ethical, social, economic, political, scientific, and technological aspects. Course routinely scheduled with courses 189 and 289. Letter grading. Mr. Villasenor (W)

183DA. Design of Robotic Systems I. (4) (Formerly numbered Electrical Engineering 183DA.) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisite: course 102. Recommended: courses 141, 142. Course 183DA is requisite to 183DB. Enforced requisite: course 170A. Limited to senior Electrical Engineering majors. Topics in robotic design include integrated electronics, mechanical 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 dynamic motion planning, planning and adaptation, and human-robot interaction. Additional topics may include distributed and multi-robot systems, bio-inspired robotics, physical modeling, and societal implications. Open-ended projects vary annually. Student teams create and analyze robotic systems for various applications. Oral and written presentation of projects required. In Progress grading (credit to be given only on completion of course 183BD). Mr. Mehta (W)

183DB. Design of Robotic Systems II. (4) (Formerly numbered Electrical Engineering 183DB.) Laboratory, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 183DA. Recommended: courses 141, 142. Limited to senior Electrical Engineering majors. Topics in robotic design include integrated electro-mechanical 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 dynamic motion and path planning, learning and adaptation, and human-robot interaction. Additional topics may include distributed and multi-robot systems, bio-inspired robotics, physical modeling, and societal implications. Open-ended projects vary annually. Student teams create and analyze robotic systems for various applications. Oral and written presentation of project results. Letter grading. Mr. Mehta (W)

184A-184DB. Independent Group Project Design. (2-2) (Formerly numbered Electrical Engineering 184A-184DB.) Laboratory, five hours; discussion, one hour; enforced requisite: courses M116, 110L. Course 184DA is enforced requisite to 184DB. Courses centered on group project that runs year long to give students intensive experience on hardware design, microcontroller programming, and project coordination. Several projects include autonomous ro-200bots 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 computer-aided design and amplifier-based design, microcontroller programming, feedback control, actuation, and motor control. In Progress (184DA) and letter (184DB) grading. Mr. Briggs (Not offered 2019-20)

M185. Introduction to Plasma Electronics. (4) (Formerly numbered Electrical Engineering M185S.) (Same as Physics M122.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 101A or Physics M101. Course introduces basic operational principles of LC oscillators and transistors, device characteristics and plasma circuit and signal processing techniques. Parallel physical electric devices and circuits. Letter grading. Mr. Mori (F)

188. Special Courses in Electrical Engineering. (4) (Formerly numbered Electrical Engineering 188S.) Lecture, four hours; recitation, one hour; outside study, eight hours. Special topics in electrical engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. Mr. Kaiser, Mr. Pottie (F)

189. Advanced Honors Seminars. (1) Seminar, three hours. Limited to 20 students. Designed as adjunct to undergraduate lecture course. Exploration of topics in greater depth than lecture and discussion. Readings, papers, or other activities and led by lecture instructor. May be applied toward honors credit for eligible students. Honors content noted on transcript: course 189 and letter grade (W).

194. Research Group Seminars: Electrical Engineering. (2 to 4) (Formerly numbered Electrical Engineering 194.) 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. (FWSp)

199. Directed Research in Electrical Engineering. (2 to 8) (Formerly numbered Electrical Engineering 199.) Seminar, to be arranged by resident and/or visiting faculty members. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or equivalent required. Course 199 is open only with instructor approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (FWSp)

Graduate Courses

201A. VLSI Design Automation. (4) (Formerly numbered Electrical Engineering 201A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 115C. Fundamentals of design automation of VLSI circuits and systems, including introduction to circuit and system platforms such as field programmable gate arrays and multicore systems; high-level synthesis, logic synthesis, and technology mapping; physical design; and testing and verification. Letter grading. Mr. Gupta (Sp)

201C. Modeling of VLSI Circuits and Systems. (4) (Formerly numbered Electrical Engineering 201C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 115C. Detailed study of VLSI circuit and system models considering performance, signal integrity, power and thermal ef- fects, manufacturability, and technology mapping and verification. Course 201C is recommended for students interested in principles of modeling and optimization codevelopment. Letter grading. Mr. He (W)

201D. Design in Nanoscale Technologies. (4) (Formerly numbered Electrical Engineering 201D.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 115C. Challenges of digital circuit design and layout in deeply scaled technologies, with focus on design-manufacturing interactions. Sum- mary of large-scale digital design flow; basic manu- facturing flow; lithographic patterning, resolution en- hancement, and mask preparation; yield and varia- tion modeling; circuit reliability and aging issues; design rules and their origins; layout design for manu- facturing; test structures and process control; circuit ans architecture methods for variability mitigation. Letter grading. Mr. Gupta (Not offered 2019-20)

202A. Embedded Systems. (4) (Formerly numbered Electrical Engineering M202A.) Lecture, one hour; discussion, one hour; outside study, seven hours. Enforced requisite: course 115C. Challenges of digital circuit design and layout in deeply scaled technologies, with focus on design-manufacturing interactions. Sum-
M202B. Energy-Aware Computing and Physical Systems. (4) (Formerly numbered Electrical Engineering M202B.) (Same as Computer Science M213B.) Lecture; four hours; outside study, eight hours. Preparation: graduate level linear algebra and elementary computer architecture. Examination of the impact of physical parameters on design and energy consumption in modern computing systems. Physical phenomena underlying power dissipation and system performance. Energy efficiency trends and activities in cutting-edge research and industry. May be repeated for credit with the consent of the instructor, change in the technological context, or new content. Letter grading. (Not offered 2019-20)

209AS. Special Topics in Circuits and Embedded Systems. (4) (Formerly numbered Electrical Engineering 209AS.) Lecture, four hours; discussion, one hour; outside study, seven hours. Special topics in one or more aspects of circuits and embedded systems, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication circuits and systems; and embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with the consent of the instructor. S/U or letter grading. (Not offered 2019-20)

209BS. Seminar: Circuits and Embedded Systems. (2 to 4) (Formerly numbered Electrical Engineering 209BS.) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of circuits and embedded systems, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication circuits and systems; and embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with the topic change. S/U or letter grading. Letter grading. (Not offered 2019-20)


211A. Digital Image Processing I. (4) (Formerly numbered Electrical Engineering 211A.) Lecture, three hours; discussion, one hour; laboratory, four hours; outside study, four hours. Preparation: computer programming experience. Required requisites: courses 211A and 221A. Image processing theory and techniques. Topics include two-dimensional linear system theory, image transforms, and enhancement. Concepts covered in lecture applied in computer laboratory assignments. Letter grading. (Not offered 2019-20)


214A. Digital Speech Processing. (4) (Formerly numbered Electrical Engineering 214A.) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, seven hours. Required course: 211A. Theory and applications of digital processing of speech signals. Mathematical models of human speech production and perception mechanisms. Speech analysis and synthesis techniques include linear prediction, filter-bank models, and morphemic filtering. Applications to speech synthesis, automatic recognition, and hearing aids. Letter grading. (Not offered 2019-20)


215C. Analysis and Design of RF Circuits and Systems. (4) (Formerly numbered Electrical Engineering 215C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Required course: 215A. Principles of RF circuit and system design, with emphasis on miniaturized receivers and transmitters. Basic concepts, communications background, transceiver architectures, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading. (Formerly numbered Electrical Engineering 215B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Required courses: 115C, 215A. Analysis and comparison of modern logic families and memories. Neural networks. Accuracy of various simulation models and simulation methods for digital circuits. Letter grading. (Not offered 2019-20)


216A. Design of VLSI Circuits and Systems. (4) (Formerly numbered Electrical Engineering 216A.) Lecture, four hours; discussion, two hours; laboratory, four hours; outside study, two hours. Preparation: courses M16 or Computer Science M51A, and 115A. Recommended: course 215C. Design and application in
221C. Microwave Semiconductor Devices. (4) (Formerly numbered Electrical Engineering 221C.) Lecture, one hour, outside study, eight hours. Requisites: course 223. Fundamental synthesis and design techniques of microwave semiconductor devices, including design and optimization of active devices; noise and linearity considerations of FETs and HEMTs. Letter grading. Mr. Yao (Not offered 2019-20)

222. Integrated Circuits Fabrication Processes. (4) (Formerly numbered Electrical Engineering 222.) Lecture, four hours; discussion, one hour. Requisites: courses 221A, 221B. Topics: electronic devices, materials, processing technologies, and circuit layouts. Letter grading. Mr. K.L. Wang, Mr. Yeo (Not offered 2019-20)

223. Solid-State Electronics I. (4) (Formerly numbered Electrical Engineering 223.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisites: course 221A, 221B. Conduction and transport of charge carriers in solids, band theory, materials, and devices. Letter grading. Mr. M. Rubin (Not offered 2019-20)

224. Solid-State Electronics II. (4) (Formerly numbered Electrical Engineering 224.) Lecture, four hours; outside study, eight hours. Requisites: course 223. Topics include fabrication processes, energy bands, the periodic potential, and Bloch's theorem. Letter grading. Mr. K.L. Wang (F)

225. Physics of Semiconductor Nanostructures and Devices. (4) (Formerly numbered Electrical Engineering 225.) Lecture, four hours; outside study, eight hours. Requisites: courses 221A, 221B. Physical, electrical, and electronic properties of quantum wire, quantum dot, and quantum well semiconductor nanostructures. Letter grading. Mr. M. Rubin (W)

229. Seminar: Advanced Topics in Solid-State Electronics. (2) (Formerly numbered Electrical Engineering 229S.) Seminar, two hours; outside study, six hours. Preparatory work: successful completion of PhD major field examination. Seminar on current research topics in solid-state and quantum electronics (Section 1) or in electronic circuit theory and applications (Section 2). Students report on tutorial topic and research topic in their dissertation area. May be repeated for credit. S/U grading. (Not offered 2019-20)

229S. Advanced Electrical Engineering Seminar. (2) (Formerly numbered Electrical Engineering 229S.) Seminar, two hours; outside study, six hours. Preparation: successful completion of PhD major field examination. Seminar on current research topics in solid-state and quantum electronics (Section 1) or in electronic circuit theory and applications (Section 2). Students report on tutorial topic and research topic in their dissertation area. May be repeated for credit. S/U grading. (Not offered 2019-20)

230A. Detection and Estimation in Communication. (4) (Formerly numbered Electrical Engineering 230A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 131A. Applications of estimation and detection concepts in communication and signal processing; random signal and noise characteristics by analysis and simulations; mean square (MS) and maximum likelihood (ML) estimations and algorithms; detection under ML, Bayes, and Neyman-Pearson (NP) criteria; signal-to-noise ratio (SNR) and error probability evaluations. Introduction to Monte Carlo simulations. Letter grading. Mr. Yeo (F)


230C. Signal Processing in Communications. (4) (Formerly numbered Electrical Engineering 230C.) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 230A. Concepts and implementations of signal processing in communication and signal processor design. Spectral analysis using Fourier transform and windowing, parametric modeling, eigen-decomposition methods, time-frequency analysis, wavelet transform, and sub-band processing. Array processing using beamforming for SNIR enhancement, smart antenna, and source separation and localization. Introduction to compressive sampling and applications. Letter grading. Mr. Yao (Not offered 2019-20)

230D. Algorithms and Processing in Communication Systems. (4) (Formerly numbered Electrical Engineering 230D.) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 230A. Review of traditional linear adaptive algorithms, RLS, LMS, gradient, and singular-value decompositions, and LS estimation with applications to estimation and detection in communication, radar, speech, image, and array processing systems. Selected topics in optimal algorithms and VLSI architectures for high performance and high throughput real-time estimation, detection, decoding, and beamforming applications. Letter grading. Mr. Yao (Not offered 2019-20)

231A. Information Theory: Channel and Source Coding. (4) (Formerly numbered Electrical Engineering 231A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 131A. Fundamentals of information compression, transmission, processing, and learning. Topics include limits and algorithms for lossless data compression, source coding, rate distortion, channel capacity, rate versus distortion in lossy compression, and basics of information theory for network. Letter grading. Mr. Diggavi (Sp)

231B. Network Information Theory. (4) (Formerly numbered Electrical Engineering 231B.) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 230A. Review of traditional linear adaptive algorithms, RLS, LMS, gradient, and singular-value decompositions, and LS estimation with applications to estimation and detection in communication, radar, speech, image, and array processing systems. Selected topics in optimal algorithms and VLSI architectures for high performance and high throughput real-time estimation, detection, decoding, and beamforming applications. Letter grading. Mr. Diggavi (Sp)

231E. Coding Theory. (4) (Formerly numbered Electrical Engineering 231E.) Lecture, four hours; outside study, eight hours. Requisites: course 131A. Fundamentals of error control codes and decoding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading. Mr. Wesel (Not offered 2019-20)

232A. Stochastic Models with Applications to Telecommunication Systems. (4) (Formerly numbered Electrical Engineering 232A.) Lecture, four hours; outside study, eight hours. Requisites: courses 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 with application to balking, semi-Markov and semi-regenerative stochastic processes. Decision and reward processes. Applications to traffic and queueing analysis of basic telecommunication and computer computer communications, internet, and management systems. Letter grading. Mr. Rubin (Not offered 2019-20)


261. Microwave and Millimeter Wave Circuits. (Formerly numbered Electrical Engineering 261.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 163A. Rectangular and circular microstrip circuits. Microstrip measurement. Gain, noise, and dielectric waveguide distributed circuits, with applications in microwave and millimeter wave integrated circuits. Substrate materials, surface wave phenomena. Analytical methods for discontinuity effects. Design of passive microwave and millimeter wave circuits. Letter grading. Mr. Itoh (W)


266. Computational Methods for Electromagnetics. (Formerly numbered Electrical Engineering 266.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 162A, 163A. Computational techniques for partial differential and integral equations: finite-difference, finite-element, method of moments. Applications include transmission line resonators, integrated circuits, solid-state device modeling, electromagnetic scattering, and antennas. Letter grading. Mr. Itoh (Not offered 2019-20)

270. Applied Quantum Mechanics. (Formerly numbered Electrical Engineering 270.) Lecture, four hours; discussion, seven hours. Preparation: modern physics (or course 123A), linear algebra, and ordinary differential equations courses. Principles of quantum mechanics for applications in lasers, solid-state physics, and nonlinear optics. Topics include eigenfunction expansions, observables, Schrödinger equation, uncertainty principle, central force problems, Hilbert spaces, Workbook approximation, matrix mechanics, density matrices, and radiation theory. Letter grading. Mr. Stafiej (F)

271. Classical Laser Theory. (Formerly numbered Electrical Engineering 271.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisites: course 170A. Microscopic and macroscopic laser phenomena and propagation of optical pulses using classical formalism. Letter grading. Mr. Josh (W)


274. Optical Communication and Sensing Design. (Formerly numbered Electrical Engineering 274.) Lecture, three hours; outside study, nine hours. Requisites: courses 170A and 170B or equivalent. 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. Application of fiber optic transceiver circuits, including preamplifier, quantizer, clock and data recovery, laser driver, and predistortion circuits. Letter grading. Mr. Jalali (Sp)

279AS. Special Topics in Physical and Wave Electronics. (4) (Formerly numbered Electrical Engineering 279AS.) Lecture, four hours; discussion, on hour; outside study, seven hours. Special topics in one or more aspects of physical and wave electronics, such as electromagnetic devices 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 (W,Sp)

279BS. Seminar: Physical and Wave Electronics. (2 to 4) (Formerly numbered Electrical Engineering 279BS.) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of physical and wave electronics, such as electromagnetic devices 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 2019-20)

279CS. Green IGERT Brown-Bag Seminar. (1) (Formerly numbered Electrical Engineering 279CS.) Seminar, one hour. Required of students in Course None (Green Industry IGERT) Research. Literature presented by graduate students and experts from around country who conduct research in energy harvest, storage, and conservation. S/U grading. Mr. Kao (W,Sp)

CM282. Science, Technology, and Public Policy. (Formerly numbered Electrical Engineering CM282.) (Same as Public Policy CM282.) Lecture, three hours. Recent and continuing advances in science and technology are rapidly changing public policy issues. Consideration of selection of critical policy issues, each of which has substantial ethical, social, economic, political, scientific, and
Scope and Objectives
At the heart of materials science and engineering is the understanding and control of the microstructure of solids. Microstructure is used broadly in reference to electronic and atomic structure of solids—and defects within them—at size scales ranging from atomic bond lengths to airplane wings. The structure of solids over this wide range dictates their structural, electrical, biological, and chemical properties. The phenomenological and mechanistic relationships between microstructure and the macroscopic properties of solids are, in essence, what materials science is all about.

Materials engineering builds on the foundation of materials science and is concerned with the design, fabrication, and optimal selection of engineering materials that must simultaneously fulfill dimensional, property, quality control, and economic requirements.

The undergraduate program in the Department of Materials Science and Engineering leads to the B.S. degree in Materials Engineering. Students are introduced to the basic principles of metallurgy and ceramic and polymer science as part of the department’s Materials Engineering major. A joint major field, Chemistry/Materials Science, is offered to students enrolled in the Department of Chemistry and Biochemistry (College of Letters and Science).

The department also has a program in electronic materials that provides a broad-based background in materials science, with opportunity to specialize in the study of those materials used for electronic and optoelectronic applications. The program incorporates several courses in electrical and computer engineering in addition to those in the materials science curriculum.

The graduate program allows for specialization in one of the following fields: ceramics and ceramic processing, electronic and optical materials, and structural materials.

Department Mission
The Department of Materials Science and Engineering faculty members, students, and alumni foster a collegial atmosphere to produce (1) highly qualified students through an educational program that cultivates excellence, (2) novel and highly innovative research that advances basic and applied knowledge in materials, and (3) effective interactions with the external community through educational outreach, industrial collaborations, and service activities.

Undergraduate Program
Educational Objectives
The materials engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The Materials Engineering major at UCLA prepares undergraduate students for employment and/or advanced studies within industry, the national laboratories, state and federal agencies, and academia. To meet the needs of these constituencies, the objectives of the undergraduate program are to produce graduates who (1) possess a solid foundation in materials science and engineering, with emphasis on the fundamental scientific and engineering principles that govern the microstructure, properties, processing, and performance of all classes of engineering materials, (2) understand materials processes and the application of general natural science and engineering principles to the analysis and design of materials systems of current and/or future importance to society, (3) have strong skills in independent learning, analysis, and problem solving, with special emphasis on design of engineering materials and processes, communication, and an ability to work in teams, and (4) understand and are aware of the broad issues relevant to materials, including professional and ethical responsibilities, impact of materials engineering on society and environment, contemporary issues, and need for lifelong learning.

Undergraduate Study
The Materials Engineering major is a designated capstone major. Students undertake two individual projects involving materials selection, treatment, and serviceability. Successful completion requires working knowledge of physical properties of materials and strategies and methodologies of using materials properties in the materials selection process. Students learn and work independently and practice leadership and teamwork in and across disciplines. They are also expected to communicate effectively in oral, graphic, and written forms.

Materials Engineering B.S.
Capstone Major
The materials engineering program is designed for students who wish to pursue a professional career in the materials field and desire a broad understanding of the relationship between microstructure and properties of materials. Metals, ceramics, and polymers, as well as the design, fabrication, and testing of metallic and other materials such as oxides, glasses, and fiber-reinforced composites, are included in the course contents.
Learning Outcomes
The Materials Engineering major has the following learning outcomes:

- 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 Science and Engineering / 103
Materials Science and 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 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 111, C112, 143A, or 162.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE- Requirement.

Electronic Materials Option
Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20; Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B (or Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C.

The Major
Required: Electrical and Computer Engineering 100, 101A, 121B, Materials Science and Engineering 104, 110, 110L, 120, 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 111, C112, 143A, or 162.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE- Requirement.

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

The following introductory information is based on 2019-20 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

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

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

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

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

Ceramics and ceramic processing: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, 211, 246D, 298.

Electronic and optical materials: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, 221, 222, 223, 298.

Structural materials: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, 211, 243A, 243C, 250B, 298.

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

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 133A, M171L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Thesis Plan
In addition to the course requirements, under the thesis plan students are required to
write a thesis on a research topic in materials science and engineering supervised by the thesis adviser. An M.S. thesis committee approves the thesis.

Comprehensive Examination Plan
Consult the graduate adviser for details. If the comprehensive examination is failed, students may be reexamined once with the consent of the graduate adviser.

Materials Science and Engineering Ph.D.

Major Fields or Subdisciplines
Ceramics and electronic and optical materials, and structural materials.

Course Requirements
There is no formal course requirement for the Ph.D. degree, and students may substitute coursework by examinations. Normally, however, students take courses to acquire the knowledge needed to satisfy the written preliminary examination requirement. In this case, a grade-point average of at least 3.33 in all courses is required, with a grade of B– or better in each course.

The basic program of study for the Ph.D. degree is built around one major field and one minor field. The major field has a scope corresponding to a body of knowledge contained in nine courses, at least six of which must be graduate courses, plus the current literature in the area of specialization. Materials Science and Engineering 599 may not be applied toward the nine-course total. The major fields named above are described in a Ph.D. major field syllabus, each of which can be obtained in the department office.

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

Written and Oral Qualifying Examinations
During the first year of full-time enrollment in the Ph.D. program, students take the oral preliminary examination that encompasses the body of knowledge in materials science equivalent to that expected of a bachelor’s degree. If students opt not to take courses, a written preliminary examination in the major field is required. Students may not take an examination more than twice.

After passing both preliminary examinations, students take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. Faculty members holding joint appointments with the department are considered inside members.

Fields of Study

Ceramics and Ceramic Processing
The ceramics and ceramic processing field is designed for students interested in ceramics and glasses, including electronic materials. As in the case of metallurgy, primary and secondary fabrication processes such as vapor deposition, sintering, melt forming, or extrusion strongly influence the microstructure and properties of ceramic components used in structural, electronic, or biological applications. Formal course and research programs emphasize the coupling of processing treatments, microstructure, and properties.

Electronic and Optical Materials
The electronic and optical materials field provides an area of study in the science and technology of electronic materials that includes semiconductors, optical ceramics, and thin films (metal, dielectric, and multilayer) for electronic and optoelectronic applications.

Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications that include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/ optical properties in these materials systems.

Structural Materials
The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.

Facilities
Facilities in the Materials Science and Engineering Department include:

- Ceramic Processing Laboratory
- Glass and Ceramics Research Laboratories
- Mechanical Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Microscopy laboratories with a transmission electron microscope (100 keV), access to several field-emission transmission electron microscopes (80–300 keV), and a scanning electron microscope equipped with a quantitative chemical/compositional analyzer, a stereo microscope, micro-cameras, and metallurgical microscopes
- Nano-Materials Laboratory
- Nondestructive Testing Laboratory
- Organic Electronic Materials Processing Laboratory
- Semiconductor and Optical Characterization Laboratory
- Thin Film Deposition Laboratory, including molecular beam epitaxy and wafer bonders
- X-Ray Diffraction Laboratory
- X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility

Faculty Areas of Thesis Guidance

Professors
Gregory P. Carman, Ph.D. (Virginia Tech, 1991) Electromagnetoeelasticity models and characterization, thin film shape memory, nanoscale multifunctional, magnetoelastics and piezoelectric materials
Jane P. Chang, Ph.D. (MIT, 1998) Materials processing, gas-phase and surface reaction, plasma enhanced chemistries, atomic layer deposition, chemical microelectromechanical systems, and computational surface chemistry
Yong Chen, Ph.D. (UC Berkeley, 1996) Nanoscale science and engineering, micro- and nanofabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits and systems
Bruce S. Dunn, Ph.D. (UCLA, 1974)
Synthesis and characterization of electrome-
charical materials, energy storage, sol-gel
materials and byproducts.

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

Mark S. Goorsky, Ph.D. (MIT, 1989)
Electronic materials processing, strain relax-
ation in epitaxial semiconductors and device
structures, high-resolution X-ray diffraction of
semiconductors, ceramics, and high-strength
alloys

Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engi-
nearly solids, mechanics of thin film and
interfaces, failure mechanisms and characteri-
sation of composite materials, ice mechanics

Yu Huang, Ph.D. (Harvard, 2003)
Nano-material fabrication and development,
bio-nano structures

System scaling technology, advanced pack-
aging 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

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

Suneel Kodambaka, Ph.D. (U. Illinois Urbana-
Champaign, 2006)
In situ microscopy, surface thermodynamics,
kinetics of crystal growth, phase transforma-
tions and chemical reactions, thin film physics

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

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

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

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

Dwight C. Streit, Ph.D. (UCLA, 1986)
Properties of electronic materials, characteri-
zation techniques, correlation of material and
device performance.

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

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoscale physics, materials and devices
nano-electronics, magnets and photonics,
nonlinear interactions of correlated devices and
nanosystems

Paul S. Weiss, Ph.D. (U. Berkeley, 1986)
Atomic-scale surface chemistry and physics,
 molecular devices, nanolithography, bio-
physics and neuroscience, nanometer-scale

electromotion and storage, surface interactions,
surface motion, dynamics, and direct mani-
pulation, extending capabilities of scanning
tunneling microscopy, molecular-scale con-
trol and measurement of composition and
properties in membranes

(MIT, 1990)
Processing, characterization, and controlled
delivery of biological molecules of bioerodible
polymers; design and fabrication of tissue
engineering scaffolds and precursor tissue
analog; tissue-material interactions and
dental biomaterials

Yahong Xie, Ph.D. (UCLA, 1986)
Physical properties and device application of
graphene and other van der Waals materials;
semiconductor physics, heterostructures, and
devices; epitaxy of semiconductor thin films;
nanofabrication

Jenn-Ming Yang, Ph.D. (U. Delaware, 1986)
Nanomechanical testing, nanostructured
materials, ceramic and ceramic matrix com-
posites, hybrid materials and composites,
material synthesis and processing

Yang Yang, Ph.D. (U. Massachusetts Lowell,
1992)
Organic and inorganic semiconductor materi-
als and devices with emphasis on solution
processes; fundamental understanding of
material properties; optoelectronic devices
(LEDs, PVs, TFT, sensors)

Professors Emeriti

Alan J. Ardell, Ph.D. (Stanford, 1964)
Irradiation-induced precipitation, high-tem-
perature deformation of solids, electron
microscopy, physical metallurgy of aluminium/
lithium alloys, precipitation hardening

David L. Douglas, Ph.D. (Ohio State, 1958)
Oxidation and sulfidation kinetics and mecha-
nisms, materials compatibility, defect struc-
tures, diffusion

John D. Mackenzie, Ph.D. (Imperial C. London,
England, 1954)
Glass science, ceramics, electrical properties
of amorphous materials, materials recycling

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

King-Ning Tu, Ph.D. (Harvard, 1968)
Kinetic processes in chemical reactions, metal-silicon
interfaces, electromigration, Pb-free intercon-
nects, 3D IC packaging

Associate Professor

Jaime Marian, Ph.D. (UC Berkeley, 2002)
Computational materials modeling and simu-
lation in solid mechanics, irrigation damage,
plasticity, phase transformations, thermody-
namics and kinetics of alloy systems, algo-
rithm and method development for bridging
time and length scales and parallel computing

Assistant Professors

Amartya Banerjee, Ph.D. (U. Minnesota, 2013)
Computational materials science, first principles
molecular dynamics and simulation of
novel materials, electronic materials, energy
materials, multiscale methods and algorithms,
mechanics of materials and structures, nu-
merical methods and scientific computation

Ximin He, Ph.D. (U. Cambridge, England, 2011)
Biologically inspired materials based on stim-
uli-responsive polymers and micro-/nano-
structure fabrication for applications in bio-
medicine, environment, and energy

Aaswath P. Raman, Ph.D. (Stanford, 2013)
Metamaterials, optical and photonic materials,
nanophotonics, plasmonics, thermal sciences,
energy systems, computational methods

Eric P. Bescher, Ph.D. (UCLA, 1987)
Advanced cementitious materials, sol-gel
materials, organic/inorganic hybrids

Sergey Prikhodko, Ph.D. (Kurdyumov Institute
for Metal Physics NASU, Ukraine, 1994)
Characterization of materials by means of
microscopes and spectroscopes

Magdalena Balonis-Sant, Ph.D. (U. Aberdeen,
Scotland, 2010)
Development of functional materials for
extending the service life of concrete infra-
structure, design of new cementation agents
with reduced CO2 footprint, conservation and
reinforcement of concrete structures

Marta Pozuelo, Ph.D. (Complutense U. Madrid,
Spain, 2004)
In situ nanomechanical characterization of
metallic materials

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 stu-
dents with credit for course 104. Introduction to basic
concepts of materials science and new materials vital
to advanced technology. Microstructural analysis and
various material properties discussed in conjunction
with such applications as biomedical sensors, pollu-
tion control, and microelectronics. Letter grading.

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

90L. Physical Measurement in Materials Engineer-
ing. (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.

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 have a minimum of 30 units
standing and enrolled in a minimum of 12 units (ex-
cluding this course). Individual contract required;
consult Undergraduate Research Center. May be re-
peated. P/NP grading.

Upper-Division Courses

Lecture, three hours; discussion, one hour; outside study,
eight hours. Requisites: Chemistry 20A, 20B, 20L,
Physics 1A, 1B. General introduction to different
types of materials used in engineering designs:
mets, ceramics, plastics, and composites, relation-
ship between structure (crystals and microstructure)
and properties of technological materials. Illustration
of their fundamental differences and their applica-
tions in engineering. Letter grading.

Mr. Dunn (F, W, Sp)

M105. Principles of Nanoscience and Nanotech-
ology. (Same as Engineering M101.) Lecture,
four hours; discussion, one hour; outside study,
seven hours. Enforced requisites: Chemistry 20A/
20B, Physics 1C. Introduction to basic concepts of
nanotechnology, including structure, properties, and
fabrication of technologically important nanoscale systems.
New phenomena that emerge in very small systems (typi-
cally with feature sizes below few hundred nanome-
110. Introduction to Materials Characterization A
   Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 104. Modern methods of materials characterization: fundamentals of crystallography, properties of X rays, X-ray scattering; powder method, Laue method; determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray spectroscopy; design of materials characterization procedures. Letter grading. 
   Mr. Kodambaka (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 scattering techniques; powder method, crystal structure determination, high-resolution X-ray diffraction methods, and special projects. Letter grading. 
   Mr. Goorsky (B)

111. Introduction to Materials Characterization B
   (Electron Microscopy). (4) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy; emissive and reflective modes; chemical analysis; electron optics of both instruments. Letter grading. 
   Mr. Kodambaka (W)

   Ms. Kakoulli (Sp)

120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 103 or 110 (or Chemistry 113A). Introduction to electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectrical 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. Structures of elemental and compound semiconductors. Electrical and optical properties, defect chemistry, and doping. Electronic materials analysis and characterization, including electrical, optical, and other techniques. Heterostructure band-gap engineering, development of new materials for optoelectronic applications. Letter grading. 
   Ms. Huang (Sp)

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

122. Principles of Electronic Materials Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced 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, LPE, and MBE; metals and dielectrics. Letter grading. 
   Mr. Goorsky (W)

130. Phase Relations in Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 104. Summary of thermodynamic laws, equilibrium, critical solutions, 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, eight hours. Enforced requisite: course 130 or Chemistry 110A. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectic decomposition, design of heat treatment processes of alloys, growth of intermediate phases, gas-solid reactions, design of oxidation-resistant alloys, recrystallization, and grain growth. Letter grading. 
   Mr. Dunn (W)

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 processes to study diffusion and interdiffusion, growth of intermediate phases, recrystallization, and grain growth in metals. Analysis of data. Comparison of results with theory. Letter grading. 
   Mr. Kodambaka (W)

   J-M. Yang (Sp)

134. Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 104, 130, 146. Introduction to ceramics and glasses being used as important materials of engineering such as processing techniques, and unique properties. Examples of design and control of properties for certain specific applications in engineering. Letter grading. 
   Mr. Dunn (F)

   Mr. Dunn (Not offered 2019-20)

   Mr. Dunn (Sp)

162. Electronic Ceramics. (4) Lecture, four hours; outside study, seven hours. Requisites: course 130, 146, Physics 1C. Utilization of ceramics in microelectronics; thick film and thin film resistors, capacitors, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics; ferromagnetic ceramics and devices, and computer-aided ceramic wave guide applications and design. Letter grading. 
   Mr. Dunn (Not offered 2019-20)

CM163. Electrochemical Processes. (4) Same as Chemical Engineering CM114.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 130 (or Mechanical and Aerospace Engineering 106A), Chemical Engineering 102B. Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes. Primary emphasis on fundamental approach to analyze electrochemical processes. Special topics include: anodic and cathodic processes on metal and semiconductor surfaces, electrodoposis, electroless deposition, electrolysis, fuel cells, aqueous and non-aqueous batteries, solid-state electrochemistry. May be concurrently scheduled with course CM263. Letter grading.

170. Engaging Elements of Communication: Oral Communication. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive oral presentation and communication skills provided by building on strengths of individual personal styles in creation of positive interpersonal relations. Skill set prepares students for different types of academic and professional presentation to audiences. Learning environment is highly supportive and interactive as it helps students creatively develop
Graduate Courses

200. Principles of Materials Science I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 120. Introduction to biomaterials, tissue engineering, and medical devices. Examination of materials and their applications in health care.


211. Introduction to Materials Characterization B (Electron Microscopy). (4) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: courses 104, 110. Characterization of microstructure and composition 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. Letter grading.

212. Cultural Materials Science II: Characterization Methods in Conservation of Materials. (4) Same as Conservation M212L.) Lecture, four hours; recitation, one hour; outside study, eight hours. Examination of materials and their applications in conservation and restoration.

213. Cultural Materials Science I: Analytical Imaging and Documentation in Conservation of Materials. (4) (Same as Conservation M213.) Lecture, two hours; laboratory, two hours. Basic and advanced techniques on digital photography, computer-aided recording tools, and scientific imaging to determine and document condition (defects) and technological features of archaeological and ethnographic materials. Development of basic theoretical knowledge on imaging and photonics technology and practical skills on conservation photo-documentation, analytical (forensic) photography, and advanced new imaging technologies. Letter grading.

214. 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 with topic or instructor change. Letter grading.

215. Cultural Materials Science Laboratory: Technical Study. (4) (Same as Conservation M215L.) Laboratory, four hours. Requisites: courses M215 (or M216) and one course from Conservation M260 through Conservation M264 (or Conservation M212) and Conservation M210 (or Conservation M210L). Research-based laboratory through object-based problem-solving approach in conservation materials science. Experimental techniques, characterization, and analysis 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.

216. Science of Conservation Materials and Methods I. (4) (Same as Conservation M216.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 120. Study of major physical and chemical principles affecting properties and performance of semiconductor materials. Topics include bonding, carrier statistics, band-gap engineering, optical and transport properties, semiconductor systems, and characterization.

220. Materials Science of Surfaces. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Examination of physics behind majority of modern thin film deposition technologies based on vapor phase transport. Basic vacuum technology and gas kinetics. Deposition methods used in high-technology applications. Theory and experimental details of physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition processes.

221. Science of Electronic Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Examination of physics behind majority of modern thin film deposition technologies based on vapor phase transport. Basic vacuum technology and gas kinetics. Deposition methods used in high-technology applications. Theory and experimental details of physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition processes.
243. Dislocations and Strengthening Mechanisms in Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 143A. Elastic and plastic behavior of crystals, geometry, mechanics, and interaction of dislocations, stacking faults, grain boundaries, and shear bands. Letter grading. Mr. Xie (F, odd years)

246A. Mechanical Properties of Nonmetallic Crystalline Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 160. Materials and environmental factors affecting mechanical properties of nonmetallic crystalline solids, including atomic bonding and structure, atomic-scale defects, microstructural features, residual stresses, properties of glasses and cermets, fatigue, stress corrosion cracking, and surface conditions. Letter grading. Mr. Dunn (W)

246B. Structure and Properties of Glass. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 160. Structure of amorphous solids and glasses. Conditions of glass formation and theories of glass structure. Mechanical, electrical, and optical properties of glass and relationship to structure. Letter grading. Mr. Dunn (W, even years)

246D. Electronic and Optical Properties of Ceramics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 160. Principles governing electronic properties of ceramic single crystals and glasses and effects of processing and microstructure on these properties. Electronic conduction, ferroelectricity, and photochromism. Magnetic properties of amorphous, and ultrasonic transmission. Unique application of ceramics. Letter grading. Mr. Dunn (Sp, even years)

247. Nanoscale Materials: Challenges and Opportunities. (4) Lecture, four hours; discussion, eight hours. Latest developments in the field of nanomaterials. Literature studies of up-to-date subjects in novel materials and their potential applications, including nanoscale materials and biomaterials. Letter grading. Ms. Huang (W)

248. Materials and Physics of Solar Cells. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Comprehensive introduction to materials and physics of photovoltaic cell, covering basic physics of semiconductors in photovoltaic devices, physical models of cell operation, characteristics and design of common types of solar cells, and approaches to increasing solar cell efficiency. Recent progress in solar cells, such as organic solar cell, thin-film solar cells, and multiple junction solar cells provided to increase student knowledge. Tour of research laboratory included. Letter grading. Mr. Y. Yang (Sp)


251. Chemistry of Soft Materials. (4) Lecture, four hours. Introduction to organic soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft materials: organic molecules, synthetic polymers, and biomolecules and biomaterials. Extensive discussion of structure-property relationship, spectrscopic and experimental techniques, and preparation methods for various soft materials. Letter grading. Mr. Pei (F)

252. Organic Polymer Electronic Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to organic electronic materials with emphasis on the material processing. Topics include conjugated polymers; highly doped, highly conducting polymers; applications as processable metals and in various electronic, optical, and electrochemical devices. Synthesis of semiconductor polymers for organic light-emitting diodes, solar cells, thin-film transistors. Introduction to emerging field of organic electronics. Letter grading. Mr. Pei (F)

261. Risk Analysis for Engineers and Scientists. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Topics include definition and fundamental concepts of risk, sociotechnical context of risk assessment and risk management, perception and personal risk taking, risk communication, risk regulation, and response. Letter grading. Mr. Dunn (Sp, even years)

271. Electronic Structure of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 130 (or Mechanical and Aerospace Engineering 105A), Chemical Engineering 102B. Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes. Primary emphasis on fundamental approach to analyze electrochemical processes. Specific topics include electrochemical reactions on metal and semiconductor surfaces, electrodeposition, electroless deposition, electrolysiss, fuel cells, aqueous and non-aqueous batteries, solid-state electrochemistry. Currently scheduled with course CM163. Letter grading.

270. Computer Simulations of Materials. (4) Lecture, four hours; discussion, eight hours. Introduction to modern methods of computational modeling in materials science. Topics include basic statistical mechanics, classical molecular dynamics, and Monte Carlo methods, with emphasis on understanding basic physical ideas and learning to design, run, and analyze computer simulations of materials. Use of examples from current literature to show how these methods can be used to study interesting phenomena in materials science. Hands-on computer experiments. Letter grading. Mr. Marian (F)

271. Electronic Structure of Materials. (4) Lecture, four hours; discussion, eight hours. Preparation: basic knowledge of quantum mechanics. Recommended prerequisite: course 250B. Introduction to modern first-principles electronic structure calculations for various types of modern materials. Properties of electrons and interatomic bonding in molecules, crystals, and liquids, with emphasis on practical methods for calculation and using it to calculate physical properties such as elastic constants, equilibrium structures, binding energies, vibrational frequencies, electronic band gaps and band structures 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 prerequisite: course 271. 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. Emphasis on how new physical phenomena emerge only in very small systems, using simple concepts from quantum mechanics and thermodynamics. Topics include structure, defects, 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 solutions, and proposed realizations of quantum computing. Discussion of current and future directions of this rapidly growing field using examples from modern scientific literature. Letter grading. Mr. Marian (F)

CM280. Introduction to Biomaterials. (4) (Same as Bioengineering CM278.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment requirements, and biocompatibility. Concurrently scheduled with course CM180. Letter grading. Mr. Wu (Not offered 2019-20)

282. Exploration of Advanced Topics in Materials Science and Engineering. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Researchers from leading research institutions around the world deliver lectures on advanced research topics in materials science and engineering. Student groups present summary previews of topics prior to lecture. Class discussions follow each presentation. May be repeated for credit. S/U grading. Mr. J.-M. Yang

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.


M297C. Composites Manufacturing. (4) (Same as Mechanical and Aerospace Engineering M297C.) Lecture, four hours; outside study, eight hours. Requisites: course 151, Mechanical and Aerospace Engineering 166C. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/compression molding, filament winding, pultrusion, resin transfer molding, automation, material removal and assembly, metal and ceramic matrix composites, quality assurance. Letter grading.

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate materials science and engineering students. Seminars may be organized in advanced technical fields. Approval from instructor may be required. Letter grading.

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employed as teaching 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,WSp)
Mechanical and Aerospace Engineering

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Timothy S. Fisher, Ph.D., Chair
H. Pirouz Kavehpour, Ph.D., Vice Chair
Chang-Jin (C.J) Kim, Ph.D., Vice Chair
Ajit K. Mal, Ph.D., Vice Chair

Professors
Mohamed A. Abdou, Ph.D.
Robert N. Candler, Ph.D.
Gregory P. Carman, Ph.D.
Yong Chen, Ph.D.
Pei-Yu Chiou, Ph.D.
Vijay K. Dhir, Ph.D.
Jeffrey D. Eldredge, Ph.D.
Timothy S. Fisher, Ph.D. (John P. and Claudia H. Schauerman Endowed Professor of Engineering)
 Rajit Gadhi, Ph.D.
 Nasr M. Ghoniem, Ph.D.
 Vijay Gupta, Ph.D.
 Dennis W. Hong, Ph.D.
 Tetsuya Iwasaki, Ph.D.
 Y. Sungtaek Ju, Ph.D.
 Ann R. Karagozian, Ph.D.
 H. Pirouz Kavehpour, Ph.D.
 Chang-Jin (CJ) Kim, Ph.D. (Volgenau Endowed Professor of Engineering)
 Adrienne G. Lavine, Ph.D.
 Xiaochun Li, Ph.D. (Raytheon Company Professor of Manufacturing Engineering)
 Kuo-Nan Liou, Ph.D.
 Ajit K. Mal, Ph.D.
 Robert T. M’Closkey, Ph.D.
 Ali Mosleh, Ph.D., NAE (Evalyn Knight Professor of Engineering)
 Jayathi Y. Murthy, Ph.D., Dean
 Laurent G. Pilon, Ph.D.
 Jacob Rosen, Ph.D.
 Jason L. Speyer, Ph.D. (Ronald and Valerie Sugar Endowed Professor of Engineering)
 Tsu-Chin Tsao, Ph.D.
 Xiaolin Zhong, Ph.D.

Professors Emeriti
Oddvar O. Bendiksen, Ph.D.
Ivan Catton, Ph.D. (Research Professor)
Peretz P. Friedmann, Sc.D.
James S. Gibson, Ph.D.
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor Emeritus of Aeronautics)
Robert E. Kelly, Sc.D.
J. John Kim, Ph.D. (Rockwell Collins Professor Emeritus of Engineering)
Anthony F. Mills, Ph.D.
D. Lewis Mingori, Ph.D.
Peter A. Monkewitz, Ph.D.
Philip F. O’Brien, M.S.
Lucien A. Schmit, Jr., M.S.
Owen I. Smith, Ph.D.
Richard Stern, Ph.D.
Russell A. Westmann, Ph.D.
Daniel C.H. Yang, Ph.D.

Scope and Objectives
The Department of Mechanical and Aerospace Engineering offers curricula in aerospace engineering and mechanical engineering at both the undergraduate and graduate levels. The scope of the departmental research and teaching program is broad, encompassing dynamics, fluid mechanics, heat and mass transfer, manufacturing and design, nanoelectromechanical and microelectromechanical systems, structural and solid mechanics, and systems and control. The applications of mechanical and aerospace engineering are quite diverse, including aircraft, spacecraft, automobiles, energy and propulsion systems, robotics, machinery, manufacturing and materials processing, microelectronics, biological systems, and more.

At the undergraduate level, the department offers accredited programs leading to B.S. degrees in Aerospace Engineering and in Mechanical Engineering. At the graduate level, the department offers programs leading to M.S. and Ph.D. degrees in Mechanical Engineering and in Aerospace Engineering. An M.S. in Manufacturing Engineering is also offered.

Department Mission
The mission of the Mechanical and Aerospace Engineering Department is to educate the nation’s future leaders in the science and art of mechanical and aerospace engineering. Further, the department seeks to expand the frontiers of engineering science and to encourage technological inno-
Undergraduate Program

Educational Objectives

The aerospace engineering and mechanical engineering programs are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

In consultation with its constituents, the Mechanical and Aerospace Engineering Department has set its educational objectives as follows: within a few years after graduation, the students will be successful in careers in aerospace or mechanical or other engineering fields, and/or in graduate studies in aerospace or mechanical or other engineering fields, and/or in further studies in other fields such as medicine, business, and law.

Undergraduate Study

The Aerospace Engineering and Mechanical Engineering majors are designated capstone majors. Within their capstone courses, Aerospace Engineering students are exposed to the conceptual and design phases for aircraft development and produce a structural design of a component, such as a lightweight aircraft wing. Mechanical Engineering students work in teams in their capstone courses to propose, design, analyze, and build a mechanical or electro-mechanical device. Graduates of both programs should be able to apply their knowledge of mathematics, science, and engineering in technical systems; design a system, component, or process to meet desired needs; function as productive members of a team; identify, formulate, and solve engineering problems; and communicate effectively, both orally and in writing.

Aerospace Engineering B.S.

Capstone Major

The aerospace engineering program is concerned with the design and construction of various types of fixed-wing and rotary-wing (helicopters) aircraft used for air transportation and national defense. It is also concerned with the design and construction of spacecraft, the exploration and utilization of space, and related technological fields.

Aerospace engineering is characterized by a very high level of technology. The aerospace engineer is likely to operate at the forefront of scientific discoveries, often stimulating these discoveries and providing the inspiration for the creation of new scientific concepts. Meeting these demands requires the imaginative use of many disciplines, including fluid mechanics and aerodynamics, structural mechanics, materials and aeroelasticity, dynamics, control and guidance, propulsion, and energy conversion.

Learning Outcomes

The Aerospace Engineering major has the following learning outcomes:

- Application of knowledge of mathematics, science, and engineering
- Function as a productive member of a team that considers multiple aspects of an engineering problem
- Design of a system, component, or process to meet desired needs
- Effective oral and written communication
- Identification, formulation, and solution of engineering problems

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A; Mechanical and Aerospace Engineering 1, M20 (or Computer Science 31), 82; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 150A, 157, 166A, 171A; two departmental breadth courses (Electrical and Computer Engineering 100 and Materials Science and Engineering 104—if one or both of these courses are taken as part of the technical breadth requirement, students must select a replacement upper-division course or courses from the department—except for Mechanical and Aerospace Engineering 156A—or, by petition, from outside the department); one of the following two tracks (16 units): aeronautics (150B, C150P, 154A, 154S) or space (C150R, 161A, 161B, 161C); three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Mechanical and Aerospace Engineering 157A); one major field elective course (4 units) from the track not chosen (150B or C150P, C150R or 161A) and one major field elective course (4 units) from Mechanical and Aerospace Engineering 150B, C150P, C150R, 154A, 154B, 154S, 161A, 161B, 161C (unless taken as a required course), or from 94, 131A, C131G, 133A, 135, 136, C137, C138, CM140, 150C, C150G, C150N, 154B, 161D, 162A, 166C, M168, M169A, 171B, 172, 174, C175A, 181A, 182B, 182C, 183A, M183B, C183C, 185, C186, C187L.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Mechanical Engineering

B.S.

Capstone Major

The mechanical engineering program is designed to provide basic knowledge in thermodynamics, fluid mechanics, heat transfer, solid mechanics, mechanical design, dynamics, control, mechanical systems, manufacturing, and materials. The program includes fundamental subjects important to all mechanical engineers.
Learning Outcomes

The Mechanical Engineering major has the following learning outcomes:

- Application of knowledge of mathematics, science, and engineering
- Function as a productive member of a team that considers multiple aspects of an engineering problem
- Design of a system, component, or process to meet desired needs
- Effective oral and written communication
- Identification, formulation, and solution of engineering problems

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A; Mechanical and Aerospace Engineering M20 (or Computer Science 31), 82, 94; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Electrical and Computer Engineering 110L, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 131A or 133A, 156A, 157, 162A, 171A, 183A (or M183B); two departmental breadth courses (Electrical and Computer Engineering 100 and Materials Science and Engineering 104—if one or both of these courses are taken as part of the technical breadth requirement, students must select a replacement upper-division course or courses from the department—except for Mechanical and Aerospace Engineering 166A—or, by petition, from outside the department); three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Mechanical and Aerospace Engineering 162D, 162E); and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 131A (unless taken as a required course), C131G, 133A (unless taken as a required course), 135, 136, C137, C138, CM140, 150A, 150B, 150C, C150G, C150P, C150R, 154A, 154B, 154S, 155, C156B, 157A, 161A through 161D, 166C, M168, 169A, 171B, 172, 174, C175A, 181A, 182B, 182C, 183A (unless taken as a required course), M183B (unless taken as a required course), C183C, 185, C186, C187L.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Graduate Study

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

The following introductory information is based on 2019-20 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

The Department of Mechanical and Aerospace Engineering offers the Master of Science (M.S.) degree in Manufacturing Engineering, Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Aerospace Engineering, and Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Mechanical Engineering.

All new M.S. and Ph.D. students who are pursuing an M.S. degree in the Mechanical and Aerospace Engineering Department must meet with their advisers in their first term at UCLA. The goal of the meeting is to discuss the students’ plans for satisfying the M.S. degree requirements. Students should obtain an M.S. planning form from the department Student Affairs Office and return it with their advisers’ signature by the end of the first term.

Aerospace Engineering M.S. and Mechanical Engineering M.S.

Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses (and 36 units) are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor’s degree may not be applied toward a graduate degree at UCLA. The courses should be selected so that the breadth requirements and the requirements at the graduate level are met. The breadth requirements are only applicable to students who do not have a B.S. degree from an ABET-accredited aerospace or mechanical engineering program.

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, M152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 133A, M171L, 199, Materials Science and Engineering 110, 120, 130, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Aerospace Engineering

Breadth Requirements. Students are required to take at least three courses from the following four categories: (1) Mechanical and Aerospace Engineering 154A or 154B or 154S, (2) 150B or C150P, (3) 155 or 166A or 169A, (4) 161A or 171A.

Mechanical Engineering

Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162D or 183A.

Comprehensive Examination Plan

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, or (3) take and pass three comprehensive examination questions offered in association with three mechanical and aerospace engineering graduate courses. Contact the department Student Affairs Office for more information.

Thesis Plan

The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Manufacturing Engineering M.S.

Areas of Study

Consult the department.
Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses (and 36 units) are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor’s degree may not be applied toward a graduate degree at UCLA. Choices may be made from the following major areas:

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M165L, M133A, M171L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 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 263A, 262C, 263D, C296A, M297C.

Additional Courses. The remaining courses may be taken from other major fields of study in the department or from the following: Architecture and Urban Design 227D, Computer Science 241B, Management 241A, Management-PhD 241A, 241B, Mathematics 120A, 120B.

Comprehensive Examination Plan

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, or (3) take and pass three comprehensive examination questions offered in association with three graduate courses. Contact the department Student Affairs Office for more information.

Thesis Plan

The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students would normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Aerospace Engineering Ph.D. and Mechanical Engineering Ph.D.

Major Fields or Subdisciplines

Design, robotics, and manufacturing (mechanical engineering only); fluid mechanics; micro-nano engineering; structural and solid mechanics; systems and control; thermal science and engineering.

Ph.D. students may propose ad hoc major fields, which must differ substantially from established major fields and satisfy one of the following two conditions: (1) the field is interdisciplinary in nature or (2) the field represents an important research area for which there is no established major field in the department (condition 2 most often applies to recently evolving research areas or to areas for which there are too few faculty members to maintain an established major field).

Students in an ad hoc major field must be sponsored by at least three faculty members, at least two of whom must be from the department.

Course Requirements

The basic program of study for the Ph.D. degree is built around major and minor fields. The established major fields are listed above, and a detailed syllabus describing each Ph.D. major field can be obtained from the Student Affairs Office.

The program of study for the Ph.D. requires students to perform original research leading to a doctoral dissertation and to master a body of knowledge that encompasses material from their major field and breadth material from outside the major field. The body of knowledge should include (1) six major field courses, at least four of which must be graduate courses, (2) one minor field, (3) any three additional courses, at least two of which must be graduate courses, that enhance the study of the major or minor field.

The major field syllabus advises students as to which courses contain the required knowledge, and students usually prepare for the written qualifying examination (formerly referred to as the preliminary examination) by taking these courses. However, students can acquire such knowledge by taking similar courses at other universities or even by self-study.

The minor field embraces a body of knowledge equivalent to three courses, at least two of which must be graduate courses. Minor fields are often subsets of major fields, and minor field requirements are then described in the syllabus of the appropriate major field. Established minor fields with no corresponding major field can also be used, such as applied mathematics and applied plasma physics and fusion engineering. Also, an ad hoc field can be used in exceptional circumstances, such as when certain knowledge is desirable for a program of study that is not available in established minor fields.

Grades of B— or better, with a grade-point average of at least 3.33 in all courses included in the minor field, and the three additional courses mentioned above are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only).

Written and Oral Qualifying Examinations

After mastering the body of knowledge defined in the major field, students take a written qualifying (preliminary) examination covering this knowledge. Students must have been formally admitted to the Ph.D. program or admitted subject to completion of the M.S. degree by the end of the term following the term in which the examination is given. The examination must be taken within the first two calendar years from the time of admission into the Ph.D. program. Students must be registered during the term in which the examination is given and be in good academic standing (minimum GPA of 3.25). The student’s major field proposal must be completed prior to taking the examination. Students may not take an examination more than twice. Students in an ad hoc major field must pass a written qualifying examination that is approximately equivalent in scope, length, and level to the written qualifying examination for an established major field.

After passing the written qualifying examination, students take the University Oral Qualifying Examination within four calendar years from the time of admission into the Ph.D. program. The nature and content of the examination are at the discretion of the doctoral committee but include a review of the dissertation prospectus and
may include a broad inquiry into the student’s preparation for research.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department.

Fields of Study

Design, Robotics, and Manufacturing

The program is developed around an integrated approach to design, robotics, and manufacturing. It includes research on manufacturing and design aspects of mechanical systems, material behavior and processing, robotics and manufacturing systems, CAD/CAM theory and applications, computational geometry and geometrical modeling, composite materials and structures, automation and digital control systems, microdevices and nanodevices, radio frequency identification (RFID), and wireless systems.

Fluid Mechanics

The graduate program in fluid mechanics includes experimental, numerical, and theoretical studies related to a range of topics in fluid mechanics, such as turbulent flows, hypersonic flows, microscale and nanoscale flow phenomena, aeroacoustics, biofluid mechanics, chemically reactive flows, chemical reaction kinetics, numerical methods for computational fluid dynamics (CFD), and experimental methods. The educational program for graduate students provides a strong foundational background in classical incompressible and compressible flows, while providing elective breadth courses in advanced specialty topics such as computational fluid dynamics, microfluidics, biofluid mechanics, hypersonics, reactive flow, fluid stability, turbulence, and experimental methods.

Micro-Nano Engineering

The micro-nano engineering field focuses on science and engineering issues ranging in size from nanometers to millimeters and includes both experimental and theoretical studies covering fundamentals to applications. The study topics include microscience, top-down and bottom-up 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-thermo-mechanical 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 micro fabrication/nanofabrication.

Ad Hoc Major Fields

The ad hoc major fields program has sufficient flexibility that students can form academic major fields in their area of interest if the proposals are supported by several faculty members. Previous fields of study included acoustics, system risk and reliability, and engineering thermodynamics. Nuclear science and engineering, a former active major field, is available on an ad hoc basis only.

Centers, Facilities, and Laboratories

The Mechanical and Aerospace Engineering Department has a number of experimental centers, facilities, and laboratories at which both fundamental and applied research is being conducted. More information is at https://www.mae.ucla.edu.

Active Materials Laboratory

Gregory P. Carman, Director

The 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.

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 inter-vehicle modem communication.

Beam Control Laboratory

James S. Gibson, Director

The laboratory involves students, faculty, and postdoctoral scholars to develop novel methods for laser-beam control in applications including directed energy systems and laser communications. Algorithms developed at UCLA for adaptive and optimal control and filtering, as well as system identification, are being used in adaptive optics.
and beam steering. UCLA high-bandwidth controllers correct both higher-order wavefront errors and tilt jitter to levels not achievable by classical beam control methods.

**Biomechatronics Laboratory**  
Veronica J. Santos, Director  
The 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 laboratory performs research at the interface between robotics, biological systems, and medicine. Primary research fields are medical robotics and biorobotics including surgical robotics, and wearable robotics as they apply to human motor control, neural control, human- and brain-machine interfaces, motor control (stroke) rehabilitation, brain plasticity, haptics, virtual reality, tele-operation, and biomechanics (full-body kinematics and dynamics, and soft/hard tissues biomechanics).

**Boiling Heat Transfer Laboratory**  
Vijay K. Dhir, Director  
The laboratory performs experimental and computational studies of phase-change phenomena. It is equipped with various flow loops, state-of-the-art data acquisition systems, holography, high-speed imaging systems, and a gamma densitometer.

**Center for Advanced Multifunctional Materials and Systems (CAMMS)**  
Christopher S. Lynch, Director  
CAMMS is involved in all aspects of multifunctional (smart) materials characterization, modeling, and applications. Materials are characterized under combined mechanical, thermal, electrical, and magnetic loading. Constitutive laws are developed that govern domain switching and phase transformations. Component-level applications include miniature solid-state piezoelectric actuators; and nanoscale magneto-electric memory, antenna, and motors. Systems-level applications (team projects) include controlled optics for deep-space observing satellites, ultra-low-frequency magneto-mechanical antennas, morphing aircraft structures, and next-generation computer memory.

**Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS)**  
Gregory P. Carman, Director  
TANMS is a multi-institutional engineering research center (ERC) focused on research, technology translation, and education associated with magnetism on the small scale. The TANMS vision is to develop a fundamentally new approach that couples electricity to magnetism using engineered nanoscale multiferroic elements, to enable increased energy efficiency, reduced physical size, and increased power output in consumer electronics. This new approach overcomes scaling limitations present Oersted’s magnetism control discovery of 1820. TANMS goal is to translate its research discoveries to industry while seamlessly integrating a cradle-to-career education philosophy involving its students, and future engineers, in unique research and entrepreneurial experiences.

**Chen Research Group**  
Yong Chen, Director  
The group studies nanofabrication, nanoscale electronic materials and devices, micro-nano electronic/optical/bio/mechanical systems, and ultra-scale spatial and temporal characterization.

**Collaborative Center for Aerospace Sciences (CCAS)**  
Ann R. Karagozian, Director  
CCAS is a multi-/trans-disciplinary research center focused on fundamental and applied basic studies relevant to aerospace systems. Research projects that broadly span the computational and experimental arenas are conducted at UCLA and at Air Force Research Laboratory (AFRL/RQ) at Edwards Air Force Base northeast of campus. UCLA faculty, students, and postdoctoral researchers collaborate with AFRL scientists and engineers on high-impact problems to advance U.S. capabilities in aerospace systems.

**Complex Fluids and Interfacial Physics Laboratory**  
H. Pirouz Kavehpour, Director  
The laboratory is multidisciplinary, with areas of research ranging from rheology of biofluids to energy storage. The group is directed towards development of fundamental engineering and scientific knowledge.

**Cybernetic Control Laboratory (CyCLab)**  
Tetsuya Iwasaki, Director  
CyCLab aims to develop biologically inspired control theories for rhythmic movements and dynamic pattern formation with applications to robotic vehicles, devices for human assist, and rehabilitation.

**Design and Manufacturing Laboratory**  
The laboratory offers an environment for synergistic integration of design and manufacturing. Available equipment includes four CNC machines, two rapid-prototyping systems, coordinate measuring, X-ray radiography, robots with vision systems, audiovisual equipment, and a distributed network of more than 30 workstations.

**Energy and Propulsion Research Laboratory**  
Ann R. Karagozian, Director  
The laboratory involves the application of modern diagnostic methods and computational tools to the development of improved combustion, propulsion, and fluid flow systems. Research includes aspects of fluid mechanics, chemistry, optics, and numerical methods, as well as thermodynamics and heat transfer.

**Energy Innovation Laboratory**  
Richard E. Wirz, Director  
The laboratory investigates high-impact renewable energy science and technology. Its current work primarily focuses on large-scale thermal energy storage for grid-scale applications and advanced wind energy capture.

**Flexible Research Group**  
Jonathan B. Hopkins, Director  
The group is dedicated to the design and fabrication of flexible structures, mechanisms, and materials that achieve extraordinary capabilities. The laboratory is equipped with state-of-the-art synthesis tools, optimization software, and a number of commercial and custom-developed additive fabrication technologies for fabricating complex flexible structures at the macro- to nano-scale.

**Fusion Science and Technology Center**  
Mohamed A. Abdou, Director  
The center includes experimental facilities for conducting research in fusion science and engineering, and multiple scientific disciplines in thermonuclear and nuclear energy.
mechanics, heat/mass transfer, and materials interactions. The center includes experimental facilities for liquid metal magneto-hydrodynamic fluid flow, thick and thin liquid metal systems exposed to intense particle and heat flux loads, and metallic and ceramic material thermomechanics.

**Ho Systems Laboratory – Personalized Medicine**

Chih-Ming Ho, Director
The laboratory researches phenotypic personalized medicine (PPM). It has discovered that drug-dose inputs are correlated with phenotypic outputs with a parabolic response surface (PRS). With a few calibration tests to determine the coefficients of its quadratic governing algebraic equation, PRS dictates the composition and ratio of a globally optimized drug combination. Based on the PRS platform, phenotypic personalized medicine (PPM) can realize unprecedented adaptability to identify the optimized drug combination for a specific patient. PRS is an indication-agnostic and mechanism-free platform technology, which has been successfully demonstrated in about 30 diseases.

**Hu Research Laboratory (H-Lab)**

Yongjie Hu, Director
H-Lab is focused on understanding and engineering nanoscale transport phenomena and nanomaterials for wide applications including energy conversion, storage, and thermal management. The lab uses a variety of experimental and theoretical techniques to investigate nanoscale transport processes, with a particular emphasis on design and chemical synthesis of advanced materials, ultrafast optical spectroscopy, pulsed electronics, and thermal spectral mapping techniques.

**Laser Spectroscopy and Gas Dynamics Laboratory**

Raymond M. Spearrin, Director
The laboratory conducts research driven by applications in propulsion and energy, with extensions to health and environment. Lab activities are united by a core focus in experimental thermofluids and applied spectroscopy. Projects commonly span fundamental spectroscopy science to design and deployment of prototype sensors to investigate dynamic flow-fields.

**Materials Degradation Characterization Laboratory**

Ajit K. Mal, Director
The laboratory is used for characterization of the degradation of high-strength metallic alloys and advanced composites due to corrosion and fatigue, determination of adverse effects of materials degradation on the strength of structural components, and research on fracture mechanics and ultrasonic nondestructive evaluation.

**Materials in Extreme Environments Laboratory (MATRIX)**

Nasr M. Ghoniem, Director
MATRIX seeks answers to two fundamental questions: What are the physical phenomena that control the mechanical properties of engineering materials operating in extreme environmental conditions; and knowing such behavior, can we design engineering materials to be more resilient.

**M’Closkey Laboratory**

Robert T. M’Closkey, Director
The laboratory develops miniature, high-performance angular-rate sensors called vibratory gyroscopes. A separate long-term project seeks to understand the mixing dynamics of a jet injected into a cross-flow.

**Mechatronics and Controls Laboratory**

Tsu-Chin Tsao, Director
The 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 laboratory is equipped with a fume hood, clean air bench, optical table, DI water generator, plating setup, probe station, various microscopes, test and measurement systems, and CAD programs for mask layout. It is used for micromachining and MEMS research, and complements the UCLA Samueli Nanoelectronics Research Facility.

**Modeling of Complex Thermal Systems Laboratory**

Adrienne G. Lavine, Director
The 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. Pilone, Director
The 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.
Multiscale Thermosciences Laboratory (MTSL)
Y. Sungtaek Ju, Director
MTSL is focused on heat and mass transfer phenomena at the nano- to macro-scales. A wide variety of applications are explored, including novel materials and devices for energy conversion; combined cooling, heating, and power generation; thermal management of electronics and buildings; energy-water nexus; and biomedical MEMS/NEMS devices.

Nanoscale Transport Research Group
Timothy S. Fisher, Director
The group works on a broad range of problems, primarily involving transport processes by electrons, phonons, photons, and fluids. It seeks to solve problems with high importance to applications in energy transport, conversion, and storage, that are relevant to major industrial segments (aerospace, micro/nanoelectronics, and sensors). The lab solves these problems through a holistic, balanced approach that spans nanomaterial synthesis, basic material characterization and modeling, and functional characterization and simulation. The group includes the Center for Integrated Thermal Management of Aerospace Vehicles (CITMAV), which develops new solutions to highly transient transport problems that occur in aerospace applications.

Optofluidics Systems Laboratory
Pei-Yu Chiou, Director
The 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 group researches photobiological fuel production, mesoporous materials, electrochemical capacitors, waste heat energy harvesting, foams/microfoams, biomedicai optics, and energy efficiency.

Plasma and Beam Assisted Manufacturing Laboratory
The laboratory is an experimental facility for processing and manufacturing advanced materials by high-energy means (plasma and beam sources). It is equipped with plasma diagnostics, two vortex gas tunnel plasma guns, powder feeder and exhaust systems, vacuum and cooling equipment, high-power DC supplies (400kw), vacuum chambers, and large electromagnets. Current research is focused on ceramic coatings and nano-phase clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

Plasma and Space Propulsion Laboratory
Richard E. Citrin, Director
The laboratory investigates plasma processes related to advanced space propulsion systems using a combination of experimental, computational, and analytical perspectives. Its research is directly inspired by the rapidly emerging field of electric propulsion (EP). Other applications of its work include microplasmas, plasma processing, and fusion.

Robotics and Mechanisms Laboratory (RoMeLa)
Dennis W. Hong, Director
RoMeLa is a facility for robotics research and education with an emphasis on studying humanoid robots and novel mobile robot locomotion strategies. Research is in the areas of robot locomotion and manipulation, soft actuators, platform design, kinematics and mechanisms, and autonomous systems. RoMeLa is active in research-based international robotics competitions, winning numerous prizes including third place in the DARPA Urban Challenge. The laboratory also took first place in the RoboCup international autonomous robot soccer competition (kid-size and adult-size humanoid divisions), and was world champion five times in a row. It also brought the prestigious Louis Vuitton Cup Best Humanoid award to the U.S. for the first time, and most recently was one of six Track A teams chosen to participate in the DARPA Robotics Challenge disaster response robot competition.

Scifacturing Laboratory
Xiaochun Li, Director
The laboratory creates a creative, interdisciplinary platform for science-driven manufacturing (scifacturing) as the next level of manufacturing. It seeks to enable application of physics and chemistry to empower breakthroughs in manufacturing. The laboratory links molecular, nano-, and micro-scale knowledge to scalable processes/systems in manufacturing and materials processing. Current focus areas include scale-up nanomanufacturing, solidification nanomanufacturing of super-materials with dense nanoparticles, structurally integrated micro- and nano-systems (especially sensors and actuators) for manufaturing, clean energy and biomedical manufacturing, meso/micro 3D printing, and laser materials processing.

Smart Grid Energy Research Center (SMERC)
Rajit Gadh, Director
SMERC performs research; creates innovations; and demonstrates advanced internet-of-things, sense-and-control technologies, and data-enabled machine learning to enable development of the next-generation electric utility grid—the smart grid. SMERC also furnishes thought leadership through its ESMPM 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 electric vehicle integration (G2V and V2G), automated demand response (ADR), microgrids, distributed energy resources, renewable integration, battery energy storage integration, and autonomous vehicle infrastructure.

Simulations of Flow Physics and Acoustics Laboratory (SOFIA)
Jeffrey D. Eldredge, Director
SOFIA 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 viscous streaming; the fluid dynamics of biological and biologically-inspired locomotion; interactions of fluid flows with flexible surfaces; transitiional and turbulent hypersonic boundary layer flows; vortex estimation techniques for autonomous control of formation flight; and new computational tools for simulation of biomedical flows.

Thermochemical Energy Storage Laboratory
Adrienne G. Lavine, Director
The laboratory is focused on use of reversible chemical reactions to store energy for renewable energy applications. The current focus is on ammonia synthesis for supercritical steam generation in a concen-
trating solar power plant. The ammonia synthesis reactor testing platform consists of three subsystems (dissociation, synthesis, and steam generation) that work in unison to create a closed-loop synthesis gas generator that can operate for an indefinite period of time.

**Thin Films, Interfaces, Composites, Characterization Laboratory**

Vijay Gupta, Director

The 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 polycapillary focusing equipment for microstructural characterization; for measurement and control study of thin film interface strength.

**Turbulence Research Group**

J. John Kim, Director

The group is primarily focused on the study of turbulence and stability. It has a long history of studying incompressible flow, and has recently begun studying compressible flow problems. All its work is carried out numerically with computational fluid dynamic (CFD) codes, which are written in-house. Its current research interests include real gas effects on compressible turbulent boundary-layer flow, drag reduction through the use of superhydrophobic surfaces on incompressible turbulent boundary-layer flow, and the effects of distributed roughness on compressible turbulent boundary-layer flows.

**Faculty Areas of Thesis Guidance**

**Professors**

Mohamed A. Abbou, Ph.D. (U. Wisconsin, 1973)

Fusion, nuclear and mechanical engineering, design, testing, and system analysis, thermal-mechanics; thermal hydraulics; fluid dynamics, heat, and mass transfer in the presence of magnetic fields (MHD flows); neutronics; radiation transport; plasma-matter interactions; blankets and high heat flux components; experiments, modeling and analysis

Robert H. Candler, Ph.D. (Stanford, 2006)

MEMS/NEMS for compact free-electron lasers, miniature medical devices, nanoscale magnetic structures and devices, additive manufacturing, fundamental limits of micro- and nanoscale devices

Gregory P. Carman, Ph.D. (Virginia Tech, 1991)

Electromagnetoelastodynamics models including micromagnetics, elastodynamics, and Maxwell coupled solutions. Characterization of piezoelectric ceramics, magnetostriiction shape memory alloys, and multiferroic materials.

Yong Chen, Ph.D. (UC Berkeley, 1996)

Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, microscale electronics, mechanical, optical, biological, and sensing devices, circuits and systems

Pei-Yu Chiou, Ph.D. (UC Berkeley, 2005)

BioMEMS, biophotonics, electrokinetics, optical manipulation, optoelectronic devices

Vijay K. Dhir, Ph.D. (U. Kentucky, 1972)

Two-phase heat transfer, boiling and condensation, thermal hydraulics of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling

Jeffrey D. Eldredge, Ph.D. (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, Ph.D. (Cornell, 1998)

Heat and mass transfer, interfacial transport, nanomaterial synthesis, nano- and micro-device fabrication, non-equilibrium thermodynamics, subcontinuum modeling and measurements of heat and mass transfer, electrochemistry, and thermal energy storage, mechanics and transport in granular materials and porous media, plasma science and technology, aerospace thermal systems


Smart grid, electric vehicle and grid integration, microgrid, distributed energy resource, solar- and renewable-grid integration, demand re-spense, autonomous electric vehicle, machine learning from transportation data, radio frequency identification (RFID), Internet of things

Naser M. Ghoniem, Ph.D. (U. Wisconsin, 1977)

Mechanics of materials in severe environments (nuclear, aerospace, transportation); radiation interaction with materials (e.g., laser, ions, plasma, electrons, and neutrons); multi-scale modeling; physics and mechanics of material defects; fusion energy; materials for space propulsion

Vijay Gupta, Ph.D. (MIT, 1989)

Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

Dennis W. Hong, Ph.D. (Purdue, 2002)

Analysis and visualization of contact force solution space for multi-legged mobile robots

Tetsuya Iwasaki, Ph.D. (Purdue, 1993)

Dynamical systems, robust and optimal controls, nonlinear oscillators, resonance entrainment, modeling and analysis of control circuits for animal locomotion, central pattern generators, body-fluid interaction during undulatory and oscillatory swimming

Y. Sungtaek Ju, Ph.D. (Stanford, 1999)

Heat and mass transfer, energy-water nexus, MEMS and nanotechnology

Ann R. Karagozian, Ph.D. (Caltech, 1982)

Fluid mechanics and combustion with applications to air breathing, rocket propulsion, and energy-generation systems, focusing on control of instabilities improved efficiency, and reduced emissions

H. Piroz Kavelhoun, Ph.D. (MIT, 2003)

Microscale fluid mechanics, transport phenomena in biological systems, biofluids, coating flows and physics of contact line phenomena, complex fluids, non-isothermal flows, energy storage, microfluidics

Chang-Jin (CJ) Kim, Ph.D. (UC Berkeley, 1991)

Microelectromechanical systems (MEMS), micro/nano devices and fabrication technologies, microfluidics especially involving surface tension and droplets

Adrienne Lavine, Ph.D. (UC Berkeley, 1984)

Heat transfer; thermomechanical behavior of shape memory alloys, thermal aspects of manufacturing processes, natural and mixed convection

Xiaochun Li, Ph.D. (Stanford, 2001)

Embedded sensors in layered manufacturing

Kuo-Nan Liou, Ph.D. (New York U., 1970)

Radiative transfer and satellite remote sensing with application to clouds and aerosols in the earth’s atmosphere

Ajit K. Mal, Ph.D. (UC Berkeley, 2005)

Nanoscale heat transfer; computational fluid dynamics, simulation of fluid flow and heat transfer for industrial applications, sub-micron thermal transport, multiscale multiphysics simulations and uncertainty quantifications

Laurent G. Pilon, Ph.D. (Purdue, 2002)

Interfacial and transport phenomena, radiation transfer, materials synthesis, multi-phase flow, heterogeneous media

Jacob Rosen, Ph.D. (Tel Aviv U., Israel, 1997)

Natural integration of a human arm/powered exoskeleton system

Jason L. Speyer, Ph.D. (Harvard, 1968)

Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics

Tsu-Chin Tsao, Ph.D. (UC Berkeley, 1988)

Mechatronics and control with applications in mechanical systems, manufacturing, vehicles, medical robots, and energy

Xiaolin Zhong, Ph.D. (Stanford, 1991)

Computational fluid dynamics, advanced high-order CFD methods, hypersonics flow, numerical simulation of transient hypersonic flow with nonequilibrium real-gas effects, instability and laminar-turbulent transition of hypersonic boundary layers

**Professors Emeriti**

Oddvar O. Bendiksen, Ph.D. (UCLA, 1980)

Classical and computational aerelasticity, structural dynamics and unsteady aerodynamics

Ivan Catton, Ph.D. (UCLA, 1966)

Heat transfer and fluid mechanics, transport phenomena in porous media, nucleonics heat transfer and thermal hydraulics, natural and forced convection, thermal/hydrodynamic stability, turbulence


Aeroelasticity of helicopters and fixed-wing aircraft, structural dynamics of rotating systems, rotor dynamics, unsteady aerodynamics, active control of structural dynamics, structural optimization with aerelastic constraints

James S. Gibson, Ph.D. (U. Texas Austin, 1975)

Control and identification of dynamical systems; optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation
Grasp and manipulation, hand biomechanics, time and length scales and parallel computing

Dynamics and control, stability theory, nonlinear methods, applications to space and ground vehicles

Fluid mechanics, internal acoustics and noise produced by turbulent jets

Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components

Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor chemical vapor deposition

Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics

Mechanics of solid bodies, fracture mechanics, adhesive mechanics, composite materials, theoretical soil mechanics, mixed boundary value problems

Robotics and mechanisms; CAD/CAM systems, computer-controlled machines

Convergence of structural biology, dynamics, and controls using specialized biomolecular frameworks

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

Grasp and manipulation, hand biomechanics, haptics, human-machine systems, machine learning, machine perception, neural control of movement, prosthetics, robotics, stochastic modeling, tactile sensor

Development of computation fluid dynamics that incorporate unsteady aerodynamics, flow control, and network theory

Electric propulsion (ion, Hall, electrosprays, cathodes); micro-electric propulsion; partially ionized plasmas; miniature plasma devices; spacecraft/space mission design; wind energy; solar thermal energy; thermal energy storage

Artur Davoyan, Ph.D. (Australian National U., 2011) Devising and development of new approaches for space propulsion and power using unique nanomaterials

Jonathan B. Hopkins, Ph.D. (MIT, 2010) Design and manufacturing of microstructural architectures, flexure systems, and compliant mechanisms; screw theory kinematics; precipitation design; novel micro- and nanofabrication processes; MEMS

Yongjie Hu, Ph.D. (Harvard, 2011) Heat transfer and electron transport in nanostructures; instrumenting thermal, electronic, optoelectronic, and thermoelectric devices and systems; energy conversion, storage, and thermal management; ultrafast optical spectroscopy and high-frequency electronics; nanoscale design, processing, and manufacturing

M. Khalid Jawed, Ph.D. (MIT, 2016) Data-driven approach to modeling the mechanics of structures and fluid-structure interaction using robotics, automation, computation, and machine learning

Liuhua Jin, Ph.D. (Harvard, 2014) Mechanics of soft materials; continuum mechanics and applications in technologoes; additive manufacturing, soft robotics and stretchable electronics, nanomechanics, and multiscale modeling

Raymond M. Spearrin, Ph.D. (Stanford, 2015) Septroscopy and gas dynamics, advanced optical sensors including laser absorption and fluorescence with experimental application to propulsion, energy systems and other reacting flow fields

Lecturers

Ravness C. Amar, Ph.D. (UCLA, 1974) Heat transfer and thermal science

Amiya K. Chatterjee, Ph.D. (UCLA, 1976) Elastic wave propagation and penetration dynamics

Robert J. Kinsey, Ph.D. (UCLA, 1991) Modeling, simulation, and analysis of spacecraft dynamics and pointing control systems; nonlinear dynamics of spinning bodies; concurrent engineering methods for space mission conceptual design

Damian M. Toohy, M.S. (MIT, 2004) Guidance, navigation, and control for autonomous aircraft, launch vehicles, and missile systems, adaptive control techniques, automatic control reallocation for aircraft and reentry vehicles

Adjunct Professors

Dan M. Goebel, Ph.D. (UCLA, 1981) Hollow cathodes, magnetic ion sources for neutral beam injection

Leslie M. Lackman, Ph.D. (UCLA Berkeley, 1967) Structural analysis and design, composite structures, engineering management

Christopher S. Lynch, Ph.D. (UC Santa Barbara, 1992) Field coupled materials, constitutive behavior, thermo-electro-mechanical properties, sensor and actuator applications, fracture mechanics and failure analysis

Wilbur J. Marner, Ph.D. (U. South Carolina, 1969) Thermal sciences, system design

Neil G. Siegel, Ph.D. (USC, 2011) Organizing complex systems around critical skills and mitigation of risks arising from system dynamic behavior

Adjunct Associate Professor

131A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses M20 (or Civil Engineering M20) or Computer Science 31), 82, Electrical Engineering 100. Introduction to modeling of physical systems, with emphasis on mechanical, fluid, thermal, and electrical systems. Description of these systems with coverage of impulse response, convolution, frequency response, first- and second-order system transient response, Laplace transforms, ordinary differential equations. Fourier series, and boundary value problems and applications of these principles in analysis and design of closed and open systems. Letter grading. Mr. Pilon (Sp).

C138. Introduction to Statistical Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses M20 (or Civil Engineering M20 or Computer Science 31), 82, 105A. Transport phenomena; heat conduction, mass species diffusion, convective heat and mass transfer, and radiation. Engineering applications in thermal and environmental control. Letter grading. Ms. Karagozian, Mr. M'Closkey, Mr. Tsao (F, W, Sp).


C150G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 103, 150A. Thermal behavior of living systems. Design of microcirculation; role of fluid dynamics in arterial disease. Concurrently scheduled with course C250G. Letter grading. Mr. Eldredge (Not offered 2019-20).

150P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 105A, 150A. Rocket propulsion: combustion fundamentals; chemical rockets (liquid, gas, and solid propellants), hybrid rockets, electric (ion, plasma) rockets, nuclear rockets, and solar-powered vehicles. Current issues in launch vehicle technologies. Concurrently scheduled with course C250P. Letter grading. Mr. Karagozian, Mr. Spearrin (F, W).

1510R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 103, 105A, 150A. Rocket propulsion: combustion fundamentals; chemical rockets (liquid, gas, and solid propellants), hybrid rockets, electric (ion, plasma) rockets, nuclear rockets, and solar-powered vehicles. Current issues in launch vehicle technologies. Concurrently scheduled with course C250R. Letter grading. Ms. Karagozian, Mr. Wirz (Sp).

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 154S. Classical preliminary design of aircraft, including weight estimation, performance and stability, and control consideration. Term assignment consists of preliminary design of low-speed aircraft. Letter grading. Mr. Wirz (W).


154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 150A, 150B. Aircraft performance, flight mechanics, stability, and control; some basic ingredients needed for design of aircraft. Effects of airplane flexibility on stability characteristics. Letter grading. Mr. Wirz (F).

155. Intermediate Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 102. Axioms of Newtonian mechanics, generalized coordinates, Lagrange equations, variational principles; central force motion; kinematics and dynamics of rigid bodies. Euler equations, motion of rotating bodies, oscillatory motion, normal coordinates, orthogonality relations. Letter grading.

156A. Advanced Strength of Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 82, 101. Not open to students with credit for course 168A. Concepts of stress, strain, and material behavior. Stress in loaded beams with symmetric and asymmetric cross beams and strain components in solids, equilibrium equations, Hook's law for isotropic solids, Bending and shear deformations in beams, Deflection and interaction of beams, and incompressible fluids. Letter grading. Mr. Mal (F, W, Sp).


103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, five hours. Enforced requisites: Mathematics 32B, 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading. Mr. Kavelpour, Mr. J. Kim (F, W, Sp).

105A. Introduction to Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 205A. Global energy use and supply, electrical power generation, fossil fuel and nuclear power plants, renewable energy such as hydropower, biomass, geothermal, solar, wind, and ocean, fuel cells, transportation, energy storage and electric vehicles, and future nuclear science for medical uses. Letter grading. Mr. Abdou (Not offered 2019-20).

136. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 105A. Global energy use and supply, electrical power generation, fossil fuel and nuclear power plants, renewable energy such as hydropower, biomass, geothermal, solar, wind, and ocean, fuel cells, transportation, energy storage and electric vehicles, and future nuclear science for medical uses. Letter grading. Mr. Abdou (Not offered 2019-20).


Mr. Mal (F,WSp)

C15B. Mechanical Design for Power Transmission. (4) Lecture, four hours; discussion, outside study, six hours. Requisites: course 156A or 166A. Material selection in mechanical design. Load and stress analysis. 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 computer-aided design (CAD) and finite element analysis using ANSYS. Concurrently scheduled with course C296A. Letter grading.

Mr. Ghoniem (Sp)

157. Basic Mechanical and Aerospace Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Recommended: courses 101, 102, 103, 105A, Electrical Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading.

Mr. Ghoniem, Mr. Ju (F,WSp)

157A. Aerospace Design Laboratory. (4) Lecture, two hours; discussion, two hours; outside study, four hours. Requisites: courses 150A, 157. Recommended: 150B, C150R. Experimental illustration of important physical phenomena in area of fluid mechanics/aerodynamics, as well as hands-on experience with real-time measurement programs and use of modern experimental tools and techniques in field.

Letter grading.

Mr. Kavehpour (Sp)


Mr. Wirz (F)

161B. Introduction to Space Technology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended preparation: courses 102, 161A. Space mission design and analysis of spacecraft power, instruments, communications, structures, materials, thermal control, and attitude/orbit determination and control. Space mission design and analysis of spacecraft power, instruments, communications, structures, materials, thermal control, and attitude/orbit determination and control. Space mission design, space environment, rendezvous, entry, and launch. Letter grading.

Mr. Wirz (F)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 161B. Preliminary design and analysis by students of Earth-orbiting or interplanetary space missions and spacecraft. Students work in groups of three or four, with each student responsible primarily for one subsystem and for integration with whole. Letter grading.

Mr. Wirz (Sp)


Mr. Hopkins (F,Sp)

162B. 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. 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, CAD analysis, mechatronics, and conceptual design for team project. Letter grading.

Mr. Ghoniem, Mr. Tao (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 continue design projects started in course 162D, making use of CAD analysis and design, fluid systems laboratory, CAD analysis and design, and mechatronics laboratory. Design theory, design tools, economics, marketing, manufacturability, quality, intellectual property, design for manufacture and assembly, and design and engineering ethics. Students conduct hands-on design, fabrication, and testing. Culminating project demonstrations or competition. Preparation of design project presentations in both oral and written formats. Letter grading.

Mr. Ghoniem, Mr. Tao (Sp)

166A. Analysis of Aerospace Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 82, 101. Not open to students with credit for course 156A. Introduction to two-dimensional elasticity, stress-strain laws, yield and fatigue; bending of beams; torsion of beams; warping; torsion of thin-walled cross sections; shear flow; thin-walled structural elements; shell structures; and stiffened structures used in aerospace vehicles; elements of plate theory; buckling of columns. Letter grading.

Mr. Carman (F)

166C. Design of Composite Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 156A or 166A. History of composites, stress-strain relations for composite materials, bending and extension of symmetric laminates, failure analysis, design examples and design studies, buckling of composite components, nonsymmetric laminates, micromechanics of composites. Letter grading.

Mr. Carman (F)

M168. Introduction to Finite Element Methods. (4) (Same as Civil Engineering M135C) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 156A or 166A or Civil Engineering 130. Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual formulations; convergence properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling and construction of finite element models of noise and disturbances, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C271A. Letter grading.

161A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 82. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals; Laplace transform: properties, convolution, inversion; Fourier transform: properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading.

Mr. Ghoniem (Not offered 2019-20)


Mr. Eldredge, Mr. J. Kim (W)


Mr. Zhong (F)


Mr. C.-J. Kim (F,WSp)
C183C. Rapid Prototyping and Manufacturing. (4) Lecture, study, six hours. Enforced requisite: course 183A. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as popular means for prototyping, manufacturing, and assembly in last two decades. Machine for layered manufacturing builds parts directly from CAD models. This novel manufacturing technology enables building of parts that may have been impossible to fabricate because of their complex shapes or of variety in materials. In analogy to speed and flexibility of desktop publishing, rapid prototyping is also called desktop manufacturing with actual three-dimensional solid objects instead of mere two-dimensional images. Methodology of rapid prototyping has also been extended into meso-/micro-hanno-scale to produce three-dimensional functional miniature components. Concurrently scheduled with course C297A. Letter grading.

Mr. Li (W)

185. Introduction to Radio Frequency Identification and its Application in Manufacturing and Supply Chain. (4) Lecture, two to four hours; outside study, six hours. Enforced requisite: course M20 or Civil Engineering M20 or Computer Science 31. Manufacturing today requires assembly of individual components into assembled products, shipping of such products, and eventually use, maintenance, and recycling of such products. Radio frequency identification (RFID) chips installed on components, subassemblies, and assemblies of products allow them to be tracked automatically as they move and transform through manufacturing supply chain. RFID can be used to store information on product status to be written, stored, and transmitted wirelessly. Tag data can then be forwarded by reader to enterprise software. Study of how RFID is being used in manufacturing, with focus on automotive and aerospace. Letter grading.

Mr. Gad (Sp)


Mr. Chiu (Not offered 2019-20)

C187L. Nanoscale Fabrication, Characterization, and Electric Properties. (4) Lecture, four hours; laboratory, three hours; outside study, seven hours. Multidisciplinary course that introduces laborative techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles related to these techniques, top-down and bottom-up (self-assembly) nanofabrication, nanocharacterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C287L. Letter grading.

Mr. Y. Chen (Sp)

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) Lecture, two to four hours; outside study, eight hours. Special topics in mechanical and aerospace engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. P/NP or letter grading. (Not offered 2019-20)

194. Research Group Seminars: Mechanical and Aerospace Engineering. (2 to 4) Seminar, two hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated for credit with different faculty mentor. Culminating paper or project required. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (FWSp)

Graduate Courses


Ms. Lavine (F)

231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Radiative properties of materials and radiative energy transfer. Emphasis on fundamental concepts, introduction to radiative transfer models, and use of computational methods such as discrete ordinates and Monte Carlo methods. Letter grading.

Ms. Lavine (F)


Ms. Morin (W)

231G. Microscopic Energy Transport. (4) Formerly numbered 231G. Lecture, four hours; outside study, eight hours. Requisite: course 105D. Exploration of microscopic transport of energy in natural and fabricated structures by three carriers: electrons, phonons, and molecules. Study of statistical properties of heat carriers, classical Landauer framework, and microscopic thermal description of heat carriers, derivation of classical laws from microscopic transport equations, and deviation from classical laws at small scale. Term project. Concurrency scheduled with course C131G. Letter grading.

Mr. Ju (F)

233. Nanoscience for Energy Technologies. (4) Lecture, four hours; outside study, eight hours. Introduction to fundamental principles of energy transport, conversion, and storage at nanoscale, and recent development for these energy technologies involving nanotechnology. Focus on basics of thermal science, quantum mechanics, electro-magnetics, 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 (Sp)

235A. Nuclear Reactor Theory. (4) Lecture, four hours; outside study, eight hours. Underlying physics and mathematics of nuclear reactor (fission) core design. Diffusion theory, reactor kinetics, slowing down and thermalization, multigroup methods, introduction to transport theory. Letter grading.

Mr. Aboud (Not offered 2019-20)


Mr. Aboud (Sp)

C238. Introduction to Statistical Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Fundamentals of thermodynamics at the molecular or macroscopic level, including energy levels and electromagnetic waves and deviation from equilibrium. Statistical interpretation of macroscopic laws and processes; wide-area situational awareness, phasor measurements; analytical methods and tools for monitoring and control. Concurrently scheduled with course C137. Letter grading. Letter grading.

Mr. Gad (F)

M237B. Fusion Plasma Physics and Analysis. (4) (Same as Electrical and Computer Engineering M287.) Lecture, four hours; outside study, eight hours. Fundamental phenomena relating to thermonuclear burning conditions. Fokker/Planck equation and applications to heating by neutral beams, RF, and fusion reaction products. Bremsstrahlung, synchrotron, and attenuation function concepts. Interactions between particles and magnetic fields. Fluid description of burning plasma. Dynamics, stability, and control. Applications in tokamaks, tandem mirrors, and alternate concepts. Letter grading.

Mr. Aboud (Not offered 2019-20)


Mr. Aboud (Sp)


Mr. Aboud (Sp)

239B. Seminar: Current Topics in Transport Phenomena. (1 to 4) Seminar, four hours; outside study, eight hours. Designed for graduate students in transport phenomena. Students present current research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with different faculty mentor. S/U grading.

Mr. Aboud (Sp)

239F. Special Topics in Transport Phenomena. (2 to 4) Lecture, two to four hours; outside study, four hours. Designed for graduate students in transport phenomena. Students present current research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with different faculty mentor. S/U grading.

Mr. Aboud (Sp)
buoyancy effects, variational methods, and measure- ment techniques. May be repeated for credit with topic change. U/S grading.

239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture, two to four hours; outside study, two to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in nuclear engineering, such as reactor safety, risk-benefit trade-offs, nuclear ma- terials, and reactor design. May be repeated for credit with topic change. U/S grading.

239H. Special Topics in Fusion Physics, Engineer- ing, and Technology. (4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced treatment of subjects selected from research areas in fusion science and engi- neering, such as instabilities in burning plasmas, al- ternate fusion confinement concepts, inertial confine- ment fusion, fissiion-fusion hybrid systems, and fu- sion reactor safety. May be repeated for credit with topic change. U/S grading.

CM240. Introduction to Biomechanics. (4) (Same as Bioengineering CM240.) Lecture, four hours; dis- cussion, two hours; outside study, six hours. Requi- sites: courses 101, 102, and any 166A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power genera- tion. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading.

242. Introduction to Multiferroic Materials. (4) Lecture, four hours; outside study, eight hours. Overview of different types of multiferroic materials, including strain mediated. Basic crystal structure of single- phase multiferroics and fundamentals of multiferroics underlying ferroelectricity and ferromagnetism. Material science description of these materials, with focus on linear and nonlinear behavior with associated mathematical techniques. Presentation of analytical tools necessary to predict material re- sponse ranging from constitutive relations to gov- erning equations, including elastodynamics and Maxwell’s. Analytical and physical descriptions used to explain several devices manufactured with multifer- roics, including magnetometers, memory devices, motors, and antennas. Letter grading.

250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105A. Corequisite: course 182B. Development and application of fundamental principles of fluid mechanics at graduate level, with emphasis on incompressible flow. Flow kinematics, basic equa- tions, constitutive relations, exact solutions on the Navier/Stokes equations, vorticity dynamics, decom- position of flow fields, potential flow. Letter grading.

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Analytical principles of fluid dy- namics applied to study of fluid resistance. States of buoyancy, and other defined flows. Letter grading.

250E. Spectral Methods in Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. En- forced prerequisite: course 192 or 192C. Corequisite: 250B. Introduction to basic concepts and techniques of various spectral methods applied to solving partial differential equations. Particularly emphasis on tech- niques of solving unsteady three-dimensional Navier/ Stokes equations with emphasis on high-resolution, physics-based treatment of function, discrete Fourier transform, etc. Letter grading. Mr. J. Kim (Not offered 2019-20)

250F. Hypersonic and High-Temperature Gas Dy- namics. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 250C. Mo- lecular and chemical description of equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical kinetics, and statistical the- rodynamics for calculation gas properties, equilib- rium flows of real gases, vibrational and chemical rate processes, nonequilibrium flows of real gases, and computational fluid dynamics methods for nonequi- librium hypersonic flows. Letter grading.

Mr. Zhong (W)

250G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requi- site: course 103. Corequisite: course 182B. Vortex insect and bird flight aerodynamics; pulsatile flow in circulatory system; rheology of blood; transport in mi- crocirculation; role of fluid dynamics in arterial dis- eases; blood flow in arteries and capillaries. Letter grading. Mr. Eldredge (Not offered 2019-20)


Mr. Eldredge (Not offered 2019-20)


252A. Fluids and Heat Transfer. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 105A, 105B. Thermody- namic properties of gases, aircraft jet engine cycle analysis, aircraft cooling systems, advanced component matching, advanced aircraft engine topics. Concur- rently scheduled with course C155P Letter grading.

Ms. Karagozian (F)

252R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 103, 105A. Rocket propulsion concepts, including chemical rockets (liquid, gas, and solid propellants), hybrid rocket engines, electric (ion, plasma) rockets, nuclear rockets, and solar-powered vehicles. Current issues in launch vehicle technologies. Concurrently sched- uled with course C155P Letter grading.

Ms. Karagozian (F)

252A. Stability of Fluid Motion. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Mechanisms by which laminar flows can be- come unstable and lead to turbulence of secondary motions. Linear stability theory; thermal, centrifugal, and shear instabilities; boundary layer instability. Nonlinear aspects: sufficient criteria for stability, sub- critical instabilities. Kirchhoff’s steady states, transition to turbulence. Letter grading.

Ms. Karagozian, Mr. Zhong (F)


Mr. J. Kim (Not offered 2019-20)


Ms. Karagozian (Not offered 2019-20)

252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Basic concepts in chemical kinetics: mechanisms, detailed balances, chain- aging, semiempirical and ab initio potential surfaces, trajectory calculations, statistical reaction rate theo- ries. Practical examples of large-scale chain mecha- nisms from combustion chemistry of several ele- ments, etc. Letter grading.

Ms. Karagozian (Not offered 2019-20)

252P. Plasma and Ionized Gases. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B, 182B. Neutrals and charged particles, particle motion, magnetohydrodynamics, two-fluid plasma treatments, ion and electron diffusion, gas diffusion, Cloudy, Monte Carlo, basic plasma physics and laser emission and work function, thermal distributions, vacuum and vacuum systems, space-charge, particle collisions and ionization, plasma discharges, sheaths, and electric arcs. Letter grading.

Ms. Karagozian (F)

254A. Special Topics in Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 82, 150A, 150B, 182B, 182C. Special topics of current interest in advanced aerody- namics. Examples include transonic flow, hypersonic flow, sonic booms, and unsteady aerodynamics. Letter grading.

Mr. Zhong (Not offered 2019-20)

255A. Advanced Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 169A. Variational principles and Lagrange equations. Kinematics and dynamics of rigid bodies; procession and nutation of spinning bodies. Letter grading.

Mr. Gibson (Sp)

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. Requi- site: course 255A. Concepts of stability; state- space interpretation; stability determination by simu- lation; linearization, and Lyapunov; dimensions of the Hamiltonian as a Lyapunov function; autonomous systems; averaging and perturbation methods of nonlinear analysis; parametric excitation and non- linear oscillations; canonical and normal forms. Letter grading.

Mr. M’Closkey (Not offered 2019-20)

M256A. Linear Elasticity. (4) (Same as Civil Engi- neering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course 166A or 166B. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilib- rium equations; linear constitutive relations; plane elas- tostatic problems, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerutti. Introduction to boundary integral equation method. Letter grading.

Mr. W. Ju, Mr. Mal (F)

M256B. Nonlinear Elasticity. (4) (Same as Civil Engi- neering M303B.) Lecture, four hours; outside study, eight hours. Requisite: course 165A or 166A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elasto- statics problems, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerutti. Introduction to boundary integral equation method. Letter grading.

Mr. W. Ju, Mr. Mal (F)

M256C. Plasticity. (4) (Same as Civil Engineering M330C.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Classical rate-de- pendent viscoplasticity, Perzyna and Duvant/Lions


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 microscopic scale. Micromechanics of biological structures and tissue mechanics (tissue engineering). 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 disclinations, quantum dots, nanotubes, nanoclusters, thin films (e.g., optical thermal barrier coatings and ultrastrong nanolayer materials), nano-identification, smart (active) materials, nanobending and micromolding, and torsion. Letter grading. Mr. Gholami (Not offered 2019-20)

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with particular emphasis on applications involving research problems leading to term paper or oral presentation (possible help from guest lecturers). Letter grading. Mr. Kavehpour, Mr. Speyer (W/Sp)

259B. Seminar: Advanced Topics in Solid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study in various fields of solid mechanics on topics which may vary from term to term. Topics include dynamics, elasticity, plasticity, and stability of solids. Letter grading. Mr. Mal (Sp)

260. Current Topics in Mechanical Engineering. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, and student presentations and projects in areas of current interest in mechanical engineering. May be repeated for credit. S/U grading.


261B. Finite Element Analysis for Solids and Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or M256A, or consent of instructor. Strongly recommended prerequisite: courses M168, M256B, 261A. Application of finite element method to classical and state-of-art modeling and design problems for solids and structures. Introduction of commercial mainstream finite element software and emphasis of how to use it in advanced way. Topics include review of finite element method, static and dynamic linear elasticity, finite deformation of hyperelastic materials, instability analysis, fracture, and implementation of user-defined subroutines in ABAQUS. Term projects using computers. Letter grading. Mr. Mal (Not offered 2019-20)

262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 166C. Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology, micro/macron analysis, including classical laminated theory, shear lag theory, concentrated cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials. Active systems design, inch-worm, and biomimicry. Letter grading. Mr. Carman (Sp)

263A. Kinematics of Robotic Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: courses 155, 171A. Kinemathetical models of serial robotic manipulators, including spatial descriptions and mapping among them (Euler angles, Denavit-Hartenberg/DH parameters, equivalent angle vector), frame assignment procedure, direct kinematics, inverse kinematics (geometric and algorithmic approaches), mechanical design topics. Letter grading. Mr. Hong (W)

263B. Dynamics of Robotic Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 263A. Recommended: course 259B. 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 matrix, manipulator dynamics (Lagrange formulation), trajectory generation, introduction to parallel manipulators. Letter grading. Mr. Rosen (W)

263C. Control of Robotic Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 263B. Sensors, actuators, and control schemes for robotic systems, including computed torque control, linear feedback control, impedance and force feedback control, and advanced control techniques for power and adaptive control, hybrid control, nonholonomic systems, via- sion-based control, and perception. Letter grading. Ms. Santos (Sp)

263D. Advanced Topics in Robotics and Control. (4) Lecture, four hours; outside study, four hours. Enforced requisite: course 263C. Current and advanced topics in robotics and control, including kine- matics, dynamics, control, mechanical design, ad- vanced sensors and actuators, flexible links, manipula- tion, redundant manipulators, human-robot interaction, teleoperation, haptics. Letter grading. Mr. Rosen (Not offered 2019-20)


M269B. Advanced Dynamics of Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Analysis of linear and nonlinear re- sponse of structures to dynamic loadings. Stresses and deflections determination, damping and self-induced vibrations. Letter grading.

Mr. Mal (Not offered 2019-20)

269D. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 269B. Analysis of aeroelasticity of thin-walled structures and elementary laminates from unified viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Flow in- ducing stability and reduced-order models of systems. Letter grading. Mr. Mal (Not offered 2019-20)

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical and Computer Engineering M240A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Chemical Engineering M280A and Computer Engineering M240A. 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 minimum realizability. Stabilizability via state feedback and observers; separation principle. Con- nections with transfer function techniques. Letter grading. Mr. M'Closkey (F)

270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering M240A. Existence and uniqueness of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time systems. Linear-quadratic-Gaussian (LQG) problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implica- tions of controllability, stabilizability, observability, and detectability solutions. Linear quadratic Gaussian (W)

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

C271A. Probability and Stochastic Processes in Dynamic Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: courses 82, 107. Probability spaces, random variables, stochas- tic processes and sequences, expectation, con- ditional expectation, Gauss/Markov sequences, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C175A. Letter grading. Mr. Speyer (F)

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course C271A. Linear and nonlinear estimation theory, orthogonal projection and Bayesian filtering theory, conditional mean and risk estimators. Letter grading. Mr. Speyer (W)


271D. Seminar: Special Topics in Dynamic Sys- tems Control. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applica- tions. Topics selected from process control, differen- tial games, nonlinear estimation, adaptive filtering, in- dustrial and aerospace applications, etc. Letter grading. Mr. Speyer (Not offered 2019-20)

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171A, M270A, graduate standing. Introduction to analysis and design of multivariable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading. Mr. M’Closkey (Not offered 2019-20)

275A. System Identification. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 102, 103, M270A. Topics include scale issues, surface tension, interfacial forces, interfacial hydrodynamics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), and emulsions, micromechanical systems, and biological systems. Letter grading.

Mr. Gibson (Not offered 2019-20)


279. Dynamics and Control of Biological Oscillations. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 107, M270A. Analysis and design of dynamical mechanisms underlying biological rhythms, e.g., circadian clock, heartbeat, and entrainment to natural oscillations via feedback control. Letter grading. Mr. Iwasaki (Sp)

M280B. Microelectromechanical Systems (MEMS) Fabrication. (4) Same as Bioengineering M296B and Electrical and Computer Engineering M258B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Recommended requisite: course M183B. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, adhesion, and mechanical properties, and residual/ intrinsic stress. Letter grading. Mr. C.-J. Kim (Not offered 2019-20)

281. Microflows. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 102, 105D. Fundamental issues of being in microscopic world and mechanical engineering of microscale devices. Topics include scale issues, surface tension, superhydrophobic surfaces and interfaces, and electrohydrodynamic reactions. Letter grading.

Mr. C.-J. Kim (Fall 2022)

M282. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) Same as Bioengineering M258C 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 micro- actuators. Designing MEMS to be produced with both foundry and nonfoundry processes and microactuator design for MEMS. Design project required. Letter grading. Mr. Chiu (Not offered 2019-20)

284. Sensors, Actuators, and Signal Processing. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course M276A. Applications of using unique properties of micro transducers for distributed and real-time control of engineering problems. Associated signal processing requirements for real-time control of sensing and actuation. Mr. C.-J. Kim (Not offered 2019-20)

285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 82, 103A, 105D. Introduction to fundamental physical phenomena occurring at interfaces and applications 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), and emulsions, micromechanical systems, and biological systems. Letter grading.

Mr. Pilon (Not offered 2019-20)


M287. Nanoscience and Technology. (4) Same as Electrical and Computer Engineering M287.) Lecture, four hours; outside study, eight hours. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemistries of materials at nanoscale bottom-up (self-assembly) nanofabrication; nano- characterization; nanomaterials, nanoelectronics, and nanobiodetection technology. Introduction to new knowledge and technology. Technology is on the horizon, long-stand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nanofluidic areas. Letter grading. Mr. Y. Chen (Winter 2023)

C287L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterizations, and biodetection. Topics include chem- ical, and biological principles related to these tech- niques, top-down and bottom-up (self-assembly) nanofabrication, nanocharacterization (AES, SEM, etc.), nanomaterials, nanoelectronics, and nanobiotechnology. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C187L. Letter grading. Mr. Y. Chen (Sp)

M290A. Nanoscale and Nanotechnology. (4) (Formerly numbered 294A.) Lecture, four hours; outside study, eight hours. Requisite: linear algebra. Advanced compliant mechanism synthesis approaches, modeling techniques, and optimization techniques. Formu- lation of flexible constraint theory, principles of con- straint-based design, progressive geometry, screw theory kinematics, and freedom and constraint topol- ogies. Applications: precision motion stages, general purpose flexure bearings, micro-structural architec- tures, MEMs, optical mounts, and nanoscale posi- tioning systems. Hands-on exercises include build- ing compliant flexure kits, design and fabricate, and term project. Letter grading. Mr. Hopkins (W)

295A. Radio Frequency Identification Systems: Analysis, Design, and Applications. (4) Lecture, four hours; outside study, eight hours. Designed for graduate engineering students. Introduction to the emerging discipline of radio frequency identification (RFID), including basics of RFID, how RFID systems function, and design and analysis of RFID systems, and applications to fields such as supply chain, manufac- turing, retail, and homeland security. Letter grading. Mr. Gadhi (Not offered 2019-20)

C296A. Mechanical Design for Power Transmission. (4) Lecture, four hours; outside study, eight hours. Requisites: course M270A or equivalent. Design, analysis, and selection of power transmission devices. Letter grading. Mr. Ghoniem (Sp)

296B. High-Temperature Mechanical Design. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Recommended requisite: level of knowledge in manufacturing equivalent to course 183A and CAD capability. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as popular manufacturing technology to accelerate product creation in last two decades. Many for layered manufacturing technologies use the RP, directly from CAD models. This novel manufacturing technology enables building of parts that have tradi- tionally been impossible to fabricate because of their complex geometry or of very small scale. Rapid prototyping has also been extended into meso-/nano-scale to produce three-dimensional functional miniature components. Concurrently scheduled with course C183C. Letter grading.

Mr. Li (W)

M297B. Material Processing in Manufacturing. (4) (Formerly numbered 297A.) (Same as Materials Science M297B.) Lecture, four hours; outside study, eight hours. Enforced requisite: course M270A. Ther- modynamics, principles of material processing: phase equilibria and transitions, transport mechan- isms of heat and mass, nucleation and growth of microstructure. Applications in castings, forging, extrusion, welding, consolidation, chemical vapor deposition, infiltration, composites. Letter grading. Mr. Li (Not offered 2019-20)

M297C. Composites Manufacturing. (4) (Formerly numbered 297D.) (Same as Materials Science M297C.) Lecture, four hours; outside study, eight hours. Requisites: course 186C. Materials Science 151. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/compression molding, fila- ment winding, pultrusion, resin transfer molding, au- tomated matrix removal and assembly, metal and ceramic matrix composite, quality assurance. Letter grading. Mr. Ghoniem (Not offered 2019-20)
Master of Science in Engineering Online Programs

4732 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
310-825-6542
https://www.mssel.ucla.edu

Jenn-Ming Yang, Ph.D., Associate Dean

Scope and Objectives

The primary purpose of the Master of Science in Engineering online degree programs is to enable employed engineers and computer scientists to augment their technical education beyond the Bachelor of Science degree and to enhance their value to the technical organizations in which they are employed. The training and education that the programs offer are of significant importance and usefulness to engineers, their employers, California, and the nation. It is at the M.S. level that engineers have the opportunity to learn a specialization in depth, and those engineers with advanced degrees may also renew and update their knowledge of the technology advances that continue to occur at an accelerating rate.

The M.S. programs are addressed to those highly qualified employed engineers who, for various reasons, do not attend the on-campus M.S. programs and who are keenly interested in developing up-to-date knowledge of cutting-edge engineering and technology.

Graduate Study

For information on graduate admission, see Graduate Programs on page 26. The following introductory information is based on 2019-20 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

M.S. in Engineering Online Programs

Course Requirements

The programs consist of nine courses that make up a program of study. At least five courses must be at the 200 level, and one must be a directed study course. The latter course satisfies the University of California requirement for a capstone event (in the on-campus program the requirement is covered by a comprehensive examination or a thesis); the directed study course consists of an engineering design project that is better suited for the working engineer/computer scientist.

The programs are structured in a manner that allows employed engineers/computer scientists to complete the requirements at a part-time pace (e.g., one 100/200-level course per term). Courses are scheduled so that the programs can be completed within two academic years plus one additional term.

Areas of Study

Data Science Engineering Program

Junghoo (John) Cho, Ph.D. (Computer Science), Area Director; cho@cs.ucla.edu
Vwani P. Roychowdhury, Ph.D. (Electrical and Computer Engineering), Area Director; vwani@ee.ucla.edu

The exponential growth of data generated by machines and humans present unprecedented challenges and opportunities. From the analysis of this big data, businesses can learn key insights about their customers to make informed business decisions. Scientists can discover previously unknown patterns hidden deep inside the mountains of data. In this program, students will learn key techniques used to design and build big data systems and gain familiarity with data-mining and machine-learning techniques that are the foundations behind successful information search, predictive analysis, smart personalization, and many other technology-based solutions to important problems in business and science.

Engineering Management Program

Leslie M. Lackman, Ph.D. (Mechanical and Aerospace Engineering), Area Director; llackman@support.ucla.edu

The engineering management program focuses on providing entering and current engineering management personnel an opportunity to expand their business-related knowledge base and skills to enhance employment performance to the benefit of both the employee and employer. The program offers similar curriculum to that currently offered on campus by the professional schools.

All Internet-available lecturers are offered 24/7, with a weekly homeroom time to enhance the taped lectures and promote class interaction. The homerooms are held.
in early evenings to facilitate nonimpact with employee work schedules.

**Environment and Water Resources Program**

Jennifer A. Jay, Ph.D. (Civil and Environmental Engineering), *Area Director; jjay@seas.ucla.edu*

Plentiful high-quality water is fundamental for society. However, drought, climate change, contamination, and growing populations pose challenges for water sustainability. Engineers are needed worldwide to find novel solutions in providing access to clean water. Key elements in this degree program are surface and groundwater processes; hydroclimatology; watershed response to disturbance; remote sensing for hydrologic applications; membrane separation in aqueous systems; aquatic chemistry; environmental microbiology; and the chemical fate, geochemical modeling, and transport of contaminants in the environment.

**Mechanics of Structures Program**

Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), *Area Director; ajit@seas.ucla.edu*

The main objective of the mechanics of structures program is to provide students with the opportunity to develop the knowledge required for the analysis and synthesis of modern engineered structures. The fundamental concepts of 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.

**Reliability Engineering Program**

Ali Mosleh, Ph.D. (Civil and Environmental Engineering), *Materials Science and Engineering), Mechanical and Aerospace Engineering), Area Director; mosleh@ucla.edu*

The program is designed with a fresh perspective that addresses the current needs of the industry for ensuring reliability of engineered products and services, but also anticipates future needs and pushes frontiers into the realms of machine learning, advanced prognostics and health monitoring, and advanced methods to tackle reliability of complex cyber-physical-human (CPH) systems.

**Systems Engineering Program**

Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), *Interim Area Director; jjyng@seas.ucla.edu*

Systems engineering has broad applications that include software, hardware, materials, and electrical and mechanical systems. A set of four core courses is offered that form the foundation of the systems engineering program. The sequence of courses is designed for working professionals who are faced with design, development, support, and maintenance of complex systems.

**M.S. in Engineering—Aerospace**

Xiaolin Zhong, Ph.D. (Mechanical and Aerospace Engineering), *Area Director; xaloin@seas.ucla.edu*

The objective of this program is to provide students with a broad knowledge of major technical areas of aerospace engineering in order to fulfill the current and future needs of the aerospace industry. The major technical areas of this program include aerodynamics and computational fluid dynamics (CFD), propulsion, systems and control, and structures and dynamics. Undergraduate and graduate courses in the area of aerospace engineering cover a wide range of fundamental concepts of the science and engineering of aerodynamics, space technology, compressible flow, computational aerodynamics, aircraft and rocket propulsion systems, digital control of physical systems, linear dynamic systems, linear optimal control, design of aerospace structures, dynamics of structures, robust control system analysis and design, and probability and stochastic processes in dynamical systems.

**M.S. in Engineering—Computer Networking**

Mario Gerla, Ph.D. (Computer Science), *Area Director; gerla@cs.ucla.edu*

Three undergraduate elective courses complement the basic background of the undergraduate computer science degree with concepts in security, sensors, and wireless communications. The graduate courses expose students to key applications and research areas in the network and distributed systems field. Two required graduate courses cover the Internet and emerging sensor embedded systems. The electives probe different applications domains, including wireless mobile networks, security, network management, distributed P2P systems, and multimedia applications.

**M.S. in Engineering—Electrical**

Izhak Rubin, Ph.D. (Electrical and Computer Engineering), *Area Director; rubin@ee.ucla.edu*

The electrical engineering program covers a broad spectrum of specializations in communications and telecommunication, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

**M.S. in Engineering—Electronic Materials**

Ya-Hong Xie, Ph.D. (Materials Science and Engineering), *Area Director; yhx@ucla.edu*

The electronic materials program provides students with a knowledge set that is highly relevant to the semiconductor industry. The program has four essential attributes: theoretical background, applied knowledge, exposure to theoretical approaches, and introduction to the emerging field of microelectronics, namely organic electronics. All faculty members have industrial experience and are currently conducting active research in these subject areas.

**M.S. in Engineering—Integrated Circuits**

Dejan Markovic, Ph.D. (Electrical and Computer Engineering), *Area Director; dejan@ee.ucla.edu*

The integrated circuits program includes analog integrated circuit (IC) design, design and modeling of VLSI circuits and systems, RF circuit and system design, signaling and synchronization, VLSI signal processing, and communication system design. Summer courses are not yet offered in this program; therefore it cannot currently be completed in two calendar years.

**M.S. in Engineering—Manufacturing and Design**

Nasr M. Ghanieh, Ph.D. (Mechanical and Aerospace Engineering), *Area Director; ghanieh@ucla.edu*

An advanced program of study that covers fundamental and applied topics in modern manufacturing and mechanical design. The program includes finite element methods in design, mechanics of intelligent materials systems, nano- and micro-manufacturing, material processing, rapid prototyping, composites manufacturing, design with composites, digital control, design of power.
transmission systems, design of high-temperature components, and design of smart grids. The program prepares students with the higher educational background and the competence that are necessary for today’s rapidly changing technology needs.

**M.S. in Engineering—Materials Science**

Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Area Director; jyang@seas.ucla.edu

Materials engineering is concerned with the design, fabrication, and testing of engineering materials that must simultaneously fulfill dimensional properties, quality control, and economic requirements. Several manufacturing steps may be involved: (1) primary fabrication, such as solidification or vapor deposition of homogeneous or composite materials, (2) secondary fabrication, including shaping and microstructural control by operations such as mechanical working, machining, sintering, joining, and heat treatment, and (3) testing, which measures the degree of reliability of a processed part, destructively or non-destructively.

**M.S. in Engineering—Mechanical**

Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Area Director; ajit@seas.ucla.edu

An advanced program of study that covers fundamental and applied topics in modern manufacturing and mechanical design. The program includes finite element methods in design, mechanics of intelligent material systems, nano- and micro-manufacturing, material processing, rapid prototyping, composites manufacturing, design with composites, digital control, design of power transmission systems, design of high-temperature components, and design of smart grids. The program prepares students with the higher educational background and the competence that are necessary for today’s rapidly changing technology needs.

**M.S. in Engineering—Signal Processing and Communications**

Izhak Rubin, Ph.D. (Electrical and Computer Engineering), Area Director; rubin@ee.ucla.edu

The program provides training in a set of related topics in signal processing and communications. Students receive advanced training in multimedia systems from the fundamentals of media representation and compression through transmission of signals over communications links and networks.

**M.S. in Engineering—Structural Materials**

Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Area Director; jyang@seas.ucla.edu

The program provides students with a broad knowledge of structural materials. Courses cover fundamental concepts of science and engineering of lightweight advanced metallic and composite materials, fracture mechanics, damage tolerance and durability, failure analysis and prevention, nondestructive evaluation, structural integrity and life prediction, and design of aerospace structures. Students are required to complete a project on a topic related to structural materials.
merse incoming computing students in foundation concepts and principles of computer science, with focus on developing algorithmic thinking, problem-solving skills, methodologies, and techniques. Basic concepts of programming and C++ computing language. Offered in summer only. P/NP grading.

22. Summer Bridge Review for Enhancing Engineering Majors. (42 hours; 32 hours). Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Evaluation of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Intensive introduction of advanced topics covered in upper-division engineering courses. Offered in summer only. P/NP grading.

23. Finding Industry Internship. (2) Seminar, two hours; outside study, four hours. Designed to engage engineering students in process of formal career development. Students learn about various components of internship/job application and practice preparing relevant materials. Prepares students for career-related social interactions. Development of skills and insights to secure future opportunities, such as first industry internship. P/NP grading. (F,W,Sp)

24. Finding Undergraduate Research Opportunity. (2) Seminar, two hours; outside study, four hours. Designed for incoming engineering students, primarily those without prior experience, in process of soliciting, securing, and beginning research. Students learn about various methods and resources used to obtain laboratory positions, generation of opportunities and guidance on how to approach those openings. Offers students smooth transition into research laboratory. P/NP grading. (F,W,Sp)

25. Communicating Undergraduate Research Results. (2) Seminar, two hours; outside study, four hours. Designed to engage engineering students in process of communicating formal presentations. Students learn about various components required in publishing research. Offers templates and examples as guides for understanding technical presentations and writing. Development of skills and insights to successfully publish first research project. P/NP grading. (W)

87. Introduction to Engineering Disciplines. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Introduction to engineering as professional opportunity for fresh many students. Explores development of skills and techniques for the academy excellence while building teamwork and communication skills and examination of engineering majors offered at UCLA and of engineering careers. Hands-on experience with state-of-the-art Internet of Things (IoT) technologies and applications. Preparation for participation in advanced topics in the field. Indispensable preparation for hands-on research projects, professional training, and career planning. P/NP grading. (F,W,Sp)

29. Introduction to Engineering Design: Rockets. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Introduction for under-graduate 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-the-art solid-state imaging devices and management of technology commercialization.

96B. Introduction to Engineering Design: Digital Imaging. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Recommended for under-graduate 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-the-art solid-state imaging devices and management of technology commercialization.

96C. Introduction to Engineering Design: Internet of Things. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Recommended for under-graduate 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-the-art Internet of Things (IoT) technologies and applications. Preparation for participation in advanced topics in the field. Indispensable preparation for hands-on research projects, professional training, and career planning. P/NP grading. (Mr. Stafuddi (F,Sp)

96D. Introduction to Engineering Design: Go-Karts. (2) Lecture, 90 minutes; laboratory, 90 minutes; outside study, 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 microcontroller, with computer analysis and display. Students present their designs orally and in writing. Letter grading. (Mr. Kais (F,Sp)

96E. Introduction to Engineering Design: Electrocardiogram. (2) Lecture, 90 minutes; laboratory, 90 minutes; outside study, 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 microcontroller, with computer analysis and display. Students present their designs orally and in writing. Letter grading. (F,Sp)

96F. Introduction to Engineering Design: Rockets. (2) Lecture, 90 minutes; laboratory, 90 minutes; outside study, 90 minutes; outside study, three hours. Introduction to basic concepts in aerospace-engineered design, finite element analysis, machining, electric motor performance, steering linkages, and general mechanical design and assembly to work in teams and construct and test rocket designs. Letter grading. (F,Sp)

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 reconfigured to perform desirable functions in both intracellular and cell-free environments. Discussion of basic techniques and applications that deal with dynamic behavior, noise, and uncertainties. Design project in which students are challenged to design novel biosystems and nanosystems for non-trivial task required. Letter grading. (Mr. Liao (F,Sp)

M103. Environmental Nanotechnology: Implications and Applications. (4) (Same as Civil Engineering M165.) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended for students majoring in environmental engineering, environmental science, and environmental studies. Requisites: course M101. Introduction to potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental protection. Technical content includes three multidisciplinary areas: (1) physical, chemical, and biological properties of nanomaterials, (2) transport, reactivity, and toxicity of nanoscale materials in natural environmental systems, and (3) use of nanotechnology for energy and water purification and environmental protection, monitoring, and remediation. Letter grading. (Mr. Hoek (Sp)

110. Introduction to Technology Management and Economics for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, six hours. Fundamental principles of micro-level (individual, firm, and industry) and macro-level (government, international, and corporate) technology management. How individuals, firms, and governments impact successful commercialization of high technology products and services. Letter grading. (Mr. Monbouquette (F,W)

111. Introduction to Finance and Marketing for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of finance and marketing research and practice as they impact management of technology commercialization. Internal (within firm) and external (in marketplace) marketing and financing of high-technology innovation. Concepts include present value, future value, discounted cash flow, internal rate of return, return on assets, return on equity, return on investment, interest rates, cost of capital, and product, price, positioning, and promotion. Use of market research, segmentation, and technology management of technological innovation. Letter grading. (Mr. Monbouquette (W,Sp)

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Core concepts of entrepreneurship, finance, marketing, human resources, and accounting disciplines as they impact management of technology commercialization.
181E. Ethics and Impact of Technology on Soci- ety. (4) Lecture, five hours; discussion, three hours; outside study, four hours. Requisite: English Composition 3 or 3E. Not open for credit with course 182EW. Focuses on changing nature of technology and complex ethical issues that emerge as result in areas such as biotechnol- ogy, information technology, nanotechnology, and energy technology. Discussion of nature of these is- sues; their ethical, legal, and social ramifications; and what society values in relation to these issues. Explo- ration of philosophy, religion, and natural and social sciences in relation to these issues. Emphasis on re- search and writing within engineering environments. Writing and revision of about 20 pages total, in- cluding interim technology, design essays and one team-written research report. Readings address technical issues and written form. Satisfies engi- neering writing requirement. Letter grading.

Mr. Wesel (Not offered 2019-20)

182EW. Technology and Society. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Requisite: English Composition 3, and one course from Computer Engineering 131A, Electrical and Computer Engineering 131A, Mathematics 170, Me- chanical and Aerospace Engineering 174, or Statis- tics 100A. Not open for credit to students with credit for course 182EW. Plans engi- neering in broader societal context through examina- tion of some of key ethical, legal, regulatory and soci- al issues and frameworks relevant to design and deploy- ment of emerging technology products and services. Historical examination of ethical and legal frame- works generally and in relation to technology. Explo- ration of issues relevant to design, and frameworks related to examine their broader ramifications. Topics include driverless cars, artificial intelli- gence, global supply chain for engineering products, cryptocurrencies, and blockchain, net neu- trality, and impact of technology on employment. Of- fers students tools enabling them to think more pro- actively and holistically about ethical and societal di- mensions of their role as technology creators. Satisfies engineering writing requirement. Letter grading.

Mr. Villasenor (F)

183EW. Engineering and Society. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Requisite: English Composition 3 or 3E. Not open for credit to students with credit for course 183EW. Limited to sophomore/junior/senior engineering students. Professional and ethical con- siderations in engineering. Difference between tech- nology on society and on development of moral and ethical values. Contemporary environmental, biologi- cal, legal, and other issues created by new technolo- gies. Emphasis on research and writing within engi- neering environments. Writing and revision of about 20 pages total, including two technical issues as says and one team-written research report. Readings address technical issues and written form. Satisfies engineering writing requirement. Letter grading.

Mr. Wesel (W,Sp)


Mr. Wesel (W,Sp)

189. Special Courses in Engineering. (4) Lecture, four hours; outside study, two 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.

191. Seminar Series in Engineering Research. (1) Seminar, one hour. Seminar series in cutting-edge engineering research at UCLA. Each seminar is given by UCLA graduate student researcher or post-doc- toral student. Designed to provide upper-graduate students in any science, technology, engi- neering, and mathematics (STEM) major. Offers un- dergraduate students window into excitement of graduate student research. Student registration also offers opportunity for graduate students to learn about what their peers are doing. P/NP grading.

192. Fundamentals of Engineering Mentorship. (2) Seminar, two hours; outside study, four hours. Princi- ples and practical techniques for hands-on engineer- ing design projects in high school outreach programs. Curriculum planning, project prepa- ration, classroom management, team collaboration, diversity awareness, fostering of group cohesion, and emergency procedures. Preparation of lessons and project for summer outreach program, with practice presentations. P/NP grading.

Mr. Pottie (W,Sp)

193. Internship in Engineering. (2 to 4) Tu- torial, two to four hours. Open to juniors/seniors. Ini- tiation of engineering students. Course supervised by associate dean or designated faculty associate Dean. Further supervision is to be provided by organization for which students are doing internship. Students may be required to meet on regular basis with instructor and provide periodic reports of their experience. May not be ap- plied toward major requirements. May be repeated for credit. Individual contract with an associate dean re- quired. P/NP grading.

Mr. Wesel (W,Sp)

199. Directed Research in Engineering. (2 to 8) Tu- torial, to be arranged. Limited to juniors/seniors. Su- perseded by individual research undertaken under guidance of faculty mentor. May not be applied for credit with school approval. Individual contract required; enroll- ment petition available in Office of Academic and Student Affairs. Letter grading.

Graduate Courses

200. Program Management Principles for Engi- neers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate stu- dents. Practical review of necessary processes and procedures to successfully manage technology pro- grams. Review of fundamental concepts of planning, organizational structure, implementation, and perfor- mance tracking methods to provide program man- ager with necessary information to support decision- making processes that provide productivity on time and within budget. Letter grading.

Mr. Wesel (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, project management, reliability, and audit activities and documentation. Letter grading.

Mr. Pottie (W,Sp)

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. In- tegrated logistic support (ILS) is major driver of system life-cycle cost and one key element of system engi- neering activities. Overview of engineering disciplines critical to ILS function—reliability, maintainability, and supportability—and their relationships, taught using probability theory. Topics also include fault detections and isolations and parts obsolescence. Discussion of 8-6-4 process, overview of component and manufac- turing methodology, to ensure system reliability, maintainability, and supportability. Letter grading.

Mr. Lynch (W,Sp)

203. System Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course 201. Designed for graduate students with BS degrees in
Letter grading.

The development of systems, particularly in the military and national security sectors, involves complex processes to ensure that systems meet specified operational requirements. This includes building systems that are reliable, maintainable, and cost-effective. System assurance addresses confidence in the system's ability to perform its intended functions through analysis of framework of assurance to accomplish the mission. This involves evaluating material presented as possible. Letter grading.

Mr. J-M. Yang

121. Intellectual Property Law and Strategy. (4) Lecture, four hours; outside study, eight hours. Prior knowledge of legal doctrines or materials not required. Intellectual property law is not just topic for lawyers. Engineers who have design responsibilities must understand how legal system in some instances protects their designs and in other instances stands as obstacle to what would otherwise be most efficient design choice. Engineers with management responsibilities must understand intellectual property law implications for everything from pricing to strategic partnerships. Examination of intellectual property law, not only by learning fundamental rules associated with patent, copyright, trademark, and trade secret protection, but by studying business strategies, in which the presence and protection of intangible assets can have a significant impact on a company's success. Letter grading.

Mr. Lichtman, Mr. J-M. Yang (F)

122. Data and Business Analytics. (4) Lecture, four hours; outside study, eight hours. 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 dynamic models. 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 commun icatively in workplace, with focus on business presentation skills, visual and verbal persuasion skills, and interpersonal communication skills. Letter grading.

Mr. Abe, Mr. Cong, Mr. Wesel (W)

215. Entrepreneurship for Engineers. (4) Lecture, four hours; outside study, eight hours. Limit 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.

M495I. Supervised Teaching of Writing for Engineers. (Formerly numbered M495B.) Same as English Composition M495I. Seminar, two and one half hours; outside study, nine and one half hours. Preparation: consent of UCLA graduate adviser and graduate dean, and host campus instructor, department chair, and graduate dean. Limited to Engineering Executive Program students. Influences of human relations, laws, social sciences, humanities, and fine arts on development and utilization of natural and human resources. Interaction of technology and society past, present, and future. Change agents and resistance to change. S/U or letter (471A) grading. In Progress (471B) and S/U or letter (471C) grading.

472A-472D. Analysis and Synthesis of Large-Scale System. (3–3–1.5) Lecture, three hours (courses 472A, 472B, 472C) and 90 minutes (course 472D). Limited to Engineering Executive Program students. Examination of actual business problems of firm, community, and nation, provided through cooperation and participation with California business corporations and government agencies. Progress (472A and S/U or letter (472C) grading (credit to be given on completion of courses 472B and 472D).

473A-473B. Analysis and Synthesis of Large-Scale System. (3–3–1.5) Lecture, three hours (courses 472A, 472B, 472C) and 90 minutes (course 472D). Limited to Engineering Executive Program students. Practice 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.

M495I. Teaching Preparation Seminar: Writing for Engineers. (Formerly numbered M495B.) 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.

M495J. Supervised Teaching of Writing for Engi neers. (Formerly numbered M495C.) 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. Mentoring in group and individual meetings. Continuing 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.

M495K. Cooperative Engineering Practice. (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.
Center for Domain-Specific Computing (CDSC)
National Science Foundation (NSF) Expeditions in Computing Program and InTrans Program
Jason Cong, Ph.D. (Computer Science), Director; https://cdsc.ucla.edu

To meet ever-increasing computing needs and overcome power density limitations, the computing industry has entered the era of parallelization, with tens to hundreds of computing cores integrated into a single processor and hundreds to thousands of computing servers connected in warehouse-scale data centers. However, such highly parallel, general-purpose computing systems still face serious challenges in terms of performance, energy, heat dissipation, space, and cost. CDSC looks beyond parallelization and focuses on domain-specific customization as the next disruptive technology, to bring orders-of-magnitude power-performance efficiency improvement to important application domains.

CDSC develops a general methodology for creating novel customizable computing platforms, and the associated compilation tools and runtime management environment to support domain-specific computing. Its recent focus is on design and implementation of accelerator-rich architectures, from single chips to data centers. It also includes highly automated compilation tools and runtime management software systems for customizable heterogeneous platforms, including multi-core CPUs, many-core GPUs, and FPGAs; as well as a general, reusable methodology for customizable computing applicable across different domains. By combining these critical capabilities, the goal is to deliver a supercomputer-in-a-box or -in-a-cluster, customized to an application domain, to enable disruptive innovations in that domain. CDSC has successfully demonstrated this approach in the domains of machine learning, medical image processing, and precision medicine.

The current team consists of highly accomplished researchers with diversified backgrounds, including computer science and engineering, electrical engineering, medicine, and applied mathematics from UCLA, Cornell University, and Georgia Institute of Technology. CDSC offers many research opportunities for graduate students, and summer research opportunities for undergraduate students.

CDSC was originally funded by the National Science Foundation (NSF) with a $10 million award from the 2009 Expeditions in Computing program, which was among the largest single investments made by the NSF Computer and Information Science and Engineering (CISE) Directorate. In July 2014, CDSC was awarded an additional $3 million by Intel Corporation, with matching support from NSF under its Innovation Transition (InTrans) program. This award supports follow-on research on accelerator-rich architectures with applications to health care, in which personalized cancer treatment was added as an application domain in addition to medical imaging. Currently, CDSC research programs are supported by NSF, Semiconductor Research Corporation (SRC) Joint University Microelectronics Program (JUMP), and a number of industrial partners worldwide.

Center for Encrypted Functionalities
National Science Foundation (NSF) Secure and Trustworthy Cyberspace FRONTIER Award
Amit Sahai, Ph.D. (Computer Science), Director; http://web.cs.ucla.edu/cef/

The center tackles the deep and far-reaching problem of general-purpose program obfuscation, which aims to make an arbitrary computer program unintelligible while preserving its functionality. Viewed in a different way, the goal of obfuscation is to enable software that can keep secrets: it makes use of secrets, but such that these secrets remain hidden even if an adversary can examine the software code in its entirety and analyze its behavior as it runs. Secure obfuscation could enable a host of applications, from hiding the existence of many vulnerabilities introduced by human error to hiding cryptographic keys within software.

The center’s primary mission is to transform program obfuscation from an art to a rigorous mathematical discipline. In addition to its direct research program, the center organizes retreats and workshops to bring together researchers to carry out its mission. The center also engages in high-impact outreach efforts, such as the development of free massive open online courses (MOOCs).

Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS)
National Science Foundation (NSF) Engineering Research Center
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering), Director; Jane P. Chang, Ph.D. (Chemical and Biomolecular Engineering), Deputy Director; http://www.tanms-erc.org

TANMS is a 10-year program focused on miniaturizing electromagnetic devices using a three-pillar strategy involving research, translation, and education. The research strategy engages the best researchers from the six TANMS campuses (California State University, Northridge; Cornell University; Northeastern University; UC Berkeley; UCLA; and University of Texas at Dallas) to understand and develop new nanoscale multiferroic devices. The fundamental research activities work synergistically with the center’s 13 industrial partners to translate the concepts into applications such as memory, antennas, and motors. These research and translational efforts rely on a workforce of postgraduate, graduate, undergraduate, and K-12 students that also help educate the next generation of engineering leaders. TANMS promotes an inclusive atmosphere, producing a more innovative and diverse research environment compared to conventional engineering center cultures.

Center of Excellence for Green Nanotechnologies (CEGN)
Kang L. Wang, Ph.D. (Electrical and Computer Engineering), Director

CEGN undertakes frontier research and development in the areas of nanotechnology in energy and nanoelectronics. It tackles major issues of scaling, energy efficiency, energy generation, and energy storage faced by the electronics industry. CEGN researchers are innovating novel solutions through a number of complementary efforts that minimize power usage and cost without compromising electronic device performance. The approach is based on the integration of magnetic, carbon-based, organic, and optoelectronic materials and devices.
King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia and UCLA Samueli collaborate in CEGN under KACST’s established Joint Center of Excellence Program (JCEP) to promote educational technology transfer and research exchanges. KACST has an agreement with UCLA for research in nanoelectronics and clean energy for the next three years. KACST is both Saudi Arabia’s national science agency and its premier national laboratory. CEGN was awarded an additional $11 million through 2021 in its recent renewal effort, expanding on the work that was originally funded at $3.7 million.

**Named Data Networking Project**

National Science Foundation (NSF) Future Internet Architecture (FIA) Program
Lixia Zhang, Ph.D. (Computer Science), Principal Investigator
http://named-data.net

While the Internet has far exceeded expectations, it has also stretched initial assumptions, often creating tangles that challenge its underlying communication model. The TCP/IP architecture was designed to create a communication network where packets named only communication endpoints. Sustained growth in e-commerce, digital media, social networking, and smartphone applications has led to dominant use of the Internet as a distribution network. Solving distribution problems through a point-to-point communication protocol is complex and error-prone.

This project investigates a new Internet architecture, called named data networking (NDN), that changes the host-centric TCP/IP architecture to a data-centric architecture. This conceptually simple shift has far-reaching implications for how we design, develop, deploy, and use networks and applications. Today’s TCP/IP architecture uses addresses to communicate; NDN directly uses application data names to fetch data. TCP/IP secures the data container and communication channels; NDN directly secures the data, decoupling trust in data from trust in hosts. The project takes an application-driven, experimental approach to design and build a variety of applications on NDN to drive the development and deployment of the architecture and its supporting modules, test prototype implementations, and encourage community use, experimentation, and feedback into the design.

The new Future Internet Architectures—Next Phase (FIA-NP) program began in May 2014. The Named Data Networking Project is now under FIA-NP funding.

**Smart Grid Energy Research Center (SMERC)**

Rajit Gadh, Ph.D. (Mechanical and Aerospace Engineering), Director
http://smartgrid.ucla.edu

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 (V2G and V2C), microgrids, distributed renewable integration including solar and wind, energy storage integration within microgrids, autonomous electric vehicles, distributed energy resources, automated demand response, cybersecurity, and consumer behavior. SMERC also furnishes thought leadership through partnership between utilities, renewable energy companies, technology providers, electric vehicle and electric appliance manufacturers, Department of Energy (DOE) research laboratories, and universities, so as to collectively work on envisioning, planning, and executing the smart grid of the future. The partnership recently launched the Energy for a Smart Grid (ESmart) Industry Consortium. It is expected that this smart grid will enable integration of renewable energy sources, allow for integration of electric vehicles and energy storage, improve grid efficiency and resilience, reduce power outages, allow for competitive energy pricing, and overall become more responsive to market, consumer, and societal needs. SMERC was a participant in the Los Angeles Department of Water and Power (LADWP) Regional Smart Grid Demonstration Project, which was funded by DOE at an estimated $120 million for LADWP and its partners combined. Also, a SMERC electric vehicle microgrid demonstration project was funded by the California Energy Commission.

**WIN Institute of Neurotronics (WINs)**

Nanoelectronics Research Initiative National Institute of Excellence
Kang L. Wang, Ph.D. (Electrical and Computer Engineering), Director
http://win-nano.org

Successor to the Western Institute of Nanoelectronics, WINs focuses on cutting-edge research including nanostructures for high-efficiency solar cells, patterned nanostructures for integrated active optoelectronics on silicon, and carbon nanotube circuits.

Through the multidisciplinary research efforts of WINs, the National Institute of Standards and Technology (NIST) awarded UCLA $6 million to build the Western Institute of Nanotechnology on Green Engineering and Metrology (WIN-GEM) building as part of the Engineering Building 1 replacement, which broke ground in 2013.

**Wireless Health Institute (WHI)**

Benjamin M. Wu, D.D.S, Ph.D. (Biomedical Engineering), Director; Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical and Computer Engineering), Gregory J. Pottie, Ph.D. (Electrical and Computer Engineering), Co-Directors

Advances in engineering and computer science are enabling the design of powerful home and mobile technologies that can augment functional independence and daily activities of people with physical impairments, disabilities, chronic diseases, and the accumulative impairments associated with aging. These wireless
mobile-health technologies can serve as monitoring devices of health and activity, provide feedback to train more healthy behaviors and lessen risk factors for stroke and heart disease, and offer novel outcome measures for individual care and large clinical trials.

WHI believes that tiny sensors—including accelerometers, gyroscopes, force transducers, and visual and sound recorders worn on the body and in clothing—will become essential components for the delivery of health care and health maintenance. Sensors created by micro- and nano-technologies will simplify communications with health providers seamlessly over Internet and wi-fi transmission using telephones and other convenient devices. To pursue these applications, WHI collaborators include the highly ranked UCLA schools of Medicine, Nursing, Engineering and Applied Science, and Management; the Clinical Translational Science Institute for medical research; the Ronald Reagan UCLA Medical Center; and faculty from many campus departments. WHI education programs span high school, undergraduate, and graduate students, and physicians; and provide training in end-to-end product development and delivery for WHI program managers.

WHI strategies and products appear in diverse health care scenarios including motion sensing of the type, quantity, and quality of exercise and practice in disabled persons; prevention of pressure sores; recovery after orthopaedic procedures; assessment of the recovery of bowel motility after surgery; monitoring cardiac output and predicting an exacerbation of heart failure; advancing athletic performance; and others. UCLA and international clinical trials, funded by the National Institutes of Health and American Heart Association, have validated motion pattern recognition and sensor feedback to increase walking and exercise after stroke. Several WHI products developed by the UCLA team are now in the marketplace in the U.S. and Europe. WHI welcomes new team members; and continuously forms new collaborations with colleagues and organizations in engineering, medical science, and health care delivery.
# B.S. in Aerospace Engineering
## Aeronautics Track Curriculum

### FRESHMAN YEAR

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<th>Quarter</th>
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<tr>
<td>1st</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure¹</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 Calculus¹</td>
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<td>Mechanical and Aerospace Engineering 1 — Undergraduate Seminar²</td>
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<td>2nd</td>
<td>Chemistry and Biochemistry 208/20L — Chemical Energetics and Change/General Chemistry Laboratory¹</td>
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<td>Mathematics 31B — Integration and Infinite Series²</td>
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<td>Physics 1A — Mechanics¹</td>
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<td>3rd</td>
<td>Mathematics 32A — Calculus of Several Variables¹</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory¹</td>
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<td>UCLA Samueli GE Elective³</td>
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### SOPHOMORE YEAR

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<td>Physics 1C/4BL — Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory¹</td>
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<td>Materials Science and Engineering 104 — Science of Engineering Materials²</td>
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<td>Mathematics 33A — Linear Algebra and Applications¹</td>
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<td>Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials²</td>
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<td>Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics²</td>
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<td>Mechanical and Aerospace Engineering 1020 (Intro to Computer Programming with MATLAB) or Computer Science 31 (Intro to Computer Science I)²</td>
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<td>Mechanical and Aerospace Engineering 82 — Mathematics of Engineering²</td>
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<td>Mechanical and Aerospace Engineering 102 — Dynamics of Particles and Rigid Bodies³</td>
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<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics³</td>
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### JUNIOR YEAR

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<td>Mechanical and Aerospace Engineering 166A — Analysis of Aerospace Structures²</td>
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<td>Mechanical and Aerospace Engineering 107 — Introduction to Modeling and Analysis of Dynamic Systems²</td>
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<td>Mechanical and Aerospace Engineering 150A — Intermediate Fluid Mechanics³</td>
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<td>Mechanical and Aerospace Engineering 150B — Aerodynamics²</td>
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<td>Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems²</td>
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### SENIOR YEAR

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<td>Mechanical and Aerospace Engineering 150P — Aircraft Propulsion Systems³</td>
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<td>Mechanical and Aerospace Engineering 157 — Basic Mechanical and Aerospace Engineering Laboratory²</td>
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<td>Technical Breadth Course³</td>
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<td>Mechanical and Aerospace Engineering 157A — Fluid Mechanics and Aerodynamics Laboratory²</td>
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<td>Technical Breadth Course³</td>
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### TOTAL

180

¹. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.
³. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
⁴. See page 110 for list of electives.
# B.S. in Aerospace Engineering

## Space Track Curriculum

### Freshman Year

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<td>Mechanical and Aerospace Engineering 1—Undergraduate Seminar²</td>
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<td>Mathematics 32A—Calculus of Several Variables¹</td>
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<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory³</td>
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<td>Physics 1C/4BL—Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory³</td>
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<td>Mathematics 33A—Linear Algebra and Applications¹</td>
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<td>Mechanical and Aerospace Engineering M20 (Intro to Computer Programming with MATLAB) or Computer Science 31 (Intro to Computer Science I)²</td>
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<td>Mechanical and Aerospace Engineering 166A—Analysis of Aerospace Structures²</td>
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<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems²</td>
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<td>Mechanical and Aerospace Engineering 150A—Intermediate Fluid Mechanics²</td>
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<td>Mechanical and Aerospace Engineering 150B (Aerodynamics) or CISOP (Aircraft Propulsion Systems)³</td>
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<td>Mechanical and Aerospace Engineering 150R—Rocket Propulsion Systems³</td>
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<td>Mechanical and Aerospace Engineering 171A—Introduction to Feedback and Control Systems³</td>
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### Senior Year

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<td>Mechanical and Aerospace Engineering 157—Basic Mechanical and Aerospace Engineering Laboratory²</td>
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<td>Mechanical and Aerospace Engineering 161B—Introduction to Space Technology²</td>
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<td>Technical Breadth Course²</td>
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<td>UCLA Samueli GE Elective³</td>
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<td>Mechanical and Aerospace Engineering 157A—Fluid Mechanics and Aerodynamics Laboratory²</td>
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<td>Mechanical and Aerospace Engineering 161C—Spacecraft Design²</td>
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### Total

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<td>180</td>
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¹ Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.
² Counts as Engineering Concepts for ABET, total units Engineering Concepts = 85.
³ Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
⁴ See page 110 for list of electives.
B.S. in Bioengineering Curriculum

FRESHMAN YEAR

1st Quarter
Bioengineering 10—Introduction to Bioengineering\(^2\) .................................................. 2
Chemistry and Biochemistry 20A—Chemical Structure\(^1\) .................................................. 4
English Composition 3—English Composition, Rhetoric, and Language ..................... 5
Mathematics 31A—Differential and Integral Calculus\(^1\) .................................................. 4

2nd Quarter
Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory\(^1\) .................................................. 7
Mathematics 31B—Integration and Infinite Series\(^1\) .................................................. 4
Physics 1A—Mechanics\(^1\) .................................................................................. 5

3rd Quarter
Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity\(^1\) .................................................. 4
Mathematics 32A—Calculus of Several Variables\(^1\) .................................................. 4
Physics 18/44L—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory\(^1\) .................................................. 7

SOPHOMORE YEAR

1st Quarter
Bioengineering 100—Bioengineering Fundamentals\(^2\) .................................................. 4
Chemistry and Biochemistry 30B—Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy\(^1\) .................................................. 4
Mathematics 32B—Calculus of Several Variables\(^1\) .................................................. 4
Physics 1C—Electrodynamics, Optics, and Special Relativity\(^1\) .................................................. 5

2nd Quarter
Chemistry and Biochemistry 30AL—General Chemistry Laboratory II\(^1\) ..................... 4
Life Sciences 7A—Cell and Molecular Biology\(^1\) .................................................. 5
Mathematics 33A—Linear Algebra and Applications\(^1\) .................................................. 4
UCLA Samueli GE Elective\(^1\) .............................................................................. 5

3rd Quarter
Bioengineering 167L—Bioengineering Laboratory\(^3\) .................................................. 4
Computer Science 31 (Intro to Computer Science I) or Mechanical and Aerospace Engineering M20 (Intro to Computer Programming with MATLAB)\(^2\) .................................................. 4
Life Sciences 7C—Physiology and Human Biology\(^1\) .................................................. 5
Mathematics 33B—Differential Equations\(^1\) .................................................. 4

JUNIOR YEAR

1st Quarter
Electrical and Computer Engineering 100—Electrical and Electronic Circuits\(^2\) .......... 4
UCLA Samueli Ethics Course .................................................................................. 4
UCLA Samueli GE Elective\(^1\) .............................................................................. 5

2nd Quarter
Bioengineering 120—Biomedical Transducers\(^2\) .................................................. 4
Bioengineering Elective\(^1\) .............................................................................. 4
UCLA Samueli GE Elective\(^1\) .............................................................................. 5
Technical Breadth Course\(^1\) .............................................................................. 4

3rd Quarter
Bioengineering 110—Bioreaction Processes\(^2\) .................................................. 4
Bioengineering 176—Principles of Biocompatibility\(^2\) .................................................. 4
Bioengineering Elective\(^1\) .............................................................................. 4
Technical Breadth Course\(^1\) .............................................................................. 4

SENIOR YEAR

1st Quarter
Bioengineering 177A—Bioengineering Capstone Design \(^2\) .................................................. 4
Restricted Elective\(^2,3\) ............................................................................. 4
Technical Breadth Course\(^1\) .............................................................................. 4

2nd Quarter
Bioengineering 177B—Bioengineering Capstone Design II\(^2\) .................................................. 4
Bioengineering 180—System Integration in Biology, Engineering, and Medicine \(^2\) .................................................. 4
UCLA Samueli GE Elective\(^1\) .............................................................................. 5

3rd Quarter
Bioengineering Electives (2)\(^2,4\) .................................................................................. 8
Restricted Elective\(^2,3\) ............................................................................. 4

TOTAL ........................................................................................................... 185

---

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 74.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
5. Restricted electives include Bioengineering C101, C106, C131, C155, M260 (a petition is required for M260).
# B.S. in Chemical Engineering

## Chemical Engineering Core Option Curriculum

### FRESHMAN YEAR

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<th>Course</th>
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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>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>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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### SOPHOMORE YEAR

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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Chemical Engineering 45 — Biomedical Engineering Fundamentals</td>
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<td>Chemical Engineering 102A — Thermodynamics I</td>
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<td>Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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### JUNIOR YEAR

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<td>Chemical Engineering 101A — Transport Phenomena I</td>
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<td>Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemical Engineering 101B — Transport Phenomena II: Heat Transfer</td>
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<td>Chemical Engineering 104A — Chemical and Biomedical Engineering Laboratory II</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes</td>
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### SENIOR YEAR

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<td>Chemical Engineering 106 — Chemical Reaction Engineering</td>
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<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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### TOTAL

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 64.
3. Students should consult the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
# B.S. in Chemical Engineering
## Biomedical Engineering Option Curriculum

### FRESHMAN YEAR

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<tr>
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<td>Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering 2</td>
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<td>Chemistry and Biochemistry 20A — Chemical Structure 1</td>
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<td>Mathematics 31B — Integration and Infinite Series 1</td>
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<td>Physics 1A — Mechanics 1</td>
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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity 1</td>
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<td>Mathematics 32A — Calculus of Several Variables 1</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory 1</td>
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### SOPHOMORE YEAR

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<tr>
<td>1st</td>
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<td>Chemical Engineering 100 — Fundamentals of Chemical and Biomolecular Engineering 2</td>
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### JUNIOR YEAR

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### SENIOR YEAR

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**TOTAL** 180

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# B.S. in Chemical Engineering

## Biomolecular Engineering Option Curriculum

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**TOTAL** 180

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# B.S. in Chemical Engineering

## Environmental Engineering Option Curriculum

### FRESHMAN YEAR

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**TOTAL** 180

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### B.S. in Chemical Engineering

#### Semiconductor Manufacturing Engineering Option Curriculum

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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Chemical Engineering 107—Process Dynamics and Control ²</td>
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<tr>
<td>Chemical Engineering 108A—Process Economics and Analysis ²</td>
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<td>Technical Breadth Course ³</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Chemical Engineering 104C/104CL—Semiconductor Processing/Laboratory ²</td>
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<tr>
<td>Chemical Engineering 108B—Chemical Process Computer-Aided Design and Analysis ²</td>
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<tr>
<td>Chemical Engineering 116—Surface and Interface Engineering ²</td>
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</table>
| **TOTAL**                                            |       | 180

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 64.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
# B.S. in Civil Engineering Curriculum

## FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td></td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>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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## SOPHOMORE YEAR

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<tbody>
<tr>
<td>1st Quarter</td>
<td>Civil and Environmental Engineering 91 — Statics</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>Civil and Environmental Engineering 101 — Dynamics of Particles and Bodies</td>
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<td>Civil and Environmental Engineering C104 (Structure, Processing, and Properties of Civil Engineering Materials) or Materials Science and Engineering 104 (Science of Engineering Materials)</td>
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<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>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>Mathematics 338 (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)</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>
<th>Course Description</th>
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<td>Civil and Environmental Engineering 13A — Elementary Structural Analysis</td>
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<td>Civil and Environmental Engineering 150 — Introduction to Hydrology</td>
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<td>Civil and Environmental Engineering 153 — Introduction to Environmental Engineering Science</td>
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<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<td>Civil and Environmental Engineering 103 — Applied Numerical Computing and Modeling in Civil and Environmental Engineering</td>
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<td>Civil and Environmental Engineering 110 — Introduction to Probability and Statistics for Engineers</td>
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<td>Major Field Electives (2)</td>
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## SENIOR YEAR

<table>
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<td>UCLA Samueli GE Elective</td>
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<td>2nd Quarter</td>
<td>Major Field Electives (2)</td>
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<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>3rd Quarter</td>
<td>Major Field Elective</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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<tr>
<td>TOTAL</td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 56.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
4. Must include required courses for two of the major field areas listed on page 51.
# B.S. in Computer Engineering Curriculum

## FRESHMAN YEAR

<table>
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<tr>
<th>Quarter</th>
<th>Courses</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Computer Science 1 (Freshman Computer Science Seminar) or Electrical and Computer Engineering 1 (Undergraduate Seminar)</td>
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<td>Computer Science 3—Introduction to Computer Science I</td>
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<td></td>
<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<tr>
<td></td>
<td>Mathematics 31A—Differential and Integral Calculus</td>
<td>4</td>
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<tr>
<td>2nd Quarter</td>
<td>Computer Science 32—Introduction to Computer Science II</td>
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<tr>
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<td>Mathematics 31B—Integration and Infinite Series</td>
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<tr>
<td></td>
<td>Physics 1A—Mechanics</td>
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<tr>
<td></td>
<td>UCLA Samueli GE Elective</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science 33—Introduction to Computer Organization</td>
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<td>Engineering GE—Introduction to Engineering Design: Internet of Things</td>
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<td></td>
<td>Mathematics 32A—Calculus of Several Variables</td>
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<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields</td>
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## SOPHOMORE YEAR

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<td>Electrical and Computer Engineering 3—Introduction to Electrical Engineering</td>
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<td>Mathematics 32B—Calculus of Several Variables</td>
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<td>Mathematics 33A—Linear Algebra and Applications</td>
<td>4</td>
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<tr>
<td></td>
<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)</td>
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<tr>
<td>2nd Quarter</td>
<td>Computer Science 35L—Software Construction Laboratory</td>
<td>3</td>
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<tr>
<td></td>
<td>Computer Science M51A or Electrical and Computer Engineering M16—Logic Design of Digital Systems</td>
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<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits</td>
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<td>Mathematics 338—Differential Equations</td>
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<td>Electrical and Computer Engineering 102—Systems and Signals</td>
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<td>Mathematics 61—Introduction to Discrete Structures</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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## JUNIOR YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Courses</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Computer Science 111—Operating Systems Principles</td>
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<td>Probability Elective</td>
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<tr>
<td></td>
<td>UCLA Samueli Ethics Course</td>
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<tr>
<td>2nd Quarter</td>
<td>Computer Science 118 (Computer Network Fundamentals) or Electrical and Computer Engineering 132B (Data Communications and Telecommunication Networks)</td>
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<td>Computer Science M152A or Electrical and Computer Engineering M16L—Introductory Digital Design Laboratory</td>
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<tr>
<td></td>
<td>Computer Science 180—Introduction to Algorithms and Complexity</td>
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<td>Electrical and Computer Engineering 115C—Digital Electronic Circuits</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science M151B or Electrical and Computer Engineering M16C—Computer Systems Architecture</td>
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<td>Computer Science Elective</td>
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<tr>
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<td>Electrical and Computer Engineering Elective</td>
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<td>UCLA Samueli GE Elective</td>
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## SENIOR YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
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<td>Technical Breadth Course</td>
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</tr>
<tr>
<td></td>
<td>UCLA Samueli GE Elective</td>
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<tr>
<td>2nd Quarter</td>
<td>Computer Science Elective</td>
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</tr>
<tr>
<td></td>
<td>Electrical and Computer Engineering Design Course</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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</tr>
<tr>
<td>3rd Quarter</td>
<td>Electrical and Computer Engineering Design Course</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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<tr>
<td>TOTAL</td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 49.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
4. See page 65 or 86 for list of electives.
# B.S. in Computer Science Curriculum

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
</tr>
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<tbody>
<tr>
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<tr>
<td>Computer Science 1—Freshman Computer Science Seminar²</td>
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<tr>
<td>Mathematics 31A—Differential and Integral Calculus¹</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Computer Science 32—Introduction to Computer Science ²</td>
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<tr>
<td>Mathematics 31B—Integration and Infinite Series¹</td>
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<td>Physics 1A—Mechanics¹</td>
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<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Computer Science 33—Introduction to Computer Organization²</td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables¹</td>
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<tr>
<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields¹</td>
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<tbody>
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<td><strong>1st Quarter</strong></td>
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<tr>
<td>Computer Science 35L—Software Construction Laboratory²</td>
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<td>Computer Science M51A or Electrical and Computer Engineering M16—Logic Design of Digital Systems²</td>
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<td>Mathematics 32B—Calculus of Several Variables²</td>
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<td>Mathematics 33A—Linear Algebra and Applications¹</td>
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<tr>
<td>Mathematics 61—Introduction to Discrete Structures¹</td>
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<tr>
<td>Physics 1C—Electrodynamics, Optics, and Special Relativity¹</td>
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<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)¹</td>
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<td>Computer Science 111—Operating Systems Principles²</td>
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<td>UCLA Samueli GE Elective³</td>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Computer Science 11B—Computer Network Fundamentals²</td>
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<td>Computer Science 180—Introduction to Algorithms and Complexity²</td>
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<td>Science and Technology Elective³</td>
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<td>Computer Science 131—Programming Languages²</td>
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<td>Computer Science M151B or Electrical and Computer Engineering M156—Computer Systems Architecture²</td>
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<td>Probability Elective¹, ², ³</td>
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<td>Computer Science 181—Introduction to Formal Languages and Automata Theory²</td>
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<td>Technical Breadth Course³</td>
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<td>UCLA Samueli GE Elective³</td>
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<tbody>
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<td><strong>1st Quarter</strong></td>
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<td>Computer Science 130 (Software Engineering) or 1528 (Digital Design Project Laboratory)²</td>
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<td>Science and Technology Elective³</td>
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<td>Computer Science Electives (2)², ³</td>
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<td>Technical Breadth Course³</td>
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<td><strong>3rd Quarter</strong></td>
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<td>Computer Science Elective², ³</td>
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<td><strong>TOTAL</strong></td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 49.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
4. See page 65 for list of electives.
5. Any excess or available units not already applied to another degree requirement will satisfy these units.
**B.S. in Computer Science and Engineering Curriculum**

### FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<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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<tr>
<td>2nd</td>
<td>Computer Science 32—Introduction to Computer Science I</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>
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<td>Computer Science 33—Introduction to Computer Organization</td>
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<td>Mathematics 32A—Calculus of Several Variables</td>
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<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields</td>
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### SOPHOMORE YEAR

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<th>Quarter</th>
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<tr>
<td>1st</td>
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<td>Computer Science MS1A or Electrical and Computer Engineering M16</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>Mathematics 33A—Linear Algebra and Applications</td>
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<td>Mathematics 61—Introduction to Discrete Structures</td>
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<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)</td>
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<td>UCLA Samueli Ethics Course</td>
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<td>Computer Science 180—Introduction to Algorithms and Complexity</td>
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<td>Mathematics 33B—Differential Equations</td>
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### JUNIOR YEAR

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<td>Computer Science 131—Programming Languages</td>
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<td>Computer Science M152A or Electrical and Computer Engineering M116L Introductory Digital Design Laboratory</td>
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<td>Electrical and Computer Engineering 102—Systems and Signals</td>
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<td>3rd</td>
<td>Computer Science 118—Computer Network Fundamentals</td>
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<td>Computer Science M151B or Electrical and Computer Engineering M116C Computer Systems Architecture</td>
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<td>Electrical and Computer Engineering 115C—Digital Electronic Circuits</td>
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### SENIOR YEAR

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<td>Computer Science 181—Introduction to Formal Languages and Automata Theory</td>
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<td>Computer Science Elective</td>
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<td>UCLA Samueli GE Elective</td>
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<td>2nd</td>
<td>Computer Science Elective</td>
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<td>Electrical and Computer Engineering Elective</td>
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<td>Technical Breadth Course</td>
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<td>3rd</td>
<td>Computer Science Elective</td>
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<td>UCLA Samueli GE Elective</td>
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<td>Additional coursework to meet 180 unit requirement</td>
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<td>TOTAL</td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 49.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
4. See page 64 for list of electives.
5. Any excess or available units not already applied to another degree requirement will satisfy this unit.
### B.S. in Electrical Engineering Curriculum

#### FRESHMAN YEAR

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<td>Computer Science 31—Introduction to Computer Science 1&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A—Differential and Integral Calculus&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>2nd Quarter</td>
<td>Mathematics 31B—Integration and Infinite Series&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Physics 1A—Mechanics&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>3rd Quarter</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>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory&lt;sup&gt;1&lt;/sup&gt;</td>
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#### SOPHOMORE YEAR

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<td>Electrical and Computer Engineering 3—Introduction to Electrical Engineering&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Mathematics 32B—Calculus of Several Variables&lt;sup&gt;1&lt;/sup&gt;</td>
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<td></td>
<td>Mathematics 33A—Linear Algebra and Applications&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity&lt;sup&gt;1&lt;/sup&gt;</td>
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<tr>
<td>2nd Quarter</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;2&lt;/sup&gt;</td>
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<td>Mathematics 33B—Differential Equations&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;2&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;2&lt;/sup&gt;</td>
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<td>UCLA Samuelsi GE Elective&lt;sup&gt;3&lt;/sup&gt;</td>
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#### JUNIOR YEAR

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<th>Quarter</th>
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<tbody>
<tr>
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<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>UCLA Samuelsi GE Elective&lt;sup&gt;3&lt;/sup&gt;</td>
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<tr>
<td>2nd Quarter</td>
<td>Electrical and Computer Engineering 101A—Engineering Electromagnetics&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>UCLA Samuelsi GE Elective&lt;sup&gt;3&lt;/sup&gt;</td>
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<tr>
<td>3rd Quarter</td>
<td>Electrical and Computer Engineering Core Course&lt;sup&gt;2,4&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;2,4&lt;/sup&gt;</td>
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#### SENIOR YEAR

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<th>Course</th>
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<td>Electrical and Computer Engineering Core Course&lt;sup&gt;2,4&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering Design Course&lt;sup&gt;2&lt;/sup&gt;</td>
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<tr>
<td>2nd Quarter</td>
<td>Electrical and Computer Engineering Design Course&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Electrical and Computer Engineering Elective&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>UCLA Samuelsi GE Elective&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>3rd Quarter</td>
<td>Electrical and Computer Engineering or UCLA Samuelsi Elective&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>Technical Breadth Course&lt;sup&gt;3&lt;/sup&gt;</td>
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**TOTAL: 182**

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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 (see page 23 for details).
4. See page 84 for list of core courses.
# B.S. in Materials Engineering Curriculum

## Materials Engineering Option Curriculum

### FRESHMAN YEAR

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<tr>
<th>Quarter</th>
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<td>1st</td>
<td>Chemistry and Biochemistry 20A—Chemical Structure¹</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 Materials²</td>
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<td>Mathematics 31A—Differential and Integral Calculus³</td>
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<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory¹</td>
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<td>Mathematics 31B—Integration and Infinite Series¹</td>
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<td>Physics 1A—Mechanics¹</td>
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<td>Materials Science and Engineering 104—Science of Engineering Materials²</td>
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<td>Mathematics 32A—Calculus of Several Variables¹</td>
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<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields¹</td>
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### SOPHOMORE YEAR

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<td>Materials Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory²</td>
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<td>Mathematics 32B—Calculus of Several Variables¹</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity¹</td>
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<td>Materials Science and Engineering 90L—Physical Measurement in Materials Engineering²</td>
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<td>Materials Science and Engineering 150—Introduction to Polymers²</td>
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<td>Mathematics 33A—Linear Algebra and Applications¹</td>
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<td>Civil and Environmental Engineering M20 (Intro to Computer Programming with MATLAB) or Computer Science 31 (Intro to Computer Science I)²</td>
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<td>Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)¹</td>
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### JUNIOR YEAR

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<tr>
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<td>Materials Science and Engineering 130—Phase Relations in Solids²</td>
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<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials²</td>
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<td>Materials Science and Engineering 131/131L—Diffusion and Diffusion-Controlled Reactions/Laboratory²</td>
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<td>Materials Science and Engineering 143A—Mechanical Behavior of Materials²</td>
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<td>UCLA Samueli GE Elective³</td>
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<td>3rd</td>
<td>Civil and Environmental Engineering 108—Introduction to Mechanics of Deformable Solids²</td>
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<td>Materials Science and Engineering 132—Structures and Properties of Metallic Alloys²</td>
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<td>Materials Engineering Laboratory Course³</td>
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### SENIOR YEAR

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<tr>
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<td>Materials Science and Engineering 160—Introduction to Ceramics and Glasses²</td>
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<td>Upper-Division Mathematics Course³</td>
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<td>Materials Science and Engineering 140A—Materials Selection and Engineering Design A²</td>
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<td>Materials Science and Engineering 140B—Materials Selection and Engineering Design B²</td>
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<td>Technical Breadth Course³</td>
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<td>UCLA Samueli GE Elective³</td>
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**TOTAL**                                                                 | 180   |

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 54.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
4. See counselor in 6426 Boelter Hall for details.
5. See page 103 for list of approved mathematics courses.
# B.S. in Materials Engineering

## Electronic Materials Option Curriculum

### FRESHMAN YEAR

<table>
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<th>Quarter</th>
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<tr>
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<td>Materials Science and Engineering 10—Freshman Seminar: New Materials²</td>
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<td>Mathematics 31A—Differential and Integral Calculus¹</td>
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<td>Mathematics 31B—Integration and Infinite Series¹</td>
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<td>Mathematics 32A—Calculus of Several Variables¹</td>
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<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields¹</td>
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<td>UCLA Samueli GE Elective³</td>
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### SOPHOMORE YEAR

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<th>Course</th>
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<td>Materials Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory²</td>
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<td>Mathematics 32B—Calculus of Several Variables¹</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity¹</td>
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<td>Electrical and Computer Engineering 101A—Engineering Electromagnetics²</td>
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<td>Materials Science and Engineering 90L—Physical Measurement in Materials Engineering²</td>
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<td>Materials Science and Engineering 122—Principles of Electronic Materials Processing³</td>
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<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits²</td>
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<td>Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)³</td>
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<td>UCLA Samueli GE Elective³</td>
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### JUNIOR YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
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<tbody>
<tr>
<td>1st</td>
<td>Electronic Materials Laboratory Course²</td>
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<tr>
<td></td>
<td>Materials Science and Engineering 130—Phase Relations in Solids²</td>
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<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials³</td>
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<td>Technical Breadth Course³</td>
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<td>2nd</td>
<td>Materials Science and Engineering 120 (Physics of Materials)²</td>
<td>4</td>
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<td></td>
<td>Materials Science and Engineering 131/13L—Diffusion and Diffusion-Controlled Reactions/Laboratory²</td>
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<td>UCLA Samueli GE Elective³</td>
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<td>Materials Science and Engineering 121/121L—Materials Science of Semiconductors/Laboratory²</td>
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<td>Materials Science and Engineering 132—Structures and Properties of Metallic Alloys²</td>
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<td>Electronic Materials Elective²</td>
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</table>

### SENIOR YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
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<tbody>
<tr>
<td>1st</td>
<td>Electrical and Computer Engineering 121B—Principles of Semiconductor Device Design²</td>
<td>4</td>
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<td>UCLA Samueli GE Elective³</td>
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<td></td>
<td>Upper-Division Mathematics Course³</td>
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<tr>
<td>2nd</td>
<td>Electronic Materials Elective (Materials Science and Engineering 150—Introduction to Polymers or 160—Introduction to Ceramics and Glasses)²</td>
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<tr>
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<td>Materials Science and Engineering 140A—Materials Selection and Engineering Design A²</td>
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<td>Technical Breadth Course³</td>
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<td>UCLA Samueli Ethics Course</td>
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<td>3rd</td>
<td>Electronic Materials Elective²</td>
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<tr>
<td></td>
<td>Electronic Materials Laboratory Course²</td>
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<td></td>
<td>Materials Science and Engineering 140B—Materials Selection and Engineering Design B²</td>
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<td>UCLA Samueli GE Elective³</td>
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</tbody>
</table>

**TOTAL** 182

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 54.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
4. See counselor in 6426 Boelter Hall for details.
5. See page 103 for list of approved mathematics courses.
# B.S. in Mechanical Engineering Curriculum

## Freshman Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</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>Mathematics 31A—Differential and Integral Calculus</td>
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<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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<td>Physics 1A—Mechanics</td>
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<td>Mathematics 32A—Calculus of Several Variables</td>
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<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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## Sophomore Year

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<tr>
<td>1st</td>
<td>Materials Science and Engineering 104—Science of Engineering Materials</td>
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<td></td>
<td>Mathematics 32B—Calculus of Several Variables</td>
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<tr>
<td></td>
<td>Physics 1C/4BL—Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<tr>
<td>2nd</td>
<td>Mathematics 33A—Linear Algebra and Applications</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 94—Introduction to Computer-Aided Design and Drafting</td>
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<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 105A—Introduction to Engineering Thermodynamics</td>
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<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></td>
<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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<tr>
<td>1st</td>
<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits</td>
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<td>Mechanical and Aerospace Engineering 156A—Advanced Strength of Materials</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 108A (Intro to Manufacturing Processes) or M183B (Intro to Microscale and Nanoscale Manufacturing)</td>
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<td>UCLA Samueli Ethics Course</td>
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<td>2nd</td>
<td>Mechanical and Aerospace Engineering 105D—Transport Phenomena</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems</td>
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<td>UCLA Samueli GE Elective</td>
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<tr>
<td>3rd</td>
<td>Mechanical and Aerospace Engineering 131A (Intermediate Heat Transfer) or 133A (Engineering Thermodynamics)</td>
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<td>Mechanical and Aerospace Engineering 157—Basic Mechanical and Aerospace Engineering Laboratory</td>
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<td>Mechanical and Aerospace Engineering 162A—Introduction to Mechanisms and Mechanical Systems</td>
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<td>Technical Breadth Course</td>
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## Senior Year

<table>
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<tr>
<th>Quarter</th>
<th>Course</th>
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<tbody>
<tr>
<td>1st</td>
<td>Electrical and Computer Engineering 110L—Circuit Measurements Laboratory</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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<tr>
<td>2nd</td>
<td>Mechanical and Aerospace Engineering 162D—Mechanical Engineering Design</td>
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<td>Mechanical 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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<tr>
<td>3rd</td>
<td>Mechanical and Aerospace Engineering 162E—Mechanical Engineering Design</td>
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<td>Mechanical Engineering Elective</td>
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<td>UCLA Samueli GE Elective</td>
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</table>

**TOTAL**                                                                                          181

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 23 for details).
Index

A
ABET, 29, 41, 50, 63, 84, 102, 110, 111
academic excellence workshops, 14
academic residence requirement, 22
active materials laboratory, 113
administrative officers, 4
admission to the school, 19
  freshman, 19
  graduate student, 27
  transfer student, 19
advanced multifunctional materials and systems center (CAMS), 114
advanced placement examination credit, 19, 20–21, 24
advising, 7, 25
CEED, 14
aerospace engineering, see mechanical and aerospace engineering department, 109
American Indian science and engineering society (AISES), 15
architecture specialization laboratory (PolyArch), 71
Ashe student health center, 10
autonomous reasoning group, 70
autonomous intelligent networked systems center (CAINS), 72
autonomous vehicle systems instrumentation laboratory (AVSIL), 113

B
bachelor of science degree requirements, 22
beam control laboratory, 113
big data and genomics laboratory, 70
biocybernetics laboratory, 70
bioengineering department, 28
  bachelor of science degree, 29
  course descriptions, 34
  curriculum, 136
  faculty areas of thesis guidance, 33
  fields of study, 30
  graduate study, 30
  undergraduate study, 29
bioinformatics minor, 66
biomechatronics laboratory, 114
biomolecular engineering laboratories, 43
bionics laboratory, 114
boiling heat transfer laboratory, 114
bridge review for enhancing engineering students (BREES), 14
building earthquake instrumentation network, 55
chemical kinetics, catalysis, reaction engineering, and combustion laboratory, 44
chemistry of construction materials laboratory, 55
Chen research group, 114
circuits laboratories, 89
civil and environmental engineering department, 50
  bachelor of science degree, 51
  civil engineering curriculum, 142
  course descriptions, 57
  environmental engineering minor, 51
  facilities, 54
  1. instructional laboratories, 54
  2. research laboratories, 55
  3. faculty areas of thesis guidance, 56
  4. fields of study, 54
  5. graduate study, 52
  6. undergraduate study, 51
  7. clean energy research center Los Angeles (CERC-LA), 89
  8. cognitive systems laboratory, 70
  9. collaborative center for aerospace sciences (CCAS), 114
  10. compilers laboratory, 72
  11. complex fluids and interfacial physics laboratory, 114
  12. complex thermal systems modeling laboratory, 115
  13. computational genetics laboratory, 70
  14. computer graphics and vision laboratory, 71
  15. computer science centers, 72
  16. computer systems architecture laboratories, 71
  17. graphics and vision laboratories, 71
  18. information and data management laboratories, 71
  19. network systems laboratories, 72
  20. software systems laboratories, 72
  21. faculty areas of thesis guidance, 74
  22. fields of study, 67
  23. graduate study, 66
  24. undergraduate study, 64
  25. computing resources, 9
  26. concurrent systems laboratory, 71
  27. connection laboratory, 72
  28. continuing education, UCLA extension, 9
correspondence directory, 7
counseling, 7, 25
CEED, 14
curricula tables, BS degrees
  1. aerospace engineering
  2. aeronautics track, 134
  3. space track, 135
  4. bioengineering, 136
  5. chemical engineering
  6. biomedical option, 138
  7. biomolecular option, 139
  8. core option, 137
  9. environmental option, 140
  10. semiconductor manufacturing option, 141
civil engineering, 142
computer engineering, 143
computer science and engineering, 145
computer science, 144
electrical engineering, 146
materials engineering
  1. electronic materials option, 148
  2. materials option, 147
mechanical engineering, 149
curricula tables, BS degrees, 134
cybernetic control laboratory (CyCLab), 114

D
Dash international student center, 10
degrees
  1. bachelor of science (B.S.), 22
  2. doctor of philosophy (Ph.D.), 26
  3. engineer (Engr.), 26
  4. master of engineering (M.Engr.), 26
  5. master of science (M.S.), 26
  6. master of science in engineering online, 26
department requirements, 24
departmental scholar program, 16
design and manufacturing laboratory, 114
digital arithmetic and reconfigurable architecture laboratory, 71
disabilities, services for students with, 10
disclosure of student records, 2
domain-specific computing center (CDSC), 73, 131

e-health research laboratory (ER Lab), 71
electrical and computer engineering department, 83
degrees
  1. bachelor of science degrees, 84
  2. computing resources, 88
course descriptions, 93
curriculum
  1. computer, 143
  2. electrical, 146
facilities and programs, 88
faculties
  1. areas of thesis guidance, 91
  2. faculty groups and laboratories, 91
  3. graduate study, 86
  4. interdisciplinary research facilities, 90
  5. research centers and laboratories, 89
  6. undergraduate study, 84
electrochemical engineering and catalysis laboratories, 44
electromagnetics laboratories, 89
electron microscopy laboratories, 104
electronic materials processing laboratory, 44
emerging storage systems development center (CoDESS), 89
encrypted functionalities center, 73, 131
endowed chairs, 4
energy and propulsion research laboratory, 114
energy innovation laboratory, 114
laser spectroscopy and gas dynamics laboratory, 115
library facilities
science and engineering library (SEL), 9
university library system, 9
living accommodations, 11
loans, 11

M
M‟Closkey laboratory, 115
machine learning and genomics laboratory, 70
master of science in engineering online programs, 125
graduate study, 125
materials and plasma chemistry laboratory, 44
materials degradation characterization laboratory, 115
materials in extreme environments laboratory (MATRIX), 115
materials science and engineering department, 101
bachelor of science degree, 102
course descriptions, 105
curriculum, 147, 148
facilities, 104
faculty areas of thesis guidance, 104
fields of study, 104
graduate study, 103
undergraduate study, 102
mechanical and aerospace engineering department, 109
bachelor of science degrees, 110
centers, facilities, and laboratories, 113
course descriptions, 116
curriculum
aerospace, 134, 135
mechanical, 149
faculty areas of thesis guidance, 117
fields of study, 113
graduate study, 111
undergraduate study, 110
mechanical testing laboratory, 104
mechanical vibrations laboratory, 55
mechanics of soft materials laboratory, 115
mechatronics and controls laboratory, 115
MESA schools program, 13
metallagraphic sample preparation laboratory, 104
micro- and nano-manufacturing laboratory, 115
multiscale thermosciences laboratory (MTSL), 116

N
named data networking project, 132
nanoelectronics research facility (Nanolab), 90
nano-materials laboratory, 104
nanoparticle technology and air quality engineering laboratory, 45
nanoscale transport research group, 116
national science foundation (NSF), 14, 131, 132
national society of black engineers (NSBE), 15
natural language processing group, 71
network design automation laboratory, 72
networked and application systems group (NAS), 72
neurotronics institute (WINs), 132
nondestructive testing laboratory, 104
nondiscrimination, 16

O
official publications, 16
master of science in engineering, 125
optofluidics systems laboratory, 116
organic electronic materials laboratory, 116
organizations, student, 15

P
photonics and optoelectronics laboratories, 90
physics of amorphous and inorganic soils laboratory (PARISlab), 56
Pilon research group, 116
plasma and beam assisted manufacturing laboratory, 116
plasma electronics facilities, 90
policies and regulations, 24
polymer and separations research laboratory, 45
precoclege outreach programs, 13
prizes and awards, 16
process systems engineering laboratory, 45

R
reinforced concrete laboratory, 55
research centers, externally funded, 131
research intensive series in engineering for underrepresented populations (RISE-UP), 14
robotics and mechanisms laboratory (RoMeLa), 116

S
scalable analytics institute, 73
scholarship requirement, 22
scholarships, 11, 15
school requirements, 22
schoolwide programs and courses, 127
course descriptions, 127
golf study, 127
scifacturing laboratory, 116
semiconductor and optical characterization laboratory, 104
services for students with disabilities, 10
shop services center, 9
simulations of flow physics and acoustics laboratory (SOFiA), 116
smart grid energy research center (SMERC), 116, 132
SMASH precollege program, 13
societies, student and honorary, 15
society of Latino engineers and scientists (SOLES), 15
society of women engineers (SWE), 15
software engineering and analysis laboratory (SEAL), 72
software systems group, 72
soil mechanics laboratory, 55, 56
solid-state electronics facilities, 90
special programs, activities, and awards, 13
statistical and relational artificial intelligence laboratory (StarAI), 70
statistical machine learning laboratory, 70
structural design and testing laboratory, 55
student health center, 10
student organizations, 15
student societies, 15
student study center, 14
study list, 24
summer bridge program, 14
synthetic control across lengthscales for
advancing rechargeables center, 132

T
teaching assistantships, 12
technical breadth requirement, 23
thermochemical energy storage laboratory, 116
thin film deposition laboratory, 104

thin films, interfaces, composites, character-
ization laboratory, 117
translational applications of nanoscale multi-
ferroic systems center (TANMS), 14, 114, 131
translational research center, Koç, 89
turbulence research group, 117

U
unit requirement, 22
university requirements, 22

V
VAST laboratory, 71
vision and image sciences collective, 71
vision laboratory, 71

vision, cognition, learning, and art center, 71

W
web information systems laboratory, 72
WIN institute of neurotronics (WINs), 132
wireless health institute (WHI), 73, 90, 132
wireless networking group (WiNG), 72
women in engineering, 15
writing requirement, 22

X
X-ray diffraction laboratory, 104
X-ray photoelectron spectroscopy and
atomic force microscopy facility, 104