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DISCLOSURE OF STUDENT RECORDS

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

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

As a matter of practice, UCLA does not publish student addresses or telephone numbers in the campus electronic directory unless released by the student. The term “public information” in this policy is synonymous with the term “directory information” in FERPA.

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

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

A copy of the federal and state laws, University policies, and the print UCLA Telephone Directory may be inspected in the office of the Information Practices Coordinator, 500 UCLA Wilshire Center. Information concerning students’ hearing rights may be obtained from that office and from the Office of Student Conduct, 1206 Murphy Hall.

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

Cover: Students participate in Engineering Open House activities. Page 80: Photo credit Katherine Zhuo/Daily Bruin.
The Henry Samueli School of Engineering and Applied Science at UCLA has a long legacy of excellence in research, education, and service to society.

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

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

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

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

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

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

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

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

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

Jayathi Y. Murthy
Dean
Henry Samueli School of Engineering and Applied Science

Officers of Administration
Jayathi Y. Murthy, Ph.D., Professor and Dean of the Henry Samueli School of Engineering and Applied Science
Scott J. Brandenberg, Ph.D., Professor and Associate Dean, Diversity and Inclusion
Jia-Ming Liu, Ph.D., Professor and Associate Dean, Academic Personnel
Harold G. Monbouquette, Ph.D., Professor and Associate Dean, Research and Physical Resources
Richard D. Wesel, Ph.D., Professor and Associate Dean, Academic and Student Affairs
Jenn-Ming Yang, Ph.D., Professor and Associate Dean, International Initiatives and Online Education
Mary Okino, Ed.D., Assistant Dean, Chief Financial Officer
Brandon Baker, M.S., Assistant Dean, External Affairs
Panagiotis D. Christofides, Ph.D., Professor and Chair, Chemical and Biomolecular Engineering Department
Mario Gerla, Ph.D., Professor and Chair, Computer Science Department
Song Li, Ph.D., Professor and Chair, Bioengineering Department
Christopher S. Lynch, Ph.D., Professor and Chair, Mechanical and Aerospace Engineering Department
Gregory J. Pottie, Ph.D., Professor and Chair, Electrical and Computer Engineering Department
Jonathan P. Stewart, Ph.D., Professor and Chair, Civil and Environmental Engineering Department
Dwight C. Streit, Ph.D., Professor and Chair, Materials Science and Engineering Department

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 elected officials 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 nearly 45,000 students enrolled in 127 undergraduate and 211 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 the University is Chancellor Gene D. Block. He oversees all aspects of the University’s three-part mission of education, research, and service.

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

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

UCLA engineering faculty members are active participants in many interdisciplinary research centers. The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) strives to revolutionize development of consumer electronics by engineering materials that optimize energy efficiency, size, and power output on the small scale. The Focus Center on Function Accelerated nanoMaterial Engineering (FAME) aims to revolutionize semiconductor technologies by developing new nanoscale materials and structures that take advantage of properties unavailable at larger scales. The WIN Institute of Neurotronics (WINs) focuses on cutting-edge technology, including nanostructures. The Center of Excellence for Green Nanotechnologies undertakes frontier research and development in the areas of nanotechnology in energy and nanoelectronics. The Center for Domain-Specific Computing (CDS) is developing high-performance, energy efficient, customizable computing that could revolutionize the way computers are used in healthcare and other important applications. The Smart Grid Energy Research Center (SMERC) conducts research, creates innovations, and demonstrates advanced wireless/communications, Internet, and sense-and-control technologies to enable the development of the next generation of the electric utility grid. The Wireless Health Institute (WHI) is a community of UCLA experts and innovators from a variety of disciplines dedicated to improving healthcare delivery through the development and application of wireless network-enabled technologies integrated with current and next-generation medical enterprise computing. The Named Data Networking (NDN) Project is investigating the future of the Internet’s architecture, capitalizing on its strengths and addressing weaknesses, to accommodate emerging patterns of communication. The NSF Center for Encrypted Functionalities (CEF) explores program obfuscation which uses new encryption methods to make a computer program, and not just its output, invisible to an outside observer, while preserving how it works—its functionality—thus enhancing cybersecurity. The B. John Garck Institute for the Risk Sciences is committed to the advancement and application of the risk sciences to save lives, protect the environment, and improve system performance. Finally, the California NanoSystems Institute (CNSI)—a joint endeavor with UC Santa Barbara—develops the information, biomedical, and manufacturing technologies of the twenty-first century.

In addition, the school has identified critical areas for collaborative research that will have a major impact on the future of California and the world. Among these are biomedical informatics; alternative energy solutions; secure electronic transfer of information; new tools for the entertainment industry; systems, dynamics, and control; advanced technologies for water reclamation; and new approaches and technologies for aerospace engineering. And the school has established the Institute for Technology Advancement (ITA) dedicated to the effective transition of high-impact innovative research from UCLA to product development and commercialization. ITA nurtures and incubates breakthrough ideas to create new industrial products, as well as provides a learning platform for faculty members and students to engage in transitional technology research.
The school offers 40 academic and professional degree programs. The Bachelor of Science degree is offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Engineering, Computer Science, Computer Science and Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering. The undergraduate curricula leading to these degrees provide students with a solid foundation in engineering and applied science and prepare graduates for immediate practice of the profession as well as advanced studies. In addition to engineering courses, students complete about one year of study in the humanities, social sciences, and/or fine arts.

Master of Science and Ph.D. degrees are offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Electrical Engineering, Manufacturing Engineering (M.S. only), Materials Science and Engineering, and Mechanical Engineering. The schoolwide online Master of Science in Engineering degree program includes 11 individual degrees. The Engineer degree is a more advanced degree than the M.S. but does not require the research effort and orientation involved in a Ph.D. dissertation. For information on the Engineer degree, see Graduate Programs on page 24. A one-year program leading to a Certificate of Specialization is offered in various fields of engineering and applied science.

**Endowed Chairs**

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

- L.M.K. Boelter Chair in Engineering
- 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
- Leonard Kleinrock Chair in Computer Science
- Evalyn Knight Chair in Engineering
- Levi James Knight, Jr., Chair in Engineering
- Richard G. Newman AECOM Endowed Chair in Civil Engineering
- Nippon Sheet Glass Company Chair in Materials Science
- Northrop Grumman Chair in Electrical Engineering
- Northrop Grumman Chair in Electrical Engineering/Electromagnetics
- Northrop Grumman Opto-Electronic Chair in Electrical Engineering

Ralph M. Parsons Foundation Chair in Chemical Engineering
Jonathan B. Postel Chair in Computer Systems
Jonathan B. Postel Chair in Networking
Raytheon Company Chair in Electrical Engineering
Raytheon Company Chair in Manufacturing Engineering
Charles P. Reames Endowed Chair in Electrical Engineering
Ben Rich Lockheed Martin Chair in Aeronautics
Rockwell Collins Chair in Engineering
William Frederick Seyer Chair in Materials Electrochemistry
Ronald and Valerie Sugar Endowed Chair in Engineering
Simontec 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 Endowed Chair in Engineering
Wintek Endowed Chair in Electrical Engineering

**The Engineering Profession**

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

**Aerospace Engineering**

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

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

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

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

**Bioengineering**

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

**Chemical and Biomolecular Engineering**

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

Major areas of fundamental interest within chemical engineering are

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

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

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

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

**Civil and Environmental Engineering**

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

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

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

**Computer Science and Engineering**

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

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

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

**Electrical and Computer Engineering**

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

**Manufacturing Engineering**

Manufacturing engineering is an interdisciplinary field that integrates the basic knowledge of materials, design, processes, computers, and system analysis. The manufacturing engineering program is part of the Mechanical and Aerospace Engineering Department.

Specialized areas are generally classified as manufacturing processes, manufacturing planning and control, and computer-aided manufacturing.

Manufacturing engineering as an engineering specialty requires the education and experience necessary to understand, apply, and control engineering procedures in manufacturing processes and production methods of industrial commodities and products. It involves the generation of manufacturing systems, the development of novel and specialized equipment, research into the phenomena of fabricating technologies, and manufacturing feasibility of new products.

Coursework, independent studies, and research are offered in the manufacturing processes area, leading to an M.S. degree. This includes computer-aided design and computer-aided manufacturing, robotics, metal forming and metal cutting analysis, nondestructive evaluation, and design and optimization of manufacturing processes.

**Materials Engineering**

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

Two programs within materials engineering are available at UCLA:

1. In the materials engineering program, students become acquainted with metals, ceramics, polymers, and composites. Such expertise is highly sought by the aerospace and manufacturing industries. Materials engineers are responsible for the selection and testing of materials for specific applications. Traditional fields of metallurgy and ceramics have been merged in industry, and this program reflects the change.

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

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

**Mechanical Engineering**

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

Applications of mechanical engineering include design of machines used in the manufacturing and processing industries, mechanical components of electronic and data processing equipment, engines and power-generating equipment, components and vehicles for land, sea, air, and space, and artificial components for the human body. Mechanical engineers are employed throughout the engineering community as individual consultants in small firms providing specialized products or services, as designers and managers in large corporations, and as public officials in government agencies.
Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2017</th>
<th>Winter 2018</th>
<th>Spring 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>First day for continuing students to check MyUCLA at</td>
<td>May 30</td>
<td>October 23</td>
<td>January 22</td>
</tr>
<tr>
<td><a href="http://my.ucla.edu">http://my.ucla.edu</a> for assigned enrollment appointments</td>
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<tr>
<td>MyUCLA enrollment appointments begin</td>
<td>June 19</td>
<td>November 6</td>
<td>February 5</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 25</td>
<td>January 3, 2018</td>
<td>March 28</td>
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<tr>
<td>Instruction begins</td>
<td>September 28</td>
<td>January 8</td>
<td>April 2</td>
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<tr>
<td>Last day for undergraduates to add courses with per-course fee</td>
<td>October 20</td>
<td>January 26</td>
<td>April 13</td>
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<td>through MyUCLA</td>
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<tr>
<td>Last day for undergraduates to drop nonimpacted courses without a</td>
<td>October 27</td>
<td>February 2</td>
<td>April 27</td>
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<td>transcript notation (with per-transaction fee through MyUCLA)</td>
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<tr>
<td>Last day for undergraduates to change grading basis (optional P/NP)</td>
<td>November 10</td>
<td>February 16</td>
<td>May 11</td>
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<td>with per-transaction fee through MyUCLA</td>
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<tr>
<td>Instruction ends</td>
<td>December 8</td>
<td>March 16</td>
<td>June 8</td>
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<tr>
<td>Final examinations</td>
<td>December 11–15</td>
<td>March 19–23</td>
<td>June 11–15</td>
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<td>Quarter ends</td>
<td>December 15</td>
<td>March 23</td>
<td>June 15</td>
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<td>HSSEAS Commencement</td>
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<td>June 16</td>
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<td>Academic and administrative holidays</td>
<td>November 10</td>
<td>January 15</td>
<td>March 30</td>
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<td>November 23-24</td>
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<td>January 1</td>
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<tr>
<td>Winter campus closure (tentative)</td>
<td>December 27–28</td>
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</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 2017</th>
<th>Winter 2018</th>
<th>Spring 2018</th>
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</thead>
<tbody>
<tr>
<td>Filing period for undergraduate applications (file online at http://</td>
<td>November 1–30,</td>
<td>—</td>
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<tr>
<td>admission.universityofcalifornia.edu/how-to-apply/apply-</td>
<td>2016</td>
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<tr>
<td>online/index.html)</td>
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<tr>
<td>Last day to file Application for Graduate Admission or readmission</td>
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<tr>
<td>with complete credentials and application fee, online at https://</td>
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<td>app.applyyourself.com/AYApplicantLogin/fI_ApplicantConnectLogin.asp?</td>
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<tr>
<td>id=ucla-grad or with Graduate Diversity, Inclusion, and Admissions</td>
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<tr>
<td>(DIA), 1248 Murphy Hall, UCLA, Los Angeles, CA 90024-1419</td>
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<tr>
<td>Last day to file Undergraduate Readmission Application at</td>
<td>August 15</td>
<td>November 25</td>
<td>February 25</td>
</tr>
<tr>
<td>1113 Murphy Hall (late applicants pay a late fee)</td>
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<td></td>
</tr>
</tbody>
</table>
Academic Counselors

Aerospace Engineering
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University of California, Los Angeles
Los Angeles, CA 90095-1361
http://www.ucla.edu

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

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

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

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

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

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

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

Facilities and Services

Teaching and research facilities at HSSEAS 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.seasosa.ucla.edu), the SEASnet computer facility (http://www.seas.ucla.edu/seasnet/), specialized libraries, offices of faculty and administration, Shop Services Center, and the Student and Faculty Shop. The California NanoSystems Institute (CNSI) building hosts additional HSSEAS collaborative research activities.

Library Facilities

University Library System

The UCLA Library, a campuswide network of libraries serving programs of study and research in many fields, is among the top 10 ranked research libraries in the U.S. Total collections number more than 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 over 57,000 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

Instructional Computer Facility

HSSEAS maintains a network of over 130 enterprise servers that provide a wide array of critical services for School of Engineering students, faculty, and staff. Network Appliance NFS servers supply reliable storage for user's personal data and e-mail, and offer nearly instant recovery of deleted files through regular snapshots.

More than 100 Unix servers, including 25 virtual machines, provide administrative and instructional support to ensure smooth operation of approximately 700 Linux and Windows workstations. The Unix servers provide back-end services such as DNS, authentication, virtualization, software licensing, web servers, interactive log-in, database, e-mail, class applications, and security monitoring.

Twenty Windows servers make up the backbone for all instructional computing labs and allow students to work remotely with computationally and resource-intensive applications. There are three computer labs and two instructional computer labs with 200 Windows workstations.

A high-speed network that links the entire infrastructure ensures a latency-free operation for users from UCLA and around the world. It consists of dual fiber uplinks to a Cisco core router that feeds and routes 20 networks, over 150 switches, and 50 Cisco wireless access points. The network serves over 8,000 users across four buildings.

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

The servers are protected by two UPS units for short-term power outages, and campus emergency power keeps critical equipment running during extended downtime.

Students and faculty have access to free retail Microsoft software through the Microsoft Dream Spark Premium program, and MathType software through the HSSEAS download service. Faculty and staff have access to Adobe professional and Microsoft Office (MCCA) software at no charge. Abaqus, Autodesk, and Dreamspark programs offer additional software at no charge to all UCLA students. Ansys offers a student version of its software for a very low fee.

The UCLA Office of Information Technology (OIT) operates high-performance computer clusters that supply cluster hosting services to campus researchers in a way that effectively manages the limited high-end data center space on campus. They offer help to researchers who need assistance in numerically intensive computing by speeding up long-running serial or parallel programs or by parallelizing existing serial code. A UCLA Grid Portal and other high-performance computing resources are also available.

The school manufacturing engineering program operates a group of workstations dedicated to CAD/CAM instruction, and the Computer Science Department operates a network of SUN, PC, and Macintosh computers. The school is connected via high-speed networks to the Internet, and computing resources at the national supercomputer centers are available.

Shop Services Center

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

Continuing Education

UCLA Extension

540 UNIX Building, 10995 Le Conte Avenue
Department of Engineering
Varaz Shahmirian, Ph.D., Director
Department of Digital Technology
Bruce Huang, Ph.D., Director

The UCLA Extension (UNEX) Departments of Engineering and Digital Technology provide one of the nation’s largest selections of continuing engineering education programs. A short-course program of 150 annual offerings draws participants from around the world for two- to four-day intensive programs. Many of these short courses are also offered on-site at companies and government agencies; see http://shortcourses.uclaextension.edu. The acclaimed Technical Management Program has been offered for more than 60 years. See http://tmp.uclaextension.edu.

The Information Systems program offers over 200 courses annually in applications program-
The Ashe Student Health and Wellness Center is a full-service medical clinic available to all registered UCLA students. Most services are subsidized by registration fees, and a current BruinCard is required for service. Its clinical staff of physicians, nurse practitioners, and nurses is board certified. It offers primary care, specialty clinics, and physical therapy. The center has its own pharmacy, laboratory, and optometry and radiology sections. Visits, core laboratory tests, X-rays, and preventive immunizations are all prepaid for students with the University of California Student Health Insurance Plan (UCSHIP).

The cost of services received outside the Ashe Center, such as emergency room services, is each student’s financial responsibility. Students are required to purchase medical insurance either through the UCLA-sponsored UCHSIP or other plans that provide adequate coverage. Adequate medical insurance is a condition of registration. See Registration in the Undergraduate Study and Graduate Study sections of this catalog.

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

For emergency care when the Ashe Center is closed, students may obtain treatment at the Ronald Reagan UCLA Medical Center Emergency Room on a fee-for-service basis. For specific UCHSIP benefits tier structure and coverage information, see the Ashe Center website and select Insurance or send e-mail to shsinsurance@ashe.ucla.edu.

The Ashe Center website processes students’ proof of immunity to Hepatitis B prior to enrollment. Information about this requirement is available on the Ashe website; for questions, send e-mail to asheimmune@ashe.ucla.edu. The plan year deductible is waived for services provided at the Ashe Center and for payable emergency room visits, urgent care visits, and network provider office visits. A copayment applies for these services. All fees incurred at the Ashe Center are billed directly to students’ BruinBill accounts. The cost of services received outside the Ashe Center is each student’s financial responsibility. Students who waive UCHSIP need to ensure that they are enrolled in a plan qualified to cover expenses incurred outside of the Ashe Center, and are responsible for knowing the benefits of and local providers for their medical plan. A student with UCHSIP who withdraws during a term continues to be eligible for health services for the remainder of the term on a fee basis. The Ashe Center is open Monday through Friday during the academic year.

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

The Center for Accessible Education (CAE) is the only campus entity authorized to determine a student’s eligibility for disability-related accommodations and services. Academic support services are determined for each regularly enrolled student with documented permanent or temporary disabilities based on specific disability-based requirements. CAE policies and practices comply with all applicable federal and state laws, including Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act (ADA) of 1990, and are consistent with University policy.

Services include campus orientation and accessibility, note takers, reader service, sign language interpreters, Learning Disability Program, registration assistance, test-taking facilitation, special parking assistance, real-time captioning, assistive listening devices, on-campus transportation, adaptive equipment, support groups and workshops, tutorial referral, special materials, housing appeals, referral to the UCLA Disabilities and Computing Program, and processing of California Department of Rehabilitation authorizations. There is no fee for any of these services. All contacts and assistance are handled confidentially.

Dashew Center for International Students and Scholars
Dashew Center for International Students and Scholars
106 Bradley Hall
http://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 provides visa assistance for faculty, researchers, and postdoctoral scholars. It also offers programming to meet the needs of the campus multicultural population.

Fees and Financial Support

Fees and Expenses
Annual UCLA student fees shown for 2017-18 are current as of publication. See the Registrar’s Office fees web page for fees break-
Living Accommodations

UCLA Housing Services
360 De Neve Drive, Box 951381
Los Angeles, CA 90095-1381
310-206-7011
https://housing.ucla.edu/student-housing

Community Housing Office
360 De Neve Drive, Box 951495
Los Angeles, CA 90095-1495
310-825-4491
https://housing.ucla.edu/community-housing

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

The Community Housing Office offers information and current listings for University-owned apartments, cooperatives, private apartments, roommates, rooms in private homes, room and board in exchange for work, and short-term housing. A current BruinCard or letter of acceptance and valid photo identification card are required for service.

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

Undergraduate Students
Financial aid at UCLA includes scholarships, grants, loans, and work-study programs. Applications for each academic year are available in January. The priority application deadline for financial aid for the 2018-19 academic year is March 2, 2018. With the exception of certain scholarships, awards are based on need as determined by national financial aid criteria. California residents must file the Free Application for Federal Student Aid (FAFSA). International students in their first year are ineligible for aid. Continuing undergraduate international students are asked to submit a separate Financial Aid Application for International Students.

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

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

HSSEAS Scholarships are awarded to entering and continuing undergraduate students based on criteria including financial need, academic excellence, community ser-
vice, extracurricular activities, and research achievement. The school works with alumni, industry, and individual donors to establish scholarships to benefit engineering students. In 2016-17, HSSEAS awarded more than 146 undergraduate scholarship awards totaling more than $677,000. The majority of these scholarships are publicized in the fall, with additional scholarships promoted throughout the academic year as applicable. For more information on all available scholarships, see 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, these awards are applied toward tuition and fees.

Federal Pell Grants are federal aid awards designed to provide financial assistance to U.S. citizens or eligible noncitizens 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
http://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 Student Loan Services and Collections before leaving UCLA for any reason. This interview helps students understand their loan agreement and plan for loan repayment. Failure to complete an exit interview results in a hold being placed on all university services and records. In addition, if the campus-based loans become delinquent following separation from UCLA, all university services and records will be withheld. For further information concerning loan repayment, 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 educa-
tional objectives. Hourly pay rates comply with minimum wage laws and vary with the nature of the work, experience, and capabilities. Employment may be on or off campus. To be eligible, undergraduate and graduate students must demonstrate financial need and be a U.S. citizen or eligible noncitizen. Submission of the FAFSA is required.

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

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

Graduate Students
A high percentage of HSSEAS graduate students receive departmental financial support.

Merit-Based Support
Three major types of merit-based support are available in the school:
1. Fellowships from University, private, or corporate funds
2. Employment as a teaching assistant
3. Employment as a graduate student researcher

Fellowships usually provide stipends competitive with those of other major universities, plus tuition and nonresident supple-mental tuition (where applicable). These stipends may be supplemented by a teaching assistantship or graduate student researcher appointment. The awards are generally reserved for new students.

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

Graduate student researcher (GSR) appointments are awarded to students on the basis of scholastic achievement and promise as creative scholars. Appointees perform research under the supervision of a faculty member in research work. Full-time employment in summer and interterm breaks is possible, depending on the availability of research funds from contracts or grants.

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

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

Applicants for departmental financial support must be accepted for admission to HSSEAS in order to be considered in the 2017-18 competition. Applicants should check the deadline for submitting the UCLA Application for Graduate Admission and the Fellowship Application for Entering Graduate Students with their preferred department.

Need-Based Aid
Unlike the awards above, which are based solely on merit and administered by HSSEAS, the University also provides work-study and low-interest loans based on financial need exclusively.

Need-based awards are administered by Financial Aid and Scholarships, A129J Murphy Hall. Financial aid applicants must file the Free Application for Federal Student Aid (FAFSA).

Continuing graduate students should contact Financial Aid and Scholarships in December 2017 for information on 2018-19 application procedures.

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

School of Engineering Fellowships
Fellowship packages offered by HSSEAS may include fellowship contributions from the following sources:

Atlantic Richfield Company (ARCO) Fellowship. Chemical and Biomolecular Engineering Department; supports study in chemical engineering

Balu and Mohini Balakrishnan Endowed Fellowship. Supports doctoral study in any engineering department

William and Mary Beedle Fellowship. Chemical and Biomolecular Engineering Department; supports study in chemical engineering

John H. Bent Merit Scholarship. Bioengineering Department; supports graduate students with preference given to candidates interested in development or application of powered surgical instruments

John J. and Clara C. Boettler 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 Hanarayan 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.

Intel Fellowship. Mechanical and Aerospace Engineering Department; supports doctoral students.

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 National Taiwan University, or National Chiao Tung University in Taiwan.

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.

The Kalosworks.org Fellowship. Supports graduate study in electrical engineering with preference for U.S. citizens.

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

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

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

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

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

Special Programs, Activities, and Awards

Center for Excellence in Engineering and Diversity

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

Precollege Outreach Programs

Summer Math and Science Honors Academy (SMASH). A rigorous and innovative education program, SMASH increases opportunities for educationally and financially disadvantaged urban school students to excel in the fields of science, technology, engineering, and math (STEM) at the college level for five weeks each summer. SMASH scholars also receive year-round academic support including SAT preparation, college counseling, financial aid workshops, and other activities to ensure continued academic success. Thirty new SMASH scholars are selected each year to attend the residential program each of three summers (after their 9th, 10th, and 11th grade years). Approximately 80 students participated in SMASH during summer 2017.

MESA Schools Program (MSP). Through CEED, HSSEAS partners with middle and high school principals to implement MSP services, which focus on outreach and student development in engineering, mathematics, science, and technology. At individual school sites, four mathematics and science teachers serve as MSP advisers and coordinate the activities and instruction for 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. HSSEAS/CEED currently serves 18 schools in the Los Angeles Unified School District and four schools in the Inglewood Unified School District.

Undergraduate Programs

CEED currently supports some 290 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 magnetism control through application of an electric field while providing a pathway to commercial endeavors. Its unique needs include diverse participant characteristics that encompass how we think, how we do things, and our humanity—including but not limited to age, color, culture, disability, diversity of thought, ethnicity, gender, geographic and national origin, language, life experience, perspective, race, religion, sexual identity, socioeconomic status, and technical expertise—aimed to increase creativity and innovation.

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

The TANMS vision is to move from diversity and inclusion advocate to active leader in the ERC community, and provide an educational pathway from cradle to career for the nation’s best and brightest, fully representative and inclusive of the talents of every community. TANMS recognizes diversity as a national imperative to take specific actions by its leadership to source and include a complete talent pool, especially those critically underrepresented populations, and all its population segments and characteristics, in the TANMS academic leadership, technical workforce, and efforts to develop the next generation of engineers, scientists, and entrepreneurs in multiferroic systems.

**Scholarships/Financial Aid**

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

**Student Organizations**

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

**American Indian Science and Engineering Society**

AISES encourages American Indians to pursue careers as scientists and engineers while preserving their cultural heritage. The goal of AISES is to promote unity and cooperation and to provide a basis for the advancement of American Indians while providing financial assistance and educational opportunities. AISES devotes most of its energy to its outreach program where members conduct monthly science academies with elementary and precollege students from Indian Reservations. Serving as mentors and role models for younger students enables UCLA AISES students to further develop professionalism and responsibility while maintaining a high level of academics and increasing cultural awareness.

**National Society of Black Engineers**

https://sites.google.com/site/uclansbe/
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**
http://www.uclasoles.com

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

SOLES also strives to familiarize the UCLA community with the richness and diversity of the Latino culture and the scientific accomplishments of Latinos. SOLES organizes cultural events such as Latinos in Science, Cinco de Mayo, and cosponsors the Women in Science and Engineering (WISE) Day with AISES and NSBE. By participating in campus events such as Career Day and Engineers Week, the organization’s growing membership strives to fulfill the needs of the individual and the community.

**Women in Engineering**

Women make up about 24 percent of the HSSEAS undergraduate enrollment and 23 percent of the graduate enrollment. Today’s opportunities for women in engineering are excellent, as both employers and educators try to change the image of engineering as a males-only field. Women engineers are in great demand in all fields of engineering.

**Society of Women Engineers**
http://www.seas.ucla.edu/swe/

The Society of Women Engineers (SWE), recognizing that women in engineering are still a minority, has established a UCLA student chapter that sponsors field trips and engineering-related speakers (often professional women) to introduce the various options available to women engineers. The UCLA chapter of SWE, in conjunction with other Los Angeles schools, also publishes an annual resume 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 http://www.engineering.ucla.edu/student-clubs.

- 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/BattleBots
- — Avengeering
- BEAM Building Engineers and Mentors
- BMES Biomedical Engineering Society
- — Bruin Amateur Radio Club
- BruinKSEA Korean-American Scientists and Engineers Association
- — Bruin Spacecraft Group
- CalGeo California Geotechnical Engineers Association
- Chi Epsilon Civil Engineering Honor Society
- — 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 Rho Engineering social sorority
- PIE Pilipinos in Engineering
- REC Renewable Energy Club at UCLA
- — Robotics Club
- — Rocket/Space Project at UCLA
- SAE Society of Automotive Engineers
- SASE Society of Asian Scientists and Engineers
- SOLES Society of Latino Engineers and Scientists
- — Society of Petroleum Engineers
- SWE Society of Women Engineers
- Tau Beta Pi Engineering honor society
- TEC Technical Entrepreneurial Community
- Theta Tau Professional engineering fraternity
- Triangle Social fraternity of engineers, architects, and scientists
- Upsilon Pi Epsilon International honor society for the computing and information disciplines
- VEX Robotics Club at UCLA

**Student Representation**

The student body takes an active part in shaping 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 HSSEAS annual commencement program as well as by campuswide announcement.

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

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

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

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

**Departmental Scholar Program**

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

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

For details, consult the Office of Academic and Student Affairs in 6426 Boelter Hall well in advance of application dates for admission to graduate standing.

**Exceptional Student Admissions Program**

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

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

**Official Publications**

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

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

**Grading Policy**

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

**Grade Disputes**

If students believe that they have been graded unfairly, they should first discuss the issue with the instructor of the course. If the dispute cannot be resolved between the student and the instructor, the student may refer the issue to the Associate Dean for Academic and Student Affairs, 6426 Boelter Hall.

The associate dean may form an ad hoc committee to review the complaint. The ad hoc committee members are recommended by the appropriate department chair and the associate dean. The student receives a copy of the ad hoc committee's report as well as a copy of the associate dean's recommendation. The student's file will contain no reference to the dispute.

The associate dean informs the students of their rights with respect to complaints and appeals at UCLA.

**Nondiscrimination**

The University of California, in accordance with applicable federal and state laws and University policies, does not discriminate on the basis of race, color, national origin, religion, sex, gender identity, pregnancy (including pregnancy, childbirth, and medical conditions related to pregnancy and childbirth), physical or mental disability, medical condition (cancer-related or genetic characteristics), ancestry, marital status, age, sexual orientation, citizenship, or service in the uniformed services (including membership, application for membership, performance of service, application for service, or obligation for service in the uniformed services). The University also prohibits sexual harassment. This nondiscrimination policy covers admission, access, and treatment in University programs and activities.

Students may grieve any action that they believe discriminates against them on the ground of race, color, national or ethnic origin, alienage, sex, religion, age, sexual orientation, gender identity, marital status, veteran status, or perceived membership in any of these categories which results in injuries to the student by contacting the Office of the Dean of Students, 1104 Murphy Hall. Refer to UCLA Procedure 230.1 available in 1104 Murphy Hall or at http://www.adminpolicies.ucla.edu/app/Default.aspx?id=230-1, for more information and procedures.

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

In accordance with applicable federal and state laws and University policy, including Title II of the Americans with Disabilities Act, Section 504 of the Rehabilitation Act of 1973, and University of California policy PACAOS-20 (Policy on Nondiscrimination), UCLA does not discriminate on the basis of physical or mental disability. Retaliation for participation in University procedures relating to complaints of discrimination is also prohibited. This nondiscrimination policy covers admission, access, and treatment in University programs and activities. UCLA is committed to prohibiting disability-based discrimination and harassment, and retaliation, performing a prompt and equitable investigation of complaints alleging discrimination, and properly remedying discrimination when it occurs. Examples of discrimination against students with disabilities include, but are not limited to: failure to engage with the student in a discussion of reasoning accommodations; failure to implement approved reasonable accommodations such as the provision of notes or extra time on tests; and exclusion of a qualified student from any course, course of study, or other educational program or activity because of the student's disability. Disability-based harassment is conduct which is sufficiently severe, pervasive, or persistent so as to interfere with or limit an individual's ability to participate in or benefit from the services, activities, or opportunities offered by the University.
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 University of California Policy on Sexual Violence and Sexual Harassment (hereafter referred to as the SVSH Policy) at http://policies.ucop.edu/doc/4000385/SVSH. 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 http://www.sexualharassment.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 Coordinator, 2241 Murphy Hall, 310-206-3417, titleix@conet.ucla.edu. If a student reports sexual harassment or sexual violence to a responsible employee, as defined under the SVSH Policy, the responsible employee must report it to the Title IX Coordinator.

Responsible employees include academic personnel, faculty members, and most other employees who are not defined as a confidential resource under the SVSH Policy.

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

Other Forms of Harassment

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

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

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 any of the Harassment Information Centers listed immediately above.

In addition to providing support for those who believe they have been victims of harassment, Harassment Information Centers offer persons the opportunity to learn about the phenomena of harassment and intimidation; to understand the formal and informal mechanisms by which misunderstandings may be corrected and, when appropriate, student perpetrators may be disciplined; and to consider which of the available options is the most useful for the particular circumstances.

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

The Henry Samueli School of Engineering and Applied Science (HSSEAS) 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.abet.org.

Admission

Applicants to HSSEAS must satisfy the general admission requirements of the University. See the Undergraduate Admission website at http://www.admission.ucla.edu for details. Applicants must apply directly to HSSEAS by submitting 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.

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

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

Admission as a Freshman

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

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

Credit for Advanced Placement Examinations

Students may fulfill part of the school requirements with credit allowed at the time of admission for College Board Advanced Placement (AP) Examinations with scores of 3, 4, or 5. Students with AP Examination credit may exceed the 213-unit maximum by the amount of the credit. AP Examination credit for freshmen entering fall quarter 2017 fulfills HSSEAS requirements as indicated on the AP 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 requires applicants to have completed a minimum of 60 transferable semester units (90 quarter units) and two transferable English courses prior to enrolling at UCLA. In addition, to be considered all applicants to HSSEAS 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 HSSEAS include college-specific course numbers for these requirements and can be found at http://www.assist.org. Applicants who are lacking two or more of the courses are unlikely to be admitted.

Required preparation for HSSEAS majors:


2. Calculus-based physics courses in mechanics, electricity and magnetism, and waves, sound, heat, optics, and modern physics.

3. Chemistry, including two terms of general chemistry. Bioengineering and Chemical Engineering majors are also required to complete two terms of organic chemistry. The Computer Science and Computer Science and Engineering majors do not require chemistry. Electrical Engineering majors must complete only one term of chemistry.

4. Computer programming: applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors may take any C++, C, or Java course to meet the admission requirement, but to be competitive the applicant must take a C++ course equivalent to UCLA Computer Science 31. Applicants to Chemical Engineering may take any C++, C, Java, or MATLAB course to satisfy the admission requirement, but lack of a MATLAB course equivalent to UCLA Mechanical and Aerospace Engineering M20 or Civil and Environmental Engineering M20 will delay time to graduation. Applicants to all other engineering majors may take any C++, C, Java, or MATLAB.
**Henry Samueli School of Engineering and Applied Science**  
**Advanced Placement Examination Credit**  

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

<table>
<thead>
<tr>
<th>AP Examination</th>
<th>Score</th>
<th>UCLA Lower-Division Units and Course Equivalents</th>
<th>Credit Allowed for University and GE Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art History</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Art, Studio</td>
<td></td>
<td>8 units maximum for all tests</td>
<td></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) 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 units maximum for both tests</td>
<td></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>
<td>------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Chinese Language and Culture</td>
<td>3, 4, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, 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, 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, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics</td>
<td></td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Mathematics (AB Test: Calculus)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 units</td>
<td>May be applied toward Mathematics 31A</td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units plus 4 units</td>
<td>4 units may be applied toward Mathematics 31A</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8 units</td>
<td>Mathematics 31A plus 4 units that may be applied toward Mathematics 31B</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, 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, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics 2</td>
<td>3, 4, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (B Test)</td>
<td>3, 4, 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, 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, 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
</tbody>
</table>
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.

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 three types of requirements for the Bachelor of Science degree:
1. University requirements
2. School requirements
3. Department requirements

### University Requirements

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

### School Requirements

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

#### Unit Requirement

To receive a bachelor’s degree in any HSSEAS 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 University requirement of at least a C (2.0) grade-point average in all courses taken at any University of California campus, students must achieve at least a 2.0 grade-point average in upper-division University courses offered in satisfaction of the subject and elective requirements of the curriculum. A 2.0 minimum grade-point average in upper-division mathematics, upper-division core courses, and the major field is also required for graduation. Grade point averages are not rounded up.

#### Academic Residence Requirement

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

#### Writing Requirement

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

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

#### Writing I

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

The Writing I requirement may also be satisfied by (1) scoring 4 or 5 on one of the College Board Advanced Placement Examinations in English, (2) a combination of a score of 720 or better on the SAT Reasoning Test, Writing section (last administered in January 2016) and superior performance on the English Composition 3 Proficiency Examination, (3) completing a course equivalent to English Composition 3 with a grade of C or better (C- or a Passed grade is not acceptable) taken at another institution, or (4) scoring 5, 6, or 7 on an International Baccalaureate Higher Level Examination.

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

#### Engineering Writing

The engineering writing requirement is satisfied by selecting one approved engineering writing (EW) course from the HSSEAS writing course list or by selecting one approved Writing II (W) course. The course must be completed with a grade of C or better (C- or a Passed grade is not acceptable). Writing courses are published in the Schedule of Classes at https://sa.ucla.edu/ro/public/soc. Writing courses also approved for general education credit may be applied toward the relevant general education foundational area.
Technical Breadth Requirement

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

Ethics Requirement

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

General Education Requirements

General education (GE) is more than a checklist of required courses. It is a program of study that (1) reveals to students the ways that research scholars in the arts, humanities, social sciences, and natural sciences create and evaluate new knowledge, (2) introduces students to the important ideas and themes of human cultures, (3) fosters appreciation for the many perspectives and the diverse voices that may be heard in a democratic society, and (4) develops the intellectual skills that give students the dexterity they need to function in a rapidly changing world.

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

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

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

Foundations of Knowledge

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

Five courses (24 units minimum) are required. Engineering writing requirement courses also approved for GE credit may be applied toward the relevant GE foundational areas. Students must meet with a counselor in the Office of Academic and Student Affairs to determine the applicability of GE Cluster courses toward the engineering writing or GE requirements.

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

Foundations of the Arts and Humanities

Two 5-unit courses selected from two different subgroups:
- Literary and Cultural Analysis
- Philosophical and Linguistic Analysis
- Visual and Performance Arts Analysis and Practice

The aim of courses in this area is to provide perspectives and intellectual skills necessary to comprehend and think critically about our situation in the world as human beings. In particular, the courses provide the basic means to appreciate and evaluate the ongoing efforts of humans to explain, translate, and transform their diverse experiences of the world through 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

The aim of courses in this area is to introduce students to the ways in which humans organize, structure, rationalize, and govern their diverse societies and cultures over time. The courses focus on a particular historical question, societal problem, or topic of political and economic concern in an effort to demonstrate how issues are objectified for study, how data is collected and analyzed, and how new understandings of social phenomena are achieved and evaluated.

Foundations of Scientific Inquiry

One course (4 units minimum) from the Life Sciences subgroup or one course from Bioengineering CM145/Chemical Engineering CM145, Chemistry and Biochemistry 153A, or Civil and Environmental Engineering M166/Environmental Health Sciences M166:
- Life Sciences

This requirement is automatically satisfied for Bioengineering and Chemical Engineering majors. The requirement is satisfied for Civil Engineering majors by the natural science requirement.

The aim of courses in this area is to ensure that students gain a fundamental understanding of how scientists formulate and answer questions about the operation of both the physical and biological world. The courses also deal with some of the most important issues, developments, and methodologies in contemporary science, addressing such topics as the origin of the universe, environmental degradation, and the decoding of the human genome. Through lectures, laboratory experiences, writing, and intensive discussions, students consider the important roles played by the laws of physics and chemistry in society, biology, Earth and environmental sciences, and astrophysics and cosmology.

Foundations Course Lists

Creating and maintaining a general education curriculum is a dynamic process; consequently, courses are frequently added to the list. For the most current list of approved courses that satisfy the Foundations of Knowledge GE plan, consult an academic counselor or see http://www.registrar.ucla.edu/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 the Henry Samueli School of Engineering and Applied Science GE requirements. The school does not accept partial IGETC.

Department Requirements

Henry Samueli School of Engineering and Applied Science departments generally set two types of requirements that must be satisfied for the award of the degree: 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 section of this announcement.

The Major
Students must complete their major with a scholarship average of at least a 2.0 (C) in all courses in order to remain in the major. Each course in the major department must be taken for a letter grade. See the Departments and Programs section of this announcement for details on each major.

Policies and Regulations
Degree requirements are subject to policies and regulations, including the following:

Student Responsibility
Students should take advantage of academic support resources, but they are ultimately responsible for keeping informed of and complying with the rules, regulations, and policies affecting their academic standing.

Study List
Study lists require approval of the dean of the school or a designated representative. It is the student’s responsibility to present a study list that reflects satisfactory progress toward the Bachelor of Science degree, according to standards set by the faculty. Study lists or programs of study that do not comply with these standards may result in enforced withdrawal from the University or other academic action.

Undergraduate students in the school are expected to enroll in at least 12 units each term. Students enrolling in less than 12 units must obtain approval by petition to the dean prior to enrollment in courses. The normal program is 16 units per term. Students may not enroll in more than 21 units per term unless an Excess Unit Petition is approved in advance by the dean.

Minimum Progress
Full-time HSSEAS undergraduate students must complete a minimum of 36 units in three consecutive terms in which they are registered.

Credit Limitations
Advanced Placement Examinations
Some portions of Advanced Placement (AP) Examination credit are evaluated by corresponding UCLA course number. If students take the equivalent UCLA course, a deduction of UCLA unit credit is made prior to graduation. See the AP table.

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

Community College/Lower Division Transfer Limitation
Effective for students admitted fall 2017 and later, after completing 105 lower-division quarter units toward the degree in all institutions attended, students are allowed no further unit credit for courses completed at a community college or for lower-division courses completed at any institution outside of the University of California. The University of California does not grant transfer credit for community college or lower-division courses beyond 105 quarter units, but students may still receive subject credit for this coursework to satisfy lower-division requirements. Units earned through Advanced Placement (AP), International Baccalaureate (IB), and/or A-Level examinations are not included in the limitation. Units earned at any UC campus (through extension, summer, cross-campus, UCEAP Intercampus Visitor Program, and regular academic year enrollment) are not included in the limitation. To convert semester units into quarter units, multiply the semester units by 1.5; for example, 12 semester units x 1.5 = 18 quarter units. To convert quarter units into semester units, multiply the quarter units by 0.667; for example, 12 quarter units x 0.667 = 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 units or less, only the most recently earned letter grades and grade points are computed in the grade-point average (GPA). After repeating 16 units, the GPA is based on all letter grades assigned and total units attempted. The grade assigned each time a course is taken is permanently recorded on the transcript.

1. To improve the grade-point average (GPA), students may repeat only those courses in which they receive a grade of C– or lower; NP or U grades may be repeated to gain unit credit. Courses in which a letter grade is received may not be repeated on a P/NP or S/U basis. Courses originally taken on a P/NP or S/U basis may be repeated on the same basis or for a letter grade.

2. Repetition of a course more than once requires the approval of the College or school or the dean of the Graduate Division and is granted only under extraordinary circumstances.

3. Degree credit for a course is given only once, but the grade assigned each time the course is taken is permanently recorded on the transcript.

4. There is no guarantee that in a later term a course can be repeated (such as in cases when a course is deleted or no longer offered). In these cases students should consult with their academic counselor to determine if there is an alternate course that can be taken to satisfy a requirement. The alternate course would NOT count as a repeat of the original course.

Minors and Double Majors
HSSEAS students in good academic standing may be permitted a minor or double major. The minor or second major must be outside the school (e.g., Electrical Engineering major and Economics major). HSSEAS students are not permitted to double major with two school majors (e.g., Chemical Engineering and Civil Engineering). Students may file an Undergraduate Request to Double Major or Add Minor form at the Office of Academic and Student Affairs. The school determines final approval of a minor or double major request; review is done on a case by case basis, and filing the request does NOT guarantee approval.

While HSSEAS considers minor or double major requests, specializations are not considered at this time. Students interested in a minor or double major should meet with their counselor in 6426 Boelter Hall.

Advising
It is mandatory for all students entering undergraduate programs to have their course of study approved by an academic counselor. After the first term, curricular and career advising is accomplished on a formal basis. Students are assigned a faculty adviser in their particular specialization in their freshman year. In addition, all undergraduate students are assigned, by major; to an academic counselor in the Office of Academic and Student Affairs who provides them with advice regarding general requirements for the degrees and University and school regulations and procedures. It is the students’ responsibility to periodically meet with their academic counselor in the Office of Academic and Student Affairs, as well as with their faculty adviser, to discuss curriculum requirements, programs of study, and any other academic matters of concern.

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

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

HSSEAS 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 University procedures and answer questions related to general requirements.

Honors

Dean’s Honors List

Students following the engineering curricula are eligible to be named to the Dean’s Honors List each term. Minimum requirements are a course load of at least 15 units (12 units of letter grade) with a grade-point average equal to or greater than 3.7. Students are not eligible for the Dean’s Honors List if they receive an Incomplete (I) or Not Passed (NP) grade or repeat a course. Only courses applicable to an undergraduate degree are considered toward eligibility for Dean’s Honors.

Latin Honors

Students who have achieved scholastic distinction may be awarded the bachelor’s degree with honors. Students eligible for 2017-18 University honors at graduation must have completed 90 or more units for a letter grade at the University of California and must have attained a cumulative grade-point average at graduation which places them in the top five percent of the school (GPA of 3.907 or better) for summa cum laude, next five percent (GPA of 3.822 or better) for magna cum laude, and the next 10 percent (GPA of 3.693 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 HSSEAS degree requirement, engineering students must also have a 3.907 grade-point average for summa cum laude, a 3.822 for magna cum laude, and a 3.693 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 HSSEAS BS degree requirement are excluded from these upper-division averages.
Graduate Programs

The Henry Samueli School of Engineering and Applied Science (HSSEAS) offers courses leading to the Master of Science and Doctor of Philosophy degrees, 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 an overall grade-point average of 3.25.

Concurrent Degree Program

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

Master of Science in Engineering Online Degree

The primary purpose of the Master of Science in Engineering online self-supporting degree program is to enable employed engineers and computer scientists to augment their technical education beyond the Bachelor of Science degree and to enhance their value to the technical organizations in which they are employed. For further information, see http://msol.ucla.edu.

The individual degrees include:

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

Master of Engineering Degree

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

Engineer Degree

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

Ph.D. Degrees

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

Established Fields of Study for the Ph.D.

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

Bioengineering Department
- 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
- Graphics and vision
- Information and data management
- Software systems

Electrical and Computer Engineering Department
- Circuits and embedded systems
- Physical and wave electronics
- Signals and systems
Materials Science and Engineering Department
Ceramics and ceramic processing
Electronic and optical materials
Structural materials

Mechanical and Aerospace Engineering Department
Applied mathematics (established minor field only)
Applied plasma physics (minor field only)
Design, robotics, and manufacturing (DROM)
Dynamics
Fluid mechanics
Heat and mass transfer
Nanoelectromechanical/microelectromechanical systems (NEMS/MEMS)
Structural and solid mechanics
Systems and control
For more information on specific research areas, contact the individual faculty member in the field that most closely matches the area of interest.

Admission
Applications for admission are invited from graduates of recognized colleges and universities. Selection is based on promise of success in the work proposed, which is judged largely on the previous college record.
Candidates whose engineering background is judged to be deficient may be required to take additional coursework that may not be applied toward the degree. The adviser helps plan a program to remedy any such deficiencies, after students arrive at UCLA.
Entering students normally are expected to have completed the B.S. degree requirements with at least a 3.0 grade-point average in all coursework taken in the junior and senior years.
Students entering the Engineer/Ph.D. program normally are expected to have completed the requirements for the master’s degree with at least a 3.25 grade-point average and to have demonstrated creative ability. Normally the M.S. degree is required for admission to the Ph.D. program. Exceptional students, however, can be admitted to the Ph.D. program without having an M.S. degree.
For information on the proficiency in English requirements for international graduate students, see Graduate Admission in the Graduate Study section of the UCLA General Catalog.
To submit a graduate application, see http://www.seasoasa.ucla.edu/graduate-admissions-2/. From there connect to the site of the preferred department or program and go to the online graduate application.

Graduate Record Examination
Educational Testing Service
P.O. Box 6000, Princeton, NJ 08541-6000
http://www.gre.org
Applicants to the HSSEAS graduate programs are required to take the General Test of the Graduate Record Examination (GRE). Specific information about the GRE may be obtained from the department of interest.
Obtain applications for the GRE by contacting Educational Testing Service.
Bioengineering

5121 Engineering V
Box 951620
Los Angeles, CA 90095-1600
310-267-4985
bioeng@eaa.ucla.edu
http://bioeng.ucla.edu

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

Professors
Denise Aberle, M.D.
Pei-Yu Chiu, Ph.D.
Mark S. Cohen, Ph.D., in Residence
Ian A. Cook, M.D., in Residence
Linda L. Demer, M.D., Ph.D.
Timothy J. Deming, Ph.D.
Dino Di Carlo, Ph.D.
Robin L. Garrell, Ph.D.
Warren S. Grundfest, M.D., FACS
Dean Ho, Ph.D.
Tzung Hsiai, M.D., Ph.D., in Residence
Bahram Jalali, Ph.D.
Daniel T. Kamei, Ph.D.
H. Pirouz Kavehpour, Ph.D.
Chang-Jin (CJ) Kim, Ph.D. (Volgenau Endowed Professor of Engineering)
Debiao Li, Ph.D., in Residence
Song Li, Ph.D.
James C. Liao, Ph.D. (Ralph M. Parsons Foundation Professor of Chemical Engineering)
Wentai Liu, Ph.D.
Aman Mahajan, M.D., Ph.D., in Residence
Aydogan Ozcan, Ph.D.
Jacob Rosen, Ph.D.
Jacob J. Schmidt, Ph.D.
Kalyanam Shivkumar, M.D., Ph.D., in Residence
Ren Sun, Ph.D.
Yi Tang, Ph.D.
Michael A. Teitel, M.D., Ph.D.
Cun Yu Wang, D.D.S., Ph.D.
Gerard C.L. Wong, Ph.D.
Benjamin M. Wu, D.D.S., Ph.D.
Yang Yang, Ph.D.

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

Associate Professors
Chi On Chui, Ph.D.
Daniel B. Ennis, Ph.D., in Residence
Andrea M. Kasko, Ph.D.

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

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

Adjunct Assistant Professors
Chase Linsley, Ph.D.

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

Affiliated Faculty

Professors
Peyman Benharash, M.D. (Cardiothoracic Surgery)
Marvin Bergsneider, M.D., in Residence (Neurosurgery)
Douglas L. Black, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Alex A.T. Bui, Ph.D. (Radiological Sciences)
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering)
Yong Chen, Ph.D. (Mechanical and Aerospace Engineering)
Thomas Chou, Ph.D. (Biomathematics, Mathematics)
Samson A. Chow, Ph.D. (Biomathematics, Mathematics)
Joseph L. Demer, M.D., Ph.D. (Neurology, Ophthalmology)
Katrina M. Dipple, M.D., Ph.D. (Human Genetics, Pediatrics)
Joseph J. DiStefano III, Ph.D. (Computer Science, Medicine)
Bruce S. Dunn, Ph.D. (Materials Science and Engineering)
V. Reggie Edgerton, Ph.D. (Integrative Biology and Physiology)
Jeffrey D. Eldredge, Ph.D. (Mechanical and Aerospace Engineering)
Alan Garfinkel, Ph.D. (Cardiology, Integrative Biology and Physiology)
Christopher C. Giza, Ph.D., in Residence (Neurosurgery, Surgery)
Thomas G. Graeber, Ph.D. (Molecular and Medical Pharmacology)
Robert G. Gunvalus, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Vijay Gupta, Ph.D. (Mechanical and Aerospace Engineering)
Y. Sungtaek Ju, Ph.D. (Mechanical and Aerospace Engineering)

Scope and Objectives

The interface between biology and engineering is an exciting area for discovery and technology development in the twenty-first century. The Department of Bioengineering offers an innovative curriculum and state-of-the-art facilities for cutting-edge research. The bioengineering program is a structured offering of unique forward-looking courses dedicated to producing graduates who are well-grounded in the fundamental sciences.
and highly proficient in rigorous analytical engineering tools necessary for lifelong success in the wide range of possible bioengineering careers. Combined with a strong emphasis on research, the program provides a unique engineering educational experience that responds to the growing needs and demands of bioengineering.

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

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

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

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

**Bioengineering B.S.**

**Capstone Major**

**Preparation for the Major**

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

**The Major**

Students must complete the following courses:

1. Bioengineering 100, 110, 120, 165EW (or Engineering 183EW or 185EW), 167L, 176, 180, Electrical and Computer Engineering 100; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Bioengineering 177A, 177B).

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

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

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

**Biomaterials and Regenerative Medicine:**

Bioengineering C104, C105, CM140, C147, C183, C185, 199 (8 units maximum), Materials Science and Engineering 104, 110, 111, 120, 130, 132, 140, 143A, 150, 151, 160, 161. The above materials science and engineering courses may be used to satisfy the technical breadth requirement.

**Biomedical Devices:**

Bioengineering C131, M153, C172, 199 (8 units maximum), Electrical and Computer Engineering 102, Mechanical and Aerospace Engineering C187L. The electrical and computer engineering or mechanical and aerospace engi-

*Undergraduate Bioengineering students work on a lab project as part of the department’s new cell engineering course.*
neering courses listed above may be used to satisfy the technical breadth requirement.
For Bioengineering 199 to fulfill a track requirement, the research project must fit within the scope of the track field, and the research report must be approved by the supervisor and vice chair.
For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/Academics/GE-Requirements.

Graduate Study
For information on graduate admission, see Graduate Programs, page 25.
The following introductory information is based on the 2017-18 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at https://grad.ucla.edu. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.
The Bioengineering Department offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Bioengineering.

Bioengineering M.S.
Course Requirements
A minimum of 13 courses (44 units) is required.
For the comprehensive track, at least 11 courses must be from the 200 series, three of which must be Bioengineering 299 courses. Students must also take one 495 course. One 100-series course may be applied toward the total course and unit requirement. No units of 500-series courses may be applied toward the minimum course requirements except for the field of medical imaging informatics where 2 units of course 597A are required.
For the thesis track, at least 10 of the 13 courses must be from the 200 series, three of which must be Bioengineering 299 courses. Students must also take two 598 courses involving work on the thesis and one 495 course.
To remain in good academic standing, M.S. students must maintain an overall grade-point average of 3.0 and a grade-point average of 3.0 in graduate courses.

Comprehensive Examination Plan
The comprehensive examination plan is available in all fields, and requirements vary for each field. Specific details are available from the graduate adviser. Students who fail the examination may repeat it once only, subject to the approval of the faculty examination committee. Students who fail the examination twice are not permitted to submit a thesis and are subject to termination. The oral component of the Ph.D. preliminary examination is not required for the M.S. degree.

Thesis Plan
Every master's degree thesis plan requires the completion of an approved thesis that demonstrates student ability to perform original independent research. New students who select this plan are expected to submit the name of the thesis adviser to the graduate adviser by the end of their first term in residence. The thesis adviser serves as chair of the thesis committee.
A research thesis (8 units of Bioengineering 598) is to be written on a bioengineering topic approved by the thesis adviser. The thesis committee consists of the thesis adviser and two other qualified faculty members who are selected from a current list of designated members for the graduate program.

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

Written and Oral Qualifying Examinations
Academic Senate regulations require all doctoral students to complete and pass University written and oral qualifying examinations prior to doctoral advancement to candidacy. Under Senate regulations the University Oral Qualifying Examination is open only to students and appointed members of their doctoral committees. In addition to University requirements, some graduate programs have other precandidacy examination requirements. What follows are the requirements for this doctoral program.
The Ph.D. preliminary examination tests a core body of knowledge, and requirements vary for each field. Specific details are available from the graduate adviser. Students who fail the examination may repeat it once only, subject to the approval of the faculty examination committee. Students who fail the examination twice are subject to a recommendation for termination. Within three terms after passing the Ph.D. preliminary examination, students are strongly encouraged to take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into student preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.
A doctoral committee consists of a minimum of four qualified UCLA faculty members. Three members, including the chair, are selected from a current list of designated inside members for the graduate program. The outside member must be a qualified UCLA faculty member who does not appear on this list.
A final oral examination (defense of the dissertation) is required of all students.

Fields of Study

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

Course Requirements
Group I: Core Courses on General Concepts. At least three courses selected from Bioengineering C201, C204, C205, C206.
Group II: Field Specific Courses. At least three courses selected from Bioengineering CM202 (or CM203 or Molecular, Cell, and Developmental Biology 165A), Bioengineering M153 (or Electrical and Computer Engineering M153 or Mechanical and Aerospace Engineering M183B), Electrical and Computer Engineering 100.
Group III: Field Elective Courses. The remainder of the courses must be selected from one of the following three areas:


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

Biomedical Signal and Image Processing

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

Course Requirements

Group I: Core Courses on General Concepts. Three courses selected from Bioengineering C201 (or CM286) and either CM202 and CM203, OR Molecular, Cell, and Developmental Biology 144 and Physiological Science 166.

Group II: Field Specific Courses. At least three courses selected from Electrical and Computer Engineering 239AS, 266, Neurobiology M200C, Neuroscience CM272, M287, Physics and Biology in Medicine 205, M219, M248, and one course from Bioengineering 163EW, Biomaterials M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.


Biosystems Science and Engineering

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

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

Course Requirements

Group I: Core Courses on General Concepts. Two physiology/molecular, cellular, and organ systems biology courses from either Bioengineering CM202 and CM203, OR Physiological Science 166 and Molecular, Cell, and Developmental Biology M140, M144 and another approved equivalent course, and two dynamic biosystems modeling, estimation, and optimization courses from Bioengineering CM286, and either Biomathematics 220 or 296B.


Group III: Field Ethics Course. One course selected from Bioengineering 163EW, Biomathematics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

Medical Imaging Informatics

Medical imaging informatics (MI) is the rapidly evolving field that combines biomedical informatics and imaging, developing and adapting core methods in informatics to improve the usage and application of imaging in healthcare. Graduate study encompasses principles from across engineering, computer science, information sciences, and biomedicine. Imaging informatics research concerns itself with the full spectrum of low-level concepts (e.g., image standardization and processing, image feature extraction) to higher-level abstractions (e.g., associating semantic meaning to a region in an image, visualization and fusion of images with other biomedical data) and ultimately, applications and the derivation of new knowledge from imaging. Medical imaging informatics addresses not only the images themselves, but encompasses the associated (clinical) data to understand the context of the imaging study, to document observations, and to
correlate and reach new conclusions about a disease and the course of a medical problem. Research foci include distributed medical information architectures and systems, medical image understanding and applications of image processing, medical natural language processing, knowledge engineering and medical decision-support, and medical data visualization. Coursework is geared toward students with science and engineering backgrounds, introducing them to these areas in addition to providing exposure to fundamental biomedical informatics, imaging, and clinical issues. The area encourages interdisciplinary training with faculty members from multiple departments and emphasizes the practical translational development and evaluation of tools/applications to support clinical research and care.

Course Requirements

Group II: Field Specific Courses. M.S. comprehensive students must take three courses and Ph.D. students must take six courses from any of the following concentrations:
- Computer Understanding of Images: Computer Science M266A, M266B, Electrical and Computer Engineering 211A, Physics and Biology in Medicine 210, 214, M219, M230
- Information Networks and Data Access in Medical Environment: Computer Science 240B, 244A, 246
- Probabilistic Modeling and Visualization of Medical Data: Biostatistics M232, M234, M235, M236, Computer Science 241B, 262A, M262C, Epidemiology 212, Information Studies 272, 277

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

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

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

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

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


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

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

Course Requirements
Group I: Core Courses on General Concepts. Three courses selected from Bioengineering C201 (or CM286) and either CM202 and CM203, OR Molecular, Cell, and Developmental Biology 144 and Physiological Science 166.

Group II: Field Specific Courses. Bioengineering M260, M261A, M284, and one course from 165EW, Biomatics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

Group III: Field Elective Courses. Two courses from one of the following two concentrations:
- Neuroscience: Bioengineering C206, M263, Neuroscience M201, M202, 205

Faculty Areas of Thesis Guidance

Professors
Denise Aberle, M.D. (U. Kansas, 1979) Medical imaging informatics: imaging-based clinical trials, medical data visualization
Pei-Yu Chou, Ph.D. (UC Berkeley, 2005) Optoelectronics 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.
IAN A. COOK, M.D. (Yale, 1987)
Brain function in normal states and cognitive disorders, blood brain barrier, effects of antidepres-
sants on the brain, methods of treatment for mood disorders especially depression
LINDA L. DEMER, M.D., Ph.D. (Johns Hopkins, 1983)
Vascular biology, bioengineering, vascular cal-
cification, matrix metalloproteinase
TIMOTHY J. DEMING, Ph.D. (UC Berkeley, 1993)
Polymer synthesis, polymer processing, supramolecular materials, organometallic catalysis, biomaterials, polyamides
DINO DI CARLO, Ph.D. (UC Berkeley, 2006)
Microfluidics, biophysical microdevices, cellular diagnostics, cell analysis and engineering
ROBIN L. GARRELL, Ph.D. (U. Michigan, 1984)
Bioanalytical and surface chemistry with emphasis on fundamentals and applications of adhesion and wetting
WARREN S. GRUNDFEST, M.D., FACS (Columbia, 1980)
Excimer laser, minimally invasive surgery, biol-
ological spectroscopy
DEAN HO, Ph.D. (UCLA, 2005)
Nanodiamond hydrogel-based drug delivery system, nanodiamond-embedded patch device as a localized drug delivery implantable microfilm, nanodiamond film technology for noninvasive localized drug delivery
Tzung Hsiai, M.D. (U. Chicago, 1993), Ph.D. (UCLA, 2001)
Cardiovascular mechatronics, MEMS and nanosensors, vascular endothelial dynam-
ics, molecular imaging of atherosclerotic lesions, reactive nitrogen species (RNS) and reactive oxygen species (ROS)
BAHRAM JAALI, Ph.D. (UCLA, 1989)
RF photonics, fiber-optic integrated circuits, integrated optics, microwave photonics
DANIEL T. KAMEI, Ph.D. (MIT, 2001)
Molecular cell bioengineering, rational design of molecular therapeutics, systems-level analyses of cellular processes, drug delivery, diagnostics
H. Pnouz KAVEHPOUR, Ph.D. (MIT, 2003)
Microscale fluid mechanics, transport phenom-
ena in biological systems, photonic contact line phenomena, complex fluids, non-isothermal flow, micro- and nano-heat guides, microfluidic devices
CHANG-JIN (CJ) KIM, Ph.D. (U. Berkeley, 1991)
Microelectromechanical systems: micro/nano fabrication technologies, structures, actuators, devices, and systems; microfluidics involving surface tension (especially droplets)
DEBBAO 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. (U. San Diego, 1997)
Stem cell engineering, tissue engineering and vascular remodeling, mechanobiology/mecha-
notransduction
JAMES C. LIAO, Ph.D. (U. Wisconsin-Madison, 1987)
Metabolic engineering, synthetic biology, bioenergy
WEITAI LIU, Ph.D. (U. Michigan, 1983)
Neural engineering
ARMAN MAHJAN, M.D. (U. Delhi, India, 1991), Ph.D. (UCLA, 2006)
Arrhythmia, cardiac imaging, patent and parietal ovale repair, transseptal atrial mapping, echocardiography, thoracic electrocardiography, valvuloplasty
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 nanoscale, membrane protein engineering, biomimetic hybrid devices
KALAYAN SHIVKUMAR, M.D. (U. Madras, India, 1990), Ph.D. (UCLA, 1999)
Mechanisms of cardiac arrhythmias in humans, complex and therapeutic approaches to myocardial infarction
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
Immune system development and cancer; regula-
tion of gene expression in development and malignancy; linking RNA processing with mito-
ochondrial homeostasis, metabolism and prolif-
eration; nanoparticles evaluate of malignant transformation
Molecular signaling (NF-KB and Wnt) tumor-
invasive growth and death, and metastasis, adult mesenchymal stem cells, dental stem cells and regen-
erative medicine, inflammation and innate immunity
GERALD C.L. WONG, Ph.D. (U. Berkeley, 1994)
Antimicrobials and antibiotic-resistant patho-
gens, bacterial communities, cystic fibrosis, apoptosis proteins and cancer therapeutics, dis-
fraction and water purification, self-assem-
bly in biology and biotechnology; physical chemistry of solvation, soft condensed matter physics, biophysics
Biomaterials, cell-material interactions, materi-
als processing, tissue engineering, prosthetic and regenerative dentistry
YANG WANG, Ph.D. (U. Massachusetts Lowell, 1992)
Conjugated polymers and applications in opto-
electronic devices such as light-emitting diodes, photodiodes and field-effect transistors

Professors Emeriti

CHIH-MING HSU, Ph.D. (Johns Hopkins, 1974)
Molecular fluidic phenomena, microelectro-
mechanical systems (MEMS), biosensor technolo-
gies, biomolecular sensor arrays, control of cellular complex systems, rapid search of com-
binatorial medicine
Stem cell identification, regenerative medicine, systems biology

Associate Professors

CHI ON CHUI, Ph.D. (Stanford, 2004)
Nanoelectronics and optoelectronic devices and technology; heterostructure semiconductor devices, monolithic integration of heterogeneous technology, exploratory nanotechnology
DANIEL B. ENNIS, Ph.D. (Johns Hopkins, 2004)
MRI, cardiovascular pathophysiology, image processing, continuum mechanics, tensor anal-
ysis, soft tissue biomechanics
ANDREA M. KASKO, Ph.D. (U. Akron, 2004)
Polymer synthesis, hybrid devices, tissue engi-
nering, cell-material interactions

Assistant Professors

AARON S. MEYER, Ph.D. (MIT, 2014)
Molecular cell 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, muscle, cord injury, gene therapy, hydrogels, cell-material interac-
tions, high-throughput biological techniques, nervous system extracellular matrix, neural stem cells and development

Adjunct Associate Professor

Skin tissue engineering, bone tissue engineer-
ing, vascular tissue engineering, wound healing

Adjunct Assistant Professors

CHASE LISLE, Ph.D. (UCLA, 2015)
Biomaterials, tissue engineering, drug delivery, additive manufacturing

Kayvan Niazi, Ph.D. (UCLA, 2000)
Molecular and cellular bioengineering, immuno-
therapeutics

GEORGE N. SADICK, Ph.D. (U.C. Santa Barbara, 2011)
Ultrasound transducer and system engineering, bulk acoustic wave resonators and filters, RF and microwave circuit and system design

ZACHARY TAYLOR, Ph.D. (U.C. Santa Barbara, 2010)
THz imaging, laser-generated shockwaves

Affiliated Faculty

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

Lower-Division Courses

10. Introduction to Bioengineering. (2) Lecture, two hours; discussion, one hour; outside study, three hours. Preparation: high school biology, chemistry, mathematics, physics, introduction to scientific and technological bases for established and emerging subfields of bioengineering, including biosensors, bioinstrumentation, and biosignal processing, bio-
mechanics, biomaterials, tissue engineering, biotech-
nology, biological imaging, biomedical optics and la-
sers, neuroengineering, and biomolecular machines. Letter grading.

Mr. Deming (F)

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

98. 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 (ex-
cluding this course). Individual contract required; consult Undergraduate Research Center. May be re-
peated. P/NP grading.

Upper-Division Courses

100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 32A, Physics 1A. Fundamental basis for analysis and design of biological and biomedical devices and systems. Classical and statistical thermodynamic analy-

Mr. Kamei (F)

C101. Engineering Principles for Drug Delivery. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 33B, Physics 1B. Application of engineering princi-
ples for designing and understanding delivery of ther-
apeutics. Discussion of physics and mathematics re-
quired for understanding colloidal stability. Analysis of concepts related to both modeling and experimen-
tation of endocytosis and intracellular trafficking
mechanisms. Analysis of diffusion of drugs, coupled with computational and engineering mathematics approach. Concurrently scheduled with course C201. Letter grading. Mr. Kamei (F)

CM102. Human Physiological Systems for Bioengineering I. (4) Same as Physiological Science CM102.) Lecture, three hours; laboratory, two hours. Preparation in depth of human biology, behavior, 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, cell). At cellular level, emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visit to biomedical facilities. Concurrently scheduled with course CM202. Letter grading. Mr. Grundfest (F)


C104. Physical Chemistry of Biomacromolecules. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: courses 20B, 30A, Life Sciences 2, 3, 23L. To understand biological models and design synthetic replacements, it is imperative to understand their physical chemical interactions. Such as protein, DNA, RNA, and protein-DNA, can be analyzed and characterized by applying fundamental principles of physical chemistry. Application of polymer structure and conformation, bulk and solution thermodynamics and phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as protein conformation, solvation of charged species, and separation and characterization of biomacromolecules. Concurrently scheduled with course C204. Letter grading. Mr. Wong (F)

C105. Engineering of Bioconjugates. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20B, 30A, Life Sciences 2, 3, 23L. Highly recommended: one organic chemistry course. Bioconjugate chemistry is science of coupling biomolecules for wide range of applications. Oligomeric systems may be coupled to one another through 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 ligations, including choice and design of conjugate linkers depending on type of biomolecule and desired application. Basic principles governing electrophoretic mobility and non-netted charge linkers. Presentation and discussion of design and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C205. Lecture, three hours; laboratory, four hours; outside study, seven hours. Mr. Kamei (Sp)

C110. Topics in Bioelectricity for Bioengineers. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 23L. Basic principles governing electrophoretic mobility and non-netted charge linkers. Presentation and discussion of design and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C206. Letter grading. Mr. Schmidt (W)

C113B. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cellular biology, and biotechnology. Understanding of different types of interactions that exist between biomolecules, such as van der Waals interactions, entropic and enthalpic electrostatic interactions, hydrophobic intermolecular interactions and solvent interactions, polymeric interactions, deformation interactions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Concurrently scheduled with course C239B. Letter grading. Mr. Wong (W)

C115. Molecular Biotechnology for Engineers. (4) Same as Chemical Engineering CM115.) Lecture, four hours; discussion, one hour; outside study, seven hours. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cellular biology, and biotechnology. Understanding of different types of interactions that exist between biomolecules, such as van der Waals interactions, entropic and enthalpic electrostatic interactions, hydrophobic intermolecular interactions and solvent interactions, polymeric interactions, deformation interactions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Concurrently scheduled with course C239B. Letter grading. Mr. Wong (W)

C120. Biomedical Transducers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 30A, Electrical Engineering 100, Mathematics 32B, Physics 1C. Principles of transduction, design characteristics for different measurements, reliability and performance characteristics, and data processing and recording. Emphasis on silicon-based microfabricated and nanofabricated sensors. Novel materials, biocompatibility, biosensors, microfluidics. Ac-tuator design and interfacing control. Letter grading. Mr. Grundfest, Mr. Schmidt (W)

C131. Nanopore Sensing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 100, 120, Life Sciences 2, 3, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of fluctuating ionic conductance through artificial or protein nanopores. Properties of pore conduction, such as single nucleotide 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, path clamp and single channel measurements and instrumentation, noise, time series analysis, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C231. Letter grading. Mr. Schmidt (Sp)

C139A. Biomolecular Materials Science I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cellular biology, and biotechnology. Understanding of different types of interactions that exist between biomolecules, such as van der Waals interactions, entropic and enthalpic electrostatic interactions, hydrophobic intermolecular interactions and solvent interactions, polymeric interactions, deformation interactions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Concurrently scheduled with course C239A. Letter grading. Mr. Wong (W)

C139B. Biomolecular Materials Science II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Course C139A is not requisite to

C139B. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cellular biology, and biotechnology. Understanding of different types of interactions that exist between biomolecules, such as van der Waals interactions, entropic and enthalpic electrostatic interactions, hydrophobic intermolecular interactions and solvent interactions, polymeric interactions, deformation interactions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Concurrently scheduled with course C239B. Letter grading. Mr. Wong (W)

CM140. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM140.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: Mechanical and Aerospace Engineering 101, 102, and 156A or 166A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading. Mr. Gupta (W)

CM141. Mechanics of Cells. (4) (Same as Mechanical and Aerospace Engineering CM141.) Lecture, four hours. Introduction to physical structures of cell biology and physical principles that govern how they function mechanically. Introduction of continuum mechanics and statistic mechanics to develop quantitative mathematical models of structural mechanics in cells. Structure of macromolecules, polymers as entangled springs, random walks and diffusion, mechanosensitive proteins, single-molecule force-extension, DNA packing and transcription regulation, lipid bilayer membranes, mechanics of tissue engineering, molecular and cellular biology, muscle mechanics, pattern formation. Concurrently scheduled with course CM241. Letter grading. (Not offered 2017-18)

CM145. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Life Sciences 3, 23L. Selected topics in molecular biology that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis, polymer engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM245. Letter grading.

C147. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artificial tissues. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological testing. Case studies include skin, artificial skin, bone, artificial blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of tissue engineering products. Manufacturing constraints, clinical limitations and challenges that face biomedical engineers in design and development of tissue-engineering devices. Concurrently scheduled with course C247. Letter grading. Mr. Fan (Sp)

CM152. Introduction to Microscale and Nanoscale Manufacturing. (4) (Same as Chemical Engineering M152, Electrical and Computer Engineering M153, and Mechanical and Aerospace Engineering M183B.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to general
C171. Laser-Tissue Interaction II: Biologic Spectroscopy. (4) Lecture, four hours; outside study, eight hours. Requisite: course C170. Designed for physical scientists, engineers, and students in medicine. Introduction to optical spectroscopy principles, design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy biologic and molecular response. Concurrently scheduled with course C271. Letter grading.

Mr. Grundfest (W)


Mr. Wu (Sp)

C177A. Bioengineering Capstone Design I. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisites: courses 167L, 176L. Lectures, seminars, and discussions on aspects of biomedical device and therapeutic design, including topics such as seed finding, intellectual property, entrepreneurship, regulation, and project management. Working in teams, students develop innovative solutions to address current problems in medicine and bi ology. Sourcing and ordering of materials and supplies required to build devices for testing and evaluation. Different experimental and computational methods. Scientific presentation of progress. Letter grading.

Mr. Di Carlo (F)

C177B. Bioengineering Capstone Design II. (4) Lecture, three hours; discussion, two hours; laboratory, six hours; outside study, four hours. Requisite: course 177A. Lectures, seminars, and discussions on aspects of biomedical device and therapeutic design, including meetings with scientific/clinical advisors and guest lectures from scientists in industry. Working in teams, students develop innovative solutions to address current problems in medicine and biology. Students conduct directed experiments and computational mod eling, give oral presentations, write reports, and participate in bioengineering design competition. Letter grading.

Mr. Dunn (W)

C178. Introduction to Biomechanics (Same as Materials Science CM180). Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, and 20L, or Materials Science 4A, 58. Emphasis in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitable to task, surface chemistry processing, and treatment of materials, and biocompatibility. Concurrently scheduled with course CM278. Letter grading.

Ms. Kasko (F)

C179. Biomaterials-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisite: course CM179. In-depth exploration of host cell response to biomaterials: vascular response, interface, and clotting, biocompatibility, animal models, inflammation, infection, extracellular matrix, cell adhesion, and role of mechanical forces. Concurrently scheduled with course C279. Letter grading.

Mr. Dunn, Mr. Wu (W)


Mr. Dunn, Mr. Wu (Sp)

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

Ms. Kasko (Sp)

M184. Introduction to Computational and Systems Biology. (Formerly numbered Biomedical Engineering M184.) (Same as Computational and Systems Biology M184 and Computer Science M184.) Lecture, two hours; outside study, four hours. Enforced requisites: one course from Civil Engineering M20, Computer Science 33, Mechanical and Aerospace Engineering M20, or Program in Computing 10A, and Mathematics 3B or 31B. Survey course designed to introduce students to computational and systems models in biology, medicine, and engineering, with an emphasis on systems biology. Corequisites: course 180L. Part I of two-part series. Molecular basis of normal physiology and pathophysiology, and engineering design principles of cardiovascular and pulmonary systems. Fundamentals of physiology and selected medical therapeutic devices. Letter grading.

Mr. DiStefano (F)

C185. Introduction to Tissue Engineering. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course CM102 or CM202, Chemistry 20A, 20B, 20L. Tissue engineering addresses the principles of biology and physics of tissue engineering with an emphasis on tissue regeneration. Students design and implement a tissue engineering device. Letter grading.

Ms. Kasko (W)

CM186. Computational Systems Biology: Model ing and Simulation (Same as Computational and Systems Biology M186, Computer Science CM186, and Ecology and Evolutionary Biology M178.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: Electrical Engineering 102. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization, control, and regulation, and applications to systems biology. Control system, multicompartimental, predator-prey, pharma-
Cokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biomedical pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementing them for simulation and analysis. Both numerical simulation and analysis, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM206. Letter grading.

CM187. Research Communication in Computational and Systems Biology. (4) (Same as Computational and Systems Biology M187 and Computer Science 106.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: 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 search for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM287. Letter grading. 


CM204. Physical Chemistry of Biomacromolecules. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Survey of chemical fundamentals of polymer physical chemistry. Investigation of polymer structure and conformation, and solid state and solution thermodynamics and phase behavior, polymer kinetics, polymer-polymer interactions. 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 C104. Letter grading. 

CM205. Engineering of Bioconjugates. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry is science of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface in gene circuit, or 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 and reaction conditions associated with biomolecular membranes and channel proteins, with special emphasis on endocytosis. Basic physical principles governing electrophotostatics in dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, cables, action equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course C105. Letter grading. Mr. Schmidt (F)

CM206. Topics in Bioelectricity for Bioengineers. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20B, Life Sciences 2, 3, Mathematics 33B, Physics 1C. Coverage of topics associated with biological membranes and channel proteins, with special emphasis on electrophotostatics. Basic physical principles governing electrophotostatics in dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, cables, action equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course C106. Letter grading.

CM207. Polymer Chemistry for Bioengineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course CM204 or CM205. Fundamental concepts of chemical reactions, including step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control chain length, chain length distributions, functional groupings, chain copolymerization, and stereochemistry in polymerization. Presentation of applications of different polymerization techniques. Concepts of step-growth, chain transfer, coordination polymerization, and effects of synthesis route on polymer properties. Lectures include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C107. Letter grading. Mr. Deming (W)

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

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

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

M219. Principles and Applications of Magnetic Resonance Imaging. (4) (Formerly numbered Biomedical Engineering M219.) (Same as Physics and Biology in Medicine M219.) Lecture, three hours; discussion, one hour. Basic principles of magnetic resonance (MR), physics, and image formation. Emphasis on hardware, Bioequations, descriptions of image contrast mechanisms, spin and gradient echoes, Fourier transform imaging methods, structure of pulse sequences, and various scanning parameters. Introduction to advanced techniques in rapid imaging, quantitative imaging, and spectroscopy. Letter grading.

M220. Introduction to Medical Informatics. (2) Lecture, two hours; outside study, four hours. Designed for graduate students. Introduction to research topics and issues in medical informatics for students new to field. Definition of this emerging field of study, current research efforts, and future directions in research. Key sources of current medical informatics to expose students to different application domains, such as information system architectures, data and process modeling, information extraction and representations, information retrieval and visualization, research, telemedicine. Emphasis on current research endeavors and applications. S/U grading.

M221. Human Anatomy and Physiology for Medical and Imaging Informatics. (4) (Formerly numbered Biomedical Engineering M221) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on understanding and visualization of anatomy and physiology through medical images. Topics relevant to acquisition, representation, and visualization of anatomical knowledge in computerized clinical applications. Topics include chest, cardiac, neurology, gastrointestinal/genitourinary, endocrine, and musculoskeletal systems. Introduction to basic imaging chain-end functional modules. Studies require more formal understanding of human anatomy/physiology. Letter grading. Mr. El-Saden (F)

223A-223B-223C. Programming Laboratories for Medical and Imaging Informatics I, II, III. (4-4-4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Programming laboratories to support coursework in other medical and imaging informatics core curric-
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 standardized indices/terminologies (SNOMED, UMLS). Letter grading.

M226. Medical Decision Making. (4) (Same as Information Studies M255.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to decision making and decision processes related to process of care and outcomes. Basic probability and statistics to understand research results and evaluations, and to determine implications of clinical decision pro-

cesses (Bayes theorem, decision trees). Study de-
sign, hypothesis testing, and estimation. Focus on technical advances in medical decision support sys-
tems and expert systems, with review of classic and
current research. Introduction to common statistical
decision-making software packages to familiar-
ize students with current tools. Letter grading.

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 decision making paradigms that allow them to engage broad spectrum of bioengineering problems, such as those in drug and gene delivery and tissue engineering. May be taken independently for credit. Concurrently scheduled with course C139A. Letter grading.

M239B. Biomolecular Materials Science II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cell biology, and tissue engineering. Emphasis on differ-
ent types of interactions that exist between bio-
molecules, such as van der Waals interactions, en-
tropically modulated electrostatic interactions, hydro-
phobic interactions, interactions involved in biomolec-
ular recognition, and others. Illustration of these ideas using examples from bioen-

gineering and biomedical engineering. Students should be able to make simple calculations and esti-
mates that allow them to engage the broad scope of bioengineering problems, such as those in drug and gene delivery and tissue engineering. May be taken independently for credit. Concurrently scheduled with course C139B. Letter grading.

CM240. Introduction to Biomechanics. (4) (Same as Chemical and Aerospace Engineering CM240.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanical and Aero-
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C247. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requirements: course CM202, Chemistry 20A, 20B, 20L, Life Sciences 104. Enzymes or 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, scaffold processes, and physical and chemical and biological testing. Case studies include skin and artifical skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kidney, and other organ engineering. Critical advancement of industrial perspective of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course CM147. Letter grading.

Mr. Wu (Sp)

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

Mr. Candler (Sp)

M250B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Electrical and Computer Engineering M250B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: course M153. Advanced discussion of microfabrication processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in processes issues such as surface oxidation, chemical and electrochemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading.

Mr. Wu (Sp)


Mr. D. Chu (Sp)

M260. Neuroengineering. (4) (Same as Electrical and Computer Engineering M255 and Neuroscience M206.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 6B. Introduction to principles and technologies of bioelectricity and neural signal recording, processing, and stimulation. Topics include bioelectricity, neuroengineering, local field potentials, EEG, ECoG, intracellular and extracellular recording, microelectrode technology, neural signal processing (neural frequency bands, filtering, spike detection, spike sorting, stimulation, artificial neural networks), brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading.

Mr. Liu (Sp)


M263. Neural Systems and Anatomy. (4) (Same as Neuroscience M263.) Lecture, four hours; discussion/laboratory, two hours. Prior to first laboratory meeting, students must complete Biochemistry Pathogens training course through UCLA UCLion, Health and Safety. Fundamentals of systems neuroscience, with emphasis on integration of cellular, circuit, and systems analyses aimed at understanding sensorimotor processing, learning, and cognition. Anatomy laboratory includes brain dissections. Letter grading.

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

C270L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) Laboratory, four hours; outside study, two hours. Corequisites: course C270. Introduction to simulation and experimental techniques used in studying laser-tissue interactions. Topics include computer simulations of light propagation in tissue, measuring absorption spectra of tissue/tissue phantoms, making tissue phantoms, determination of optical properties of different tissues, techniques of temperature distribution measurements. Concurrently scheduled with course C170L. Letter grading.


Mr. Grundfest (W)

C272. Design of Minimally Invasive Surgical Tools. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, Mathematics 32A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of FDA regulatory policy and surgical procedures. Topics include optical devices, endoscopic visual display devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instrumentation, and integration of devices with therapy. Examination of clinical application of device design, fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel devices. Concurrently scheduled with course C172. Letter grading.

CM278. Introduction to Biomaterials. (4) (Same as Materials Science CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, and 20L, or Materials Science 104. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM145. Letter grading.


Mr. Wu (Sp)

C282. Biomaterial Interfaces. (4) Lecture, four hours; laboratory, eight hours. Requisite: course CM178 or CM278. Function, utility, and biocompatibility of biomaterials depend critically on their surface and interface properties. Discussion of the synthesis and composition of biomaterials and nanoscales, macroscales, and microscales, techniques for characterizing structure and properties of biomaterial interfaces, and methods for designing and developing biomaterials with prescribed structure and 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 therapeutics require comprehensive understanding of modern biology, physiologic and therapeutic principles. Advanced delivery of genes and drugs and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug pharmacodynamics and clinical pharmacology. Application of physical 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 delivery. Introduction to biomaterials with specialized structural and interface properties. Exploration of both hardware and computer models of representation of devices and compounds used in delivery and release. Concurrently scheduled with course C183. Letter grading.

Ms. Kasiko (Sp)

M284. Functional Neuroimaging: Techniques and Applications. (4) (Same as Neuroscience M285, Physics and Biology in Medicine M285, Psychiatry M285, and Psychology M278.) Lecture, three hours. In-depth examination of activation imaging, including fMRI and functional 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 visits and design and implementation of functional MRI experiment. S/U or letter grading.

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

Mr. Candra (W)

CM286. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Computer Science CM286.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Requisites: course CM102 or CM202, Chemistry 20A, 20B, 20L. Computational systems modeling and computer simulation methods for studying biological/biomedical processes, in vitro and in vivo. Techniques include the use of computational models to simulate processes at multiple scales, and macroscales, techniques for characterizing structure and properties of biomaterial interfaces, and methods for designing and developing biomaterials with prescribed structure and properties in vitro and vivo. Letter grading. Ms. Maynard (W)

Robert M. Wu (Not offered 2017-18)
thms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM286A or course CM287. Research Communication in Computational and Systems Biology. (4) (Same as Computer Science CM287.) Lecture, four hours; outside study, eight hours. Requisite: course CM286C. Closely directed, interactive, and noncompartamental research experience in active quantitative systems biology research laboratory. Direction on how to focus on topics of current and future interest in scientific community, appropriate to student interests and capabilities. Critiques of oral presentations and written progress reports explain how to proceed with search for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM187, Letter grading. Mr. DiStefano (Sp).

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

295A. Biomaterial Research.

295B. Biomaterials and Tissue Engineering Research.

295C. Minimally Invasive and Laser Research.

295D. Hybrid Device Research.

295E. Molecular Cell Bioengineering Research.

295F. Biomaterials and Biodegradable Polymers.

295G. Biomicrofluidics and Bionanotechnology Research.

295H. Biomimetic System Research.

295J. Neural Tissue Engineering and Regenerative Medicine.

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: Electrical Engineering 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Development of dynamic systems modeling methodology for physiological, biomedical, pharmacological, chemical, and related systems. Control system modeling, nonlinear, noncompartamental, and input/output models, linear and nonlinear. Emphasis on model applications, limitations, and relevance in biomedical sciences and other limited data environments. Problem solving in PC laboratory. Letter grading. Mr. DiStefano (F).

M296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Same as Biomathematics M270, Computer Science M296B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course CM286C or M296A or Biomathematics 220. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano (W).


M296D. Introduction to Computational Cardiology. (4) (Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac electrophysiology processes, ionic models of action potentials (AP). Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and efficiency. Letter grading. Mr. Kogan (FSp).

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

299. Seminar: Bioengineering Topics. (2) Seminar, two hours; outside study, four hours. Designed for graduate bioengineering students. Seminar by teaching assistant 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 micro-hybrid devices, scaffold engineering, and bioinformatics. S/U grading. Mr. Wu (F/W,Sp).

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personal 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 repeated for credit. S/U grading.

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

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate bioengineering students. Reading and preparation for Ph.D. comprehensive examination. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate bioengineering students. Preparation for oral qualifying examination, including preliminary self-study and defense. S/U grading.

598. Research for and Preparation of M.S. Thesis. (2 to 16) Tutorial, to be arranged. Limited to graduate bioengineering students. Supervised independent research for M.S. candidates, including thesis proposal. S/U grading.

599. Research for and Preparation of Ph.D. 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

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

Professors
Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)
Panagiotis D. Christofides, Ph.D. (William D. Van Vorst Professor of Chemical Engineering Education)
Yoram Cohen, Ph.D.
James F. Davis, Ph.D., Vice Provost
Vijay K. Dhir, Ph.D.
James C. Liao, Ph.D. (Ralph M. Parsons Foundation Professor of Chemical Engineering)
Yunfeng Lu, Ph.D.
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Stanley J. Osher, Ph.D.
Philippe Sautet, Ph.D.
Tatiana Segura, Ph.D.
Yi Tang, Ph.D., Chancellor’s Professor

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

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

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

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

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

Undergraduate Program

Educational Objectives

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

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

Undergraduate Study

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

Chemical Engineering B.S.

Capstone Major

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

Chemical Engineering Core Option

Preparation for the Major

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

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 110, C111, C112, 113, C114, C115, C116, C118, C119, C121, C125, C128, C135, C140.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://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; Chemical and Biomolecular Engineering M20 or Mechanical and Aerospace Engineering M20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 104A, 104D, 107, 109, C115, C125, CM145; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one biomedical elective course (4 units) from Bioengineering C105, C106, Chemical Engineering C112, Chemistry and Biochemistry C105, 153A, or C159 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser).

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

Biomolecular Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 104A, 104D, 107, 109, C115, C125, CM145; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one biomolecular elective course (4 units) from Bioengineering C105, C106, Chemical Engineering C112, Chemistry and Biochemistry C105, 153A, or C159 (another chemical engineering elective may be substituted with approval of the faculty adviser).
The following introductory information is based on the 2017-18 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at https://grad.ucla.edu. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.

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

Chemical Engineering M.S.

Areas of Study

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

Course Requirements

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

All M.S. degree candidates are required to enroll in Chemical Engineering 299 during each term in residence.

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 133A, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Semiconductor Manufacturing Specialization

Students are required to complete 10 courses (44 units) with a minimum 3.0 grade-point average overall and in the graduate courses. A minimum of five 200-series courses (20 units) are required, including

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All M.S. degree candidates are required to enroll in Chemical Engineering 299 during each term in residence.

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 133A, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.
Chemical and Biomolecular 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 C214, 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, 245, and a graduate engineering mathematics course. Two additional courses must be taken from those offered by the department. The final course can be selected from offerings in life sciences, physical sciences, mathematics, or engineering. Students are encouraged to take more courses in their field of specialization. The minor field courses should be selected in consultation with the research adviser. A minimum 3.33 grade-point average in graduate courses is required. A program of study to fulfill the course requirements must be submitted for approval to the departmental Student Affairs Office no later than one term after successful completion of the preliminary oral examination.

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

Written and Oral Qualifying Examinations
Academic Senate regulations require all doctoral students to complete and pass University written and oral qualifying examinations prior to doctoral advancement to candidacy. Under Senate regulations the University Oral Qualifying Examination is open only to students and appointed members of their doctoral committees.

In addition to University requirements, some graduate programs have other precandidacy examination requirements. What follows are the requirements for this doctoral program.

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

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

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

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

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

Facilities
Biomolecular Engineering Laboratories
The Biomolecular Engineering laboratories are equipped for cutting-edge genetic, molecular, and cellular engineering teaching and research. Facilities and equipment include bioreactors, fluorescence microscopy, real-time PCR thermocycler, UV-visible and fluorescence spectrophotometers, HPLC and LC-mass spectrometer, aerobic and anaerobic bioreactors from bench top to 100-liter pilot scale, protein purification facility, potentiostat/galvanostat and impedance analyzer for electrosynthesis, membrane extruder and multiplex laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and phosphoinositol for biochemical assays involving radiolabeled compounds.
Microbial cells are genetically and metabolically engineered to produce compounds that are used as fuel, chemicals, drugs, and food additives. Novel gene-metabolic circuits are designed and constructed in microbial cells to perform complex and non-native cellular behavior. These designer cells are cultured in bioreactors, and intracellular states are monitored. Such investigations are coupled with genomic and proteomic efforts, and mathematical modeling, to achieve system-wide understanding of the cell.

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

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

The Chemical Kinetics, Catalysis, and Reaction Engineering Laboratory is equipped with advanced research tools for experimental and computational studies of chemical kinetics, reaction engineering, and catalytic and adsorptive materials. Analytical instruments include a quadrupole mass spectrometer (QMS) system to sample reactive systems with electron impact and photoionization capabilities; several fully computerized gas chromatograph/mass spectrometer (GC/MS) systems for gas analysis; a computerized gas chromatograph/sulfur chemiluminescence detector (GC/SCD) system for gas analysis of sulfur-containing compounds; and a 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 Electrochemical Engineering and Catalysis Laboratories are used to study metal, alloy, and semiconductor corrosion processes, electrodeposition and electroless deposition of metals, alloys, and semiconductors for GMR and MEMS applications, electrochemical energy conversion (fuel cells) and storage (batteries), and bioelectrochemical processes and biomedical systems.

The electroorganic synthesis facility is for the development of electrochemical processes to transform biomass-derived organic compounds into useful chemicals, fuels, and pharmaceuticals. The catalysis facility is equipped to support various types of catalysis projects, including catalytic hydrocarbon oxidation, selective catalytic reduction of NOx, and Fischer-Tropsch synthesis.

**Electronic Materials Processing Laboratory**

The Electronic Materials Processing Laboratory focuses on the synthesis and patterning of multifunctional complex oxide films and nanostructures with tailored electronic, chemical, thermal, mechanical, and biological properties. Experimental and theoretical studies are combined to understand the process chemistry and surface kinetics in atomic layer deposition, plasma etching and deposition processes, gas-phase surface functionalization, and solution phase synthesis. Novel devices including advanced microelectronics, optoelectronics, chemical sensors, and energy storage devices are realized at nano-dimensions as the technologies become more enabling based on these fundamental studies.

The laboratory is equipped with a state-of-the-art advanced rapid thermal processing facility with in-situ vapor phase processing and atomic layer deposition capabilities; advanced plasma processing tools including thin film deposition and etching; and diagnostics including optical emissions spectroscopy, Langmuir probe, and quadruple mass spectrometry; a surface analytical facility including X-ray photoelectron spectroscopy, Auger electron spectroscopy, ultraviolet photoelectron spectroscopy, reflection high energy electron diffraction, spectroscopic ellipsometry, photoluminescence, and infrared spectroscopy; and a complete set of processing tools available for microelectronics and MEMS fabrication in the Nanoelectronic Research Facility. With the combined material characterization and electronic device fabrication, the reaction kinetics including composition and morphology, and the electrical property of these materials can be realized for applications in the next generation electronic devices and chemical or biological MEMS.

**Materials and Plasma Chemistry Laboratory**

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

The atmospheric plasma laboratory is equipped with multiple plasma sources and state-of-the-art diagnostic tools. The plasmas generate, at low temperature, beams of atoms and radicals well-suited for surface treatment, cleaning, etching, deposition, and sterilization. Applications are in the 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 Nanoparticle Technology and Air Quality Engineering
Polymer and Separations Research Laboratory

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

Process Systems Engineering Laboratory

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

Faculty Areas of Thesis Guidance

Professors Emeriti

Robert F. Hicks, Ph.D. (UC Berkeley, 1964) 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

Professors

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


Assistant Professors

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

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

Soft materials, self-assembly, polymer chemistry and polymer physics, scattering rheology
Lower-Division Courses

10. Technology and Environment. (4) Lecture, four hours; outside study, eight hours. Natural and anthropogenic flows of materials at global and regional scales. Case studies of natural cycles include global warming (CO₂ cycles), stratospheric ozone depletion (chlorine and ozone cycles), and global nitrogen cycles. Flow of materials in industrial economies compared and contrasted with natural flows; presentation of lifecycle methods for evaluating environmental impact of products, and experimental methods. P/NP or letter grading. Mr. Manousiouthakis (Not offered 2017-18)

11. Introduction to Chemical and Biomolecular Engineering. (1) Lecture, one hour; outside study, two hours. General introduction to fields of chemical and biomolecular engineering. Description of how chemical and biomolecular engineering analysis and design skills are applied for creative solution of current problems in chemical engineering practice. Fundamentals of mass transfer, Fick law of diffusion, diffusion in chemically reacting flows, interphase mass transfer, multicomponent systems. 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 (W)

102B. Thermodynamics II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 102A. Fundamentals of classical and statistical thermodynamics in chemical and biological sciences. Phase equilibria in single and multicomponent systems. 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. Christofides (F)

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

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

Upper-Division Courses

100. Fundamentals of Chemical and Biomolecular Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisites: Mathematics 33A, 33B, 20L. Fundamentals of modern biomolecular engineering. Topics include structure and function of biomolecules, central dogma of molecular biology, cellular information and energy processing, and experimental methods, with strong emphasis on applications in medicine, industry, and bioenergy. Letter grading.

101A. Transport Phenomena I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: course 100, 101B. Electrical Engineering 104 (or C125), 106 (or C115). Introduction to analysis of fluid flow in chemical, biological, materials, and molecular processes. Fundamentals of momentum transport, Newtonian law of viscosity, mass and momentum conservation in laminar flow, Navier-Stokes equations, and engineering analysis of flow systems. Letter grading.
Mr. Monbouquette (F)

Mr. Chang (W)

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

104C. Semiconductor Processing. (3) Lecture, four hours; outside study, five hours. Enforced requisite: course 101C. 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.

Mr. Christofides (F)
110. Intermediate Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Enrollment limited to 40. Principles of engineering applications of statistical and phenomenological thermodynamics. Determination of partition function in terms of simple molecular models and spectroscopic data; nonideal gases; phase transitions; phase diagrams; process thermodynamics and coupled transport processes. Letter grading. (Not offered 2017-18)  

C111. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryoengineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and enve- loped needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C211. Letter grading.  

Mr. Yuan (F)  

C112. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A, Chemistry 20A. Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymeric deformation, diffusion, and interfaces. Polymers. Polymers in biomedical applications and in microelectronics. Concurrently scheduled with course C212. Letter grading.  

Mr. Cohen (W)  

113. Air Pollution Engineering. (4) Lecture, four hours; discussion, one hour; outside study, six hours. Enforced requisites: courses 101C, 102B. Integrated approach to air pollution, including concentra- tions of atmospheric pollutants, air pollution stan- dards, air pollution sources and control technology, and relationship of air quality to emission sources. Links air pollution to multimedia environmental as- sessments. Speciation problems include combustion gases, metals and semiconductors, and chemical and biological pollutants. May be concurrently scheduled with course C214. Letter grading.  

Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of photoelectrochemistry with emphasis on fundamental principles of light energy conversion to electrical energy in photovoltaic cells, and photoelectrochemical devices. May be concurrently scheduled with course C214. Letter grading.  

Ms. Chang (Sp)  

C114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 101C. Use of previously learned concepts of chemical engineering, 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. Segura (F)  

C115. Biochemical Reaction Engineering. (4) Le- cture, four hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 113A, Introduction to surfaces and interfaces of engineering materials, specifically catalytic surfac and thin films for solar cells, MEMS, and nanotechnology. Topics include the fundamentals of metal and semiconductor surface formation, passivation, elec- trodeposition, electrodeposition of metals, batteries and fuel cells. Electrochemical processes in MEMS and bioelectronic processes. May be concurrently scheduled with course CM216. Letter grading.  

Lecture, four hours; discussion, one hour; preparation, two hours; outside study, five hours. Requer- mended requisites: courses 101C, 102B. Pollutant sources, estimation of source releases, waste minimi- zation, transport and fate of chemical pollutants in environment, intermediate transfer of pollutants, multi- dimensional transport and fate in environment, exposure assessment and fundamentals of risk assessment, risk reduction strategies. Concurrently scheduled with course C218. Letter grading.  

Mr. Cohen (Not offered 2017-18)  

C119. Pollution Prevention and Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 103. This course introduces pollution prevention techniques and introduces the tools needed to understand and implement pollution prevention strategies. The course will focus on the analysis of industrial process systems and an ability to use these tools to design new systems, analyze existing systems, and develop strategies to improve environmental performance. Letter grading.  

Mr. Manousiouthakis (Not offered 2017-18)  

C121. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101A, 101C. Fundamentals of membrane sci- ence 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 and selectivity). Examples pro- vided from various applications including bio- technology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C221. Letter grading.  

Mr. Rahardianto (F)  

C124. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 2, 3, 23L. Introduction to biological materials for re- generative medicine, in vitro cell culture, and drug delivery. Biological principles of cellular microenviron- ment and design of extracellular matrix analogs using biology and chemistry. Use of new technologies including bio- technology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C221. Letter grading.  

Mr. Rahardianto (F)  

C125. Bioseparations and Bioprocess Engineer- ing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course CM123. Topics include microbial fermentations, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, en- zymes, food additives, or pharmaceuticals that are present in bioreactors. May be concurrently scheduled with course CM225. Letter grading.  

(CM127. Synthetic Biology for Biofuels. (4) Same as Chemistry CM127.) Lecture, four hours; discus- sion, one hour; outside study, seven hours. Requir- ments: Chemistry 133A, Life Sciences 3, 23L. Engi- neering microorganisms for complex phenotype is common goal of metabolic engineering and synthetic biology. Production of advanced biofuels involves de- signing and constructing novel metabolic networks in cells. Such efforts require profound understanding of biochemistry, protein structure, and biological regula- tions and are aided by tools in bioinformatics, sys- tems biology, and chemical engineering. Use of systems modeling for metabolic networks to design microorgan- isms for energy applications. Concurrently scheduled with course CM227. Letter grading.  

(CM145. Molecular Biotechnology for Engineers. (4) Same as Bioengineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Life Sciences 3, 23L. Select- ed topics in molecular biology that form the foun- dation of biotechnology and biomedical industry today. Topics include recombiant DNA technology, mole- cular research tools, manipulation of gene expression, directed mutagenesis and directed evolution, DNA- based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioin- formatics, isolation of human genes, gene therapy, and gene therapy. Engineering. Concurrently scheduled with course CM245. Letter grading.  

Mr. Chen (F)  

M153. Introduction to Microscale and Nano- scale Manufacturing. (4) Same as Bioengineering M153, Mechanical 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 microfabrication and nanofabrication. Focus on concepts, physics, and instruments of various micro- fabrication and nanofabrication techniques that have been broadly applied in industry and academia, in- cluding various photolithography technologies, phys- ical and chemical deposition methods, and physical and chemical etching methods. Hands-on experi- ence for fabricating microstructures and nanostruc- tures in modern cleanroom environment. Letter grading.  

Mr. Chiu (FSp)  

158. 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 with credit with topic or instructor change. Letter grading.  

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

199. Directed Research in Chemical Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/senior. Supervised individual research or investigation of selected topic under guidance of faculty mentor. Culminating paper or project required. May be re- peated for credit with written approval of individual contract required; enrollment petition available in Office of Academic and Student Affairs. Letter grading.  

(F,WSp)
Graduate Courses

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

201. Methods of Molecular Simulation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 200 or Chemistry C223A or Physics 215A. Modern simulation techniques for classical molecular systems, Monte Carlo and molecular dynamics in various ensembles. Applications to liquids, solids, and polymers. Letter grading. (Not offered 2017–18)

210. Advanced Chemical Reaction Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 115 or 134, 136. Primarily of chemical reactor analysis and design. Particular emphasis on simultaneous effects of chemical reaction and mass transfer on noncatalytic and catalytic reactions in fixed and fluidized beds. Letter grading. Mr. Simonetti (W).

211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Fundamentals of cryogenics and cryoengineering, including relation to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-temperature behavior of various cryostructural materials. Application of design of cryosystems and other special conditions. Concurrently scheduled with course C111. Letter grading. Mr. Yuan (F).


213. Electrochemical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course C114. Transport phenomena in electrochemical systems; relationships between molecular transport, corrosion, and electrochemistry. Emphasis on applications to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading. Mr. Nobe (Not offered 2017–18).


219. Pollution Prevention for Chemical Processes. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course 101C. Advanced treatment of mass transfer, with applications to industrial separation processes, gas cleaning, pulmonary bioengineering, controlled release systems, and reactor design; molecular and constitutive theories of diffusion, interfacial transport, membrane transport, convective mass transfer, concentration boundary layers, turbulent transport. Letter grading. Mr. Srivastava (W).

221. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 102A, 102B or Materials Science 130. Fundamentals of engineering and biochemical applications to industrial electrochemical processes and metallic corrosion. Primary emphasis on fundamental approach to analysis of electrochemical and corrosion processes. Surface properties and contamination of metals and semiconductors, electrochemical metal and semiconductor surface finishing, passivity, electrodeposition, electroless deposition, batteries and fuel cells, electrochemistry and biochemical processes. May be concurrently scheduled with course C114. Letter grading. Ms. Chang (Sp).

222. Advanced Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Advanced treatment of mass transfer, with applications to industrial separation processes, gas cleaning, pulmonary bioengineering, controlled release systems, and reactor design; molecular and constitutive theories of diffusion, interfacial transport, membrane transport, convective mass transfer, concentration boundary layers, turbulent transport. Letter grading. Mr. Rahardianto (F).

223. Design for Environment. (4) Lecture, four hours; outside study, eight hours. Limited to graduate chemical engineering, materials science and engineering, or Master of Engineering program students. Design of products for meeting environmental objectives; lifecycle inventories; lifecycle impact assessment; design for energy efficiency; design for waste minimization, computer-aided design tools, materials selection methods. Letter grading. (Not offered 2017–18)

224. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 2, 3, 23L. Introduction to design and synthesis of biomaterials for regenerative medicine, in vitro cell culture, and drug delivery. Theoretical principles of design of biomaterials and design of extracellular matrix analogs using biological and engineering principles. Biomaterials for growth factor, and DNA and siRNA delivery as therapeutics and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C124. Letter grading. Ms. Segura (Not offered 2017–18).

225. Bioseparations and Bioprocess Engineering. (4) Same as Bioengineering C225. Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101C. Separation strategies, unit operations, and economic factors used to design processes for purifying materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Concurrently scheduled with course C125. Letter grading. Ms. Segura (Not offered 2017–18).

226. Synthetic Biology for Biofuels. (4) Same as Chemistry CM227. Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 153A, Life Sciences 3, 23L. Engineering microorganisms for complex phenotype is common goal of metabolic engineering and synthetic biology. Production of advanced biofuels involves designing and constructing synthetic microorganisms. Cells. Such efforts require profound understanding of biochemistry, protein structure, and biological regulations and are aided by tools in bioinformatics, systems biology, and molecular biology. Fundamentals of metabolic biochemistry, protein structure and function, and bioinformatics. Use of systems modeling for metabolic networks to design microorganisms for energy applications. Concurrently scheduled with course CM127. S/U or letter grading. (Not offered 2017–18)

228. Hydrogen. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Chemistry 20A, 20B, 20C. Production and chemical properties of hydrogen. Various methods of production, including production through methane steam reforming, electrolysis, and thermochromic cycles. Description in depth of several uses of hydrogen, including hydrogen combustion and hydrogen fuel cells. Concurrently scheduled with course C128. Letter grading. Mr. Manousiouthakis (Sp).


231. Molecular Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 106 or 110. Analysis and design of molecular-beam systems. Molecular-beam sampling of reactive mixtures in combustion chambers or gas jets. Molecular-beam studies of gas-surface interactions, including energy accommodations and heterogeneous reactions. Applications to air pollution control and to catalysis. Letter grading. (Not offered 2017–18)

croelectronics, and solid-state laser. May be concurrently scheduled with course C116. Letter grading. Mr. Lu (Sp).

217. Electrochemical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course C114. Transport phenomena in electrochemical systems; relationships between molecular transport, corrosion, and electrochemistry. Emphasis on applications to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading. Mr. Nobe (Not offered 2017–18).


220. Advanced Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Advanced treatment of mass transfer, with applications to industrial separation processes, gas cleaning, pulmonary bioengineering, controlled release systems, and reactor design; molecular and constitutive theories of diffusion, interfacial transport, membrane transport, convective mass transfer, concentration boundary layers, turbulent transport. Letter grading. Mr. Cohen (Not offered 2017–18).

222. Stochastic Modeling and Simulation of Chemical Processes. (4) Lecture, four hours; outside study, eight hours. Introduction, definition, ratio-}

233. Frontiers in Biotechnology. (2) Formerly numbered CM233J. Lecture, one hour. Requisite: Life Sciences 1, 2, 3, 4, 23L, Mathematics 31A, 31B, 228B, 270A. Integration of science and business in biotechnology. Academic research leading to licensing and founding of companies that turn research breakthroughs into marketable products. Invited lectures from academia and industry cover emerging areas of biotechnology from combination of science, engineering, and business points of view. S/U or letter grading. (Not offered 2017-18)

234. Plasma Chemistry and Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate chemistry or engineering students. Application of chemistry, physics, and engineering principles to design and operation of plasma and ion-beam reactors used in etching, deposition, oxidation, and cleaning of materials. Examination of atomic, molecular, and ionic phenomena involved in plasma and ion-beam processing of semiconductors, etc. Letter grading. Mr. Chang (Not offered 2017-18)

C235. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 107. Introduction to advanced process control. Topics include (1) Lyapunov stability for autonomous nonlinear systems including converse theorems, (2) input to state stability, interconnected systems, and small gain theorems, (3) design of robust controllers for various classes of nonlinear systems, (4) model predictive control of linear and nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of distributed parameter systems. Concurrently scheduled with course C135. 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 of deposited films, and relationship between process conditions and film properties. Letter grading. (Not offered 2017-18)


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 foundations of biotechnology and biomolecular industries today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading. Ms. Chen (F)


250. Computer-Aided Chemical Process Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses CM201A, CM220A. Advanced dy-research methods in chemical process design; computer aids in process engineering; process modeling; systematic flowsheet invention; process synthesis; optimal design and operation of large-scale chemical processing systems. Letter grading. Mr. Manousiouthakis (W)


270. Principles of Reaction and Transport Phenomena. (4) Lecture, four hours; laboratory, eight hours. Fundamentals in transport phenomena, chemical reaction, and kinetics and thermodynamics at molecular level. Topics include Boltzmann equation, microscopic chemical kinetics, transition state theory, and statistical analysis. Examination of engineering applications to other fields. Letter grading. Ms. Chang 270R. Advanced Research in Semiconductor Manufacturing. (6) Laboratory, nine hours; outside study, nine hours. Limited to graduate chemical engineering students in M.S. semiconductor manufacturing option. Supervised research in processing semiconductor materials and devices. Letter grading. Ms. Chang 280A. Linear Dynamic Systems. (4) (Same as Electrical and Computer Engineering M280A, Mechanical and Aerospace Engineering M270A.) Lecture, four hours; outside study, eight hours. Requisite: Electrical and Computer Engineering 141 or Mechanical and Aerospace Engineering 171A. State-space description of linear and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvalues and eigenvectors, singular values, Cayley-Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle. Connections with transfer function techniques. Letter grading. Mr. Christofides (Not offered 2017-18)

280BC. Optimal Control. (4) (Same as Electrical and Computer Engineering M240C and Mechanical and Aerospace Engineering M270C.) Lecture, four hours; outside study, eight hours. Requisite: Electrical and Computer Engineering 240B or Mechanical and Aerospace Engineering 270B. Applications of variational methods, Pontryagin maximum principle. Hamilton-Jacobi equations (dynamic programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading.


283C. Analysis and Control of Infinite Dimensional Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M280A, M282A. Designed for graduate students. Advanced dynamical analysis and controller synthesis methods for nonlinear infinite dimensional systems. Topics include (1) linear operator and stability theory (basic results on Hilbert and Banach spaces; Lyapunov theory, convergence theory in function spaces), (2) nonlinear model reduction (linear and nonlinear Galerkin method, proper orthogonal decomposition), (3) nonlinear robust control (stabilization and parabolic partial differential equations (PDEs), (4) applications to transport-reaction processes. Letter grading. Mr. Christofides (Not offered 2017-18)


290. Special Topics. (2 to 4) Seminar, four hours. Requisite: privilege of each offering. Concurrently scheduled as offered by department. Advanced and current study of one or more aspects of chemical engineering, such as chemical process dynamics and control, fuel cells and batteries, membrane transport, advanced chemical 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 Engineering M248S and Mechanical and Aerospace Engineering M299A.) Seminar, two hours; outside study, six hours. Limited to graduate engineering students. Presentations of research topics by leading academic and industrial researchers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.

296A-296Z. Research Seminars. (2 to 4) Seminar, to be arranged. Requisites: for each offering announced in advance by department. Letters, discussions, student presentations, and projects in areas of current interest. May be repeated for credit. S/U grading. (F,W,Sp)

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

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, 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)

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

495B. Teaching with Technology for Teaching Assistants. (2) Seminar, two hours; outside study, four hours; one-day intensive training at beginning of Fall Quarter. Limited to graduate chemical engineering students. Designed for teaching assistants interested in learning more about effective use of technology and ways to incorporate that technology into their classroom for benefit of student learning. S/U grading.
Civil and Environmental Engineering

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Associate Professors
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David Jassby, Ph.D.
Shailly Mahendra, Ph.D. (Henry Samueli Fellow)
Gaurav Sant, Ph.D. (Henry Samueli Fellow, Edward K. and Linda L. Rice Endowed Professor of Materials Science)
Jian Zhang, Ph.D.

Assistant Professors
Mathieu Bauchy, Ph.D.
Henry V. Burton, Ph.D., S.E. (Englekirk Presidential Endowed Professor of Structural Engineering)
Tirum W. Gallien, Ph.D.
Sanjay Mohanty, Ph.D.

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

Adjunct Associate Professors
Donald R. Kendall, Ph.D., P.E.
Issam Najm, Ph.D., P.E.
Daniel E. Pradel, Ph.D., G.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 graduates with a solid foundation in basic mathematics, science, and humanities, as well as fundamental knowledge of relevant engineering principles, (2) provide students with the capability for critical thinking, engineering reasoning, problem solving, experimentation, and teamwork, (3) prepare graduates for advanced study and/or professional employment within a wide array of industries or governmental agencies, (4) produce graduates who understand ethical issues associated with their profession and who are able to apply their acquired knowledge and skills to the betterment of society, and (5) foster in students a respect for the educational process that is manifest by a lifelong pursuit of learning.

Undergraduate Study

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

Civil Engineering B.S.

Capstone Major

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 1, M20 (or Computer Science 31); Mathematics 31A, 31B, 32A, 32B, 33A, 33B (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, Environmental 12, Life Sciences 1, 2, 7A, Microbiology, Immunology, and Molecular Genetics 5, 6, or Neuroscience 10.

The Major

Required: Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A, Civil and Environmental Engineering 91, 102, 103, C104 (or Materials Science and Engineering 104), 108, 110, 120, 135A, 150, 153, Mechanical and Aerospace Engineering 103; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and at least eight major field elective courses (32 units) from the lists below with at least two design courses, one of which must be a capstone design course and two of which must be laboratory courses. 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.

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

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

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

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

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

Additional Elective Options: Atmospheric and Oceanic Sciences 141, Earth, Planetary, and Space Sciences 100, 101, Environment 157, Mechanical and Aerospace Engineering 166C, M168.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://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 the undergraduate counselors before enrolling in any courses for the minor.

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

Graduate Study

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

The following introductory information is based on the 2017-18 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at https://grad.ucla.edu. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.

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

Civil Engineering M.S.

Course Requirements

There are two plans of study that lead to the M.S. degree: the capstone plan (also known as comprehensive examination) and the thesis plan. At least nine courses (36 units) are required, a majority of which must be in the Civil and Environmental Engineering Department. At least five of the courses must be at the 200 level. In the thesis plan, seven of the nine must be formal 100- or 200-series courses. The remaining two may be 598
courses involving work on the thesis. In the capstone (comprehensive examination) plan, 500-series courses may not be applied toward the nine-course requirement. 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. Each major field has a set of required preparatory courses which are normally completed during undergraduate studies. Equivalent courses taken at other institutions can satisfy the preparatory course requirements. The preparatory courses cannot be used to satisfy course requirements for the M.S. degree; courses must be selected in accordance with the lists of required graduate and elective courses for each major field.

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees.

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, 255A, 261B, M262A, 263A, 266, 267.


Environmental and Water Resources Engineering

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

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

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

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


Geotechnical Engineering

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

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

Major Field Elective Courses. Civil and Environmental Engineering 222, 225, 226, 227, 228, 245.


Structural/Earthquake Engineering

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

Required Graduate Courses. Civil and Environmental Engineering 235A, 246, and at least three courses from 235B, C239, 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; 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,
Structural Mechanics

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

Elective Courses. Undergraduate—maximum of two courses from Civil and Environmental Engineering M135C, C137, 137L; graduate—Civil and Environmental Engineering M230A, M230B, M230C, 233, 235C, 238, 244, 246, 247, Mechanical and Aerospace Engineering 269B.

Structures and Civil Engineering Materials

Required Preparatory Courses. General chemistry and physics with laboratory exercises, multivariate calculus, linear algebra, and differential equations, introductory thermodynamics, structural analysis (Civil and Environmental Engineering 135A, 135B), steel or concrete design (course 141 or 142). Other undergraduate preparation could include Civil and Environmental Engineering C104, 120, 121, 140L, and Materials Science and Engineering 104.
Required Graduate Courses. Civil and Environmental Engineering C204, M230A (or 243A), 235A, C282.
Elective Courses. At least one course from civil engineering materials (Civil and Environmental Engineering 226, 253, 258A, 261B, M262A, 266, or 267) and if M230A is selected, one course from structural mechanics (M230B, M230C, 232, 236, or M237A) or if 243A is selected, one course from structural/earthquake engineering (241, 243B, 244, 245, 246, or 247).

Capstone (Comprehensive Examination) Plan

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

Thesis Plan

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

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

Civil Engineering Ph.D.

Major Fields or Subdisciplines

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

Course Requirements

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

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 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.

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-clinker factor cements and concretes, reducing the carbon footprint of construction materials, and increasing the service life of civil engineering infrastructure.

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

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

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

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

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

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

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

Instructional Laboratories

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

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

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

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

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

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

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

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

Research Laboratories

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

Environmental Engineering Laboratories
The Environmental Engineering Laboratories are used for conducting water and wastewater analysis, including instrumental techniques such as GC, GC/MS, HPLC, TOC, IC, and particle counting instruments. A wide range of wet chemical analysis can be made in this facility with 6,000 square feet of laboratory space and an accompanying 4,000-square-foot rooftop facility where large pilot scale experiments can be conducted. Additionally, electron microscopy is available in another laboratory.

Recently studies have been conducted on oxygen transfer, storm water toxicity, transport of pollutants in soil, membrane fouling, removal from drinking water, and computer simulation of a variety of environmental processes.

Experimental Mechanics Laboratory
The Experimental Mechanics Laboratory supports two major activities: the Optical Metrology Laboratory and the Experimental Fracture Mechanics Laboratory.

In the Optical Metrology Laboratory, tools of modern optics are applied to engineering problems. Such techniques as holography, speckle-interferometry, Moiré analysis, and fluorescence-photo mechanics are used for obtaining displacement, stress, strain, or velocity fields in either solids or liquids. Recently, real-time video digital processors have been combined with these modern optical technical techniques, allowing direct interfacing with computer-based systems such as computer-aided testing or robotic manufacturing.

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

Laboratory for the Chemistry of Construction Materials (LC²)
Laboratory for the Chemistry of Construction Materials (LC²) research efforts are directed towards development and design of sustainable, low-carbon-dioxide-footprint materials for infrastructure construction applications. To this end, its research group develops fundamental constituent chemistry-microstructure-engineering performance descriptors of cementitious materials to correlate and unify the fundamental variables that describe the overall response of the material. These efforts are directed toward addressing the practical needs of the wider construction community and developing “new concretes” for the next generation of infrastructure construction applications. The overall research theme aims to rationalize use of natural resources in construction, promote environmental protection, and advance the cause of ecological responsibility in the concrete construction industry.

Laboratory for the Physics of Amorphous and Inorganic Soils (PARISlab)
Laboratory for the Physics of Amorphous and Inorganic Soils (PARISlab) research focuses on improving materials of engineering and industrial relevance. Its goal is to understand composition-nano- and microstructure property relationships in materials at a fundamental level. To this end, it uses a computational physical/material science approach supported by experiments. In strong collaboration with the Laboratory for the Chemistry of Construction Materials (LC²), PARISlab works to establish a new paradigm in civil engineering by tackling the sustainability of infrastructure materials at different scales, from atoms to structures.

Large-Scale Structure Test Facility
The Large-Scale Structure Test Facility allows investigation of the behavior of large-scale structural components and systems subjected to gravity and earthquake loadings. The facility consists of a high-bay area with a 20 ft. x 50 ft. strong floor with anchor points at 3 ft. on center. Actuators with servohydraulic controllers are used to apply monotonic or cyclic loads. The area is serviced by two cranes. The facilities are capable of testing large-scale structural components under a variety of axial and lateral loadings. Associated with the laboratory is an electro-hydraulic universal testing machine with force capacity of 100 tons. The machine is used mainly to apply tensile and compressive loads to specimens so that the properties of the materials from which the specimens are made can be determined. It can also be used in fatigue-testing of small components.

Soil Mechanics Laboratory
The Soil Mechanics Laboratory is used for standard experiments and advanced research in geotechnical engineering, with equipment for static and dynamic triaxial and simple shear testing. Modern computer-controlled 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-stress interaction, liquefaction, data acquisition, data assimilation, 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, bioadhesion and biofouling

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

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

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

Steven A. Margulis, Ph.D. (UCLA, 2002)
Surface hydrology, hydrometeorology, remote sensing, water chemistry

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

Water chemistry; physical and chemical processes in drinking water treatment

Sanjay Mohanty, Ph.D. (U. Colorado Boulder, 2011)
Effect of water change on water quality and quantity, suspension of 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

Geomicrobiology and terrestrial laser-topographic modeling, geological and environmental engineering, geology, engineering geology, applied geophysics

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

George Mylonakis, Ph.D., P.E. (SUNY Buffalo, 2005)
Soil mechanics and dynamics, earthquake engineering, geomechanics, wave propagation, foundation engineering

Thomas Sabol, Ph.D., S.E. (UCLA, 1985)
Seismic performance and structural design issues for steel and concrete seismic force resisting systems; application of probabilistic methods to earthquake damage quantification

Adjunct Associate Professors

Donald R. Kendall, Ph.D., P.E. (UCLA, 1989)
Hydraulics, groundwater hydrology, advanced engineering economics, stochastic processes

Issam Najm, Ph.D., P.E. (U. Illinois Urbana-Champaign, 1990)
Water chemistry; physical and chemical processes in drinking water treatment

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

Lower-Division Courses

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

M20. Introduction to Computer Programming with MATLAB. (4) (Same as Mechanical and Aerospace Engineering M20.) Lecture, two hours; discussion, two hours; laboratory, two hours; outside study, six hours. Requisite: Mathematics 33A. Fundamentals of computer programming taught in context of MATLAB computing environment. Basic data types and control structures, input/output. Functions. Data visualization. MATLAB-based data structures, development of efficient codes. Introduction to object-oriented programming. Examples and exercises from engineering, mathematics, and physical sciences. Letter grading. Mr. Eldredge, Mr. Taciroglu (F, W, Sp)

581SL. Climate Change, Water Quality, and Ecosystem Functioning. (6) Lecture, four hours; service learning, two hours; outside study, nine hours. Science related to climate change, water quality, and ecosystem health. Topics include carbon and nutrient cycling, hydrologic cycle, ecosystem structure and services, biodiversity, basic aquatic chemistry, and impacts of climate change on ecosystem functioning and water quality. Participation in series of science education projects to elementary or middle school audience. Letter grading. Ms. Jay (Sp)
102. Dynamics of Particles and Bodies. (2) Lecture, two hours; discussion, two hours; outside study, six hours. Requisites: course 91, Physics 1A. Introduction to fundamentals of dynamics of single particles, systems of particles, and rigid bodies. Topics include kinematics and kinetics of particles, work and energy, impulse and momentum, multiparticle systems, kinematics and kinetics of rigid bodies in two- and three-dimensional motions. Letter grading. Mr. Bauchy (W)

103. Applied Numerical Computing and Modeling in Civil and Environmental Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course M20 or (Computer Science 31A, 31B, 32B, 32E, Physics 1A, 1B, 1C). Corequisite: course 108. Discussion of aspects of cement and concrete materials, including manufacture of cement and production of concrete. Aspects of cement composition and basic chemical reactions, microstructure, properties of plastic and hardened concrete, chemical admixtures, and quality control and 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 and ability to explain, analyze, and describe engineering performance of civil engineering materials. Concurrently scheduled with course C204. Letter grading.

Mr. Marquis, Mr. Tacrogu (Sp)


Mr. Sant (W)


108L. Experimental Structural Mechanics. (4) (Formerly numbered 130L.) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 108. Laboratories to experimentally verify fundamental concepts and principles of mechanics of solids. Emphasis on experimental and theoretical analysis of single-degree-of-freedom systems, with particular attention to soil-particle interactions. Letter grading.

Mr. Vucetic (W,Sp)

110. Introduction to Probability and Statistics for Engineers. (4) Lecture, four hours; discussion, one hour when scheduled; outside study, four hours. Requisites: Mathematics 32A, 33A. Recommended: course M20. Introduction to fundamental concepts and applications of probability and statistics in civil engineering. Application of statistical methods used in engineering design and testing. Data analysis, probability distribution, estimation, prediction, and hypothesis testing. Use of computer software. Letter grading. Ms. Jay (Sp)

115. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 108. Analysis of stress and strain, moment distribution, and behavior, extending to compressive and flexural analysis. Design of beams and columns. Letter grading. Mr. Stewart (Sp)

118. Soil Mechanics Laboratory. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisite or corequisite: course 120. Laboratory experiments to be performed by students to obtain soil parameters required for 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. Vucetic (W,Sp)


130. Elementary Structural Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 108. Analysis of stress and strain, moment distribution, and behavior, extending to compressive and flexural analysis. Design of beams and columns. Letter grading. Mr. Jy (Sp)

135A. Elementary Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Analysis of statically determinate trusses, beams, and frames; deflections in elementary structures; virtual work; analysis of indeterminate structures using force methods; deflection by virtual work; moment and energy concepts. Letter grading. Mr. Jy (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. Vucetic (W,Sp)

M135C. Introduction to Finite Element Methods. (4) (Same as Mechanical and Aerospace Engineering M168L.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 130 or M135A. Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; convergence properties; isoparametric formulation of multidimensional heat-conduction elasticity; numerical integration. Practical use of FEM software: geometric and analytical modeling; preprocessing and postprocessing techniques; term projects with computers. Letter grading. Mr. Demurugl, Mr. Wallace (W)

135L. Structural Design and Testing Laboratory. (4) Lecture, two hours; laboratory, five hours; outside study, five hours. Requisites: courses M20, 135A. Limited enrollment. Computer-aided optimum design via computer-aided construction, instruction 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. Wallace (F,Sp)

C137. Elementary Structural Dynamics. (4) (Formerly numbered 137.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics course for civil engineers. Concepts of structural dynamics, forced vibration of single degree of freedom systems, introduction to response history and response spectrum
147. Design and Construction of Tall Buildings. (4) Lecture, four hours; discussion; two outside study; six hours. Required: course 155B. 141. Design of structural engineer, architect, and other design professionals in design process. Development of archi-
tectural design of tall buildings. Influence of building code, zoning, and finance. Advantages and limita-
tions of different structural systems development. Computer modeling, analysis, and performance as-
sessment of buildings. Letter grading.
Mr. Wallace (Sp)

147. Design and Construction of Tall Buildings. (4) Lecture, four hours; discussion; two outside study; six hours. Required: course 155B. 141. Design of structural engineer, architect, and other design professionals in design process. Development of archi-
tectural design of tall buildings. Influence of building code, zoning, and finance. Advantages and limita-
tions of different structural systems development. Computer modeling, analysis, and performance as-
sessment of buildings. Letter grading.
Mr. Wallace (Sp)

141. Steel Structures. (4) Lecture, four hours; dis-
cussion; two hours; outside study, six hours. Requi-
Mr. Wallace (F)

142. Design of Reinforced Concrete Structures. (4) Lecture, four hours; discussion; two hours; out-
side study, six hours. Required: course 135A, Beams, columns, and slabs in reinforced concrete structures. Properties of reinforced concrete mate-
rials. Design of beams and slabs for flexure, shear, anchorage of reinforcement, and deflection. Design of columns for axial force, bending, and shear. Uti-
lize strength design methods. Letter grading.
Ms. Zhang (W)

142. Reinforced Concrete Structural Laboratory. (4) Lecture, four hours; discussion; six hours. Requi-
site: courses 135B, 142. Limited enrollment. Design considerations used for reinforced concrete beams, columns, slabs, and joints examined in laboratory experiments. Links between theory, building codes, and experi-
Mr. Wallace (Not offered 2017-18)

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

144. Structural Systems Design. (4) Lecture, four hours; discussion; two outside study, six hours. Required: course 141 or 142. Design course for civil engineer, with focus on design and performance of complete building structural sys-
tems. International Building Code (IBC) and ASCE 7 dead, live, wind, and earthquake loads. Design of re-
fined concrete and structural steel buildings. Computer modeling, analysis, and performance as-
sessment of buildings. Letter grading.
Mr. Wallace (Sp)

156B. Environmental Engineering Unit Operations and Processes Laboratory. (4) Lecture, four hours; laboratory, six hours; outside study, four hours. Requi-
site: Chemistry 20A, 20B. Chemical processes and analysis of typical natural waters and wastewaters for inorganic and organic constituents. Selected experi-
ments include analysis of solids, nitrogen species, oxygen demand, and chlorine residual, that are used in unit operation experiments that include reactor dy-
namics, aeration, gas stripping, coagulation/floccu-
tion, and membrane separation. Letter grading.
Mr. Stenstrom (F)

157A. Hydrologic Modeling. (4) Lecture, four hours; discussion; two outside study; six hours. En-
forced requisite: course 150 or 151. Introduction to hydrologic modeling. Topics selected from areas of (1) open-channel flow, including one-dimensional steady flow and unsteady flow, (2) pipe flow and water distribution systems, (3) rainfall-runoff mod-
eling, and (4) groundwater flow and contaminant transport. Credits may be applied toward the Institute of Environmental Science and Technology. Letter grading.
Ms. Gaiullen (F)

157B. Design of Water Treatment Plants. (4) Lec-
ture, four hours; discussion; two outside study, six hours. Requisite: course 155. Process design of wastewater treatment plants, including primary and secondary treatment, detailed design review of existing plants, process control, and cost estimation. Letter grading.
Mr. Stenstrom (Sp)

157L. Hydrologic Analysis. (4) Lecture, two hours; laboratory, five hours; outside study, five hours. Requi-
site: course 150. Collection, compilation, and inter-
pretation 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 prob-
lems in hydrology and water resources. Letter grading.
Mr. Gebremichael (W)

164. Hazardous Waste Site Investigation and Re-
mediation. (4) Lecture, four hours; outside study, six hours. Course 153. Overview of hazardous waste types and potential sources. Tech-
niques in measuring and modeling subsurface flow and contaminant transport in subsurface. Design project illustrating remedial investigation and feasi-
ibility study. Letter grading. Mr. Mohanty (W)

M165. Environmental Nanotechnology: Implica-
tions and Applications. (4) Same as Engineering M103.) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: Engineering M101. Introduction to potential implica-
tions of nanotechnology to environmental systems as well as potential application of nanotechnology to en-
vironmental protection. Technical contents include three multidisciplinary areas: (1) physical, chemical, and biological properties of nanomaterials, (2) trans-
persive, reactive, and toxicological impacts of natural environmental systems, and (3) use of nano-
technology for energy and water production, plus en-
vironmental protection, monitoring, and remediation. Letter grading.
Mr. Maheshwari (Sp)

M166. Environmental Microbiology. (4) Same as Environmental Health Sciences M166. Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 153. Micro-
bial cell and its metabolic, genetic and its potentials, growth of microbes and ki-
genics of growth, microbial ecology and diversity, mi-

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)
crobiology 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 techniques within environmental microbiology, sampling of environmental samples, classical and modern molecular techniques for enumeration of microbes from environmental samples, techniques for determination of microbial activity in environmental samples, laboratory setups for studying environmental microbiology. Letter grading. Ms. Mahendra (Not offered 2017-18) 180. Introduction to Transportation Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/senior Civil Engineering students and Public Affairs graduate students. General characteristics of transportation systems, including streets and highways, rail, transit, air, and water. Capacity considerations, including planning, design, and operations. Components of roadway design, including horizontal and vertical alignment, cross sections, and pavements. Letter grading. Mr. Brandenberg (Sp) 181. Traffic Engineering Systems: Operations and Control, (4) Lecture, four hours; fieldwork/laboratory, two hours; outside study, six hours. Designed for juniors/seniors. Applications of traffic flow theories; data collection and analyses; intersection capacity analyses; simulation models; traffic signal design; signal timing design, implementation, and performance evaluation; Intelligent Transportation Systems concept, architecture, and integration. Letter grading. Mr. Brandenberg (F) C182. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: courses C104, 108, 120, Materials Science 104. Correlation, analysis, and metrication of aspects of pavement design, including material 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 aspects of pavement performance and highlighting their relevance in pavement design. Concurrently scheduled with course C282. Letter grading. Mr. Sant (Sp) 188. Special Courses in Civil and Environmental Engineering. (2 to 6) Lecture, to be arranged; outside study, to be arranged. Special topics in civil engineering for undergraduate students who took on experiential 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. (W) 194. Research Group Seminars: Civil and Environmental Engineering. (2 to 8) Seminar, two to eight hours; outside study, four to 16 hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field of faculty member’s research group. CULminating paper or project required. May be repeated for credit. Letter grading. 199. Directed Research in Civil and Environmental Engineering. (2 to 6) 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. 200. Civil and Environmental Engineering Graduate Seminar. (2) Formerly numbered 249 and 259A. Seminar, four hours; outside study, two hours. Various topics in civil and environmental engineering that may include earthquake engineering, environmental engineering, geotechnical engineering, and water resources engineering, materials engineering, structural engineering, and mechanical structures. May be repeated for credit. S/U grading. 204. Structure, Processing, and Properties of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Discussion of aspects of cement and concrete material, including manufacture of cement and production of concrete. Aspects of cement composition and basic chemical reactions, microstructure, properties of plastic and hardened concrete, chemical admixtures, and quality control and 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 performance of civil engineering 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. Required: course 101, Chemistry 20A, 20B, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Corequisite: 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 selection with respect to targeted civil engineering applications. Concurrently scheduled with course C105. Letter grading. Mr. Bauchy (Sp) 206. Modeling and Simulation of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: Chemistry 20A, 20B, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Fundamental examination of modeling and numerical simulations for civil engineering materials, with focus on practical examples and applications so students can independently run simulations of prototype scale relevant to targeted problems. Letter grading. Mr. Bauchy (F) 220. Advanced Soil Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Soil deformation and settlement analysis. Shear strength of granular and cohesive soils. In situ and laboratory methods for soil property evaluation. Letter grading. Mr. Brandenberg (F) 221. Advanced Foundation Engineering. (4) Lecture, four hours; outside study, eight hours. Required: courses 121, 220. Stress distribution. Bearing capacity and settlement of shallow foundations, including spread footings and mat foundations. Performance of driven pile and drilled shaft foundations under vertical and lateral loading. Construction considerations. Letter grading. Mr. Brandenberg (Sp) 222. Introduction to Soil Dynamics. (4) Lecture, four hours; outside study, eight hours. Required: course 120. Review of engineering problems in soil dynamics. Fundamentals of theoretical soil dynamics: response of sliding block-on-plane to cyclic earthquake loads, applications of theories of single degree-of-freedom (DOF) system, multiple DOF system and one-dimensional wave propagation. Fundamentals of cyclic soil behavior: stress-strain- pore water pressure relationships. Soil liquefaction and damping, cyclic settlement and concept of volumetric cyclic threshold shear strain. Introduction to modeling of cyclic soil behavior. Letter grading. Mr. Stewart, Mr. Vucetic (Not offered 2017-18) 223. Slope Stability and Earth Retention Systems. (4) Lecture, four hours; outside study, eight hours. Required: courses 120, 121, 220. Basic concepts of stability of earth slopes, including shear strength, de- sign charts, limit equilibrium analysis, seepage analysis, staged construction, and rapid drawdown. Theory of stress, mechanism of failure, design criteria, and construction methods of earth 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, pore 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 behavior of residual 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. Vucetic (Not offered 2017-18) 225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Required: courses 220, 245 (may be taken concurrently). Analysis of earthquake-induced ground failure, including soil liquefaction, cyclic softening of clays, seismic compression, surface fault rupture, and seismic slope stability. Effects of cyclic loading on earthquake ground motions. Soil-structure interaction, including inertial and kinematic interaction and foundation deformations under seismic loading. Letter grading. Mr. Stewart, Mr. Vucetic (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 level waste. Letter grading. Mr. Stewart, Mr. Vucetic (W) 227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of computer modeling of soils using finite element method, and to constitutive modeling based on elasticity and plasticity theories. Special emphasis on numerical applications and identification of model relevant parameters in soil behavior. Letter grading. Mr. Stewart, Mr. Vucetic (Not offered 2017-18) 228. Engineering Geology: Geologic Principles for Engineers. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Engineering geology involves interpretation, evaluation, analysis, and application of geologic information and data to civil works. Topics include geologic characterization and classification of soil and rock units. Relationships developed between landforms, active, past, and ancient geologic processes, ground and surface water, and properties of soil and rock. Landform changes occur in response to dynamic processes, including changes in climate, slope formation, fluvial (river) dynamics, coastal dynamics, and deep-seated processes like volcanism, sediment transport 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, Mr. Vucetic (F) M230A. Linear Elasticity. (4) Same as Mechanical and Aerospace Engineering M236A. Lecture, four hours; outside study, eight hours. Requisite: Mechanical theory of elasticity. Engineering problems in linear and elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastic problems, stress and strain, displacements, strains, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerrutti. Introduction to boundary integral equation method. Letter grading. Mr. Ju, Mr. Mal (F)
M230B. Nonlinear Elasticity. (4) Same as Mechanical and Aerospace Engineering M256B. Lecture, four hours; discussion, eight hours. Requisites: course M230A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations, balance laws, Cauchy and Piola stresses, energy of motion, balance of energy, stored energy, constitutive relations, elasticity, hyperelasticity, thermoeelasticity; linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mal (W)


232. Theory of Plates and Shells. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Small deflection theories of plates and shells; plates; energy methods; free vibrations; membrane theory of shells; axially symmetric deformations of cylindrical and spherical shells, including bending. Letter grading. Mr. Zang (F)


235A. Advanced Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 135A. Recommended: course 135B. Review of matrix force and displacement methods of structural analysis; virtual work theorem, virtual forces, and displacements; theorems on stationary value of total and complementary potential energy, minimum total potential energy, Maxwell/Betti theorems, effects of approximations, introduction to finite element analysis. Letter grading. Mr. Burton (F)

235B. Finite Element Analysis of Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 135B. Review of matrix force and displacement methods of structural analysis; virtual work theorem, virtual forces, and displacements; theorems on stationary value of total and complementary potential energy, minimum total potential energy, Maxwell/Betti theorems, effects of approximations, introduction to finite element analysis. Letter grading. Mr. Taciroglu (W)

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


M237A. Dynamics of Structures. (4) Same as Mechanical and Aerospace Engineering M226A. Lecture, four hours; outside study, eight hours. Requisite: courses 235A, 235C. Determination of normal modes and frequencies by differential and integral equation solutions. Transient and steady state response. Emphasis on derivation and solution of governing equations using matrix formulation. Letter grading. Mr. Bendiksen, Mr. Ju, Mr. Taciroglu (F)


239. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite required: course 135B. Basic structural dynamics course for civil engineering students. Elastic free and forced vibrations of single degree of freedom systems, introduction to response history and response spectrum analysis approaches and single and multidof freedom systems. Axial, bending, and torsional vibration. Finite element implementations. Letter grading. Mr. Ma (F)

241. Advanced Steel Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses C137, 141, 235A. Performance characterization of steel structures for static and earthquake loads. Behavior state analysis and building code provisions for special requirements, earthquakes, and seismic bracing. Analysis of composite steel-concrete structures. Letter grading. Mr. Sabol, Mr. Wallace (Sp)

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

243B. Response and Design of Reinforced Concrete Structural Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 243A, 246. Informal introduction to the response and behavior of reinforced concrete buildings to earthquake ground motions. Topics include use of elastic and inelastic response spectra, role of structural configuration and design, use of pre- scriptive versus performance-based design methodologies, and application of elastic and inelastic analysis techniques for new and existing construction. Letter grading. Mr. Wang (Sp)

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

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

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

247. Earthquake Hazard Mitigation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 130, and M237A or 246. Introduction to seismic isolation, vibration control, and dynamic systems. Topics include isolation, visco-elastic and hysteretic behavior, elastomeric bearings under compression and bending, buckling of bearings, sliding bearings, passive energy dissipation devices, response of structures with isolation and passive energy dissipation devices, static and dynamic analysis procedures, code provisions and design methods for seismically isolated structures. Letter grading.

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


250C. Hydrometeorology. (4) Lecture, four hours; outside study, eight hours. Requisites: courses C137, 141, 135B. In-depth study of hydrometeorological processes. Role of hydrology in climate system, precipitation and evaporation processes, atmospheric radiation, evaporation, and the hydrological cycle. Occurrence of rain and snow and vegetation surface and overlying atmosphere, flux and transport in turbulent boundary layer, basic remote sensing principles. Letter grading. Mr. Margulis (W)

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

251A. Rainfall-Runoff Modeling. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 251B. Introduction to hydrologic modeling concepts, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analysis, and application of models for flood forecasting and water resource management. Letter grading. Mr. Margulis (Not offered 2017-18)

251B. Contaminant Transport in Groundwater. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250B, 252. Phenomenology and mechanisms of hydrodynamic dispersion, governing equations of mass transport in porous media, various analytical and numerical solutions, determination of dispersion parameters by laboratory and field experiments, biological and reactive transport in multiphase
flow, remediation design, software packages and applications. Letter grading.

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

251D. Hydrologic Data Assimilation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250C. Introduction to basic concepts of classical and Bayesian parameter estimation. Focus on the use of hydrologic data assimilation. Applications geared toward assimilating disparate observations into dynamic models of hydrologic systems. Letter grading. Mr. Margulis (Not offered 2017-18)

252. Engineering Economic Analysis of Water and Environmental Planning. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: Engineering 11a, 11b. Letter grading. 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 in planning; principles of renewable resources; benefit-cost analysis with applications to water resources and environmental planning. Letter grading. Mr. Yeh (Not offered 2017-18)


254A. Environmental Aquatic Inorganic Chemistry. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 254A, 254B. Review of inorganic chemistry; microorganisms and microbial chemical reaction engineering, coagulation and flocculation, granular filtrations, sedimentation, carbon adsorption, gas transfer, disinfection, oxidation, and membrane processes. Letter grading. Mr. Najm (W)

255B. Biological Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 254A, 255A. Fundamentals of environmental engineering microbiology; kinetics of microbial growth and biological oxidation; applications for activated sludge, gas transfer, fixed-film processes, aerobic and anaerobic processes, 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: courses 250A, 250B, 250D. Current research topics in inverse problem of parameter estimation, experimental design, conjunctive use of surface and groundwater, multiblock water resource systems. Topics vary from term to term. Letter grading. Mr. Yeh (Sp)

261. Colloidal Phenomena in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: course 255B. In-depth treatment of selected topics related to biological treatment of waters and wastewaters, such as biodegradation of xenobiotics, pharmaceuticals, emerging pollutants, toxicity, and nutrients. Discussion of theoretical aspects, experimental observations, and recent literature. Application to important and emerging environmental problems. Letter grading. Mr. Stenstrom (Not offered 2017-18)

262A. Introduction to Atmospheric Chemistry. (4) Same as Atmospheric and Oceanic Sciences M262A. Lecture, four hours; outside study, eight hours. Requisites: Chemistry 20B. Principles of chemical kinetics, thermochemistry, spectroscopy, and photochemistry; chemical composition and history of Earth's atmosphere; biogeochemical cycles of key atmospheric constituents. Data on troposphere and stratosphere, upper atmosphere chemical processes; air pollution; chemistry and climate. S/U or letter grading. Mr. Hoek (Not offered 2017-18)

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; growth of urban complexes; meteorological factors and air pollution potential; meteorological aspects of air pollution. S/U or letter grading. (Not offered 2017-18)

263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Transport processes in surface water, groundwater, and atmosphere. Emphasis on exchanges across phase boundaries: sedimentation, advection, Jay quotation of particles, droplets, and bubbles; small-scale dispersion and mixing; effect of reactions on transport; linkages between physical, chemical, and biological processes. Letter grading. Mr. Mohanty (Sp)

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 2017-18)

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

267. Environmental Applications of Geochemical Modeling. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Geochemical modeling is an important tool for predicting environmental impacts of contamination. Hands-on experience in modeling using geochemical software packages commonly found in environmental consulting industry. Gaming 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 receptor modeling. Research/modeling projects 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 2017-18)

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

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

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Discussions of non-credit nature involving student papers. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading. (F,Sp)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprentice responsibilities are to assist faculty mentor teaching section, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprentice responsibilities are to assist faculty mentor teaching course. (F,Sp)

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

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

397B. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading. (F,Sp)

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

399. Research and for Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Supervised independent research for Ph.D. students. Usually taken after students have been advanced to candidacy. S/U grading.
Assistant Professors
Kai-Wei Chang, Ph.D.
Tyson Condie, Ph.D. (Symantec Term Professor of Computer Science)
Jason Ernst, Ph.D.
Raghu Meka, Ph.D.
Anthony J. Nowatzki, Ph.D.
Sriram Sankaranarayanan, Ph.D.
Yizhou Sun, Ph.D.
Guy Van den Broeck, Ph.D.

Senior Lecturers S.O.E.
Paul R. Eggert, Ph.D.
David A. Smallberg, M.S.

Senior Lecturer S.O.E. Emeritus
Leon Levine, M.S.

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

Adjunct Associate Professor
Giovanni Pau, Ph.D.

Adjunct Assistant Professors
Alexander Afanasyev, Ph.D.
Carey S. Nachenberg, M.S.
Ramin Ramezani, Ph.D.
Amee S. Talwalkar, Ph.D.

Scope and Objectives
Computer science is concerned with the design, modeling, analysis, and applications of computer systems. Its study at UCLA provides education at the undergraduate and graduate levels necessary to understand, design, implement, and use the software and hardware of digital computers and digital systems. The programs provide comprehensive and integrated studies of subjects in computer system architecture, computer networks, distributed computer systems, programming languages and software systems, information and data management, artificial intelligence, computer science theory, computational systems biology and bioinformatics, and computer vision and graphics.

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

The B.S. degree may be attained through the Computer Science and Engineering major, the Computer Science major, or the Computer Engineering major described below. In addition, HSSEAS offers M.S. and Ph.D. degrees in Computer Science, as well as minor fields for graduate students seeking engineering degrees. In cooperation with the John E. Anderson Graduate School of Management, the Computer Science Department offers a concurrent degree program that enables students to obtain the M.S. in Computer Science and the M.B.A. (Master of Business Administration).

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

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

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

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

Computer Engineering Undergraduate Program Educational Objectives

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

Undergraduate Study

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

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.

Preparation for the Major

**Required:** Computer Science 1, 31, 32, 33, 35L, M51A; Electrical and Computer Engineering 3, 10, 11L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, and 4AL or 4BL.

The Major

**Required:** Computer Science 111, 118, 131, M151B, M152A, 180, 181, Electrical and Computer Engineering 102, 110, 111L; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone design course (Computer Science 152B); 4 units of elective courses selected from Electrical and Computer Engineering 113, 115A, 115C, 132A, 141; 12 units of elective courses selected from Computer Science 100 through CM187; and 12 units of technical breadth courses selected from an approved list available in the Office of Academic and Student Affairs.

Students who want to deepen their knowledge of electrical engineering are encouraged to select that discipline as their technical breadth area.

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

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

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

Computer Science B.S.

Capstone Major

The computer science curriculum is designed to accommodate students who want professional preparation in computer science but do not necessarily have a strong interest in computer systems hardware. The curriculum consists of components in computer science, a minor or technical support area, and a core of courses from the social sciences, life sciences, and humanities. Within the curriculum, students study subject matter in software engineering, princi-
Computer Engineering B.S.

Capstone Major

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

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.

Preparation for the Major

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

The Major

Required: Computer Science 111, 118, 131, 135B, 1352A, 180, 181; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone software engineering or design course from Computer Science 130 or 152B; 20 units of elective courses selected from Computer Science 100 through CM187; 12 units of science and technology courses (not used to satisfy other requirements) that may include 12 units of upper-division computer science courses or 12 units of courses selected from an approved list available in the Office of Academic and Student Affairs; and 12 units of technical breadth courses selected from an approved list available in the Office of Academic and Student Affairs.

Students must take at least one course from Computer Science 130 or 132. Computer Science 130 or 152B may be 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. Four units of either Computer Science 194 or 199 may be applied as an elective by petition.

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

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/Academics/GE-Requirement.
students to the entire data-to-decision pathway spanning the entire stack from hardware and software to algorithms, applications, and user experience.

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

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

Bioinformatics Minor

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

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

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

Required Lower-Division Courses (14 units minimum): Computer Science 32 or Programming in Computing 10C, Life Sciences 3 or 7A, 23L, Mathematics 33A.

Required Upper-Division Courses (18 units minimum): Computer Science 180 (or Mathematics 182), M184, two courses selected from Computer Science CM121, CM122, and CM124, and one course selected from Chemistry and Biochemistry C100, 153B, Civil and Environmental Engineering 110, Computer Science CM121, CM122, CM124, 170A, CM186, CM187, Ecology and Evolutionary Biology 135, 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, page 25.

The following introductory information is based on the 2017-18 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at https://grad.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

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

Computer Science M.S.

Course Requirements

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

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 199, Materials Science and Engineering 110, 120, 130, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

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

For the MS degree, students must also complete at least three terms of Computer Science 201 with grades of Satisfactory.

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

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

Comprehensive Examination Plan

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

**Thesis Plan**

In the thesis plan, seven of the nine courses must be formal courses, including at least four from the 200 series. The remaining two courses may be 598 courses involving work on the thesis. The thesis is a report on the results of student investigation of a problem in the major field of study under the supervision of the thesis committee, which approves the subject and plan of the thesis and reads and approves the complete manuscript. While the problem may be of one of a 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; information and data management; and software systems.

**Course Requirements**

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

To satisfy the major field requirement, students are expected to attain a body of knowledge contained in five courses, as well as the current literature in the area of specialization. In particular, students are required to take a minimum of three graduate courses in the major field of Ph.D. research, selecting these courses in accordance with guidelines specific to the major field. Guidelines for course selection in each major field are available from the departmental Student Affairs Office. Grades of B- or better, with a grade-point average of at least 3.33 in all courses used to satisfy the major field requirement, are required. Students are required to satisfy the major field requirement within the first nine terms after enrolling in the graduate program. Each minor field normally embraces a body of knowledge equivalent to two courses, at least one of which is a graduate course. Grades of B- or better, with a grade-point average of at least 3.33 in all courses included in the minor field, are required. By petition and administrative approval, a minor field may be satisfied by examination.

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

For the Ph.D. degree, students must also complete at least three terms of Computer Science 201 with grades of Satisfactory (in addition to the three terms of 201 that may have been completed for the M.S. degree). Competence in any or all courses may be demonstrated in one of three ways:

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

For requirements for the Graduate Certificate of Specialization, see Engineering School-wide Programs.

**Written and Oral Qualifying Examinations**

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

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

**Fields of Study**

**Artificial Intelligence**

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

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

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

1. **Problem Solving.** Analysis of tasks, such as playing chess or proving theorems, that require reasoning about relatively long sequences of primitive actions, deductions, or inferences.

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

3. **Expert systems.** Study of large amounts of specialized or highly technical knowledge that is often probabilistic in nature. Typical domains include medical diagnosis and engineering design.

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

5. **Computer vision.** Processing of images, as from a TV camera, to infer spatial properties of the objects in the scene (three-dimensional shape), their dynamics (motion), their photometry (material and light), and their identity (recognition).

6. **Robotics.** Translation of a high-level command, such as picking up a particular object, into a sequence of low-level control signals that might move the joints of a robotic arm/hand combination to accomplish the task; often this involves using a computer vision system to locate objects and provide feedback.

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

8. **Parallel architecture.** Design and programming of a machine with thousands or even millions of simple processing elements to produce intelligent behavior; the human brain is an example of such a machine.

**Computational Systems Biology**

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

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

Core coursework is concerned with the methods and tools development for computational, algorithmic, and dynamic systems network modeling of biological systems at molecular, cellular, organ, whole organism, or population levels—and leveraging them in biosystem and bioinformatics applications.

Methodological studies include bioinformatics and systems biology modeling, with focus on genomics, proteomics, metabolomics, and higher levels of biological/physiological organization, as well as multiscale approaches integrating the parts.

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

**Computer Networks**

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

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

**Resource Allocation**

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

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

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

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

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

Computer System Architecture

Computer system architecture deals with the design, implementation, and evaluation of computer systems and their building blocks. It deals with general-purpose systems as well as embedded special-purpose systems. The field also encompasses the development of tools to enable system designers to describe, model, fabricate, and test highly complex computer systems from single-chip to computing clouds.

Computer systems are implemented as a combination of hardware and software. Hence, research in the field of computer architecture often involves both hardware and software issues. The requirements of application software and operating systems, together with the capabilities of compilers, play a critical role in determining the features implemented in hardware. At the same time, the computer architect must also take into account the capabilities and limitations of the underlying implementation technology as well as of the design tools.

The goal of research in computer architecture is to develop building blocks, system organizations, design techniques, and design tools that lead to improved performance and reliability as well as reduced power consumption and cost.

Corresponding to the richness and diversity of computer systems architecture research at UCLA, a comprehensive set of courses is offered in the areas of advanced processor architecture, arithmetic processor systems, parallel and distributed architectures, fault-tolerant systems, reconfigurable systems, embedded systems, and computer-aided design of VLSI circuits and systems.

1. Novel architectures encompass the study of computations that are performed in ways that are quite different than those used by conventional machines. Examples include various domain-specific architectures characterized by high computational rates, low power, and reconfigurable hardwares 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.

Graphics and Vision

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

Information and Data Management

The information and data management 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.

**Software Systems**

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

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

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

**Facilities**

Departmental laboratories and centers for instruction and research include:

**Artificial Intelligence Laboratories**

**Automated Reasoning Group**
Adnan Y. Darwiche, Director
http://reasoning.cs.ucla.edu

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

**Cognitive Systems Laboratory**
Judea Pearl, Director
http://singapore.cs.ucla.edu/cogsys.html

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

**Computational Systems Biology Laboratories**

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

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

**Computational Genetics Laboratory**
Eleazar Eskin, Director
http://zarlab.cs.ucla.edu/about/

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

**Computer Systems Architecture Laboratories**

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

The Concurrent Systems Laboratory is used for investigating the design, implementation, and evaluation of computer systems that use state-of-the-art technology to achieve high performance and high reliability. Projects involve both software and hardware, and often focus on parallel and distributed systems in the context of general-purpose as well as embedded applications.

**Digital Arithmetic and Reconfigurable Architecture Laboratory**
Milos D. Ercegovac, Director
http://arith.cs.ucla.edu

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

**Embedded and Reconfigurable System Design Laboratory**
Majid Sarrafzadeh, Director
http://er.cs.ucla.edu

The Embedded and Reconfigurable System Design Laboratory is used for studying reconfigurable cores in embedded systems that provide the required adaptability and reconfigurability, and the design and CAD aspects of low-power embedded systems.

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

The VAST Laboratory is used for computer-aided design of VLSI circuits and systems. Areas include high-level and logic-level synthesis, technology mapping, physical design, interconnect modeling and optimization of various VLSI technologies such as full-custom designs, standard cells, programmable logic devices (PLDs), multichip modules (MCMs), system-on-a-chip (SOCs), system-in-a-package (SiPs), and design for nano-technologies.
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 (MAGIX)
Demetri Terzopoulos, Director
http://www.cs.ucla.edu/magix

The laboratory conducts research on computer graphics, especially targeted towards the video game and motion picture industries, with emphasis on geometric, physics-based, and artificial-life modeling and animation, including motion capture techniques, biomechanical simulation, behavioral animation, and graphics applications of machine learning, AI, and robotics.

UCLA Collective on Vision and Image Sciences
http://visciences.ucla.edu

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

UCLA Vision Laboratory
Stefano Soatto, Director
http://vision.ucla.edu

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

Information and Data Management Laboratories

Information and Data Management Group
(Multiple Faculty)
http://www.cs.ucla.edu/idm/

The group is a collaboration of all UCLA faculty from the information and data management field. It is interested in multiple research areas including big data, archival information systems, knowledge discovery and data mining, Earth Science Partners’ private network, genomics graph database development, multimedia information stream system technology, Smart Space middleware architecture, and technologically based assessment of language and literacy, to name just a few.

Web Information Systems Laboratory
Carlo A. Zaniolo, Director
http://wis.cs.ucla.edu/wis/

This research group investigates Web-based information systems and seeks to develop enabling technology for such systems by integrating the Web with database systems. Current research efforts include the DeAL system, a next-generation catalog system; SemScapes, an NLP-based framework for mining unstructured or free text; EARL (Early Accurate Result Library) for Hadoop; Panta Rei, a study of support for schema evolution in the context of snapshot databases and transaction-time databases; Stream Mill, a complete data stream management system; and ArchiS, a powerful archival information system.

Network Systems Laboratories

Internet Research Laboratory (IRL)
Lixia Zhang, Principal Investigator
http://irl.cs.ucla.edu

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

Laboratory for Advanced System Research (LASR)
Peter L. Reiher, Principal Investigator
http://lasr.cs.ucla.edu

The laboratory engages in research to develop advanced operating systems, distributed systems, middleware, and security systems.

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

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

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

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

Software Systems Laboratories

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

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

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

Computer Science Centers

Center for Autonomous Intelligent Networked Systems (CAINS)
http://www.cains.cs.ucla.edu

The center was established in 2001 with researchers from several laboratories in the Computer Science and Electrical and Computer Engineering departments. It serves as a forum for intelligent-agent researchers and visionaries from academia, industry, and government, with an interdisciplinary focus on fields such as engineering, medicine, biology, and social sciences. Information and technology are exchanged through symposia, seminars, short courses, and collaboration in joint research projects sponsored by government and industry.
Research projects include use of unmanned autonomous vehicles, coordination of vehicles into computing clouds, and integration of body sensors and smart phones into m-health systems. Ongoing research encompasses personal and body networks, cognitive radios, ad hoc multihop networking, vehicular networks, dynamic unmanned backbone, underwater unmanned vehicles, mobile sensor platforms, and network coding.

Center for Domain-Specific Computing (CDSC)
http://www.cdsc.ucla.edu
CDSC was established in 2009 with the support of a $10 million grant from NSF’s Expeditions in Computing program to develop high-performance, energy-efficient, customizable computing that will revolutionize the way computers are used in health care and other important applications. Domain-specific computing uses customizable architectures and high-level computer languages tailored to particular application domains.

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

Center for Information and Computation Security (CICS)
http://www.cs.ucla.edu/security/
The center was established in 2003 to promote all aspects of research and education in cryptography and computer security. It explores novel techniques for securing national and private-sector information infrastructures across various network-based and wireless platforms as well as wide-area networks. The inherent challenge is to provide guarantees of privacy and survivability under malicious and coordinated attacks. The center has 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 big data, and the increased sophistication of analytics that can be used to extract patterns and trends from the data.

Wireless Health Institute (WHI)
Benjamin M. Wu, D.D.S., Ph.D. (Bioengineering), Director; Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical and Computer Engineering), Gregory J. Pottie, Ph.D. (Electrical and Computer Engineering), Co-Directors
WHI is leading initiatives in health care solutions in the fields of disease diagnosis, neurological rehabilitation, optimization of clinical outcomes for many disease conditions, geriatric care, and many others. WHI also promotes this new field in the international community through the founding and organization of the leading Wireless Health conference series, Wireless Health 2010, 2011, 2012, 2013, and 2014.

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

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

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

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

The departmental research network includes Oracle servers and shared workstations, on the school ethernet TCP/IP local network. A wide variety of peripheral equipment is also part of the facility, and many more research-group workstations share the network; the total number of machines exceeds 1000, the majority running the Linux operating system. The network consists of switched 10/100/1000 ethernet to the desktop with a gigabit backbone connection. The department LAN is connected to the campus gigabit backbone. An 802.11n wireless network is also available to faculty, staff, and graduate students.
Administrative Structure
The central facilities and wide-area networking are operated by the campuswide Communications Technology Services. Access to the departmental and SEASnet machines is controlled so as to maximize the usefulness of these computers for education and research, but no direct charges are involved.

Technical Support Staff
The support staff consists of hardware and software specialists. The hardware laboratory supports network connections, configures routers, switches, and network monitoring tools. The software group administers the department UNIX servers, providing storage space and backup for department users.

Faculty Areas of Thesis Guidance

Professors

Christopher J. Lee, Ph.D. (Stanford, 1993) Bioinformatics and information theory of experiment planning, inference, and evolution
Songwu Lu, Ph.D. (U. Illinois, 1999) Integrated-service support over heterogeneous networks, e.g., mobile computing environments, Internet and ActiveNet; networking and computing, wireless communications and networks, computer communication networks, dynamic game theory, dynamic networks, and information economics
Todd D. Millstein, Ph.D. (U. Washington, 2003) Programming language design, static type systems, formal methods, software model checking, compilers
† Raffai Ostrovsky, Ph.D. (MIT, 1992) Theoretical computer science algorithms, cryptography, complexity theory, randomization, network protocols, geometric algorithms, data mining
Jens Palsberg, Ph.D. (Aarhus U., Denmark, 1992) Compilers, embedded systems, programming languages
Miodrag Potkonjak, Ph.D. (UC Berkeley, 1991) Computer-aided analysis and synthesis of system-level designs, behavioral synthesis, and interaction between high-performance application-specific computations and communications
Glenn D. Reinman, Ph.D. (UC San Diego, 2001) Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, multicore and multiprocessor design
† Amit Sahai, Ph.D. (MIT, 2000) Theoretical computer science, cryptography, computer security, algorithms, error-correcting codes and learning theory
† 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
Marib S. Srivastava, Ph.D. (UC Berkeley, 1992) Energy-aware networking and computing, embedded networked sensing, embedded software, low-power wireless systems and applications of wireless and embedded technology
Demetri Terzopoulos, Ph.D. (MIT, 1984) Computer graphics, computer vision, medical image analysis, computer-aided design, artificial intelligence
Wei Wang, Ph.D. (UCAL, 1999) Data mining, bioinformatics and computational biology, databases
Carlo A. Zaniolo, Ph.D. (UCAL, 1976) Knowledge bases and deductive databases, parallel execution of PROLOG programs, formal software specification, 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

† Also Professor of Mathematics
* Also Professor of Medicine
‡ Member of Brain Research Institute

Song-Chun Zhu, Ph.D. (Harvard, 1996) Computer vision, statistical modeling and computing, vision and visual arts, machine learning

Professors Emeriti

Aligrida A. Avizienis, Ph.D. (U. Illinois, 1960) Digital computer architecture and design, fault-tolerant computing, digital arithmetic
Alfonso F. Cerdanas, 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
Wesley W. Chu, Ph.D. (Stanford, 1966) Distributed computing, distributed database, memory management, computer communications, performance measurement and evaluation for distributed systems and multimedia packet-switched systems
† Michael G. Dyer, Ph.D. (Yale, 1982) Artificial intelligence; natural language processing: connectionist, cognitive, and animal-based modeling
Sheila A. Greibach, Ph.D. (Harvard, 1963) Theoretical computer science, computational complexity, program schemes and semantics, formal languages, automata, computability
† Alan Kinggenger, 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
D. Scott Parker, Jr., Ph.D. (U. Illinois, 1979) 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. Remmels, Ph.D. (UCLA, 1973) Digital computer architecture and design, fault-tolerant computing, digital arithmetic
† Jacques J. Vidal, Ph.D. (U. Paris-Sorbonne, France 1961) Information processing in biological systems, with emphasis on neuroscience, cybernetics, online laboratory computer systems, and pattern recognition, analog and hybrid systems/ signal processing

‡ Also Professor of Medicine
Rupak Majumdar, Ph.D. (UC Berkeley, 2003)  
Computer-aided verification of hardware and software systems; logic and automata theory; embedded, hybrid, and probabilistic systems  
Peter S. Pao, Ph.D. (U. Michigan, 1975)  
Optimizing technology investment and drive growth, knowledge management and technology networking to encourage free flow of knowledge and performance exchange  
Peter L. Reiher, Ph.D. (UCLA, 1987)  
Computer and network security, ubiquitous computing, file systems, distributed systems

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. Cumulating 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. Geria (F)

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


Mr. Palsberg, Mr. Smallberg (FW,Sp)


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

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

Mr. Eggert, Mr. Reinman (FW,Sp)

M51A. Logic Design of Digital Systems. (4) (Same as Electrical and Computer Engineering M16.) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading.  
Mr. Ercegovac, Mr. Potkonjak (FW,Sp)

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

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

procedure call (RPC), asynchronous RPC, distributed file systems, transactions. Protection and security. Exercises involving applications using, and internals of, real-world operating systems. Letter grading.

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

112. Modeling Uncertainty in Information Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 111 and one course from Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Designed for seniors/juniors. Probability and stochastic processes as applied in computer science. Basic methodological tools include random variables, conditional probability, expectation and higher moments, Bayes theorem, Markov chains. Application of stochastic algorithms, event-driven simulation, analysis of algorithms and data structures, reliability, communication protocol and queuing models. Letter grading.

Mr. Sanadidi, Mr. Soatto (W)

114. Peer-to-Peer Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 118. Optional: course 218. Fundamental concepts on peer-to-peer networks, such as architecture, routing algorithms, and related network management protocols (Join, Leave, death management, routing, table repair). Video streaming and Internet Protocol Television (IPTV) applications, with emphasis on client-server architectures such as PDAs and smart phones. Introduction to mesh-based and tree-based topologies for live streaming, with emphasis on key aspects of peer selection and management. Design trade-offs (peer capacity, network delay). Hands-on approach to guide students to development and testing of actual system on PlanetLab. Letter grading. (F, W, Sp)

Mr. Gerla (Not offered 2017-18)

M117. Computer Networks: Physical Layer. (4) (Same as Electrical and Computer Engineering M117.) Lecture, four hours; discussion, two hours; outside study, six hours. Not open to students with credit for course M117.1L. Introduction to fundamental computer communication concepts underlying and supporting modern networks, with focus on wireless communications and media access layers of network protocol stack. Systems include wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth, ZigBee). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for personal applications such as wireless access to health and environment awareness, and experimental laboratory sessions included. Letter grading.

Mr. Dzhyanidze (F, W, Sp)

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

Letter grade options.

Mr. Afanasyev, Mr. Lu (F, W, Sp)

M119. Fundamentals of Embedded Networked Systems. (4) (Same as Electrical and Computer Engineering M119.) Lecture, four hours; discussion, two hours; outside study, seven hours. Enforced requisites: Civil and Environmental Engineering 110 or Electrical and Computer Engineering 131A or Mathematics 170A or Statistics 100A, course 118 or Electrical and Computer Engineering 161A, and Statistics 100A. Design trade-offs and principles of operation of cyber physical systems such as devices and systems constituting Internet of Things. Topics include signal propagation and modeling, sensor/micro node architecture and operation, and applications. Letter grading.

Mr. Srivastava (Sp)

CM121. Introduction to Bioinformatics. (4) (Same as Chemistry CM160A.) Lecture, four hours; discussion, two hours. Enforced requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Prior knowledge of biology not required. Designed for engineering students as well as students from biological sciences and medical school. Introduction to bioinformatics and methodologies, with emphasis on concepts 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. Lee (F)

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

Mr. Eskin (W)

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

Mr. Sankaraman (Sp)

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

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

131. Programming Languages. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisites: courses 33, 35L. Basic concepts in design and use of programming languages, including abstract data types, control mechanisms, type systems, declarations, compilation. Study of several different language paradigms, including functional, object-oriented, and logic programming. Letter grading.

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

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 131, 181. Compiler structure; lexical and syntactic analysis; semantic analysis and code generation; theory of parsing. Letter grading. (F, W, Sp)

Mr. Eggert, Mr. Britton (F)

133. Parallel and Distributed Computing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 111 (may be taken with a grade of C– or better), 130, shared memory parallel architectures; asynchronous parallel languages: MPI, Maissie: primitives for parallel computation: specification of parallelism, interpro cess communication and synchronization; design of parallel programs for scientific computation and distributed systems. Letter grading.

Mr. Choi (W)


Mr. Cho, Mr. Condle (F)

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

Mr. Choi (W)

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 useful patterns in large databases and anomalies in massive databases), knowledge engineering, and wide spectrum of data mining application areas such as bioinformatics, e-commerce, environment studies, financial markets, fraud detection, data processing, network monitoring, and social service analysis. Letter grading.

Ms. Wang (F, W)

M146. Introduction to Machine Learning. (4) (Same as Electrical and Computer Engineering M146.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Civil and Environmental Engineering 110 or Electrical and Computer Engineering 131A or Mathematics 170A or Sta...
M171L. Data Communication Systems Laboratory. (2) (Same as Electrical and Computer Engineering M161LC.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 33, and M51A or Electrical and Computer Engineering M115A. Recommended: courses 111, and M152A or Electrical and Computer Engineering M116L. Computer system organization and design, implementation of CPU datapath and control, instruction set design, memory hierarchy (cache, main memory, virtual memory) organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grade only. Mr. Sankaraman (F, Sp)

151C. Design of Digital Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses M151B, M152A. Design of computer programs and complex digital systems, from design principles through construction and testing. Use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits using programmable array logic device project. Letter grading. Mr. Ercegovac (Not offered 2017-18)

152A. Introductory Digital Design Laboratory. (2) (Same as Electrical and Computer Engineering M116L.) Laboratory, four hours; outside study, two hours. Enforced requisite: course M51A or Electrical and Computer Engineering M116. 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 programmable array logic devices. Project. Letter grading. Mr. Potkonjak (F,Sp)

152B. Digital Design Project Laboratory. (4) Laboratory, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M151B or Electrical Engineering M116C. Recommended: Engineering 6. Design and implementation of complex digital subsystems using field-programmable gate arrays (e.g., processors, special-purpose processors, device controllers, and interfaces) for engineering students to develop and implement designs and to document and give oral presentations of their work. Letter grading. Mr. Sarrafzadeh (F,Sp)

161. Fundamentals of Artificial Intelligence. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 180. Introduction to fundamental problem solving and knowledge representation paradigms of artificial intelligence. Introduction to Lisp with regular programming assignments. State-space and problem reduction methods, brute-force and heuristic search, planning techniques, two-player games. Knowledge structures: finite-state machine 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,Sp)

170A. Mathematical Modeling and Methods for Computer Science. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisites: course 180, Mathematics 33B. Introduction to methods for modeling and simulation using interactive computing environments. Extensive coverage of symbolic and numeric computation, matrix algebra, statistics, floating point, optimization, and spectral analysis. Emphasis on applications in simulation of physical systems. Letter grading. Mr. Parker (Not offered 2017-18)

170L. Mathematical Modeling and Methods for Computer Science Laboratory. (2) (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 M117. Interpretation of analog-signaling aspects of digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, logic analyzers, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modem and terminal characteristics, and digital communications. Prerequisites: choice of data structures and representations; complexity measures: time, space, upper, lower bounds, asymptotic complexity; programming. Letter grading. Mr. Tekal, Mr. Sarrafzadeh (F,Sp)

181. Introduction to Formal Languages and Automata Theory. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 150. Design of Computer Science majors. Grammars, automata, and languages. Finite-state languages and finite-state automata. Context-free languages and pushdown automata. Unrestricted rewriting systems, recursively enumerable and recursive languages, and Turing machines. Closure properties, pumping lemmas, and decision algorithms. Introduction to computability. Letter grading. Mr. Sahai, Mr. Sherstorff (F,Sp)

183. Introduction to Cryptography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Preparation: knowledge of basic probability theory. Enforced requisite: course 180. Introduction to cryptography, computer security, asymmetric and symmetric concepts and techniques. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, secret and public-key cryptography, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, and two-party secure computation with static security. Letter grading. Mr. O’Path (F,Sp)

M184. Introduction to Computational and Systems Biology. (2) (Same as Bioengineering M184 and Computational and Systems Biology M184.) Lecture, two hours; outside study, four hours. Enforced requisites: one course from 31, Civil Engineering M20, Mechanical and Aerospace Engineering M20, or Program in Computing 10A, and Mathematics 3B or 31B. Survey course designed to introduce students to computational and systems modeling and simulation in biology and medicine, providing motivation, flavor, culture, and cutting-edge content in computational and simulation biology and medicine, and to introduce students to computational biology and medicine, providing motivation, flavor, culture, and cutting-edge content in computational and simulation biology and medicine. Letter grading. Mr. DiStefano (W)

CM186. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Bioengineering CM186, Computational and Systems Biology M186.) Lecture, two hours; discussion, two hours. Enforced requisites: course 180, Mathematics 32B, 33A, 33B, Life Sciences 4. Introduction to interdisciplinary laboratory research methods and research opportunities in computational and systems biology to prepare and initiate students for active engagement in research. Presentation of potential projects by faculty members and student visits to individual laboratories and group participation in research projects. P/NP or letter grading. Mr. DiStefano (W)
problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM286. Letter grading.

Mr. DiStefano (Sp)

CM187. Research Communication in Computational and System Sciences. (Same as Bioengineering CM187 and Computational and Systems Biology M187.) Lecture, four hours; outside study, eight hours. Prerequisite: 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 search for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM286. Letter grading.

Mr. DiStefano (Sp)

188. Special Courses in Computer Science. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Special topics in computer science for undergraduate taught on experimental or temporary basis, such as those taught by resident faculty and visiting faculty members. May be repeated for credit with topic or instructor change. Letter grading. (W,Sp)

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

199. Directed Research in Computer Science. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty 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,Sp)

Graduate Courses

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

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

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

Mr. Lu (F)


Mr. Gerla (F)

M213A. Embedded Systems. (4) Same as Electrical and Computer Engineering M202A.) Lecture, four hours; outside study, eight hours. Requisite: course 111. Designing computer science and electrical engineering students. Methodologies and technologies for design of embedded systems. Topics include hardware and software platforms for embedded systems; techniques for modeling and specification of system behavior; software organization, real-time operating system scheduling, real-time communication and packet scheduling, low-power battery and energy management, timing synchronization, fault tolerance and debugging, and techniques for hardware and software architecture optimization. Theoretical foundations as well as practical design methods. Letter grading. Mr. Potkonjak, Mr. Srivastava

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

216. Network Algorithmics. (4) Lecture, four hours; outside study, eight hours. Recommended preparation: course M284. Lecture, four hours; outside study, eight hours. Introduction to algorithms for routers and servers. Models of network devices and hardware design. Principles for efficient implementation. Lookup algorithms (exact match, prefix lookups, advanced rdict life support), fair queueing implementations, crossbar and scalable switches, with examples from well-known networking devices. Advanced topics include traffic engineering and network security. Letter grading. Letter grading. Mr. Srivastava

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

Ms. Zhang (Not offered 2017-18)

217B. Advanced Topics in Internet Research. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 217A. Designed for graduate computer science students. Overview of Internet development history and fundamental principles underlying TCP/IP protocol design. Discussion of current Internet research topics, including latest research results in routing protocols, transport protocols, network measurements, network security protocols, and clean-slate approach to network architecture design. Fundamental issues in network protocol design and implementations. Letter grading. Ms. Zhang (Not offered 2017-18)


219. Current Topics in Computer Systems Modeling Analysis. (4) Lecture, eight hours; outside study, four hours. Review of current literature in area of computer system modeling analysis in which introductory courses develop applications of and consequence of research interests. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading. Mr. Lu (Sp)

CM221. Introduction to Bioinformatics. (4) (Same as Biostatistics M221 and Computer Science and Human Genetics M260A.) Lecture, four hours; discussion, two hours. Enforced requisite courses: 32 or Program in Computing 10C with grade of C- or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Prior knowledge of biology not required. Designed for engineering students as well as students from biological sciences and medical school. Introduction to bioinformatics and 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 and Systems Biology. (Same as Bioinformatics M222 and Chemistry CM260B.) Lecture, four hours; discussion, two hours. Enforced requisite courses: 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 is not requisite to CM222. Designed for engineering students as well as students from biological sciences and medical school. Development and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM122. Letter grading. Mr. Song (W)

CM224. Computational Genetics. (4) (Same as Bioinformatics M224 and Human Genetics CM224.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite courses: 10C Program in Computing 10C with grade of C- or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Course CM224 is not requisite to CM222. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational analysis of genetic variation and computational interdisciplinary research. Topics include introduction to genetics, identification of genes involved in disease, inferring human population history, technologies for obtaining genetic information, and genetic sequencing. Focus on formulating interdisciplinary problems as computational problems
and then solving those problems using computational techniques from statistics and computer science. Concurrently scheduled with course CM124.

Lecture grading. Mr. Sankararaman (Sp)

M225. Computational Methods in Genomics. (4) (Same as Bioinformatics M225 and Human Genetics M268.) Lecture, two and one half hours; discussion, two and one half hours; outside study, six hours. Limited to bioinformatics, computer science, human genetics, and molecular biology graduate students. Introduction to computational approaches in bioinformatics. Application of computational genetics and preparation for computational interdisciplinary research in genetics and genomics. Topics include genome analysis, regulatory genomics, association analysis, copy number variation, isoforms, and mixed populations, population substructure, human structural variation, model organisms, and genomic technologies. Computational techniques and methods include those from statistics and computer science. Lecture grading.

Mr. Eskin (Not offered 2017-18)

M226. Machine Learning in Bioinformatics. (4) (Same as Bioinformatics M226 and Human Genetics M266.) Lecture, four hours; outside study, four half hours. Enforced requisite: course 32 or Program in Computing 10C with grade of C– or better. Recommended: one course from Biostatistics 100A, 110A, Civil Engineering 141A, Electrical Engineering 140A, Mathematics 170A, or Statistics 101A. Familiarity with probability, statistics, linear algebra, and algorithms expected. Designed for engineering students as well as students from biological sciences and medical school. Biology has become data-intensive science. Bottleneck in being able to make sense of biological processes has shifted from data generation to statistical models and inference algorithms that can analyze these datasets. Statistical machine learning provides important toolkit in this endeavor. Biological datasets offer new challenges to field of machine learning. Introduction to computational aspects of machine learning techniques and their application to key biological questions. Letter grading. Mr. Sankararaman (Sp)

M229S. Seminar: Current Topics in Bioinformatics. (4) (Same as Biological Chemistry M229S and Human Genetics M229S.) Seminar, four hours; outside study, eight hours. Designed for graduate engineering students. Required preparation for graduate students: undergraduate-level knowledge of data structures and object-oriented program languages. As software systems become increasingly large and complex, automated software engineering analysis and development tools play important role in various software engineering tasks, such as design, construction, evaluation, 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 tool and automated assessment of how well it fits into software development process. Introduction to current research topics in automated software engineering. S/U or letter grading. Ms. Kim (Sp)

231. Types and Programming Languages. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131. Introduction to static type systems and their usage in programming language design and software reliability. Operational semantics, simply-typed lambda calculus, type soundness properties, type safety, and error handling for mutable references, types for exceptions. Parametric polymorphism, let-bound polymorphism, polymorphic type inference. Types for objects, subtyping, combining parametric polymorphism and subtyping. Types for modules, parameterized modules, operations. Formal specification and implementation of variety of type systems, as well as readings from current research literature on modern applications of type systems. Letter grading. Mr. Millstein (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 usage for testing, program verification, and bug finding. Class hierarchy analysis, rapid type analysis, equality-based analysis, subset-based 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 variety of static analyses, as well as readings from recent research literature on methodologies and applications of static analysis. Letter grading. Mr. Palsberg

233A. Parallel Programming. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 131. Mutual exclusion and resource allocation in distributed systems. Parallel execution of programs; specification of parallelism, interprocess communication and synchronization, atomic actions, binary and multiphase rendezvous, synchronous and asynchronous languages: CSP, Ada, Linda, Maisie, UC, and others; introduction to parallel program verification. Letter grading. Mr. Cong

233B. Verification of Concurrent Programs. (4) Lecture, four hours; outside study, eight hours. Requisites: course 233A. Formal techniques for verification of concurrent programs. Topics include safety, 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

234. Computer-Aided Verification. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181. Introduction to theory and practice of formal methods for design and analysis of concurrent and embedded systems, with focus on algorithmic techniques to enhance design productivity for data and software systems. Topics include semantics of reactive systems, invariant verification, temporal logic model checking, theory of omega automata, state-space reduction techniques, compositional and hierarchical reasoning. Letter grading. Mr. Majumdar

235. Advanced Operating Systems. (4) Lecture, four hours. Preparation: C or C++ programming experience. Requisite: course 111. In-depth investigation of operating systems issues through guided construction of research operating system for PC machines and consideration of recent literature. Memory management and protection, interrupts and traps, process interaction, interactive computing, file systems, virtualization,就这么完整了。
246. Web Information Management. (4) Lecture, four hours; outside study, eight hours. Requirements: courses 112, 143, 180, and 181. Design for graduate students. Scale of Web data requires novel algo-
rithms and principles for their management and re-
trieval. Study of Web characteristics and new man-
agement techniques needed to build computer sys-
tems suitable for the Web environment. Topics include:
- Web measuring techniques, large-scale data mining
- algorithms, efficient page refresh techniques, Web-
  page ranking algorithms, and query processing
- techniques on independent data sources.

Lecture. Mr. Cho (Sp)

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

Mr. Parker (WSp)

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

Mr. Ercegovac, Mr. Tamir (F)

251B. Parallel Computer Architectures. (4) Lec-
ture, four hours; outside study, eight hours. Requi-
sites: course M151B. Recommended: course 251A. SIMD
and MIMD systems, symmetric multiprocessing, dis-
tributed-shared-memory systems, message-passing
systems, multithreaded chips, clusters, intercon-
nection networks, host-network interfaces, switching
element topology, communication technologies, such as
input/output networks, and structural equations. Lecture
grading.

Mr. Ercegovac, Mr. Tamir (Not offered 2017-18)

252A. Arithmetic Algorithms and Processors. (4) Lecture,
four hours; outside study, eight hours. Requi-
sites: course M151B. Recommended: course 251A. SIMD
and MIMD systems, symmetric multiprocessor, dis-
tributed-shared-memory systems, message-passing
systems, multithreaded chips, clusters, intercon-
nection networks, host-network interfaces, switching
element topology, communication technologies, such as
input/output networks, and structural equations. Lecture
grading.

Mr. Ercegovac, Mr. Tamir (Not offered 2017-18)

252A. Advanced Scalable Architectures. (4) Lec-
ture, four hours; outside study, eight hours. Requi-
sites: course M151B. Recommended: course 251A. State-
of-art scalable multiprocessors. Interdependency among
implementation technology, chip microarchi-
tecture, and system architecture. High-performance
building blocks, such as chip multiprocessors
(CMPs). On-chip and off-chip communication. Mech-
anisms for exploiting parallelism at multiple levels.
Current research areas. Examples of chips and sys-
tems. Letter grading. Mr. Tamir (Not offered 2017-18)

2528C. LSI in Computer System Design. (4) (Same as Electrical and Computer Engineering
M258C.) Lecture, four hours; outside study, four hours. Requisite: course M258A. LSI/LSI design and
application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. Letter grading.

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

Mr. Cong

258G. Logic Synthesis of Digital Systems. (4) Lec-
ture, four hours; outside study, eight hours. Requi-
sites: courses M258A, 258F. Detailed study of prob-
ses in logic-level synthesis of VLSI digital sys-
tems, including two-level Boolean network optimiza-
tion; multilevel Boolean network optimization; tech-
ology mapping for standard cell design and cell-
drammable gate-array (FPGA) designs; retiming
for sequential circuits; and applications of binary de-
cision diagrams (BDDs). Letter grading.

Mr. Cong

259A. Current Topics in Computer Science: System Design/Architecture. (2 to 12) Lecture, four hours;
outside study, eight hours. Review of current litera-
ture in area of computer science system design in
which instructor has developed special proficiency as
consequence of research interests. Students report on
selected topics. May be repeated for credit with
topic change. Letter grading. (W,Sp)

260. Machine Learning Algorithms. (4) Lecture,
four hours; discussion, two hours; outside study, six
hours. Recommended: coursework 180. Prob-
lems of identifying patterns in data. Machine learning
allows computers to learn potentially complex pat-
ters from data and to make decisions based on
these patterns. Imlementations of this discipline to provide both conceptual grounding and
practical experience with several learning algorithms.
Techniques and examples used in areas such as
healthcare, financial systems, commerce, and
social networking. Letter grading. Mr. Sha (F)

261A. Problem Solving and Search. (4) Lecture,
four hours; outside study, eight hours. Requisite:
course 180. In-depth treatment of systematic
problem-solving algorithms in artificial intelli-
gence, including problem spaces, brute-force search,
heuristic search, linear-space algorithms, real-time
search. Design and analysis of algorithms, syn-
tactic and semantic restrictions on knowledge bases; effect of these restric-
tions on expressiveness, compactness, and compu-
tational tractability; applications of automated
reasoning to diagnosis, planning, design, formal veri-
fication, and reliability analysis. Letter grading.

Mr. Dyer (Not offered 2017-18)

264A. Automated Reasoning: Theory and Appla-
cations. (4) Lecture, four hours; laboratory, four hours;
outside study, four hours. Requisite: course 161, In-
troduction to theory and practice of automated rea-
soning using propositional and first-order logic.
Topics include syntax and semantics of formal logic;
algorithms for logical reasoning, including satis-
fiability and entailment; soundness and comple-
tions of proof systems; limit of satisfiability checking;
and verification and validation. Lecture and labora-
tory. Letter grading.

Mr. Dyer (Not offered 2017-18)

265A. Machine Learning. (4) Lecture, four hours;
outside study, eight hours. Requisites: courses 263A,
264A, Introduction to machine learning. Learning by
analog, inductive learning, modeling creativity,
training by experience, role of episodic memory or-
ganization in learning. Examination of BACON, AM,
Eurisko, HACKER, teachable production systems,
Failure-driven learning. Letter grading.

M266A. Statistical Modeling and Learning in Vi-
sion and Cognition. (4) (Same as Statistics M232A.) Lecture, four hours; laboratory, four hours. Requisi-
tes: course 180 and linear algebra (matrix analysis), computer vision, Computer vision and pattern recognition. Study of four types of statistical models for visual perception: descriptive, cognitive, qualitative (hidden Markov), and discriminative. Comparison of prin-
ciples and algorithms for these models; presenta-
tion of unifying picture. Introduction of minimax en-
tropy and EM-type and stochastic algorithms for
learning. S/U or letter grading.

M267B. Statistical Computing and Inference in Vi-
sion and Cognition. (4) (Same as Statistics M232B.) Lecture, three hours. Preparation: basic statistics,
linear algebra (matrix analysis), computer vision, In-
troduction to broad range of algorithms for statistical inference and learning that could be used in vision,
pattern recognition, speech, bioinformatics, data
networks, and structural equations. Learning causal
structures from data. Identifying causal effects.
Covariates and confounding control. Logic and algorithmization
of counterfactuals. Probabilities of counterfactuals. Di-
rect and indirect effects. Probabilities of causation.
Identifying causes of events. Letter grading.

Mr. Pearl

2622. Current Topics in Cognitive Systems. (4) Lecture, four hours; outside study, eight hours. Requi-
tes: course 262A. Additional requisite for each off-
eering announced in advance by department. Theory
and implementation of systems that emulate or sup-
port human reasoning. Current literature and indi-
vidual studies in artificial intelligence, knowledge-
based systems, decision support systems, computa-
tional psychology, and heuristic programming theory.
May be repeated for credit with topic change. Letter
grading.

Mr. Pearl

263A. Language and Thought. (4) Lecture,
four hours; outside study, eight hours. Requisite:
course 130 or 131 or 161. Introduction to natural language
processing (NLP), with emphasis on semantics. Pre-
sentation of process models for variety of tasks, in-
cluding question answering, paraphrasing, machine
translation, word-sense disambiguation, narrative and
editorial comprehension. Examination of both sym-
plex and statistical approaches to language pro-
cessing and acquisition. Letter grading.

Mr. Pearl

263C. Animals-Based Modeling. (4) Lecture, four
hours; outside study, eight hours. Requisite: course
130 or 131 or 161. Introduction to natural language
processing (NLP), with emphasis on semantics. Pre-
sentation of process models for variety of tasks, in-
cluding question answering, paraphrasing, machine
translation, word-sense disambiguation, narrative and
editorial comprehension. Examination of both sym-
plex and statistical approaches to language pro-
cessing and acquisition. Letter grading.

Mr. Pearl

2635. Current Topics in Cognitive Systems. (4) Lecture, four hours; outside study, eight hours. Requi-
tes: course 262A. Additional requisite for each off-
eering announced in advance by department. Theory
and implementation of systems that emulate or sup-
port human reasoning. Current literature and indi-
vidual studies in artificial intelligence, knowledge-
based systems, decision support systems, computa-
tional psychology, and heuristic programming theory.
May be repeated for credit with topic change. Letter
grading.

Mr. Pearl

264A. Automated Reasoning: Theory and Appla-
cations. (4) Lecture, four hours; laboratory, four hours;
outside study, four hours. Requisite: course 161, In-
troduction to theory and practice of automated rea-
soning using propositional and first-order logic.
Topics include syntax and semantics of formal logic;
algorithms for logical reasoning, including satis-
fiability and entailment; soundness and comple-
tions of proof systems; limit of satisfiability checking;
and verification and validation. Lecture and labora-

Mr. Dyer (Not offered 2017-18)
mining. Topics include Markov chain Monte Carlo computing, sequential Monte Carlo methods, belief propagation, partial differential equations. S/U or letter grading.


Mr. Soatto (F)

288S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Designed for students undertaking thesis research. Discussion of advanced topics and current research in computational neuroscience. Neural networks and connectionism as paradigm for parallel and concurrent computation in application to problems of perception, vision, multimodal sensory integration, and robotics. May be repeated for credit. S/U grading.

269. Seminar: Current Topics in Artificial Intelligence and Computer Science (4) Seminar, two hours; outside study, six hours. Enrollment restricted to CS graduate students and approved. Review of current literature and research practice in area of artificial intelligence in which instructor has developed special expertise. Emphasis on research in artificial intelligence. Students report on selected topics. May be repeated for credit with topic change. Letter grading.

Mr. Terzopoulos (Not offered 2017-18)

C274C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enrollment restricted. course 174A. Introduction to computer animation, including basic principles of character modeling, forward and inverse kinematics, forward and inverse dynamics, motion capture animation techniques, physics-based animation of particles and systems, and motor control. Concurrently scheduled with course C174C. Letter grading.

Mr. Terzopoulos (Not offered 2017-18)

275. Artificial Life for Computer Graphics and Vision. (4) Lecture, four hours; outside study, eight hours. Enrolled restricted. course 174A. Recommended: course 161. Introduction to the topic concepts that explain computational and biological sciences, and can play in construction of advanced computer graphics and vision models for virtual reality, animation, computer vision, virtual and networked environments, and medical image analysis, etc. Focus on comprehensive models that can realistically emulate variety of living things (plants and animals) from lower animal to human to robot. Emphasis on effective computer modeling of natural phenomena of life and their incorporation into sophisticated, self-animating graphical entities. Specific topics include modeling plants using L-systems, biomechanical simulation and control, behavioral animation, reinforcement and neural-network learning of locomotion, cognitive modeling, artificial animals and humans, human facial animation, and artificial evolution. Letter grading.

Mr. Terzopoulos (Not offered 2017-18)


Mr. Ostrovsky (F)


284A-284Z. Topics in Automata and Languages. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 180. Additional requisites for each offering announced in advance by department. Selections for graduate topics. Advanced automata theory, grammar, machines, operators; pushdown automata, context-free languages and their generalizations, parsing; multidimensional grammars, developmental systems, string-matching algorithms, nondeterministic finite automata. Selections from some current and planned sections: Context-Free Languages (284A), Parsing Algorithms (284P). May be repeated for credit with consent of instructor and topic change. Letter grading.

Mr. Sahai (Not offered 2017-18)

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CM286. Computational Systems Biology: Model- ing and Simulation of Biological Systems. (5) (Same as Bioengineering CM286.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisites: Electrical Engineering 102. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at all levels of organization, from molecular Control system, multicompartmental, 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. Both theory and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementing simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading.

Mr. DiStefano (Not offered 2017-18)

CM287. Research Communication in Computational and Systems Biology. (4) (Same as Bioengineering CM287.) Lecture, four hours; outside study, eight hours. Requisite: course CM286. Closely directed, interactive, and real research experience in active quantitative systems biology research laboratory. Orientation on how to conduct research. Discussion of current interest in scientific community, appropriate to student interests and capabilities. Critiques of oral presentations and written progress reports explain how to respond to comments. Emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM187. Letter grading.

Mr. DiStefano (Not offered 2017-18)

288S. Seminar: Theoretical Computer Science. (2) Seminar, two hours; outside study, six hours. Requisites: courses 280A, 281A. Intended for students undertaking thesis research. Discussion of advanced topics and current research in algorithms and related to algorithms and complexity models for parallel and concurrent computation, and formal language and automata theory. May be repeated for credit. S/U grading.

289A-289ZZ. Current Topics in Computer Theory. (2 to 12 each) Lecture, four hours; outside study, eight hours. Requisite: course CM286. 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.


Mr. DiStefano (Not offered 2017-18)

290A. Online Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. Introduction to decision making under uncertainty and competitive analysis. Review of current research in online algorithms for problems arising in many areas, such as data and memory management, scheduling, searching and navigating in unknown terrains, and server systems. Letter grading.

290A. Randomized Algorithms. (4) Lecture, four hours; outside study, eight hours. Basic concepts and design techniques for randomized algorithms, such as probability theory, Markov chains, random walks, and probabilistic method. Applications to random generation of objects, randomized algorithm design and analysis, and randomized algorithms for problems in combinatorial geometry, convexity, one-way functions, hardness amplification, Problem sets and presentation of previous and original research related to course topics. Letter grading.

Mr. Sahai (F)
ompoment of dynamic systems modeling methodology for physiological, biomedical, pharmacochemical, chemical and related systems. Control systems, multicompartamental, noncompartmental, and input/output models, linear and nonlinear. Emphasis on model applications, limitations, and relevance in biomedical sciences and other limited data environments. Problem solving in PC laboratory. Letter grading.

Mr. DiStefano

M296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Same as Bioengineering M296B, Biomatics M270, and Medicine M270D) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biomatics 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

M296C. 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 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

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

Mr. 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 advanced topics and current research in algorithmic processes that describe and represent the information space. Tutorial, to be arranged. Limited to graduate computer science students. Supervised independent research for M.S. candidates, including thesis prospectus. S/U grading.

Mr. Korf (Not offered 2017-18)

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 their 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. Petition forms to request enrollment may be obtained from assistant dean. Graduate Study. Supervised investigation of advanced technical problems. S/U grading.

597A. Preparation for M.S. Comprehensive Examination. (1 to 2) Tutorial, to be arranged. Limited to graduate computer science students. Preparing for and preparing for M.S. comprehensive examination. S/U grading.


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

598. Research for and Preparation of M.S. Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for oral qualifying examination, including preliminary research for M.S. candidates, including thesis prospectus. S/U grading.

599. Research for and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Petition forms to request enrollment may be obtained from assistant dean. Graduate Studies. S/U grading.
Kang L. Wang, Ph.D. (Raytheon Company Professor of Electrical Engineering)  
Yuanxun Ethan Wang, Ph.D.  
Richard D. Wesel, Ph.D., Associate Dean  
Chee Wei Wong, Sc.D.  
Jason C.S. Woo, Ph.D.  
C.-K. Ken Yang, Ph.D.

Professors Emeriti
Frederick G. Allen, Ph.D.  
Francis F. Chen, Ph.D.  
Harold R. Fetterman, Ph.D.  
Stephen E. Jacobsen, Ph.D.  
Rajeev Jain, Ph.D.  
Alan J. Laub, Ph.D.  
Nhan N. Levan, Ph.D.  
Dee-Son Pan, Ph.D.  
Frederick W. Schott, Ph.D.  
Gabor C. Temes, Ph.D.  
Chand R. Viswanathan, Ph.D.  
Donald M. Wiberg, Ph.D.  
Alan N. Willson, Jr., Ph.D. (Charles P. Reames Endowed Professor Emeritus of Electrical Engineering)

Kung Yao, Ph.D.

Associate Professors
Danjiela Cabric, Ph.D.  
Robert N. Candler, Ph.D.  
Chi On Chui, Ph.D.  
Lara Dolecek, Ph.D.  
Puneet Gupta, Ph.D.  
Benjamin S. Williams, Ph.D.

Assistant Professors
Sam Emaminejad, Ph.D.  
Ankur Mehta, Ph.D.

Adjunct Professors
Ezio Biglieri, Ph.D.  
Darluu Divsalar, Ph.D.  
Dan M. Goebel, Ph.D.  
Asad M. Madni, Ph.D.  
Yi-Chi Shih, Ph.D.  
Ingrid M. Verbauwhede, Ph.D.  
Eli Yablonovitch, Ph.D.

Adjunct Assistant Professors
Pedram Khalili Amiri, Ph.D.  
Shervin Moloudi, Ph.D.  
Zachary Taylor, Ph.D.

Scope and Objectives
Electrical and computer engineers are responsible for inventions that have revolutionized our society, such as the electrical grid, telecommunications, and automated computing and control. The profession continues to make vital contributions in many domains, such as the infusion of information technology into all aspects of daily life. To further these ends, the Department of Electrical and Computer Engineering fosters a dynamic academic environment that is committed to a tradition of excellence in teaching, research, and service and has state-of-the-art research programs and facilities in a variety of fields. Departmental faculty members are engaged in research efforts across several disciplines in order to serve the needs of industry, government, society, and the scientific community. Interactions with other disciplines are strong. Faculty members regularly conduct collaborative research projects with colleagues in the Geffen School of Medicine, Graduate School of Education and Information Studies, School of Theater, Film, and Television, and College of Letters and Science.

There are three primary research areas in the department: circuits and embedded systems, physical and wave electronics, and signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunication, control systems, signal processing, data science, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, and solid-state electronics.

The program grants two undergraduate degrees (Bachelor of Science in Electrical Engineering and Bachelor of Science in Computer Engineering) and two graduate degrees (Master of Science and Doctor of Philosophy in Electrical Engineering). The graduate program provides students with an opportunity to pursue advanced coursework, in-depth training, and research investigations in several fields.

Department Mission
The education and research activities in the Electrical and Computer Engineering Department are aligned with its mission statement. In partnership with its constituents, consisting of students, alumni, industry, and faculty members, the mission of the department is to (1) produce highly qualified, well-rounded, and motivated students with fundamental knowledge of electrical engineering who can provide leadership and service to California, the nation, and the world, (2) pursue creative research and new technologies in electrical engineering and across disciplines in order to serve the needs of industry, government, society, and the scientific community, (3) develop partnerships with 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 cyber/physical 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 multi-disciplinary team structure, students identify, formulate, and solve engineering problems and present their projects to the class.

Electrical Engineering B.S. Capstone Major
The undergraduate curriculum provides all Electrical Engineering majors with preparation in the mathematical and scientific disciplines that lead to a set of courses that span the fundamentals of the 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.

**Preparation for the Major**

*Required:* Chemistry and Biochemistry 20A; Computer Science 31, 32; Electrical and Computer Engineering 2, 3, 10, 11L, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

**The Major**

*Required:* Electrical and Computer Engineering 101A, 102, 110, 111L, 113, 131A; six core courses selected from Computer Science 33, Electrical and Computer Engineering 101B, 115A, 121B, 132A, 133A, 141, 170A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 12 units of major field elective courses, at least 8 of which must be upper-division courses in Electrical and Computer Engineering or from another HSSEAS department; and one two-term electrical and computer engineering capstone design course (8 units).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://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 M117 (or M171L), 132A, 132B, and 133A and 8 capstone design units from 113DA/113DB or 180DA/180DB.

**Control Systems and Optimization:** The study of how to control a variety of systems ranging from a single physical system to continental networks, such as the electrical grid. Students might take 12 units selected from Electrical and Computer Engineering 112, 133A, 133B, 134, 141, and 142 and 8 capstone design units from 113DA/113DB or 184DA/184DB.

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

**Simulation and Data Analysis:** The study of how to derive meaningful inferences from measured data, such as speech, images, or other data, after conversion from analog to digital form. Students might take 12 units selected from Electrical and Computer Engineering 141, 132A, 133B, 134, and M146 and 8 capstone design units from 113DA/113DB.

**Suggested Tracks**

The technical breadth area requirement provides an opportunity to combine elective courses in the Electrical Engineering major with those from another HSSEAS major to produce a specialization in an interdisciplinary domain. Students are free to design a specialization in consultation with a faculty adviser.

**Bioengineering and Informatics (BI)** refers to the design of biomedical devices and the
analysis of data derived from such devices and instruments. Students might take Chemistry and Biochemistry 20B and two courses from Bioengineering 100, C101, CM102, and 110 and/or 12 units from Computer Science CM121, Electrical and Computer Engineering 114, 133B, 134, and 176 and 8 capstone design units from 180DA/180DB.

Computer Engineering (CE) concentrates on the part of the hardware/software stack related to the design of new processors and the operation of embedded systems. Students might take a 12-unit technical breadth area in computer science such as Computer Science 111, 130, and 180 and/or 12 units of electives from Electrical and Computer Engineering 115C, M116C, M116L, M117, 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, M117, and 180 and/or 12 units of electives from Electrical and Computer Engineering M116C, 132B, and 142 and 8 capstone design units from 183DA/183DB.

Computer Engineering B.S. Capstone Major

The 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.

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.

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, 10, 11L; Engineering 96C; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Computer Science 111, 118 (or Electrical and Computer Engineering 132B), M151B (or Electrical and Computer Engineering M116C), M152A (or Electrical and Computer Engineering M116L), 180; Electrical and Computer Engineering 102, 110, 111L, 113; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, Statistics 100A; 8 units of computer science and 8 units of electrical and computer engineering upper-division electives; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 8 units capstone design from either Electrical and Computer Engineering 180DA/180DB or 183DA/183DB.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://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 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 130, 131, 132, 133, 136, 181, 188, Electrical and Computer Engineering 2, 115A, 115B, 115C, M117, 132A, 133A, 141, 142, 188.

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

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

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

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

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

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

The following introductory information is based on the 2017-18 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at https://grad.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

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

Electrical Engineering M.S.

Areas of Study

Students may pursue specialization across three major areas of study: (1) circuits and embedded systems, (2) physical and wave electronics, and (3) signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunication systems, 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. 
2. 
3. 
4. 
5. 
6. 
7. 
8. 
9. 
10. 

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

Physical and Wave Electronics Area Tracks

1. 

Circuits and Embedded Systems Area Tracks

1. 

A formal graduate course is defined as any 200-level course, excluding seminar or tutorial courses

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

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

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, 213A, M216A

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 213A, 215A through 215E, M216A, 221A, 221B

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.
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.


3. **Solid-State and Microelectromechanical Systems (MEMS) Devices Track.** Courses deal with solid-state physical electronics, semiconductor device physics and design, and microelectromechanical systems (MEMS) design and fabrication. Courses include Electrical and Computer Engineering 221A, 221B, 221C, 222, 223, 225, M250B, Mechanical and Aerospace Engineering 281, 284, C287L

**Signals and Systems Area Tracks**

1. **Communications Systems Track.** Courses deal with communication and telecommunication principles and engineering applications; channel and source coding; spread spectrum communication; cryptography; estimation and detection; algorithms and processing in communication and radar; satellite communication systems; stochastic modeling in telecommunication engineering; mobile radio engineering; and telecommunication switching, queuing system, communication networks, local-area, metropolitan-area, and wide-area computer communication networks. Courses include Electrical and Computer Engineering 205A, 210A, 230A through 230D, 231A, 231E, 232A through 232E, 238, 241A

2. **Control Systems and Optimization Track.** Courses deal with state-space theory of linear systems; optimal control of deterministic linear and nonlinear systems; stochastic control; Kalman filtering; stability theory of linear and nonlinear feedback control systems; computer-aided design of control systems; optimization theory, including linear and nonlinear programming; convex optimization and engineering applications; numerical methods; nonconvex programming; associated network flow and graph problems; renewal theory; Markov chains; stochastic dynamic programming; and queuing theory. Courses include Electrical and Computer Engineering 205A, 208A, M208B, M208C, 210B, 236A, 236B, 236C, M237, M240A, 240B, 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 minimum cumulative grade-point average of 3.5 in the Ph.D. program

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

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 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)

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

Center for Engineering Economics, Learning, and Networks

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

Center for Heterogeneous Integration and Performance Scaling (CHIPS)

The UCLA Center for Heterogeneous Integration and Performance Scaling (CHIPS) addresses emerging technologies, design, and architectures to achieve a more holistic Moore’s Law for the overall system. Its 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 implement these concepts, and works closely with world-class foundries and equipment manufacturers to advance the state of the art.

Center for High-Frequency Electronics

The Center for High-Frequency Electronics has been established with support from several governmental agencies and contributions from local industries, beginning with a $10 million grant from Hewlett-Packard. The first major goal of the center is to combine, in a synergistic manner, five areas of research. These include (1) solid-state millimeter wave devices, (2) millimeter systems for imaging and communications, (3) millimeter wave high-power sources (gyrotrons), (4) GaAs gigabit logic systems, and (5) VLSI and 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 combine and correlate certain research programs as a result of the formation of the center.

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

Lei He, Director

The Clean Energy Research Center–Los Angeles (CERC–LA) was created by UCLA to tackle many of the grand challenges related to generation, transmission, storage, and management of energy. As many energy challenges are global in nature, this 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 Circuits Laboratories are equipped for measurements on high-speed analog and digital circuits and are used for the experimental study of communication, signal processing, and instrumentation systems. A hybrid integrated circuit facility is available for rapid mounting, testing, and revision of miniature circuits. These include both discrete components and integrated circuit chips. The laboratory is available to advanced undergraduate and graduate students through faculty sponsorship on thesis topics, research grants, or special studies.

Electromagnetics Laboratories

The Electromagnetics Laboratories involve the disciplines of microwaves, millimeter waves, wireless electronics, and electromechanics. Students enrolled in microwave laboratory courses, such as Electrical and Computer Engineering 163DA and 164DB, special projects classes such as Electrical and Computer Engineering 199, and/or research projects, have the opportunity to obtain experimental and design experience in the following technology areas: integrated microwave circuits and antennas, integrated millimeter wave circuits and an-tennas, numerical visualization of electromagnetic waves, electromagnetic scattering and radar cross-section measurements, and antenna near field and diagnostics measurements.

Nanoelectronics Research Facility

http://www.nanolab.ucla.edu

The state-of-the-art Nanoelectronics Research Facility (NRF) for graduate research and teaching, as well as the undergraduate microelectronics teaching laboratory, are housed in an 8,500-square-foot class 100/1000 clean room with a full complement of utilities, including high-purity deionized water, high-purity nitrogen, and exhaust scrubbers. The NRF supports research on nanometer-scale fabrication and on the study of fundamental quantum size effects, as well as exploration of innovative nanometer-scale device concepts. The laboratory also supports many other schoolwide programs in device fabrication, such as MEMS and optoelectronics.

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. Spec-
approximately 300TF/150TF (single/double precision) with a measured Linpack performance of 68.1TF (double precision). DAWSON 2 is housed within the UCLA Institute for Digital Research Engineering data center.

**Solid-State Electronics Facilities**

Solid-state electronics equipment and facilities include a modern integrated semiconductor device processing laboratory, complete new Si and III-V compound molecular beam epitaxy systems, CAD and maskmaking facilities, lasers for beam crystallization study, thin film and characterization equipment, deep-level transient spectroscopy instruments, computerized capacitance-voltage and other characterization equipment, including doping density profiling systems, low-temperature facilities for material and device physics studies in cryogenic temperatures, optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices, and characterization equipment for high-speed devices, including high magnetic field facilities for magnetotransport measurement of heterostructures. The laboratory facilities are available to faculty, staff, and graduate students for their research.

**Wireless Health Institute (WHI)**

Benjamin M. Wu, D.D.S., Ph.D. (Bioengineering), Director; Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical and Computer Engineering), Gregory J. Pottie, Ph.D. (Electrical and Computer Engineering), Co-Directors

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

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

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

**Multidisciplinary Research Facilities**

The department is also associated with several multidisciplinary research centers including

- California NanoSystems Institute (CNSI)
- Center for Heterogeneous Integration and Performance Scaling (CHIPS)
- Center for High-Frequency Electronics (CHFE)
- Center for Nanoscience Innovation for Defense (CNID)
- Center of Excellence in Green Nanotechnology (CEGN)
- Functional Accelerated Nanomaterial Engineering (FAME)
- Functional Engineered Nano Architecture Focus Center (FENA)
- Plasma Science and Technology Institute
- Translational Applications of Nanoscale Multiferroic Systems (TANMS)
- WIN Institute of Neurotronics (WINs)

**Faculty Groups and Laboratories**

Department faculty members also lead a broad range of research groups and laboratories that cover a wide spectrum of specialties, including

- Actuated Sensing and Coordinated Embedded Networked Technologies (ASCENT) Laboratory (Kaiser)
- Adaptive Systems Laboratory (Sayed)
- Algorithmic Research in Network Information Laboratory (Fragouli)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
- Autonomous Intelligent Networked Systems (Rubin)
- BioPhotonics Laboratory (Ozcan)
- 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 Biomedical Nanoelectronics Laboratory (I2BL) (Emaminejad)
- Laboratory for Embedded Machines and Ubiquitous Robotics (Mehta)
- Laser-Plasma Group (Joshi)
- MedAdvance: Machine Learning and Artificial Intelligence for Medicine (van der Schaar)
- Mesoscopic Optics and Quantum Electronics Laboratory (Wong)
- Microwave Electronics Laboratory (Itoh)
- Nanoelectronics Research Center (Candler)
- Nanostructure Devices and Technology Laboratory (Chui)
- Nanosystems Computer-Aided Design Laboratory (Gupta)
- Networked and Embedded Systems Laboratory (Silvestava)
- Neuroengineering Group (Markovic)
- Optoelectronics Circuits and Systems Laboratory (Jalali)
- Optoelectronics Group (Yablonovitch)
- Public Safety Network Systems Laboratory (Yao, Rubin)
- Quantum Electronics Laboratory (Ozcan)
- Robust Information Systems Laboratory (Dolecek)
Faculty Areas of Thesis Guidance

Professors

Asad A. Abidi, Ph.D. (U.C 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

Katsuji Arioka, Ph.D. (U. Tokyo, Japan, 1985)
High energy and astro-particle experiments

M.-C. Frank Chang, Ph.D. (National Chiao-Tung U., Taiwan, 1979)
High-speed semiconductor (GaAs, InP, and Si) devices and integrated circuits for digital, analog, microwave, and optoelectronic integrated circuit applications

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

Jason (Jingsheng) Cong, Ph.D. (U. Illinois, 1990)
Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, computer architecture, reconfigurable computing, design for nanotechnologies

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

Christina Fragouli, Ph.D. (UCLA, 2000)
Network coding, algorithms for networking, wireless networks and network security

Warren S. Grunfeld, M.D., FACS (Columbia, 1980)
Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopy, spectroscopy, photodynamic therapy (PDT), optical technology, biologic feedback control mechanisms

Lei He, Ph.D. (UCLA, 1999)
Computer-aided design of VLSI circuits and systems; coarse-grain programmable systems and field programmable gate array (FPGA), high-performance interconnect modeling and design, power-efficient computer architectures and systems, numerical and combinatorial optimization

Diana L. Huffaker, Ph.D. (U. Texas Austin, 1995)
Solid-state nanotechnology, MMIR optoelectronic devices, solar cells, Si photonic, novel materials

Tatsuo Itoh, Ph.D. (U. Illinois Urbana, 1969)
Microwave and millimeter wave electronics; guided wave structures; low-power wireless electronics; integrated passive components and antennas; photonic bandgap structures and 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 subsystem integration and neuromorphic computing

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

Mona Janjahi, Ph.D. (Stanford, 2007)
Radio frequency (RF), microwave, millimeter-wave, and terahertz circuits, high-frequency devices and circuits, integrated photonic and optoelectronics

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. (U.C Berkeley, 2006)
Power/area-eficient digital integrated circuits, VLSI architectures for wireless communications, organization methods and supporting CAD flows

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)
Bioranging, nano-photonic, nonlinear optics

Sudhakar Pamarti, Ph.D. (UC San Diego, 2003)
Mixed-signal IC design, signal processing and communication theory

Gregory J. Pottie, Ph.D. (McMaster U., Canada, 1988)
Communication systems and theory with applications to wireless sensor networks

Yahya Rahmat-Samii, Ph.D. (UCLA, 1981)
Satellite communications antennas, personal communication antennas including human interactions, active antenna sensing and radio astronomy applications, advanced numerical and genetic optimization techniques in electromagnetic, 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 nano-electronics and molecular electronics, adaptive and learning algorithms, neural networks, methods and algorithms for large-scale information processing, combinatorics and complexity, and information theory

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

Henry Samueli, Ph.D. (UCLA, 1980)
VLSI implementation of signal processing and digital communication systems, high-speed digital integrated circuits, digital filter design

Ali H. Sayed, Ph.D. (Stanford, 1992)
Adaptive systems, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplays between signal processing and control methodologies, fast algorithms for large-scale problems

Stefano Soatto, Ph.D. (Caltech, 1996)
Computer vision, 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. (U.C Berkeley, 1992)
Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems

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

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/categorical methods

Lieven Vandenberghe, Ph.D. (Katholieke U. Leuven, Belgium, 1992)
Optimization in engineering and applications in systems and control, circuit design, and signal processing

Mihaela van der Schaar, Ph.D. (Eindhoven U. Technology, Netherlands, 2001)
Multimedia processing and compression, multimedia networking, multimedia communications, multimedia architectures, enterprise multimedia streaming, mobile and ubiquitous computing

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 superlattics, microwave and millimeter electronics, quantum information

Yuanxun Ethan Wang, Ph.D. (U. Texas Austin, 1999)
Smart antennas, RF and microwave power amplifiers, numerical techniques, DSP techniques for microwave systems, phased arrays, wireless and radar systems, microwave integrated circuits

Richard D. Wesel, Ph.D. (Stanford, 1996)
Communication theory of signal processing with particular interests in channel coding.
including turbo codes and trellis codes, joint algorithms for distributed communication and detection
Ultrafast and nonlinear optics, quantum communications and computing, chip-scale optoelectronics, precision measurements and sensing
Jason G.S. Woo, Ph.D. (Stanford, 1987)
Solid-state technology, CMOS and bipolar device/circuit optimization, novel device design, modeling of integrated circuits, VLSI fabrication
G.-K. Ken Yang, Ph.D. (Stanford, 1998)
High-performance VLSI design, digital and mixed-signal circuit design

Professors Emeriti
Frederick G. Allen, Ph.D. (Harvard, 1956)
Semiconductor physics, solid-state devices, surface physics
Francis F. Chen, Ph.D. (Harvard, 1954)
Radio frequency plasma sources and diagnostics for semiconductor processing
Harold R. Fetterman, Ph.D. (Cornell, 1968)
Optical millimeter wave interactions, high-frequency optical polymer modulators and applications, solid-state millimeter wave structures and systems, biomedical applications of lasers
Stephen E. Jacobsen, Ph.D. (UC Berkeley, 1968)
Operations research, mathematical programming, nonconvex programming, applications of mathematical programming to engineering and economics

Adjunct Professors
Ezio Biglieri, Dr. Ing. (Politecnico di Torino, Italy, 1972)
Microwave/millimeter-wave active and passive components and subsystems, devices, characterization and modeling, integrated circuits, components and subsystems for sensors and communications applications
Ingmar M. Verbaaunwehe, Ph.D. (Katholieke U. Leuven, Belgium, 1991)
Embeddable systems, VLSI, architecture and circuit design and design methodologies for applications in security, wireless communications and signal processing

Associate Professors
Daniela Cabrì, Ph.D. (UC Berkeley, 2007)
Wireless communications system design, cognitive radio networks, VLSI architectures of signal processing and digital communication

Shervin Moloudi, Ph.D. (UCLA, 2008)
Telecommunication analog and high-frequency circuit design
Zachary Taylor, Ph.D. (UC Santa Barbara, 2009)
Biomedical optics, imaging system design, novel contrast-generation mechanisms

Lower-Division Courses

1. Undergraduate Seminar. (1) Seminar, one hour; outside study, two hours. Introduction by faculty members and industry lecturers to electrical engineering disciplines through current and emerging applications of autonomous systems and vehicles, biomedical devices, aerospace electronic systems, consumer products, data science, and entertainment products (amusement parks, etc.), as well as energy generation, storage, and transmission. P/NP grading.

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

3. Introduction to Electrical Engineering. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Introduction to field of electrical engineering. Basic circuits techniques with application to explanation of electrical engineering inventions such as telecommunications, computers, and general computing and control, and enabling device technology. Research frontiers of electrical engineering. Introduction to measurement and design of electrical circuits. Letter grading.

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

5. Circuit Theory I (Honors). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 (or Computer Science 1 or Materials Science 10), Mathematics 33A, Physics 1B. Corequisites: course 11L (enforced only for Computer Science and Engineering and Electrical Engineering majors), Mathematics 33B. Honors course parallel to course 2. Letter grading.

6. Circuits Laboratory I (1) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced corequisite: course 10. Experiments with basic circuits containing resistors, capacitors, inducers, and transformers. Ohm’s law voltage and current division, Thévenin and Norton equivalent circuits, superposition, transient and steady state analysis. Letter grading.

7. Circuits Laboratory I (Sp) (1) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading.

* Also Professor Emeritus of Anesthesiology

Ms. Alwan (F)

Mr. Williams (W)

Mr. Gupta, Mr. Pamarti (F, W, Sp)

Mr. Gupta, Mr. Pamarti (F, W, Sp)


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

89. Honors Seminars. (1 Seminar, three hours. Limited to 20 students. Designed as adjunct to lower division or to further exploration of topics in greater depth through supplemental readings, papers, or other activities and led by lecture course instructor. May be applied toward honors credit for eligible students. Consent noted on transcript. P/NP or letter grading.

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

Upper-Division Courses

100. Electrical and Electronic Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Mathematics 33A, 33B (or Mechanical 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, signal models, and operational amplifiers. Letter grading. Mr. Razavi (F,Sp).

101A. Engineering Electromagnetics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Mathematics 32A and 32B, or 33A and 33B, Physics 1C. Electromagnetic field concepts, wave propagation, transmission lines and Smith chart, transient responses, vector analysis, interference, boundary conditions, static and uniform 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).


110. Circuit Theory II. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: courses 10, 116 (or Computer Science M51A). Corequisite: course 111L (enforced only for Computer Science and Engineering and Electrical Engineering). Static and dynamic excitation and phasors, AC steady state analysis, AC steady state power, network functions, poles and zeros, frequency response, mutual inductance, ideal transformer, application of Laplace transforms to circuit analysis. Letter grading. Mr. Abdiz (F,Sp).

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

111L. Circuits Laboratory II. (1) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced requisites: courses 10, 11L. Enforced corequisite: course 110. Experiments with electrical circuits containing capacitors, inductors, transistors, and op-amps. Steady state power analysis, frequency response principles, op-amp-based circuit synthesis, and two-port network principles. Letter grading. Mr. Gupta, Mr. Pamarti (F,Sp).

112. Introduction to Power Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 110. Complete overview of organization and operation of interconnected power systems, principles of appropriate models for interconnected power systems and learning how to perform power flow, economic dispatch, and short circuit analysis. Introduction to power system transient dynamics. Letter grading. Mr. Tabuada (Sp).


113DA-113DB. Digital Signal Processing Design. (4-4) Real-time implementation of digital signal processing algorithms on digital processor chips. Experiments involving A/D and D/A conversion, aliasing, digital filtering, signal header, and Word transforms, and finite wordlength effects. Course project involving original design and implementation of signal processing systems for communications, speech, audio, or video using DSP chip. 113DA. Formerly numbered 113D. Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 110L or 115A. Consent of instructor is given only on completion of course 113DB. 113DB. Laboratory, four hours; outside study, eight hours. Enforced requisites: courses 113A, 113DA. Completion of projects begun in 113DA. Mr. Daneshradd 113D in F; 113DB in W.Sp.

114. Speech and Image Processing Systems Design. (4) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. Enforced requisite: course 113. Design principles of speech and image processing systems. Speech processing, design, and filtering in first half of course; design techniques for image enhancement, filtering, and transformation in second half. Lectures supplemen- ted by laboratory implementation of speech and image processing tasks. Letter grading.


115AL. Analog Electronics Laboratory I. (2) Laboratory, four hours; outside study, two hours. Enforced requisites: courses 110L or 111L. Practical determination of device characteristics, resistance determination, and use of computer-aided instrument. Emphasis on single-stage, operational amplifiers, and operational amplifier circuits. Introduction to hands-on design experience based on individual student hardware design and implementation platforms. Letter grading. Mr. Abdiz (F,Sp).

115B. Analog Electronic Circuits II. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 115A. Analysis and design of different operational amplifier and CMOS technologies. Current mirrors and active loads. Frequency response of amplifiers. Feedback and its properties. Stability issues and frequency compensation. Letter grading. Mr. Abidi, Mr. Yang (W).

115C. Digital Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115A, Computer Science M51A. Recommended: course 115B. Transistor-level digital circuit analysis and design. Modern digital logic families (static CMOS, pass-transistor, dynamic logic), integrated circuit (IC) layout, digital circuits (logic gates, flipflops/latches, counters, etc.), computer-aided simulation of digital circuits. Letter grading. Mr. Markovic (W,Sp).

115E. Design Studies in Electronic Circuits. (4) Formerly numbered 115D. Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115A. Design and implementation of circuit design through lectures to complement other laboratory-based design courses. Topics vary by instructor and include circuit analysis, operational circuits, power electronics, and instrumentation. Emphasis and may entail simulation-based design projects. Emphasis throughout on design-oriented analysis and rigorous approach to practical circuit design. Letter grading.

M116C. Computer Systems Architecture. (4) (Same as Computer Science M151B.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course M16 or Computer Science M51A, Computer Science 33. Recommended: course M116L or Computer Science M152A, Computer Science 111. Computer system organization and design, implementation of CPU datapath and control, instruction set design, memory hierarchy (caches, main memory, virtual memory) organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading. Mr. Gupta (F,Sp).

M116L. Introductory Digital Design Laboratory. (2) (Same as Computer Science M152A) Laboratory, four hours; discussion, two hours; outside study, two hours. Enforced requisites: course M16 or Computer Science M51A. Hands-on design, implementation, and debugging of digital logic circuits, use of computer-aided design tools for schematic capture, simulation, and implementation of complex circuits using programmed array logic, design projects. Letter grading. Mr. He (F,Sp).

M117. Computer Networks: Physical Layer. (4) (Same as Computer Science M117.) Lecture, two hours; discussion, two hours; laboratory, two hours; outside study, six hours. Not open to students with credit for course M171L. Introduction to fundamental computer communication concepts underlying and supporting modern networks, with focus on wireless communications and media access layers of network protocols, wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth, ZigBee). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for personal applications such as wireless health, positioning, and environmental awareness, and experimental laboratory sessions included. Letter grading. Mr. He (F,Sp).

M119. Fundamentals of Embedded Networked Systems. (4) (Same as Computer Science M119.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 151A or Civil and Environmental Engineering 170A or Mathematics 170A or Statistics 100A, course 132B or Computer Science 118, Computer Science 33. Design trade-offs and principles of operation of cyber physical sys-
tem such as devices and systems constituting In- ternet of Things. Topics include signal propagation and modeling, sensing, node architecture and opera- tion, and applications. Letter grading.

Mr. Srivastava (Sp)

121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: courses 113, 114, 115, 116, 117, 118, 119, 121A. Introduction to principles of operation of bipolar and MOS transistors, equivalent circuits, high-frequency behavior, voltage limitation. Letter grading.

Mr. W. (FW)

121DA-121DB. Semiconductor Processing and Device Design. (4-8) Design fabrication and charac- terization of p-n junction and transistors. Students will perform several testing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Introduction to CAD tools used in integrated circuit processing and device design. De- vice structure optimization tool based on MEDIC; integration tool based on STAMP. Familiarizes students with those tools. Using CAD tools, CMOS process integration to be designed. Lecture, two hours; discussion, one hour; outside study, six hours. Enforced requisites: courses 121A, 121DA-121DB.

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

123A. Fundamentals of Solid-State I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 2 or Physics 1C. Limited to junior/senior engineering majors. Fundamen- tals of solid-state, introduction to quantum me- chanics and quantum statistics applied to solid-state. Crystal structure, energy levels in solids, and band theory and semiconductor properties. Letter grading.

Ms. Hufstader (W)

123B. Fundamentals of Solid-State II. (4) Lecture, four hours; outside study, eight hours. Enforced requi- sites: course 123A. Discussion of solid-state proper- ties, lattice vibrations, thermal properties, dielectric, magnetic, and superconducting properties. Letter grading.

Ms. Hufstader (W)

128. Principles of Nanoelectronics. (4) Lecture, four hours; discussion, four hours; outside study, eight hours. Requisites: Physics 1C. Introduction to funda- mentals of nanoelectronics and nanoscale technology. Principles of fundamental quantities: electron charge, effective mass, bohr magneton, and spin, as well as theoretical approaches. From these nanoscale com- ponents, we discuss behavior of nanostructures such as analysis of dynamics, variability, and noise, contrasted with those of scaled CMOS. Incorpora- tion of design project in which students are chal- lenged to design electronics nanosystems. Letter grading.

Mr. K.L. Wang (Sp)

131A. Probability and Statistics. (4) Lecture, four hours; discussion, one hour; outside study, 10 hours. Requisites: course 110 (enrolled), Math 32B, 33B. Introduction to basic concepts of probability, in- cluding random variables and vectors, distributions and densities, moments, characteristic functions, and limit theorems leading to the central limit theorem. Letter grading.

Mr. Roychowdhury (FW)

131B. Introduction to Stochastic Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A. Introduction to concepts of stochastic processes, emphasizing continuous- and discrete-time sta- tionary processes, correlation function and spectral density, linear transformation, and mean-square esti- mation. Applications to communication, control, and signal processing. Introduction to computer simula- tion and analysis of stochastic processes. Letter grading. (Not offered 2017-18)

132A. Introduction to Communication Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 111, 113, 114, 115, 116, 119, 121A. Understanding of basic probability, basics of hy- pothesis testing, sufficient statistics and waveform communication, signal–design tradeoffs for digital communications, basics of error control coding, in- ternet protocols, statistical multiplexing, and multi- frequency division multiplexing (OFDM), basics of wire- less communications. Letter grading.

Mr. M. W. (FW)


Mr. Rubin (W)


Mr. Vandenberhe (FW)

134. Graph Theory in Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Basics of graph theory, including trees, bipar- tite graphs and matching, vertex and edge coloring, planar graphs and networks. Emphasis on reducing real-world engineering problems to graph theory for- mulations. Letter grading.

Ms. Frangoul (Sp)


Mr. Tabuada (W)


Mr. Tabuada (Not offered 2017-18)

M146. Introduction to Machine Learning. (4) (Same as Computer Science M146.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 131A or Civil and Environ- mental Engineering 110 or Mathematics 170A or Sta- tistics 100A, Computer Science 33. Introduction to breadth of data science. Foundations for modeling data, statistical principles and common tools for data analysis, and application of tools and models to data gathering and analysis. Topics in- clude statistical foundations for data generation, valida- tion, kernel methods, clustering, expectation maxi- mization, principal component analysis, decision theory, reinforcement learning and deep learning. Letter grading.

Ms. D. Dolecek (F; Sp)

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) (Same as Bioengineering M153, Chemical Engineering M153, and Mechanical and Aerospace Engineering M153.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to general manufac- turing methods, mechanisms, constrains, and micro- fabrication and nanofabrication. Focus on con- cepts, physics, and instruments of various microfab- rication and nanofabrication techniques that have been broadly applied in industry and academia, in- cluding various photolithography technologies, phys- ical and chemical deposition methods, and physical and chemical etching methods. Hands-on experi- ence for fabricating microstructures and nanostruc- tures in modern cleanroom environment. Letter grading.

Mr. Chiu (F; Sp)


Mr. Rahmat-Samii (Sp)

163A. Introductory Microwave Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101B. Theory and design of modern microwave systems such as satellite com- munication systems, radar systems, wireless sens- ors, and biological applications of microwaves. Letter grading.

Mr. Itoh, Mr. Jalali (Not offered 2017-18)

163DA. Microwave and Wireless Design I. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisites: courses 101A, 101B. Course 163DA is enforced requisite to 163DB. Limited to senior Electrical Engineering majors. Capa- ble of design course, with emphasis on microfabrication and nanofabrication techniques.line-based circuits and components to address need in industry and research community for students with micro- and wireless circuit design experiences. Standard design procedure for waveguide and trans- mission line-based microwave circuits and systems to gain experience in using Microwave CAD software such as Agilent ADS or HFSS. How to fabricate and test integrated circuits, principles. Project credit is limited to be given only on completion of course 163DB).

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

163DB. Microwave and Wireless Design II. (4) Lecture, one hour; laboratory, one hour; outside study, eight hours. Enforced requisites: courses 101A, 101B, 163DA. Limited to senior Electrical Engineering majors. Design of radio frequency circuits and sys- tems, 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, use of available design components, testing, and other real-world issues. Oral and written presentations of project results required. Letter grading. Mr. Chang, Mr. Itoh, Mr. Razavi (164DA in W; 164DB in Sp).

170A. Principles of Photonics. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisites: courses 2, 101A. Development of solid foundation on essential principles of photonics from ground up with minimum prior knowledge on this subject. Topics include optical properties of materials, optical wave propagation and modes, optical resonant structures, optical switching and gating, optical coupling and modulation, optical absorption and emission, principles of lasers and light-emitting diodes, and optical detection. Letter grading. Mr. Liu (FW).

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

170C. Photonic Sensors and Solar Cells. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: course 101A. Recommended: courses 2, 170A. Fundamentals of detection of light for communication and sensing, as well as conversion of light to electrical energy in solar cells. Introduction to radiometry, semiconductor photodetectors, noise processes and figures of merit, thermal detectors, and photovoltaic solar cells of various types and materials. Letter grading. Mr. Williams (Sp).

M171L. Data Communication Systems Laboratory. (2 to 4) (Same as Computer Science M171L) Laboratory, four to eight hours; outside study, two to four hours. Recommended preparation: course M171L. Not open to students with credit for course M171. Interpretation of analogical aspects of digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in executing data transmission experiments. Letter grading. Mr. Jaalal (Sp).

173DA-173DB. Photonics and Communication Design. (4-4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Introduction to measurement of basic photonic devices, including LEDs, lasers, detectors, and amplifiers; fiber-optic fundamentals and measurement of fiber systems. Modulation techniques, including A.M., F.M., and phase modulation; and testing of photonic devices. Letter grading.

Mr. Stafsudd (173DA in W; 173DB in Sp).

176. Photonics in Biomedical Applications. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101A. Study of different types of optical systems and their physical backgrounds. 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) Limited to senior Electrical Engineering majors. Advanced systems design introduction and project design. Signal and processing systems. Introduction to advanced topics related to projects through lecture and laboratories. Open-ended projects vary each offering. Students must design and implement credit signs that manage trade-offs among subsystem components, including cost, performance, ease of use, and other real-world constraints. Oral and written presentation of project results. Letter grading. Mr. Kaiser, Mr. Potrie (180DA in F, 180DB in W), Mr. Pottie (180DA in W, 180DB in Sp).

CM182. Science, Technology, and Public Policy. (4) (Same as Public Policy CM182.) Lecture, three hours. Recent and continuing advances in science and technology are raising profoundly important public policy issues. Consideration of selection of critical policy issues, each of which has substantial ethical, social, economic, political, scientific, and technological consequences. Course surveyed with course CM282. Letter grading.

Mr. Villasenor (Not offered 2017-18).

183DA. Design of Robotic Systems I. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Required: course 183DA-183DB. Recommended: courses 141, 142. Course 183DA is requisite to 183DB. Limited to senior Electrical Engineering majors. Topics in robotic design include integrated electromechanical design, design for manufacturing (DFM), design software, and design automation. Topics in robotic manufacturing include materials, sensors and actuators, programming, and rapid prototyping. Topics in control include manipulation, motion and path planning, learning and adaptation, and human-robot interaction. Additional topics may include distributed and multi-robot systems, bio-inspired robotics, project management, and societal implications. Open-ended projects vary annually. Students are encouraged to form teams and analyze robotic systems for various applications. Oral and written presentation of project results. Letter grading.

Mr. Markovic (Sp)

184DA-184DB. Independent Group Project Design. (2-3) Laboratory, four hours; outside study, seven hours. Enforced requisites: courses M16, 110, 110L. Course 184DA is enforced requisite to 184DB. Courses centered on group project that runs year long to give students intensive experience in design software, microcontroller programming, feedback control, automation, and motor control. In Progress (184DA) and letter (184DB) grading.

Mr. Briggs (Not offered 2017-18)

M185. Introduction to Plasma Electronics. (4) (Same as Physics M122.) Lecture, four hours; discussion, one hour; outside study, eight hours. Required: course 101A or Physics 110A. Senior-level introductory course on electronics of ionized gases and applications to materials processing, generation of coherent radiation and particle beams, and renewable energy sources. Letter grading. Mr. Mori (F).

188. Special Courses in Electrical Engineering. (4) Seminar, four hours; 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 for credit with topic or instructor change. Letter grading.

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 through supplemental readings, papers, or other activities and led by lecture course instructor. May be applied toward honors credit for eligible students. Honors content noted on transcript. P/NP or letter grading.

194. Research Group Seminars: Electrical Engineering. (2 to 4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current research in field. May be repeated for credit. Letter grading.

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

Graduate Courses

201A. VLSI Design Automation. (4) Lecture, four hours; outside study, eight hours. Required: 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. Briggs (Sp)

201C. Modeling of VLSI Circuits and Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Required: course 115C. Detailed study of VLSI circuit and system models considering performance, signal integrity, power and thermal ef-
201D. Design in Nanoscale Technologies. (4) Lecture, four hours; outside study, eight hours. Enforced prerequisite: course 115C. Challenges of digital circuit design and layout in deeply scaled technologies, with focus on both hardware and software interactions. Symposium of large-scale digital design flow; basic manufacturing flow; lithographic patterning, resolution enhancement, and mask preparation; yield and variability; and yield optimization and validation. Design rules and their origins; design layout for manufacturing; test structures and processes control; circuit architecture methods for variability mitigation. Letter grading. (Not offered 2017-18)

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

Mr. Srivastava (F)

M202B. Energy-Aware Computing and Cyber-Physical Systems. (4) (Same as Computer Science M213B.) Lecture, four hours; outside study, eight hours. Requires: course M16 or Computer Science M51A, M51B, Elec 116C, Computer Science M151B, and Computer Science 111. System-level management and cross-layer methods for power and energy consumption in computing and communication systems, ranging from low-power embedded, mobile, personal, enterprise, and data-center scale. Computing, networking, sensing, and control technologies and algorithms for improving energy sustainability in human-cyber-physical systems. Topics include modeling of energy consumption, energy sources, and energy storage; dynamic power management; power-performance scaling and energy proportionality; duty-cycling; power-aware scheduling; low-power protocols; battery modeling and management; thermal management; sensing of power consumption. Letter grading.

Mr. Srivastava (F)

202C. Networked Embedded Systems Design. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Designed for graduate computer science and electrical engineering students. Training in combination with networked embedded systems design combining embedded hardware platform, embedded operating system, and hardware/software interface. Essential graduate student background for research and industry career paths in wireless devices for applications ranging from conventional wireless mobile devices to new area of wireless health. Laboratory design modules and course projects based on state-of-the-art embedded hardware platform. Letter grading. Mr. Kaiser (Not offered 2017-18)

205A. Matrix Analysis for Scientists and Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: one undergraduate course in linear algebra. Designed for first-year graduate students in all branches of engineering, science, and related disciplines. Introduction to matrix theory and linear algebra, language in which virtually all applications of engineering can be conducted. Review of matrices taught in undergraduate courses and introduction to graduate-level topics. Lecture, three hours; discussion. Ms. Dolecek (FW)

M205. Machine Perception. (4) (Same as Computer Science M268B.) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for graduate students. Computational aspects of processing visual and other sensory information. Unified treatment of early vision in man and machine. Integration of symbolic and iconic representations in process of image segmentation. Computing multimodal sensory information by neural-network procedures. Letter grading. Mr. Soatto (F)


M208B. Functional Analysis for Applied Mathematics and Engineering. (4) (Same as Mathematics M268A.) Lecture, four hours; outside study, eight hours. Requires: course 208A (or Mathematics 115A and 115B), Mathematics 131A, 131B, 132. Topics may include L^{p} spaces, Hilbert, Banach, and separable spaces; Fourier transforms; linear functionals. Riesz representation theorem, linear operators and their adjoints; self-adjoint and compact operators. Spectral theory. Differentiation and integration of functions such as Laplacian and eigenvalue problems. Resolvent distributions and Green’s functions. Semigroups. Applications. S/U or letter grading. (Not offered 2017-18)

209AS. Special Topics in Circuits and Embedded Systems. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of circuits and embedded systems. Topics may include L^{p} spaces, Hilbert, Banach, and separable spaces; Fourier transforms; linear functionals. Riesz representation theorem, linear operators and their adjoints; self-adjoint and compact operators. Spectral theory. Differentiation and integration of functions such as Laplacian and eigenvalue problems. Resolvent distributions and Green’s functions. Semigroups. Applications. S/U or letter grading. (Not offered 2017-18)

209BS. Seminar: Circuits and Embedded Systems. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of circuits and embedded systems, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication circuits and systems; embedded processor architecture; computer-aided design and software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. S/U or letter grading. (Not offered 2017-18)

210A. Adaptation and Learning. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: prior training in probability theory, random processes, and linear algebra. Recommended requisites: courses 205A, 241A. Mean-square-error estimation and filters, least-squares estimation and filters, steepest-descent algorithms, stochastic-gradient learning, and gradient-adaptive filters. Letter grading. (Not offered 2017-18)


Mr. Sayed (Not offered 2017-18)


Mr. Villasenor (Not offered 2017-18)


213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, three hours; outside study, nine hours. Requires: course 212A. Digital signal processing and optimization tools, architectures for digital signal processing circuits; integrated circuit modules for digital signal processing; programmable signal processors; CAD tools and cell libraries for application-specific integrated circuit design; case studies of signal and image processing modules. Letter grading. (Not offered 2017-18)

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

214B. Advanced Topics in Speech Processing. (4) Lecture, three hours; computer assignment, two hours; outside study, seven hours. Requires: course M214A. Advanced techniques used in various speech applications. Theory and practice in speech recognition by humans and machine. Physiology and psychophysics of human perception. Dynamic Time Warping (DTW) and Hidden Markov Models (HMM) and their applications. Pattern classification, search algorithms. Aids for hearing impaired. Letter grading. Ms. Alwan (Sp)

215A. Analog Integrated Circuit Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requires: course 115B. Analysis and design of analog integrated circuits. MOS and bipolar device structures and models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, offset and distortion, sampling devices and discrete-time circuits, bandgap references. Letter grading.

Mr. Abidi, Mr. Razavi (F)
215B. Advanced Digital Integrated Circuits. (4)
Lecture, four hours; discussion, one hour; outside study, eight hours. Requisites: courses 121A, 215A, 216A. Analysis and comparison of modern logic families. VLSI memories (SRAM, DRAM, and ROMs). Accuracy of various simulation models and simulation methods for digital circuits. Letter grading.
Mr. Yang (W)

215C. Analysis and Design of RF Circuits and Systems. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 215A. Principles of RF circuit and system design, with emphasis on implementation in VLSI technologies. Basic concepts, communications background, transceiver architectures, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading.
Mr. Abidi, Mr. Razavi (W)

215D. Analog Microsystem Design. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 215A. Analysis and design of data conversion interfaces and filters. Sampling circuits and architecture, D/A conversion techniques, A/D converter architectures, building blocks, precision techniques, discrete- and continuous-time filters. Letter grading.
Mr. Abidi, Mr. Razavi (W)

215E. Signaling and Synchronization. (4)
Lecture, four hours; outside study, eight hours. Requisites: courses 215A, 216A. Analysis and design of circuits and techniques for signal transmission and demodulation for digital systems. Use of both digital and analog design techniques to improve data rate of electronics between functional blocks, chips, and systems. Advanced clocking methodologies, phase-locked loop design for clock generation, high-performance wire-line transmitters, receivers, and timing recovery circuits. Letter grading. Mr. Pamarti (Not offered 2017-18)

M216A. Design of VLSI Circuits and Systems. (4)
(Same as Computer Science M259A.) Lecture, four hours; discussion, two hours; laboratory, four hours; outside study, two hours. Requisites: courses M16 or Computer Science M51A, and 115A. Recommended: course 115C. LSI/VLSI design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on chips. Letter grading. Mr. Markovic (F)

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

M216C. LSI in Computer System Design. (4)
(Same as Computer Science M258C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course M216A. LSI/VLSI design and application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. Letter grading. (Not offered 2017-18)

M217. Biomedical Imaging. (4)
(Same as Bioengineering M217.) Lecture, three hours; outside study, nine hours. Requisite: course 114 or 211A. Optical imaging modalities in biomedicine. Other nonoptical imaging modalities discussed briefly for comparison purposes. Letter grading. Mr. Ozcan (W)

218. Network Economics and Game Theory. (4)
Lecture, four hours; discussion, one hour; outside study, seven hours. Discussion of how different cooperative and noncooperative games among agents can be modeled, analyzed, and optimized. Game theory, and shape emerging interactions among users in different networks and system settings. How strategic agents can successfully compete with each other for limited and time-varying resources by optimizing their decision process and learning from their past interaction with other agents. To determine their optimal actions in these distributed, informationally decentralized environments is to learn and model directly or implicitly other agents’ responses to their actions. Discussion of existing multilagent learning techniques and learning in games, including adjustment processes for learning equilibria, fictitious play, regret-learning, and other learning algorithms. Ms. van der Schar (Not offered 2017-18)

219. Large-Scale Data Mining: Models and Algorithms. (4)
Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction of variety of scalable data mining models that are predictive and causal, from different disciplines. Topics include supervised and unsupervised data modeling tools from machine learning, such as support vector machines, different regression engines, different types of regularization and kernel techniques, deep learning, and Bayesian graphical models. Emphasis on techniques to evaluate relative performance of different methods and algorithms, including potentially scalable data mining and data mining techniques that explore entire data analysis and modeling cycle: collecting and cleaning large-scale data, deriving predictive and causal models, and evaluating performance of different models. Letter grading.
Mr. Roychowdhury (W)

221A. Physics of Semiconductor Devices I. (4)
Lecture, four hours; outside study, eight hours. Physical principles and design considerations of junction devices, thin-film transistor devices. Mr. Yao (W)

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

221C. Microwave Semiconductor Devices. (4)
Lecture, four hours; outside study, eight hours. Physical principles and design considerations of microwave solid-state devices; Schottky barrier diode devices, IMPATT diodes, transferred electron devices, tunnel diodes, microwave transistors. Letter grading. Mr. K.L. Wang, Mr. Yao (Not offered 2017-18)

222. Integrated Circuits Fabrication Processes. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 2. Principles of integrated circuit fabrication processes. Technological limitations of integrated circuits design. Topics include bulk crystal and epitaxial growth, thermal oxidation, diffusion, ion-implantation, chemical vapor deposition, dry etching, lithography, and metallization. Introduction of advanced process simulation tools. Letter grading.
Mr. Yao (W)

223. Solid-State Electronics I. (4)
Lecture, four hours; outside study, eight hours. Recommended requisite: course 270. Energy band theory, electronic and hole band structure, semiconductor materials, and alloy semiconductors, defects in semiconductors. Recombination mechanisms, transport properties. Letter grading.
Mr. Yao (W)

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

225. Physics of Semiconductor Nanostructures and Devices. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 223. Theoretical methods for calculating the electronic and optical properties of semiconductor structures. Quantum size effects and low-dimensional systems. Application to semiconductor nanometer scale devices, including negative resistance diodes, transistors, and detectors. Letter grading.
Mr. K.L. Wang (Sp, alternate years)

226. Seminar: Advanced Topics in Solid-State Electronics. (4)
Seminar, four hours; outside study, eight hours. Recommended requisite: course 224. Current research areas, such as radiation effects in semiconductor devices, diffusion in semiconductors, optical and microwave semiconductor devices, nonlinear optics, and electron emission. Letter grading. (Not offered 2017-18)

228. Seminar: Advanced Electrical Engineering Seminar. (2)
Seminar, two hours; outside study, six hours. Preparation; successful completion of Ph.D. 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 should report on tutorial of their research topic in their dissertation area. May be repeated for credit. S/U grading. (Not offered 2017-18)

230A. Detection and Estimation in Communication. (4)
Lecture, four hours; discussion, one hour; outside study, seven hours. Review of course 131A. Applications of estimation and detection concepts in communication and signal processing; random signal and noise characterizations by analysis and simulation; 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. Yao (F)

230B. Digital Communication Systems. (4)
Mr. Pottie (W)

230C. Signal Processing in Communications. (4)
Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 230A. Concepts and implementations of signal processing in communication and signal processing systems. Spectral analysis using Fourier transform and windowing, parametric modeling, eigen-decomposition methods, time-frequency analysis, wavelet transform, and 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 (W)

230D. Algorithms and Processing in Communication Systems. (4)
Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 230A. Review of computational linear algebra methods on QRD, eigen- and singular-value decompositions, and LS estimation with applications to estimation and detection in communication, radar, imaging, and array processing systems. Systolic and parallel algorithms and VLSI architectures for high performance and high throughput real-time estimation, detection, decoding, and beamforming applications. Letter grading.
Mr. Pottie (Sp)

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

231B. Network Information Theory. (4)
Lecture, four hours; outside study, eight hours. Enforced requisite: course 231A. Point-to-point multiple-input multiple-output (MIMO) wireless channels: capacity and outage; single-hop networks: multiple access, broadcast, interference, and relay channels; channels and sources with side-information; basis for multiterminal lossy data compression; basics of network information flow over general noisy networks. Letter grading.
Mr. Diggavi (Not offered 2017-18)

231E. Channel Coding Theory. (4)
Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 230A. Review of fundamental error control codes and decoding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading.
Mr. Wesel (Sp)

232B. Telecommunication Switching and Queuing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Modeling, analysis, and design of queuing systems with applications to switching systems, communications networks, wireless systems and networks, and business and management systems. Modeling, analysis, and design of Markovian and non-Markovian queueing systems. Priority service queues. Queueing networks with applications to computer communications, Internet, and management networks. Letter grading. Mr. Rubin (W)


232E. Graphs and Network Flows. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Solution to analysis and synthesis problems that may be formulated as flow problems in capacity constrained (or cost constrained) networks. Development of tools of network flow theory using graph theoretic methods; application to communication, transportation, and transmission problems. Letter grading. Mr. Roychowdhury (Sp)

234A. Network Coding Theory and Applications. (4) Lecture, four hours; outside study, eight hours. Algebraic approach and main theorem in network coding, combinatorial approach and alphabet size, linear programming approach and throughput benefits, network code design algorithms, secure network coding, network coding for wireless, other applications. Letter grading. Ms. Frangou (Not offered 2017-18)

235A. Mathematical Foundations of Data Storage Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131 or equivalent. Research developments in new mathematical models and techniques for emerging large-scale, ultra-reliable, fast, and affordable data storage systems. Topics include, but are not limited to, graph-based codes and algebraic codes and decoders for modern storage devices (e.g., Flash), rank modulation, rewriting codes, algorithms for data deduplication and synchronization, and redundant array of independent disks (RAID) systems. Letter grading. Mr. Roychowdhury (Sp)

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


238. Multimedia Communications and Processing. (4) Lecture, four hours; outside study, eight hours. Requisite: course M237. Principles and algorithms of real-time multimedia communications and processing across heterogeneous Internet and wireless channels. Due to flexible and low-cost infrastructure, new networks and communication channels enable variety of delay-sensitive multimedia transmission applications and provide varying resources with limited support for quality of service required by delay-sensitive, bandwidth-intensive, and loss-tolerant multimedia applications. New concepts, principles, theories, and practical solutions for cross-layer design that can provide optimal adaptation for time-varying network characteristics, adaptive and delay-sensitive applications, and multimedia transmission environments. Discussion of online learning and learning how to make decisions in broad context, including Markov decision processes, optimal stopping, reinforcement learning, structural results for online learning, multiarmed bandit learning, multiagent learning. Letter grading. (Not offered 2017-18)

239AS. Special Topics in Signals and Systems. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of signals and systems, such as communications, control, image processing, information theory, multimedia, computer networking, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U grading. Ms. Roychowdhury (Not offered 2017-18)

239BS. Seminar: Signals and Systems. (2 to 4) Seminar, four to eight hours; outside study, four to eight hours. Special topics and current and advanced topics in one or more aspects of signals and systems, such as communications, control, image processing, information theory, multimedia, computer networking, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U grading. (Not offered 2017-18)

M240A. Linear Dynamic Systems. (4) (Same as Electrical Engineering M240 and Mechanical and Aerospace Engineering M270A.) Lecture, four hours; outside study, eight hours. Requisite: course 141 or Mechanical and Aerospace Engineering 171A. State-space descriptions of linear time-invariant and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvalues and eigenvectors, singular values, Cayley/Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle. Continuous-time transfer function techniques. Letter grading. Mr. Tabuada (F)

240B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 141, M240A. Introduction to optimal control, with emphasis on detailed study of Liapunov stability theory and design with quadratic cost criteria. Relationships to classical control system design. Letter grading. (Not offered 2017-18)

M240C. Optimal Control. (4) (Same as Chemical Engineering M280C and Mechanical and Aerospace Engineering M270C.) Lecture, four hours; outside study, eight hours. Requisite: course 240B. Applications of variational methods, Pontryagin maximum principle. Hamilton-Jacobi-Bellman equation (dynamic programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. (Not offered 2017-18)


M242A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Mechanical and Aerospace Engineering M272A.) Lecture, four hours; outside study, eight hours. Requisite: course M240A or Chemical Engineering M260A or Mechanical and Aerospace Engineering M248A. Key concepts and results for studying solutions of time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Lyapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading. Mr. Tabuada (W)

M248S. Seminar: Systems, Dynamics, and Control Topics. (2) (Same as Chemical Engineering M297 and Mechanical and Aerospace Engineering M259A.) Seminar, two hours; outside study, six hours. Limited to graduate engineering students. Presentations of research topics by leading research engineers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading. (Not offered 2017-18)

M250B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Bioengineering M250B and Mechanical and Aerospace Engineering M280B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course M153. Advanced discussion of microfabrication 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 reactions, substrate mechanical properties, and residual/intrinsic stress. Letter grading. Mr. Candler (Not offered 2017-18)
Letter grading.

Mr. Rahmat-Samii (F)

Mr. Rahmat-Samii (Sp)


Mr. Itoh (Sp)

Mr. Stafsudd (F)

271. Classical Laser Theory. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course CM250A. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding, molecular vibrations, top-down and bottom-up (self-assembled) nanofabrication; nanocharacterization; nanomaterials, nanoelectronics, and nanobio-detection technology. Introduction to new knowledge and techniques in nano areas to understand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading.
Mr. Chen (W)

284A. Advanced Engineering Electrodyamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101B, 162A. Advanced treatment of concepts in electromagnetics and their applications to modern engineering problems. Vector calculus, potential, electromagnetic system. Solutions of wave equation and special functions. Reflection, transmission, and polarization. Vector potential, duality, reciprocity, and equivalence theorems. Scattering from cylinder, half-plane, wedge, and sphere, including radar cross-section characterization. Green’s functions in electromagnetics and dyadic calculus. Letter grading.
Mr. Rahmat-Samii (F)

285B. Advanced Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M185, and 285A or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave propagation, plasma oscillations, ion acoustic waves, cyclotron waves, hydromagnetic waves, drift waves. Rayleigh/Taylor, Kelvin/Helmholtz, universal, and streamlining instabilities. Application to experiments in fully and partially ionized gases. Letter grading.
Mr. Villasenor (Not offered 2017-18)

Mr. Villasenor (Not offered 2017-18)

Mr. Itoh (W)

279AS. Special Topics in Physical and Wave Electronics. (4) Lecture, four hours: outside study, eight hours. Material on current or advanced topics in one or more aspects of physical and wave electronics, such as electromagnetic, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U or letter grading.
Mr. Williams (W,Sp)

279BS. Seminar: Physical and Wave Electronics. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of physical and wave electronics, such as electromagnetic, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading.
(Not offered 2017-18)

279CS. Clean Green IGERT Brown-Bag Seminar. (1) Seminar; two to four hours; outside study, four to eight hours. Seminars and discussions in Clean Energy for Green Industry (IGERT) Research. Literature seminar presented by graduate students and experts from around country who conduct research in energy, environment, sustainability. S/U grading.
Mr. Williams (Not offered 2017-18)


M252. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Bioengineering M252 and Mechanical and Aerospace Engineering M252B.) Lecture, four hours; outside study, eight hours. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading.
Mr. Candier (Sp)

M255. Neuroengineering. (4) (Same as Bioengineering M260 and Neuroscience M260.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 6B. Introduction to engineering and technology of biologic and neural signal recording, processing, and stimulation. Topics include bioelectricity, electrophysiology (action potentials, local field potentials, EEG, EEOX), intracellular and extracellular recording, microelectrode technology, neural signal processing (neural signal frequency bands, filtering, spike detection, spike sorting, stimulation artifact removal, brain-computer interfaces, device-brain stimulation, and prosthetics. Letter grading.
Mr. Markovic (Not offered 2017-18)

M256A-M256B-M256C. Evaluation of Research Literature in Neuroengineering. (2-2-2) (Same as Bioengineering M256A-M256B-M256C.) Lecture, two hours; outside study, four hours. Discussion and analysis of current literature related to neuroengineering research. S/U grading.
Mr. Markovic (Not offered 2017-18)

M257. Nanoscience and Technology. (4) (Same as Mechanical and Aerospace Engineering M258B.) Lecture, four hours; outside study, eight hours. Enforced requisite: course CM250A. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding, chemical reactions, top-down and bottom-up (self-assembled) nanofabrication; nanocharacterization; nanomaterials, nanoelectronics, and nanobio-detection technology. Introduction to new knowledge and techniques in nano areas to understand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading.
Mr. Chen (W)

280A. Advanced Engineering Electrodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101B, 162A. Advanced treatment of concepts in electromagnetics and their applications to modern engineering problems. Vector calculus, potential, electromagnetic system. Solutions of wave equation and special functions. Reflection, transmission, and polarization. Vector potential, duality, reciprocity, and equivalence theorems. Scattering from cylinder, half-plane, wedge, and sphere, including radar cross-section characterization. Green’s functions in electromagnetics and dyadic calculus. Letter grading.
Mr. Rahmat-Samii (F)

Mr. Rahmat-Samii (F)

299S. Seminar: Physical and Wave Electronics. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of physical and wave electronics, such as electromagnetic, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U or letter grading.
Mr. Williams (W,Sp)

Electrical and Computer Engineering / 95

Mr. Candler (Sp)
spired by complex IP questions facing technology companies today. S/U or letter grading.

Mr. Villasenor (Not offered 2017-18)

295. Academic Technical Writing for Electrical Engineers, (3) Seminar, three hours. Designed for electrical engineering Ph.D. students who have completed preliminary examinations. Students read models of good writing and learn to make rhetorical observations and writing decisions, improve their academic and technical writing skills by writing and revising conference and journal papers, and practice writing for and speaking to various audiences, including potential students, engineers outside their specific fields, and nonengineers (colleagues outside field, policymakers, etc.). Students write in variety of genres, all related to their professional development as electrical engineers. Emphasis on writing as vital way to communicate precise technical and professional information in distinct contexts, directly resulting in specific outcomes. S/U grading. (F,W,Sp)

296. Seminar: Research Topics in Electrical Engineering, (2) Seminar, two hours; outside study, four hours. Advanced study and analysis of current topics in electrical engineering. Discussion of current research and literature in research specialty of faculty member teaching course. May be repeated for credit. S/U grading. (F,Sp)

297. Seminar Series: Electrical Engineering, (1) Seminar, 90 minutes; outside study, 90 minutes. Limited to graduate electrical engineering students. Weekly seminars and discussion by invited speakers on research topics of heightened interest. S/U grading. (F,W,Sp)

298. Seminar: Engineering, (2 to 4) Seminar, to be arranged. Limited to graduate electrical engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. S/U or letter grading. (Not offered 2017-18)


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

M495. Teaching Preparation Seminar: Teaching and Writing Pedagogies for Electrical Engineers, (2) (Same as English Composition M495K). Seminar, two hours. Limited to graduate electrical engineering students. Required of all departmental teaching assistants (TAs). May be taken concurrently while holding a TA appointment. Seminar on pedagogy and logistics of being a TA with emphasis on student-centered teaching, clear communication, and multimodal teaching and learning. S/U grading. Ms. Alwan (F)

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

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

597B. Preparation for Ph.D. Preliminary Examinations, (2 to 16) Tutorial, to be arranged. Limited to graduate electrical engineering students. S/U grading.

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


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

Materials Science and Engineering

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

Professors
Russel E. Caffisch, Ph.D.
Gregory P. Carman, Ph.D.
Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)
Yong Chen, Ph.D.
Bruce S. Dunn, Ph.D. (Nippon Sheet Glass Company Professor of Materials Science)
Nasr M. Ghoniem, Ph.D.
Mark S. Goorsky, Ph.D.
Vijay Gupta, Ph.D.
Yu Huang, Ph.D.
Subramanian S. Iyer, Ph.D.
Ioanna Kakoulli, D.Phil.
Richard B. Kaner, Ph.D.
Xiaochun Li, Ph.D.
Ali Mosleh, Ph.D., NAE (Evalyn Knight Professor of Engineering)
Qibing Pei, Ph.D.
Dwight C. Streit, Ph.D.
Sarah H. Tolbert, Ph.D.
Kang L. Wang, Ph.D. (Raytheon Company Professor of Electrical Engineering)
Paul S. Weiss, Ph.D.
Benjamin M. Wu, D.D.S., Ph.D.
Ya-Hong Xie, Ph.D.
Jenn-Ming Yang, Ph.D.
Yang Yang, Ph.D. (Carol and Lawrence E. Tannas, Jr., Endowed Professor of Engineering)

Professors Emeriti
Alan J. Ardell, Ph.D.
David L. Douglass, Ph.D.
John D. Mackenzie, Ph.D. (Nippon Sheet Glass Company Professor Emeritus of Materials Science)
Kanji Ono, Ph.D.
Aly H. Shabaik, Ph.D.
King-Ning Tu, Ph.D.

Associate Professors
Suneel Kodambaka, Ph.D.
Jaime Marian, Ph.D.
Gaurav Sant, Ph.D.

Assistant Professor
Ximin He, Ph.D.

Adjunct Associate Professors
Eric P. Bescher, Ph.D.
Esther H. Lan, Ph.D.
Sergey Prikhopodko, Ph.D.

Scope and Objectives
At the heart of materials science and engineering is the understanding and control of
the microstructure of solids. Microstructure is used broadly in reference to electronic and atomic structure of solids—and defects within them—at size scales ranging from atomic bond lengths to airplane wings. The structure of solids over this wide range dictates their structural, electrical, biological, and chemical properties. The phenomenological and mechanistic relationships between microstructure and the macroscopic properties of solids are, in essence, what materials science is all about.

Materials engineering builds on the foundation of materials science and is concerned with the design, fabrication, and optimal selection of engineering materials that must simultaneously fulfill dimensional, property, quality control, and economic requirements.

The undergraduate program in the Department of Materials Science and Engineering leads to the B.S. degree in Materials Engineering. Students are introduced to the basic principles of metallurgy and ceramic and polymer science as part of the department’s Materials Engineering major. A joint major field, Chemistry/Materials Science, is offered to students enrolled in the Department of Chemistry and Biochemistry (College of Letters and Science).

The department also has a program in electronic materials that provides a broad-based background in materials science, with opportunity to specialize in the study of those materials used for electronic and optoelectronic applications. The program incorporates several courses in electrical and computer engineering in addition to those in the materials science curriculum.

The graduate program allows for specialization in one of the following fields: ceramics and ceramic processing, electronic and optical materials, and structural materials.

**Department Mission**

The Department of Materials Science and Engineering faculty members, students, and alumni foster a collegial atmosphere to produce (1) highly qualified students through an educational program that cultivates excellence, (2) novel and highly innovative research that advances basic and applied knowledge in materials, and (3) effective interactions with the external community through educational outreach, industrial collaborations, and service activities.

**Undergraduate Program Educational Objectives**

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

**Materials Engineering Option**

**Preparation for the Major**

*Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20; Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B (or Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C.*

**The Major**

*Required: Civil and Environmental Engineering 91 (or Mechanical and Aerospace Engineering 101), 108, Electrical and Computer Engineering 100, Materials Science and Engineering 104, 110, 110L, 120, 130, 131, 131L, 132, 143A, 150, 160; one upper-division mathematics course selected from Civil and Environmental Engineering 103, Electrical and Computer Engineering 102, Mathematics 132, Mechanical and Aerospace Engineering 182B, 182C; two laboratory courses (4 units) from Materials Science and Engineering 121L, 141L, 143L, 161L, or up to 2 units of 199; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Materials Science and Engineering 140); and two major field elective courses (12 units) from Chemical Engineering C114, Civil and Environmental Engineering 130, 135A, Electrical and Computer Engineering 2, 123A, 123B, Materials Science and Engineering 111, 121, 122, 151, 161, 162, Mechanical and Aerospace Engineering 156A, 166C, plus at least one elective course (4 units) from Chemistry and Biochemistry 30A, 30AL, Electrical and Computer Engineering 131A, Materials Science and Engineering 170, 171, Mathematics 170A, or Statistics 100A.*

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

**Electronic Materials Option**

**Preparation for the Major**

*Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20; Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B (or Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C.*

**The Major**

*Required: Electrical and Computer Engineering 100, 101A, 121B, Materials Science*
and Engineering 104, 110, 110L, 120 (or Electrical and Computer Engineering 2, 121, 121L, 122, 130, 131, 131L, 132, 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; one capstone design course (Materials Science and Engineering 140); and one major field elective course (4 units) from Electrical and Computer Engineering 110, 131A, Materials Science and Engineering 111, 143A, or 162.

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

Graduate Study

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

The following introductory information is based on the 2017-18 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at https://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

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

Materials Science and Engineering M.S.

Areas of Study

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

Course Requirements

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

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


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

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 103, 110L, M116L, M171L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Thesis Plan

In addition to the course requirements, under the thesis plan students are required to write a thesis on a research topic in materials science and engineering supervised by the thesis adviser. An M.S. thesis committee approves the thesis.

Comprehensive Examination Plan

Consult the graduate adviser for details. If the comprehensive examination is failed, students may be reexamined once with the consent of the graduate adviser.

Materials Science and Engineering Ph.D.

Major Fields or Subdisciplines

Ceramics and ceramic processing, electronic and optical materials, and structural materials.

Course Requirements

There is no formal course requirement for the Ph.D. degree, and students may substitute coursework by examinations. Normally, however, students take courses to acquire the knowledge needed to satisfy the written preliminary examination requirement. In this case, a grade-point average of at least 3.33 in all courses is required, with a grade of B– or better in each course.
The basic program of study for the Ph.D. degree is built around one major field and one minor field. The major field has a scope corresponding to a body of knowledge contained in nine courses, at least six of which must be graduate courses, plus the current literature in the area of specialization. Materials Science and Engineering 599 may not be applied toward the nine-course total. The major fields named above are described in a Ph.D. major field syllabus, each of which can be obtained in the department office. The minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor field is selected to support the major field and is usually a subset of the major field.

Written and Oral Qualifying Examinations

During the first year of full-time enrollment in the Ph.D. program, students take the oral preliminary examination that encompasses the body of knowledge in materials science equivalent to that expected of a bachelor’s degree. If students opt not to take courses, a written preliminary examination in the major field is required. Students may not take an examination more than twice.

After passing both preliminary examinations, students take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. Faculty members holding joint appointments with the department are considered inside members.

Fields of Study

Ceramics and Ceramic Processing

The ceramics and ceramic processing field is designed for students interested in ceramics and glasses, including electronic materials. As in the case of metallurgy, primary and secondary fabrication processes such as vapor deposition, sintering, melt forming, or extrusion strongly influence the microstructure and properties of ceramic components used in structural, electronic, or biological applications. Formal course and research programs emphasize the coupling of processing treatments, microstructure, and properties.

Electronic and Optical Materials

The electronic and optical materials field provides an area of study in the science and technology of electronic materials that includes semiconductors, optical ceramics, and thin films (metal, dielectric, and multi-layer) for electronic and optoelectronic applications.

Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications that include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/optical properties in these materials systems.

Structural Materials

The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetals, 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 Electronics 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

Theory and numerical simulation for materials physics, epitaxial growth, nanoscale systems, semiconductor device properties and design in applications to quantum well devices, quantum dots, nanocrystals and quantum computing

Gregory P. Gorman, Ph.D. (Virginia Tech, 1991)
Electromagnetoelasticity models and characterization, thin film shape memory, nanoscale multifunctions, magnetoelectics 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

Bruce S. Dunn, Ph.D. (UCLA, 1974)
Synthesis and characterization of electronic materials, energy storage, sol-gel materials and chemistry

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

Mark S. Goorsky, Ph.D. (MIT, 1989)
Electronic materials processing, strain relaxation in epitaxial semiconductors and device structures, high-resolution X-ray diffraction of semiconductors, ceramics, and high-strength alloys

Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

Yi-Yung Huang, Ph.D. (Harvard, 2003)
Nanomaterial fabrication and development, bio-nano structures

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

Chemical and physical properties of non-metallic archaeological materials, alteration processes in archaeological Virenque materials and pigments

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

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

104. Science of Engineering Materials. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20B, 20L, Physics 1A, 1B. General introduction to different types of materials used in engineering designs: metals, ceramics, plastics, and composites. Relationship between structure (crystals and microstructure) and properties of technological materials. Illustration of their fundamental differences and their applications in engineering. Letter grading. Mr. Dunn (W)/Sp. M105. Principles of Nanoscience and Nanotechnology. (4) (Same as Engineering M101.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20B, Physics 1C. Introduction to underlying science encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena that emerge in very small systems (typically with feature sizes below few hundred nanometers) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties, electron transport, structural stability, self-assembly, templated assembly and applications of various nanostructures such as quantum dots, nanoparticles, quantum wires, quantum wells and multilayers, carbon nanotubes. Letter grading. Mr. Ozolins (F).

110. Introduction to Materials Characterization A (Crystal Structure, Nanostructures, and X-Ray Scattering). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 104. Modern methods of materials characterization; fundamentals of crystallography, properties of X rays, X-ray scattering; powder method, Laue method; determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray spectroscopy; design of materials characterization procedures. Letter grading. Mr. Goryosky (F).

110L. Introduction to Materials Characterization A Laboratory. (2) Laboratory, four hours; outside study, two hours. 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.

111. Introduction to Materials Characterization B (Electron Microscopy). (4) (Formerly numbered C111.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of fundamental and technological 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 (F).


120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 104, 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. Mechanics and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading. Mr. Yang (W).

Mr. Hu (Sp)

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

Mr. Goorsky (W)

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

Mr. Goorsky (W)

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

Mr. F (Sp)

131. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decompositions, design of heat treatment processes of alloys, growth of intermetallic compounds, reactions of radiation-resistant alloys, recrystallization, and grain growth. Letter grading.

Mr. T (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 performing experiments to study interdiffusion, growth of intermediate phases, recrystallization, and grain growth in metals. Analysis of data. Comparison of results with theoretical models. Letter grading.

Mr. T (W)


Mr. J-M. Yang (Sp)

140. Materials Selection and Engineering Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: at least two courses from 132, 150, 160. Explicit guidance among myriad materials available for design in engineering. Properties and applications of steels, nonferrous alloys, polymeric, ceramic, and composite materials, coatings, Materials selection, treatment, and serviceability emphasized as part of successful design. Design projects. Letter grading.

Mr. J-M. Yang (Sp)

141L. Computer Methods and Instrumentation in Materials Science. (2) Laboratory, four hours. Preparation: basic knowledge of BASIC or C or assembly language. Limited to junior/senior Materials Science and Engineering majors. Interface and control techniques, real-time data acquisition and processing, computer-aided testing. Letter grading.

Mr. Goorsky (W)

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

Mr. J-M. Yang (W)

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

Mr. Ono (Not offered 2017-18)

150. Introduction to Polymers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Polymerization mechanisms, molecular weight and distribution, chemical structure and bonding, structure crystallinity, and morphology and their effects on properties of commodity polymers, engineering plastics, and performance of polymeric materials in various phases, gas-solid reactions, design of oxidation inhibitors. Letter grading.

Mr. Pei (W)


Mr. Dunn (Sp)

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

Mr. Dunn (F)

161. Processing of Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour. Requisite: course 160. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and electronics. Processing operations, including modern techniques of powder synthesis, greenware forming, sintering, glass melting, Microstructural properties relations in ceramics. Fracture analysis and design with ceramics. Letter grading.

Mr. Dunn (Sp)


Mr. Dunn (Sp)

162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 104, Physics 1C. Utilization of ceramics in microwaves; thick film and thin film resistors, capacitors, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics; ferroelectric ceramics and electro-optic devices; optical wave guide applications and designs. Letter grading.

Mr. Dunn (Sp)

170. Engaging Elements of Communication: Oral Communication. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive oral presentation and communication skills provided by building on strengths of individual personal styles in creation of positive interpersonal relations. Skill set prepares students for different types of academic and professional presentations for wide range of audiences. Learning environment is highly supportive and interactive as it helps students creatively develop and greatly expand effectiveness of communication and presentation skills. Letter grading.

Mr. Xie (Not offered 2017-18)

CM180. Introduction to Biomaterials. (4) Same as Biomedical Engineering CM178. (2 to 8) Lecture, one hour; discussion, two hours; outside study, seven hours. Requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for biomedical applications or restoration of tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM280. Letter grading.

Mr. Wu (Not offered 2017-18)


Mr. Y. Yang (F)


Mr. J-M. Yang (Sp)


Mr. Dunn (Sp)


Mr. Ozolins (F)

210. Diffraction Methods in Science of Materials. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Requisite: course 110. Theory of diffraction of waves (X-rays, electrons, and neutrons) in crystalline and noncrystalline materials. Long- and short-range order in crystals, structural effects of
plastic deformation, solid-state transformations, ar-
rangements of atoms in liquids and amorphous solids.
Lecture, laboratory, four hours. Recommended
requisite: courses 104, 110. 211. Introduction to
Materials Characterization B (Electro Microscopy).
(Formerly numbered C211.) Lecture, three hours; labora-
tory, two hours; outside study, seven hours. Requisites:
courses 104, 110. Chemistry of materials and
chemistry of materials; transmission electron micros-
copy; reciprocal lattice, electron diffraction, stereo-
graphic 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)
GM212. Cultural Materials Science II: Characteri-
(4) (Same as Conservation M210.) Lecture, four hours.
Preparation: general chemistry, inorganic and organic
chemistry, materials science. Principles and methods of
determining composition and structure of materials
using basic concepts from physics and chemistry. In
clude studies of crystallography, design of archaeo-
logical and ethnographic materials characterization
methods. Examine properties of archaeological and ethno-
markers, and the application of different methods to
cultural and historical materials. Letter grading.
Ms. Kakoulli (Sp)
M213L. Cultural Materials Science Laboratory:
Technical Study. (4) (Same as Conservation M210L.)
Laboratory, four hours. Enforced requisites: Conser-
vation M210 (or M216) and one course from C160
through C264. Enforced corequisite: course CM212 or
C112 or Conservation M210. Research-based labora-
atory through object-based problem-solving ap-
proach to conservation and materials science. Em-
nental techniques, characterization, and analysis of
materials science principles and reverse engineering
materials through technical tools to determine condition
defects) and technological features of archaeological and ethno-
ographic materials. Determination of basic theoreti-
cal knowledge on imaging and photons technology and
practical skills on conservation photo-document-
analysis, (forensic) photography, and advance-
new imaging techniques. Letter grading.
Ms. Kakoulli (W)
M214. Structure, Properties, and Deteriora-
tion of Materials: Rock Art, Wall Paintings,
Mosaics. (2) (Same as Conservation M264.) Lecture,
three hours. Recommended preparation: basic knowledge of
general chemistry and materials science. Introduction to
materials and techniques of rock art, wall paintings,
including painted surfaces on cement and com-
posite decorative architectural surfaces, and mos-
aics. Archaeological and ethnographic context, tech-
niques, and materials. Pigments, colorants, and
binding media. Chemical, optical, and structural properties
between composition (chemistry), structure (crystals,
molecular arrangement, and microstructure), and properties explained
using basic concepts from physics and chemistry; In-
trinsic and extrinsic resistance to weathering, Causes,
sources, and mechanisms of deterioration
(physical, chemical, and biochemical). Letter grading.
Mr. Goorsky (W)
M215. Conservation Laboratory: Rock Art, Wall
Paintings, and Mosaics. (4) (Same as Conservation
M250.) Laboratory, four hours. Enforced requisites:
course M216 (or C112 or Conservation M210),
Conservation M215. Research-based laboratory on
conservation of rock art, wall paintings (archaeological and modern
composites on cement), mosaics, and decorated ar-
chitectural surfaces. Principles and methods of analy-
ysis of materials (using materials science and re-
verse engineering processes) for characterization of
technology, constituent materials, and alteration
products; development of conservation treatment
processes; and testing of conservation methods and
conservation treatment. Letter grading.
M216. Science of Conservation Materials and
Methods I. (4) (Same as Conservation M216.) Lec-
ture, two hours; laboratory, two hours. Recommended
requisite: laboratory safety fundamental concepts course by Office of Environment, Health,
and Safety. Introduction to physical, chemical, and mechanical properties of materials
employed for preservation of archaeological and cultural materials) and their aging characteristics. Science
and application methods of traditional organic and in-
organic systems and introduction of novel technology
based on bio-mineralization processes and nano-
structured materials. Letter grading.
Ms. Kakoulli (W)
221. Science of Electronic Materials. (4) Lecture,
four hours; outside study, eight hours. Requisite:
courses 120, 130, 131, and 133 that affect semiconductor
materials. Topics include bondings, carrier statistics,
band-gap engineering, optical and transport properties,
and characterization. Letter grading.
Mr. Goorsky (Sp)
222. Growth and Processing of Electronic Materi-
als. (4) Lecture, four hours; outside study, eight hours. Requisites:
courses 120, 130, 131. Thermody-
namics and statistical theory of semiconductor growth
and device processing. Particular emphasis on fundamentals of growth (bulk and epitaxial), het-
eropitaxy, implantation, oxidation, and gettering.
Mr. Goorsky (W)
223. Materials Science of Thin Films. (4) Lecture,
four hours; outside study, eight hours. Requisites:
courses 120, 131. Fabrication, structure, and prop-
erty correlations of thin films used in microelectronics
for data and information processing. Topics include
film deposition, interfacial properties, stress and strain,
electromigration, phase changes and kinetics,
reliability. Letter grading.
Mr. Gillis (W)
224. Deposition Technologies and Their Applica-
tions. (4) Lecture, four hours; outside study, eight
hours. Examination of physics behind modern of
modern thin film deposition technologies based on
vapor deposition, plasma enhanced chemical vapor
growth and device processing. Particular emphasis on
fundamentals of growth (bulk and epitaxial), hetero-
pitaxy, implantation, oxidation, and gettering. Letter grading.
Ms. Kakoulli (W)
225. Materials Science of Surfaces. (4) Lecture,
four hours; outside study, eight hours. Requisites:
course 120, Chemistry 115A. Introduction to atomic and
electronic structure of surfaces. Survey of methods for determining composition and structure
of surfaces and near-surface layers of solid-state ma-
terials. Emphasis on scanning probe microscopy,
Auger electron spectroscopy, X-ray photoelectron
spectroscopy, ultraviolet photoelectron spectro-
copy, secondary ion mass spectrometry, ion scat-
tering, Rutherford backscattering, and nuclear
scattering. Applications in microelectronics, opto-
electronics, metalurgy, polymers, biological and bio-
compatible materials, and catalysis. Letter grading.
Ms. Gillis, Mr. Goorsky (Sp)
226. Si-CMOS Technology: Selected Topics in Ma-
terials Science. (4) Lecture, three hours; discussion,
one hour; outside study, eight hours. Recommended
preparation: Electrical Engineering 221B. Requisites:
courses 120, 130, 131. Selected topics in materials science from modern Si-CMOS technology,
including technological challenges in high k/metal gate stacks, strained Si FETs, SOI and three-dimen-
sional FETs, source/drain engineering including tran-
sient-enhanced diffusion, nonvolatile memory, and
metallization for ohmic contacts. Letter grading.
Mr. Xie (F)
243A. Fracture of Structural Materials. (4) Lecture,
four hours; laboratory, two hours; outside study, four hours. Requisite: course 143A. Fracture technolo-
gies, mechanisms, stress, fatigue, fracture in reactive envi-
rnments, alloy development, fracture-safe design.
Mr. J-M. Yang (W)
243C. Dislocations and Strengthening Mecha-
nisms in Solids. (4) Lecture, four hours; discussion,
one hour; outside study, seven hours. Requisite:
course 143A. Fracture techniques, and properties
of metals and alloys, deformation, stress,
mechanics, and interaction of dislocations,
mechanisms of yielding, work hardening, and other
strengthening. Letter grading.
Mr. Xie (F; odd years)
246A. Mechanical Properties of Nonmetallic Crys-
talline Solids. (4) Lecture, four hours; outside study,
eight hours. Requisite: course 160. Materials and en-
vironmental factors affecting mechanical properties
of nonmetallic crystalline solids, including atomic
bonding and structure, atomic-scale defects, micro-
structural features, residual stresses, temperature,
stress state, strain rate, size and surface conditions.
Letter grading.
Mr. Dunn (W)
246B. Structure and Properties of Glasses. (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. Mechani-
cal, electrical, and optical properties of glass and re-
lation to structure. Letter grading.
Mr. Dunn (W, even years)
248D. Electronic and Optical Properties of Ceram-
icas. (4) Lecture, four hours; discussion, seven
hours. Limited to graduate students. 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) Lec-
ture, four hours; discussion, two hours; outside study,
seven hours. Comprehensive introduction to mate-
rials 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 ap-
proaches 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 re-
search laboratory included. Letter grading.
Mr. Y. Yang (Sp)
250B. Advanced Composite Materials. (4) Lecture,
four hours; outside study, eight hours. Preparation:
B.S. in Materials Science and Engineering. Requisite:
course 151. Fabrication methods, structure and
properties of advanced composite materials. Fibers;
resin-, metal-, and ceramic-matrix composites. Phys-
ical, mechanical, and nondestructive characterization
techniques. Letter grading.
Mr. Y. Yang
251. Chemistry of Soft Materials. (4) Lecture,
outside study, eight hours. Introduction to organic soft materials, in-
ceterial principles of chemistry, and polymer chemistry. Topics include three main catego-
ries of soft materials: organic molecules, synthetic
polymers, and biomaterials and ceramics. Exten-
sive description and discussion of structure-property
relation, spectroscopic and experimental tech-
niques, and preparation methods for various soft
materials. Letter grading.
Mr. Pei (F)
252. Organic Polymer Electronic Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to organic electronic materials with emphasis on materials chemistry and processing. Topics include conjugated polymers; highly doped, highly conductive applications; applications as processable metals and in various electrical, optical, and electrochemical devices. Synthesis of semiconductor polymers for organic light-emitting diodes, solar cells, thin-film transistors. Introduction to emerging field of organic electronics. Letter grading. Mr. Pei (F)

270. Computer Simulations of Materials. (4) Lecture, four hours; outside study, eight hours. Introduction to modern methods of computational modeling in materials science. Topics include basic statistical mechanics, classical molecular dynamics, and Monte Carlo methods, with emphasis on understanding basic physical ideas and learning to design, run, and analyze computer simulations of materials. Use of examples from current literature to show how these methods can be used to study interesting phenomena in materials science. Hands-on computer experiments. Letter grading. Mr. Ozolina (F)

271. Electronic Structure of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: basic knowledge of quantum mechanics. Recommended requisite: course 200. Introduction to modern first-principles electronic structure calculations for various types of modern materials. Properties of electrons and interatomic bonding in molecules and solids, and liquids, with emphasis on practical methods for solving Schrödinger equation and using it to calculate physical properties such as elastic constants, equilibrium structures, binding energies, vibrational frequencies, electronic band gaps and band structures, properties of defects, surfaces, interfaces, and magnetism. Extensive hands-on experience with modern density-functional theory code. Letter grading. Mr. Ozolina (F)

272. Theory of Nanomaterials. (4) Lecture, four hours; outside study, eight hours. Strongly recommended requisite: course 200. Introduction to properties and applications of nanoscale materials, with emphasis on understanding of basic principles that distinguish nanostructures (with feature size below 100 nm) from more common microstructured materials. Explanation of new phenomena that emerge for repair and/or restoration of damaged natural tissues. Discussion of current and future directions of this rapidly growing field using examples from modern scientific literature. Letter grading. Mr. Ozolina (F)

CM280. Introduction to Biomaterials. (4) Same as Bioengineering CMS/78.) 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 replacement and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM180. Letter grading. Mr. Wu (Not offered 2017-18)

282. Exploration of Advanced Topics in Materials Science and Engineering. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Review of important institutions around 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.

M297B. Material Processing in Manufacturing. (4) (Same as Mechanical and Aerospace Engineering M297B.) Lecture, four hours; outside study, eight hours. Enforced requisite: Mechanical and Aerospace Engineering 183A. Thermodynamics, principles of material processing: phase equilibria and transitions, transport mechanisms of heat and mass, nucleation and growth of microstructure. Applications in casting/solidification, welding, consolidation, chemical vapor deposition, infiltration, composites. Letter grading.

M297C. Composites Manufacturing. (4) (Same as Mechanical and Aerospace Engineering 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. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading.

375. Teaching Apprentice Practicum. (1 to 4 Seminar, to be arranged. Preparation: apprentice 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, S)

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

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

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Reading and preparation for Ph.D. comprehensive examination. S/U grading.

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


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

Professors Emeriti
Odvdar O. Benndiksen, Ph.D.
Ivan Catton, Ph.D. (Research Professor)
Peretz P. Friedmann, Sc.D.
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor Emeritus of Aeronautics)
Robert E. Kelly, Sc.D.
Anthony F. Mills, Ph.D.
D. Lewis Mingori, Ph.D.
Peter A. Monkman, 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.
The mission of the Mechanical and Aerospace Engineering Department is to educate the nation’s future leaders in the science and art of mechanical and aerospace engineering. Further, the department seeks to expand the frontiers of engineering science and to encourage technological innovation while fostering academic excellence and scholarly learning in a collegial environment.

Undergraduate Program Educational Objectives
The aerospace engineering and mechanical engineering programs are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

In consultation with its constituents, the Mechanical and Aerospace Engineering Department has set its educational objectives as follows: within a few years after graduation, the students will be successful in careers in aerospace or mechanical or other engineering fields, and/or in graduate studies in aerospace or mechanical or other engineering fields, and/or in further studies in other fields such as medicine, business, and law.

Undergraduate Study
The Aerospace Engineering and Mechanical Engineering majors are designated capstone majors. Within their capstone courses, Aerospace Engineering students are exposed to the conceptual and design phases for aircraft development and produce a structural design of a component, such as a lightweight aircraft wing. Mechanical Engineering students work in teams in their capstone courses to propose, design, analyze, and build a mechanical or electromechanical device. Graduates of both programs should be able to apply their knowledge of mathematics, science, and engineering in technical systems; design a system, component, or process to meet desired needs; function as productive members of a team; identify, formulate, and solve engineering problems; and communicate effectively, both orally and in writing.

Aerospace Engineering B.S.
Capstone Major
The aerospace engineering program is concerned with the design and construction of various types of fixed-wing and rotary-wing (helicopters) aircraft used for air transportation and national defense. It is also concerned with the design and construction of spacecraft, the exploration and utilization of space, and related technological fields.

Aerospace engineering is characterized by a very high level of technology. The aerospace engineer is likely to operate at the forefront of scientific discoveries, often stimulating these discoveries and providing the inspiration for the creation of new scientific concepts. Meeting these demands requires the imaginative use of many disciplines, including fluid mechanics and aerodynamics, structural mechanics, materials and aeronautics, dynamics, control and guidance, propulsion, and energy conversion.

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A; Mechanical and Aerospace Engineering M20 (or Computer Science 31), 82; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 107, 150A, 150B, C150P, C150R or 161A, 154S, 157A, 157S, 166A, 171A; 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 155A—or, by petition, from outside the department); three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Mechanical and Aerospace Engineering 154A, 154B); and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 94, 105D, 131A, C132A, 133A, 135, 136, C137, CM140, CM141, 150C, C150G, C150R (unless taken as a required course), 153A, 155, C156B, 161A (unless taken as a required course), 161B, 161C, 161D, 162A, 166C, M168, 169A, 171B, 172, 174, C175A, 181A, 182B, 182C, 183A; M183B, C183C, 184, 185, C186, C187L.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://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.

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A; Mechanical and Aerospace Engi-
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), C132A, 133A (unless taken as a required course), 135, 136, C137, CM140, CM141, 150A, 150B, 150C, C150G, C150P, C150R, 153A, 154S, 155, C156B, 157A, 161A through 161D, 166C, M168, 169A, 171B, 172, 174, C175A, 181A, 182B, 182C, 183A (unless taken as a required course), M183B (unless taken as a required course), C183C, 184, 185, C186, C187L.

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

Graduate Study

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

The following introductory information is based on the 2017-18 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at https://grad.ucla.edu. Students are subject to the 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, 103, 110L, M116L, M117L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Aerospace Engineering

Breadth Requirements. Students are required to take at least three courses from the following four categories: (1) Mechanical and Aerospace Engineering 154A or 154B or 154S, (2) 150B or C150P, (3) 155 or 166A or 169A, (4) 161A or 171A.

Mechanical Engineering

Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162D or 183A.

Comprehensive Examination Plan

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is

Energy and Propulsion Research Laboratory researchers examine planar laser-induced fluorescence (PLIF) images of acetone-seeded gaseous jets in crossflow responding to different levels of helical excitation. L-R:
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, 103, 110L, M116L, M171L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

**Upper-Division Courses.** Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering M168, 174, 183A, 184, 185. Graduate Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 263A, 263C, 263D, C296A, M297C. Additional Courses. The remaining courses may be taken from other major fields of study in the department or from the following: Architecture and Urban Design 227D, Computer Science 241B, Management 240A, 241A, 241B, 242A, 243B, 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**

Dynamics; fluid mechanics; heat and mass transfer; design, robotics, and manufacturing (mechanical engineering only); nanoelectromechanical/microelectromechanical systems (NEMS/MEMS); structural and solid mechanics; systems and control.

Ph.D. students may propose ad hoc major fields, which must differ substantially from established major fields and satisfy one of the following two conditions: (1) the field is interdisciplinary in nature or (2) the field represents an important research area for which there is no established major field in the department (condition 2 most often applies to recently evolving research areas or to areas for which there are too few faculty members to maintain an established major field). Students in an ad hoc major field must be sponsored by at least three faculty members, at least two of whom must be from the department.

**Course Requirements**

The basic program of study for the Ph.D. degree is built around major and minor fields. The established major fields are listed above, and a detailed syllabus describing each Ph.D. major field can be obtained from the Student Affairs Office.

The program of study for the Ph.D. requires students to perform original research leading to a doctoral dissertation and to master a body of knowledge that encompasses material from their major field and breadth material from outside the major field. The body of knowledge should include (1) six major field courses, at least four of which must be graduate courses, (2) one minor field, (3) any three additional courses, at least two of which must be graduate courses, that enhance the study of the major or minor field.

The major field syllabus advises students as to which courses contain the required knowledge, and students usually prepare for the written qualifying examination (formerly referred to as the preliminary examination) by taking these courses. However, students 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
CAM theory and applications, computational robotics and manufacturing systems, CAD/CAM (RFID), and wireless systems.

and nanodevices, radio frequency identification and digital control systems, microdevices and composite materials and structures, automation and nanomanufacturing. It includes research on 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.

**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.

**Dynamics**

Features of the dynamics field include dynamics and control of physical systems, including spacecraft, aircraft, helicopters, industrial manipulators; analytical studies of control of large space structures; experimental studies of electromechanical systems; and robotics.

**Fluid Mechanics**

The graduate program in fluid mechanics includes experimental, numerical, and theoretical studies related to a range of topics in fluid mechanics, such as turbulent flows, hypersonic flows, microscale and nanoscale flow phenomena, aeroacoustics, 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.

**Heat and Mass Transfer**

The heat and mass transfer field includes studies of convection, radiation, conduction, evaporation, condensation, boiling and two-phase flow, chemically reacting and radiating flow, instability and turbulent flow, reactive flows in porous media, as well as transport phenomena in support of micro-scale and nanoscale thermosciences, energy, bioMEMS/NEMS, and microfabrication/nanofabrication.

**Nanoelectromechanical/Micro- electromechanical Systems**

The nanoelectromechanical/microelectromechanical systems (NEMS/MEMS) field focuses on science and engineering issues ranging in size from nanometers to millimeters and includes both experimental and theoretical studies covering fundamentals to applications. The study topics include microscience, top-down and bottom-up nanofabrication/microfabrication technologies, molecular/fluidic phenomena, nanoscale/microscale material processing, biomolecular signatures, heat transfer at the nanoscale, and system integration. The program is highly interdisciplinary in nature.

**Structural and Solid Mechanics**

The solid mechanics program features theoretical, numerical, and experimental studies, including fracture mechanics and damage tolerance, micromechanics with emphasis on technical applications, wave propagation and nondestructive evaluation, mechanics of composite materials, mechanics of thin films and interfaces, analysis of coupled electro-magneto-thermomechanical material systems, and ferroelectric materials. The structural mechanics program includes structural dynamics with applications to aircraft and spacecraft, fixed-wing and rotary-wing aeroelasticity, fluid structure interaction, computational transonic aeroelasticity, biomechanics with applications ranging from whole organs to molecular and cellular structures, structural optimization, finite element methods and related computational techniques, structural mechanics of composite material components, structural health monitoring, and analysis of adaptive structures.

**Systems and Control**

The program features systems engineering principles and applied mathematical methods of modeling, analysis, and design of continuous- and discrete-time control systems. Emphasis is on modern applications in engineering, systems concepts, feedback and control principles, stability concepts, applied optimal control, differential games, computational methods, simulation, and computer process control. Systems and control research and education in the department cover a broad spectrum of topics primarily based in aerospace and mechanical engineering applications. However, the Chemical and Biomolecular Engineering and Electrical and Computer Engineering Departments also have active programs in control systems, and collaboration across departments among faculty members and students in both teaching and research is common.

**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

Active Materials Laboratory
Gregory P. Carman, Director
The Active Materials Laboratory contains equipment to evaluate the coupled response of materials such as piezoelectric, magnetostrictive, shape memory alloys, and fiber-optic sensors. The laboratory has manufacturing facilities to fabricate magnetostrictive composites and thin film shape memory alloys. Testing active material systems is performed on one of four servo-hydraulic load frames in the lab. All of the load frames are equipped with thermal chambers, solenoids, and electrical power supplies.

Autonomous Vehicle Systems Instrumentation Laboratory
Jason L. Speyer, Director
The Autonomous Vehicle Systems Instrumentation Laboratory (AVSIL) is a testbed at UCLA for design, building, evaluation, and testing of hardware instrumentation and coordination algorithms for multiple vehicle autonomous systems. AVSIL contains a hardware-in-the-loop (HIL) simulator—designed and built at UCLA—that allows for real-time, systems-level tests of two formation control computer systems in a laboratory environment, using the Interstate Electronics Corporation GPS Satellite Constellation Simulator. The UCLA flight control software can be modified to accommodate satellite-system experiments using real-time software, GPS receivers, and inter-vehicle modern communication.

Beam Control Laboratory
James S. Gibson, Director
The Beam Control Laboratory involves students, faculty, and postdoctoral researchers to develop novel methods for laser-beam control in applications including directed energy systems and laser communications. Algorithms developed at UCLA for adaptive and optimal control and filtering, as well as system identification, are being used in adaptive optics and beam steering. UCLA high-bandwidth controllers correct both higher-order wavefront errors and tilt jitter to levels not achievable by classical beam control methods.

Biomechatronics Laboratory
Veronica J. Santos, Director
The Biomechatronics Laboratory is dedicated to improving quality of life by enhancing the functionality of artificial hands and their control in human-machine systems.

The research is advancing the design and control of human-machine systems as well as autonomous robotic systems. Current research projects involve human biomechanics, tactile sensing, control of robotic systems, and machine learning.

Bionics Laboratory
Jacob Rosen, Director
The Bionics Laboratory performs research at the interface between robotics, biological systems, and medicine. Primary research fields are medical robotics and biorobotics including surgical robotics, and wearable robotics as they apply to human motor control, neural control, human- and brain-machine interfaces, motor control (stroke) rehabilitation, brain plasticity, haptics, virtual reality, tele-operation, and biomechanics (full-body kinematics and dynamics, and soft/hard tissues biomechanics).

Boiling Heat Transfer Laboratory
Vijay K. Dhir, Director
The Boiling Heat Transfer Laboratory performs experimental and computational studies of phase-change phenomena. It is equipped with various flow loops, state-of-the-art data acquisition systems, holography, high-speed imaging systems, and a gamma densitometer.

Center for Advanced Multifunctional Materials and Systems (CAMMS)
Christopher S. Lynch, Director
CAMMS is involved in all aspects of multifunctional (smart) materials characterization, modeling, and applications. Materials are characterized under combined mechanical, thermal, electrical, and magnetic loading. Constitutive laws are developed that govern domain switching and phase transformations. Component-level applications include miniature solid-state piezoelectric pumps; morphing piezocomposite actuators; and nanoscale magneto-electric memory, antenna, and motors. Systems-level applications (team projects) include controlled optics for deep-space observing satellites, ultra-low-frequency magneto-mechanical antennas, morphing aircraft structures, and next-generation computer memory.

Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS)
Gregory P. Carman, Director
The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) is a multi-institutional engineering research center (ERC) focused on research, technology translation, and education associated with magnetism on the small scale. The TANMS vision is to develop a fundamentally new approach that couples electricity to magnetism using engineered nanoscale multiferroic elements, to enable increased energy efficiency, reduced physical size, and increased power output in consumer electronics. This new approach overcomes scaling limitations present Oersted’s magnetism control discovery of 1820. TANMS goals are to translate its research discoveries to industry, while seamlessly integrating a cradle-to-career education philosophy involving its students and future engineers in unique research and entrepreneurial experiences.

Chen Research Group
Yong Chen, Director

Collaborative Center for Aerospace Sciences (CCAS)
Ann R. Karagozian, Director
The Collaborative Center for Aerospace Sciences (CCAS) is a multi-/trans-disciplinary research center focused on fundamental and applied basic studies relevant to aerospace systems. Research projects that broadly span the computational and experimental arenas are conducted at UCLA and at Air Force Research Laboratory (AFRL/RQ) at Edwards Air Force Base northeast of campus. UCLA faculty, students, and postdoctoral researchers collaborate with AFRL scientists and engineers on high-impact problems to advance U.S. capabilities in aerospace systems.

Complex Fluids and Interfacial Physics Laboratory
H. Pirouz Kavehpour, Director
The Complex Fluids and Interfacial Physics Laboratory is multidisciplinary, with areas of research ranging from rheology of biofluids to energy storage. The group is directed towards development of fundamental engineering and scientific knowledge.

Cybernetic Control Laboratory
Tetsuya Iwasaı̇, Director
The Cybernetic Control Laboratory (CyCLab) aims to develop biologically inspired control theories for rhythmic movements and dynamic pattern formation with applications...
Design and Manufacturing Laboratory
The Design and Manufacturing Laboratory offers an environment for synergistic integration of design and manufacturing. Available equipment includes four CNC machines, two rapid-prototyping systems, coordinate measuring, X-ray radiography, robots with vision systems, audiovisual equipment, and a distributed network of more than 30 workstations.

Energy and Propulsion Research Laboratory
Ann R. Karagozian, Director
The Energy and Propulsion Research Laboratory involves the application of modern diagnostic methods and computational tools to the development of improved combustion, propulsion, and fluid flow systems. Research includes aspects of fluid mechanics, chemistry, optics, and numerical methods, as well as thermodynamics and heat transfer.

Energy Innovation Laboratory
Richard E. Wirz, Director
The Energy Innovation Laboratory investigates high-impact renewable energy science and technology. Its current work primarily focuses on large-scale thermal energy storage for grid-scale applications and advanced wind energy capture.

Flexible Research Group
Jonathan B. Hopkins, Director
The Flexible Research Group is dedicated to the design and fabrication of flexible structures, mechanisms, and materials that achieve extraordinary capabilities. The laboratory is equipped with state-of-the-art synthesis tools, optimization software, and a number of commercial and custom-developed additive fabrication technologies for fabricating complex flexible structures at the macro- to nano-scale.

Fusion Science and Technology Center
Mohamed A. Abdou, Director
The Fusion Science and Technology Center includes experimental facilities for conducting research in fusion science and engineering, and multiple scientific disciplines in thermofluids, thermomechanics, heat/mass transfer, and materials interactions. The center includes experimental facilities for liquid metal magnetohydrodynamic fluid flow, thick and thin liquid metal systems exposed to intense particle and heat flux loads, and metallic and ceramic material thermomechanics.

Ho Systems Laboratory—Personalized Medicine
Chih-Ming Ho, Director
The Ho Systems Laboratory—Personalized Medicine researches phenotypic personalized medicine (PPM). It has discovered that drug-dose inputs are correlated with phenotypic outputs with a parabolic response surface (PRS). With a few calibration tests to determine the coefficients of its quadratic governing algebraic equation, PPRS dictates the composition and ratio of a globally optimized drug combination. Based on the PPRS platform, phenotypic personalized medicine (PPM) can realize unprecedented adaptability to identify the optimized drug combination for a specific patient. PRS is an indication-agnostic and mechanism-free platform technology, which has been successfully demonstrated in about 30 diseases.

Hu Research Laboratory (H-Lab)
Yongjie Hu, Director
The H-Lab research group is focused on understanding and engineering nanoscale transport phenomena and nanomaterials for wide applications including energy conversion, storage, and thermal management. The lab uses a variety of experimental and theoretical techniques to investigate nanoscale transport processes, with a particular emphasis on design and chemical synthesis of advanced materials, ultrafast optical spectroscopy, pulsed electronics, and thermal spectral mapping techniques.

Hypersonics and Computational Aerodynamics Group
Xiaolin Zhong, Director
The Hypersonics and Computational Aerodynamics Group primarily focuses on fundamental physics-based research of hypersonic flows using advanced numerical tools; and application of discovered fundamental knowledge to real-world aerospace systems, such as development of hypersonic planes and space vehicles. Its main research areas are computational fluid dynamics (CFD), hypersonic flows, instability and transition of hypersonic boundary layers, interaction of strong shocks and turbulence, and numerical simulation of wave energy harvesting.

Laser Spectroscopy and Gas Dynamics Laboratory
Raymond M. Spearrin, Director
The Laser Spectroscopy and Gas Dynamics Laboratory conducts research driven by applications in propulsion and energy, with extensions to health and environment. Lab activities are united by a core focus in experimental thermofluids and applied spectroscopy. Projects commonly span fundamental spectroscopy science to design and deployment of prototype sensors to investigate dynamic flow-fields.

Materials Degradation Characterization Laboratory
Ajit K. Mal, Director
The Materials Degradation Characterization Laboratory is used for characterization of the degradation of high-strength metallic alloys and advanced composites due to corrosion and fatigue, determination of adverse effects of materials degradation on the strength of structural components, and research on fracture mechanics and ultrasonic non-destructive evaluation.

Materials in Extreme Environments Laboratory (MATRIX)
Nasr M. Ghoniem, Director
The Materials in Extreme Environments (MATRIX) Laboratory seeks answers to two fundamental questions: What are the physical phenomena that control the mechanical properties of engineering materials operating in extreme environmental conditions; and knowing such behavior, can we design engineering materials to be more resilient.

M’Closkey Laboratory
Robert T. M’Closkey, Director
The M’Closkey Laboratory develops miniature, high-performance angular-rate sensors called vibratory gyroscopes. A separate long-term project seeks to understand the mixing dynamics of a jet injected into a crossflow.

Mechanics of Soft Materials Laboratory
Lihua Jin, Director
The Mechanics of Soft Materials Laboratory investigates the fundamental physics and mechanics of soft materials, such as their constitutive relation, nonlinear deformation, instability, and fracture. The lab also strives to develop new materials, structures, and functions for soft robotics and stretchable electronics.

Mechatronics and Controls Laboratory
Tsu-Chin Tsao, Director
The Mechtronics and Controls Laboratory conducts research in theory and innovation in dynamic systems, controls, mechatronics, and robotics. It creates high-performance systems with novel sensors, actuators, and real-time digital signal processing and embedded control. Applications include precision motion and vibration control, manufacturing equipment and processes, medical devices, and robots.

**Micro- and Nano-Manufacturing Laboratory**  
Chang-Jin (CJ) Kim, Director  
The Micro- and Nano-Manufacturing Laboratory is equipped with a fume hood, clean air bench, optical table, DI water generator, plating setup, probe station, various microscopes, test and measurement systems, and CAD programs for mask layout. It is used for micromachining and MEMS research, and complements the HSSEAS Nanoelectronics Research Facility.

**Modeling of Complex Thermal Systems Laboratory**  
Adrienne G. Lavine, Director  
The Modeling of Complex Thermal Systems Laboratory addresses a variety of systems in which heat transfer plays an important role. Thermal aspects of these systems are coupled with other physical phenomena such as mechanical or electrical behavior. Modeling tools range from analytical to custom computer codes to commercial software.

**Morrin-Gier-Martinelli Heat Transfer Memorial Laboratory**  
Laurent G. Pilon, Director  
The Morrin-Gier-Martinelli Heat Transfer Memorial Laboratory is shared between professors Catton and Pilon. It is used for investigating single- and two-phase convective heat transfer in energy applications, various aspects of radiation transfer in biological systems, and material synthesis and characterization. It is equipped with optical tables, lasers, FTIR, photomultiplier tubes, monochromators, nanosecond pulse diodes, lock-in amplifiers, spectrophotometers, light guides, fiber optics, lenses, and polarizers. It also has various flow loops, a wind tunnel, and a particle image velocimetry (PIV) system. For material synthesis, the lab is equipped with two high-temperature furnaces, a spin coater, a dip-coating system, and UV curing lamps. The lab can perform optical, thermal, and electrical materials characterization using a guarded hot plate thermal conductivity analyzer, a 3-omega method system for thin film thermal conductivity, a normal-normal reflection probe, and an in-house electrical system for measuring dielectric constant and the q-V curve of ferroelectric materials.

**Multiscale Thermosciences Laboratory (MTSL)**  
Y. Sungtaek Ju, Director  
The Multiscale Thermosciences Laboratory (MTSL) is focused on heat and mass transfer phenomena at the nano- to macro-scales. A wide variety of applications are explored, including novel materials and devices for energy conversion; combined cooling, heating, and power generation; thermal management of electronics and buildings; energy-water nexus; and biomedical MEMS/NEMS devices.

**Nanoscale Transport Research Group**  
Timothy S. Fisher, Director  
The Nanoscale Transport Research Group works on a broad range of problems, primarily involving transport processes by electrons, phonons, photons, and fluids. It seeks to solve problems with high importance to applications in energy transport, conversion, and storage, that are relevant to major industrial segments (aerospace, micro/nanoelectronics, and sensors). The lab solves these problems through a holistic, balanced approach that spans nanomaterial synthesis, basic material characterization and modeling, and functional characterization and simulation. The group includes the Center for Integrated Thermal Management of Aerospace Vehicles (CITMAV), which develops new solutions to highly transient transport problems that occur in aerospace applications.

**Optofluids Systems Laboratory**  
Pei-Yu Chiou, Director  
The Optofluids Systems Laboratory develops heterogeneous integrated functional devices and systems for biomedical applications. Research areas include integrated photonics and fluids devices; 3D micro- and nano-manufacturing technologies; and flexible mechanical, photonics, and electronics systems.

**Pilon Research Group**  
Laurent G. Pilon, Director  
The Pilon Research Group researches photobiological fuel production, mesoporous materials, electrochemical capacitors, waste heat energy harvesting, foams/microfoams, biomedical optics, and energy efficiency.

**Plasma and Beam Assisted Manufacturing Laboratory**  
Richard E. Wirz, Director  
The Plasma and Beam Assisted Manufacturing 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**  
Dennis W. Hong, Director  
The Robotics and Mechanisms Laboratory (RoMeLa) is a facility for robotics research and education with an emphasis on studying humanoid robots and novel mobile robot locomotion strategies. Research is in the areas of robot locomotion and manipulation, soft actuators, platform design, kinematics and mechanisms, and autonomous systems. RoMeLa is active in research-based international robotics competitions, winning numerous prizes including third place in the DARPA Urban Challenge. The laboratory also took first place in the RoboCup international autonomous robot soccer competition (kid-size and adult-size humanoid divisions), and was world champion five times in a row. It also brought the prestigious Louis Vuitton Cup Best Humanoid award to the U.S. for the first time, and most recently was one of six Track A teams chosen to participate in the DARPA Robotics Challenge disaster response robot competition.

**Scifacturing Laboratory**  
Xiaochun Li, Director  
The Scifacturing Laboratory furnishes a creative, interdisciplinary platform for science-driven manufacturing (scifacturing) as the
next level of manufacturing. It seeks to enable application of physics and chemistry to empower breakthroughs in manufacturing. The laboratory links molecular, nano-, and micro-scale knowledge to scalable processes/systems in manufacturing and materials processing. Current focus areas include scale-up nanomanufacturing, solidification nanomanufacturing of super-materials with dense nanoparticles, structurally integrated micro- and nano-systems (especially sensors and actuators) for manufacturing, clean energy and biomedical manufacturing, meso/micro 3D printing, and laser materials processing.

**Smart Grid Energy Research Center (SMERC)**

Rajit Gadh, Director

The Smart Grid Energy Research Center (SMERC) performs research; creates innovations; and demonstrates advanced Internet-of-things, sense-and-control technologies, and data-enabled machine learning to enable development of the next-generation electric utility grid—the smart grid. SMERC also provides thought leadership through its ESsmart Consortium between utilities, government, policy makers, technology providers, electric vehicle manufacturers, energy technology companies, Department of Energy research labs, and universities, so as to collectively work on envisioning, planning, and executing the smart grid of the future. The grid will allow for integration of renewable energy sources. It will also reduce losses; improve efficiencies; increase grid flexibility; reduce power outages; allow for competitive electricity pricing; allow for integration of electric and autonomous vehicles; and overall become more responsive to market, consumer, and societal needs. SMERC is currently working electric vehicle integration (G2V and V2G), automated demand response (ADR), microgrids, distributed energy resources, renewable integration, battery energy storage integration, and autonomous vehicle infrastructure.

**Simulations of Flow Physics and Acoustics Laboratory (SOFIA)**

Jeffrey D. Eldredge, Director

The Simulations of Flow Physics and Acoustics (SOFIA) Laboratory explores a wide variety of phenomena that occur in fluid flows in nature and technology. It investigates low-order modeling of unsteady aerodynamics of agile, bio-inspired, micro-air vehicles; micro-particle manipulation by viscous streamlining; the fluid dynamics of biological and biologically-inspired locomotion; interactions of fluid flows with flexible surfaces; transitional and turbulent hypersonic boundary layer flows; vortex estimation techniques for autonomous control of formation flight; and new computational tools for simulation of biomedical flows.

**Thermochemical Energy Storage Laboratory**

Adrienne G. Lavine, Director

The Thermochemical Energy Storage Laboratory is focused on use of reversible chemical reactions to store energy for renewable energy applications. The current focus is on ammonia synthesis for supercritical steam generation in a concentrating solar power plant. The ammonia synthesis reactor testing platform consists of three subsystems (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 Thin Films, Interfaces, Composites, Characterization Laboratory includes a Nd:YAG laser of 1 Joule capacity with 3 ns pulse widths, a state-of-the-art optical interferometer including an ultra high-speed digitizer, sputter deposition chamber, 56 Kip capacity servohydraulic biaxial test frame, and polishing and imaging equipment for microstructural characterization, for measurement and control study of thin film interface strength.

**Turbulence Research Group**

J. John Kim, Director

The Turbulence Research Group is primarily focused on the study of turbulence and stability. It has a long history of studying incompressible flow, and has recently begun studying compressible flow problems. All its work is carried out numerically with computational fluid dynamic (CFD) codes, which are written in-house. Its current research interests include real gas effects on compressible turbulent boundary-layer flow, drag reduction through the use of superhydrophobic surfaces on incompressible turbulent boundary-layer flow, and the effects of distributed roughness on compressible turbulent boundary-layer flows.

**Faculty Areas of Thesis Guidance**

Professors

Mohamed A. Abdou, Ph.D. (U. Wisconsin, 1973)

Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermo-mechanics; thermal hydraulics; fluid dynamics, heat, and mass transfer in the presence of magnetic fields (MHD flows), neutronics; radiation transport; plasma-material interactions; blankets and high heat flux components; experiments, modeling and analysis

Gregory P. Carman, Ph.D. (Virginia Tech, 1991)

Electromagnetoelasticity models including micromagnetics, elastodynamics, and Maxwell coupled solutions. Characterization of piezoelectric ceramics, magnetostrictive shape memory alloys, and multiferroic materials.

Yong Chen, Ph.D. (U.C Berkeley, 1996)

Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanico-optical, biological, and sensing devices, circuits and systems

Pei-Yu Chiu, Ph.D. (U.C 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, vortex-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 charge transport, electrochemical and thermal energy storage, mechanics and transport in granular materials and porous media, plasma science and technology, aerospace thermal systems


Smart grid, electric vehicle and grid integration, microgrid, distributed energy resource, solar- and renewable-grid integration, demand response, autonomous electric vehicle, machine learning from transportation data, radio frequency identification (RFID), Internet of things

Nasr M. Ghoniem, Ph.D. (U. Wisconsin, 1977)

Mechanics of materials in severe environments (nuclear, aerospace, transportation); radiation interaction with materials (e.g., laser, ions, plasma, electrons, and neutrons); multiscale modeling; physics and mechanics of material defects; fusion energy; materials for space propulsion

James S. Gibson, Ph.D. (U. Texas Austin, 1975)

Control and identification of dynamical systems; optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation

Vijay Gupta, Ph.D. (MIT, 1989)

Experimental mechanics, fracture of 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 many multi-legged mobile robots

Tetsuya Iwasaki, Ph.D. (Purdue, 1993)

Dynamical systems, robust and optimal controls, nonlinear oscillators, resonance entrainment, modeling and analysis of neuronal control circuits for animal locomotion, central pattern generators, body-fluid interaction during undulatory and oscillatory swimming

Y. Sungtaek Ju, Ph.D. (Stanford, 1999)

Heat and mass transfer, energy, energy-water nexus, MEMS and nanotechnology
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

Microscale fluid mechanics, transport phenomena in biological systems, biofluids, coating flows and physics of contact line phenomena, complex fluids, non-isothermal flows, energy systems and energy storage

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

J. John Kim, Ph.D. (Stanford, 1978)  
Numerical simulation of turbulent and transitional flows, physics and control of turbulent flows, application of modern control theories to flow problems

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 applications to clouds and aerosols in the earth’s atmosphere

Christopher S. Lynch, Ph.D. (UC Santa Barbara, 1992)  
Field coupled materials, constitutive behavior, thermo-thermo-mechanical properties, sensor and actuator applications, fracture mechanics and failure analysis

Ajit K. Mal, Ph.D. (Calcutta U., India, 1964)  
Mechanics of composite materials, wave propagation, nondestructive evaluation, structural health monitoring

Robert T. Mcllroy, Ph.D. (Caltech, 1995)  
Nonlinear control theory and design with application to mechanical and aerospace systems, real-time implementation

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

Jayathi Y. Murthy, Ph.D. (U. Minnesota, 1984)  
Nanoscale heat and fluid dynamics, simulation of fluid flow and heat transfer for industrial applications, sub-micron thermal transport, multiscale multiphysics simulations and uncertainty quantifications

Laurent G. Plour, 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 S. 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, hypersonic flow, numerical simulation of transient hypersonic flow with nonequilibrium real-gas effects, instability and laminar-turbulent transition of hypersonic boundary layers

**Professors Emeriti**

Oddvar O. Bendiksen, Ph.D. (UCLA, 1980)  
Classical and computational aeroelasticity, structural dynamics and unsteady aerodynamics

Ivan P. Carter, Ph.D. (UCLA, 1966)  
Heat transfer and fluid mechanics, transport phenomena in porous media, nucleochemical heat transfer and thermal hydraulics, natural and forced convection, thermal/hydrodynamic stability, turbulence

Aerodynamic of helicopters and fixed-wing aircraft, structural dynamics of rotating systems, rotor dynamics, unsteady aerodynamics, active control of structural dynamics, structural optimization with aeroelastic constraints

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

Thermal convection, thermocapillary convection, stability of shear flows, stratified and rotating flows, interfacial phenomena, microgravity fluid dynamics

Anthony F. Mills, Ph.D. (UC Berkeley, 1965)  
Convective heat and mass transfer, condensation heat transfer, turbulent flows, ablation and transpiration cooling, perforated plate heat exchangers

D. Lewis Mininger, Ph.D. (Stanford, 1966)  
Dynamics and control, stability theory, nonlinear methods, applications to space and ground vehicles

Peter A. Monkewitz, Ph.D. (ETH Zürich, Switzerland, 1977)  
Fluid mechanics, internal acoustics and noise produced by turbulent jets

Philip F. O’Brien, M.S. (UCLA, 1949)  
Industrial engineering, environmental design, thermal and environmental engineering systems

Lucien A. Schmitt, Jr., M.S. (MIT, 1950)  
Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components

Owen I. Smith, Ph.D. (UC Berkeley, 1977)  
Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor chemical vapor deposition

Richard Stern, Ph.D. (UCLA, 1964)  
Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics

Russell A. Westmann, Ph.D. (UC Berkeley, 1962)  
Mechanics of solid bodies, fracture mechanics, adhesive mechanics, composite materials, theoretical soil mechanics, mixed boundary value problems

Daniel C.H. Yang, Ph.D. (Rutgers, 1982)  
Robotics and mechanisms; CAD/CAM systems, computer-controlled machines

**Associate Professors**

Robert N. Candler, Ph.D. (Stanford, 2006)  
MEMS and nanoscale devices, fundamental limitations of sensors, packaging, biological and chemical sensing

Jame Marian, Ph.D. (UC Berkeley, 2002)  
Computational materials modeling and simulation in solid mechanics, irradiation damage, plasticity, phase transformations, thermodynamics and kinetics of alloy systems, algorithm and method development for bridging time and length scales and parallel computing applications

Veronica J. Santos, Ph.D. (Cornell, 2007)  
Grasp and manipulation, hand biomechanics, haptics, human-machine systems, machine learning, machine perception, neural control of movement, prosthetics, robotics, stochastic modeling, tactile sensor

Richard E. Wirtz, Ph.D. (Caltech, 2005)  
Electric propulsion (ion, Hall, electrosprays, cathode); micro-electro propulsion; partially ionized plasma discharges; miniature plasma devices; spacecraft/space mission design; wind energy; solar thermal energy; thermal energy storage

**Assistant Professors**

Jonathan B. Hopkins, Ph.D. (MIT, 2010)  
Design and manufacturing of microstructural architectures, flexure systems, and compliant mechanisms; screw theory kinematics; precision machine design; novel micro- and nanofabrication processes; MEMS

Yongjie Hu, Ph.D. (Harvard, 2011)  
Heat transfer and electric transport in nanostructures; interfaces and packaging, thermal, electronic, optoelectronic, and thermoelectric devices and systems; energy conversion, storage, and thermal management; ultrafast optical spectroscopy and high-frequency electronics; nanomaterials design, processing, and manufacturing

Lihua Jin, Ph.D. (Harvard, 2014)  
Machinics of soft materials; continuum mechanics and applications in technologies; additive manufacturing, soft robotics and stretchable electronics, nanomaterials, and multiscale modeling

Raymond M. Spearrin, Ph.D. (Stanford, 2015)  
Spectroscopy and gas dynamics, advanced optical sensors including laser absorption and fluorescence with experimental application to propulsion, energy systems and other reacting flow fields

**Lecturers**

Ravneesh C. Amar, Ph.D. (UCLA, 1974)  
Heat transfer and thermal science

Amiya K. Chatterjee, Ph.D. (UCLA, 1976)  
Elastic wave propagation and penetration dynamics

Modeling, simulation, and analysis of spacecraft dynamics and pointing control systems; nonlinear dynamics of spinning bodies; concurrent engineering methods for space mission conceptual design

Damian M. Tochey, M.S. (MIT, 2004)  
Guidance, navigation, and control for autonomous aircraft, launch vehicles, and missile systems, adaptive control theory, automatic control and reallocation for aircraft and re-entry vehicles

**Adjunct Professors**

Dan M. Goebel, Ph.D. (UCLA, 1981)  
Hollow cathode, magnetic-multiple ion sources for neutral beam injection

Leslie M. Lackman, Ph.D. (UC Berkeley, 1967)  
Structural analysis and design, composite structures, engineering management

Wilbur J. Marner, Ph.D. (U. South Carolina, 1969)  
Thermal sciences, system design

Neil G. Siegel, Ph.D. (USC, 2011)  
Organizing complex projects around critical skills and mitigation of risks arising from system dynamic behavior
Optimal placement of actuators and sensors in aerospace, medical in
and manufacturing industries. P/NP grading.
Mr. Mal (F,Sp)

10.5A. Introduction to Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 102, 103, 105A. Transport phenomena; heat conduction, mass diffusion, convective heat and mass transfer, and radiation. Engineering applications in thermal and environmental control. Letter grading.
Mr. Ju, Ms. Lavine (F)

107. Introduction to Modeling and Analysis of Dynamic Systems. (4) Lecture, four hours; discussion, one hour; laboratory, two hours; outside study, five hours. Enforced requisites: courses M20 (or Computer Science 31), 82, 105D. Introduction to modeling of physical systems, with emphasis on modeling mechanical, fluid, thermal, and electrical systems. Description of these systems with coverage of impulse response, convolution, frequency response, first- and second-order systems transient response, and stability. Solution. Nonlinear differential equation descriptions with discussion of equilibrium solutions, small signal linearization, large signal response. Block diagram representation and response of interconnections of systems. Hands-on experiments reinforce lecture material. Letter grading.
Mr. M'Callum, Mr. Tsao (F,Sp)

Ms. Lavine (F)

132A. Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 105D, 107A. Principles of mass transfer by diffusion and convection. Simultaneous heat and mass transfer. Transfer in multiphase systems. Forced, and pressure diffusion, Brownian diffusion. Analysis of evaporative and transpiration cooling, cal-
talyis, and combustion. Mass exchangers, including automobile catalytic converters, electrostatic precipitators, filters, scrubbers, humidifiers, and cooling towers. Concurrently scheduled with course C232A. Letter grading.
Mr. Mal (Not offered 2017-18)

133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 102, 103. Basic equations governing fluid motion. Fundamental solu-
tions of Navier-Stokes. Basic theory of the Potential flow theory. Boundary layers. Turbulent flow in pipes and boundary layers. Com-
pressible flow: normal shocks, channel flow with fric-
tion or heat addition. Letter grading.
Mr. Eldredge, Ms. Karagozian (F,W)

150A. Intermediate Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 82, 103. Basic equations governing fluid motion. Fundamental solu-
tions of Navier-Stokes. Basic theory of the Potential flow theory. Boundary layers. Turbulent flow in pipes and boundary layers. Com-
pressible flow: normal shocks, channel flow with fric-
tion or heat addition. Letter grading.
Mr. Eldredge, Ms. Karagozian (F,W)

Upper-Division Courses

101. Statics and Strength of Materials. (4) (Formerly numbered 96.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 31A, 31B, Physics 1A. Review of vector representation of forces, resultant force and moment, equilibrium of concurrent and nonconcurrent forces. Area moments and products of inertia. Support reac-
tions—free-body diagrams. Forces in simple models of mechanical and aerospace structures. Internal
150B. Aerodynamics. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Requisites: course 103, 150A. Classical theories of potential flow theory. Incompressible flow around thin airfoils (lift and moment coefficients) and wings (lift, induced drag). Gas dynamics: oblique shocks, Prandtl-Meyer expansion, Linearized subsonic and supersonic flow analysis of airfoils and wings. Wave drag. Transonic flow. Letter grading. Mr. Zhong (Sp)

150C. Combustion Systems. (4) Lecture; four hours; outside study, eight hours. Enforced requisites: courses 103, 150A. Chemical thermodynamics of ideal gas mixtures, premixed and diffusion flames, explosions and detonations, combustion chemistry, high explosives. Combustion processes in rocket, turbine, and internal combustion engines; heating applications. Letter grading. 

Ms. Karagözian (Not offered 2017-18)

C150G. Fluid Dynamics of Biological Systems. (4) Lecture; four hours; outside study, eight hours. Requisites: course 103. Mechanics of aquatic locomotion; insect and bird flight aerodynamics; pulsatile flow in circulatory system; rheology of blood; transport in microcirculation; role of fluid dynamics in arterial diseases. Concurrently scheduled with course C150S. Letter grading. Mr. Eldredge (Sp)

C150P. Aircraft Propulsion Systems. (4) (Formerly numbered 150P) Lecture; four hours; discussion; two hours; outside study, six hours. Requisites: course 150A. Rocket propulsion system 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 scheduled with course C250P. Letter grading. Ms. Karagözian (F)

C150R. Rocket Propulsion Systems. (4) (Formerly numbered 150R) Lecture; four hours; discussion; two hours; outside study, six hours. Enforced requisites: course 150A. Rocket propulsion system 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 scheduled with course C250R. Letter grading. Ms. Karagözian, Mr. Wirz (Sp)

153A. Engineering Acoustics. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Designed for junior/senior engineering majors. Fundamental course in acoustics; propagation of sound; sources of sound. Design of field measurements. Estimation of jet and blade noise with design aspects. Letter grading. Mr. Eldredge (Not offered 2017-18)

154A. Preliminary Design of Aircraft. (4) Lecture; four hours; discussion; one hour; outside study, seven hours. Enforced requisite: course 154S. Classical preliminary design and conceptual inclusion; analysis, estimation, performance, safety and stability, and control consideration. Term assignment consists of preliminary design of low-speed aircraft. Letter grading. Mr. Lynch (W)


154S. flight Mechanics, Stability, and Control of Aircraft. (4) Lecture; four hours; discussion; one hour; outside study, seven hours. Requisites: courses 154A, 150B. Aircraft performance, flight mechanics, stability, and control. Concurrently scheduled with course C103E. Requisites for design of aircraft. Effects of airplane flexibility on stability derivatives. Letter grading. Mr. Lynch (F)

155. Intermediate Dynamics. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Requisites: course 102. Advanced Newtonian mechanics, generalized coordinates, Lagrange equation, 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. 

Mr. Ghoniem (Sp)

156A. Advanced Strength of Materials. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Requisites: courses 82, 101. Not open to students with credit for course 156A. Concepts of stress and strain in loaded beams with symmetric and asymmetric cross sections. Torsion of cylinders and thin-walled structures, shear flow. Stresses in pressure vessels, pressfit and shrink-fit problems, rotating shafts. Thin-walled beams, Contact stresses, Strength and failure, plastic deformation, fatigue, elastic instability. Letter grading. Mr. Mal (FSp)

C156B. Mechanical Design for Power Transmission. (4) Lecture; four hours; outside study, eight hours. Requisite: 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. Concurrently scheduled with course C296A. Letter grading. Mr. Ghoniem (Sp)

157. Basic Mechanical and Aerospace Engineering Laboratory. (4) Laboratory, four hours; discussion, two hours; outside study, four hours. Requisites: courses 101, 102, 103, 105A, Electrical Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading. Mr. Ghoniem, Mr. Ju (F/W,Sp)

157A. Aerospace Design Laboratory. (4) Lecture; two hours; laboratory; six hours; outside study, four hours. Requisites: courses 150A, 150B, and 157 or 157S. Experimental illustration of important physical phenomena in area of fluid mechanics/aerodynamics, as well as hands-on experience with design tools, experimental programs and use of modern experimental tools and techniques in field. Letter grading. Mr. Kavehpour (Sp)

157B. Basic Aerospace Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 102, 103, 105A, Electrical Engineering 100. Recommended: course 15. Measurements of basic physical quantities in fluid mechanics, thermodynamics, and structures. Operation of primary transducers, computer-aided data acquisition, signal processing, and data analysis. Performance of experiments to enhance understanding of physics and phenomena, and for design of experiments and design of structures/systems of relevance to aerospace engineering. Letter grading. Mr. Ghoniem, Mr. Ju (Not offered 2017-18)

161A. Introduction to Astronautics. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Enforced requisite: course 102. Recommended: course 82. Spaceflight, including two-body and three-body problem, Kepler laws, and Keplerian orbits. Ground track and taxonomy of common orbits. Orbital and transfer maneuvers, patched conics, perturbation theory, low-thrust trajectories, spacecraft parking, and rendezvous. Space mission design, space environment, rendezvous, reentry, and launch. Letter grading. Mr. Wirz (W)

161B. Introduction to Space Technology. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Recommended: courses 102, 161A. Spacecraft systems and dynamics, including spacecraft power, instruments, communications, structures, materials, thermal control, and attitude/orbit determination and control. Space mission design, launch vehicles/considerations, space propulsion. Letter grading. Mr. Wirz (W)

161C. Spacecraft Design. (4) Lecture; four hours; outside study, eight hours. Enforced requisite: course 161B. Conceptual preliminary design 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. Ghoniem (Sp)

161D. Space Technology Hardware Design. (4) Lecture; four hours; laboratory; four hours; outside study, four hours. Enforced requisite: course 161B. Design by students of hardware with applications to spacecraft technology. Design and implementation of professional machine shop and tested by students. Letter grading. Mr. Wirz (Not offered 2017-18)


162D. Mechanical Engineering Design I. (4) Lecture; two hours; laboratory; four hours; outside study, six hours. Enforced requisite: course 162D. Limited to seniors. First of two mechanical engineering capstone design courses. Students group continue design projects started in course 162D, making use of CAD design laboratory, CAD analysis laboratory, and finite element analysis laboratory. 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. Tsao (W)

162E. Mechanical Engineering Design II. (4) Lecture; two hours; laboratory; four hours; outside study, six hours. Enforced requisite: course 162D. Limited to seniors. Second of two mechanical engineering capstone design courses. Student groups continue design projects started in course 162D, making use of CAD design laboratory, CAD analysis laboratory, and finite element analysis laboratory. 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. Tsao (W)

166A. Analysis of Flight 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, beam theory, yield and fatigue; bending of beams; torsion of beams; warping; torsion of thin-walled cross sections: shear flow, shear-lag: combined bending torsion of thin-walled, 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, composite stress analysis, design and test studies, buckling of composite components, nonsymmetric laminates, micromechanics of composites. Letter grading. Mr. Carman (W)

M168. Introduction to Finite Element Methods. (4) (Same as Civil Engineering M135C.) Lecture; four hours; discussion; one hour; outside study, seven hours. Enforced 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, least squares, and Ritz approximation methods; shape functions; convergence properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric
169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 101, 102, 107. Fundamentals of vibration theory and applications. Free, forced, and damped vibration of single and multiple degrees of freedom systems, including damping. Normal modes, coupling, and normal coordinates. Vibration isolation devices, vibrations of continuous systems. Letter grading. Mr. Mal (F) 171A. Introduction to Feedback and Control Systems: Dynamic Systems Control I. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 107. Introduction to feedback principles, control systems design, and system stability. Modeling of physical systems in engineering and other fields; transform methods; controller design using Nyquist, Bode, and root locus methods; compensation; computer-aided analysis and design. Letter grading. Mr. M’Closkey (F,WSp) 171B. Digital Control of Physical Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 171A or Electrical Engineering 164. Introduction to digital control systems. Sampling theory. Z-transformation. Discrete-time system representation. Design using classical and modern control methods. Root locus, frequency response, loop-shaping compensation. Design using state-space methods: state feedback, state estimator, state estimator feedback control. Simulation of sampled data systems and practical control systems. Use of Green’s function and transform methods. Means of orthonormal functions; Galerkin method. Use of Green’s function and transform methods. Letter grading. Mr. C-J. Kim (F,WSp) 183A. Introduction to Manufacturing Processes. (4) Formerly numbered 183.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisite: Materials Science 104. Manufacturing processes. Conventional and non-conventional processes. Use of Green’s function and transform methods. Measuring devices and techniques. Letter grading. Mr. C-J. Kim (F,WSp) M183B. Introduction to Microscale and Nanoscale Manufacturing. (4) Same as Bioengineering M153. Chemical Engineering M153, and Electrical and Computer Engineering M153.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to manufacturing methods, mechanisms, constraints, and microfabrication and nanofabrication. Focus on concepts, physics, and instruments of various microfabrication and nanofabrication techniques that have been broadly applied in industry and academia, including various photolithography technologies, physical and chemical deposition methods, and physical and chemical etching techniques. Particulate fabrication and techniques for nanofabricating microstructures and nanostuctures in modern cleanroom environment. Letter grading. Mr. Chiou (F,Sp) 181C. Rapid Prototyping and Manufacturing. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 183A. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as a popular manufacturing methods. Hand-held prototype creation in the last two decades. Machine for layered manufacturing builds parts directly from CAD models. This novel manufacturing technology enables building of parts that 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. Production of three-dimensional solid objects instead of mere two-dimensional images. Methodology of rapid prototyping has also been extended into meso-/micro-/nano-scale to produce products. Concurrently scheduled with course C286. Letter grading. Mr. Chiou (F,Sp) 182C. Numerical Methods for Engineering Applications. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses M20 or (Civil Engineering M20 or Computer Science 31). Fundamentals in parametric curve and surface modeling, parametric spaces, blending functions, conics, splines and Bézier curves, coordinate transformations, algebraic and geometric form of surfaces, analytical properties of curve and surface, hands-on experience with CAD/CAM systems design and implementation. Letter grading. Mr. Mi (W) 184. Introduction to Geometry Modeling. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Enforced requisite: course 82. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals: La place transform; properties, convolution, inversion; Fourier transform: properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading. Mr. Gadh (Not offered 2017-18) 181A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 82. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals: Laplace transform; properties, convolution, inversion; Fourier transform: properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading. Mr. Gadh (Not offered 2017-18) 182B. Mathematics of Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 82. Analytical methods for solving partial differential equations arising in engineering, the generation of variables, eigenvalue problems, Sturm-Liouville theory. Development and use of special functions. Representation by means of orthogonal functions; Galerkin method. Use of Green’s function and transform methods. Letter grading. Mr. Gadh (Not offered 2017-18)
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perature; effects of variable fluid properties. Analo-
ologies among convective transfer processes. Letter
graduating. Mr. Livine (W) 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, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiation transfer in absorbing, emitting, and scattering media. Applications cover laser-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading. Mr. Pilon (Sp) 231C. Phase Change Heat Transfer and Two-Phase Flow. (4) Lecture; four hours; outside study, eight hours. Requisites: courses 131A, 150A. Two-phase flow, boiling, and condensation. Generalized constitutive equations for two-phase flow. Phenome-
nological theories of boiling and condensation, in-
cluding forced flow effects. Letter grading. Ms. Livine (W) 231G. Microscopic Energy Transport. (4) Lecture; four hours; outside study, eight hours. Requisite: course 105D. Heat carriers (photons, electrons, phonons and their energy characteristics), statistical properties of heat carriers, scattering and propagation of heat carriers, Boltzmann transport equation, classical laws from Boltzmann transport equations, deviation from classical laws at small scale. Letter grading. Mr. Jr (F) C232A. Mass Transfer. (4) Lecture; four hours; out-
side study, eight hours. Requisites: courses 105D, 131A, Principles of heat and mass transfer. Analysis of evaporative and transpiration cooling, ca-
talysis, and combustion. Mass exchangers, including automobile catalytic converters, electrostatic precipi-
tors, filters, scrubbers, humidifiers, and cooling towers. Concurrency scheduled with course C132A. Letter grading. Mr. Pilon (Not offered 2017-18) 233. Nanoscience for Energy Technologies. (4) Lecture; four hours; outside study, eight hours. Intro-
duction to fundamental principles of energy trans-
port, conversion, and storage at nanoscale, and re-
cent development for these energy technologies in-
volving nanotechnology. Focus on basics of thermal science, solid state, quantum mechanics, electro-
dynamics, and statistical mechanics. Topic discussion given for examples that connect technological appli-
cation, 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 de-
sign. Diffusion theory; reactor kinetics, slowing down and thermalization, multiphase methods, introduction to transport theory. Letter grading. Mr. Abdou (F) C237. Design and Analysis of Smart Grids. (4) Lecture; four hours; outside study, eight hours. De-
mand response; transactive/price-based load con-
trol; home-area network; smart energy profile; ad-
vanced metering infrastructure; renewable energy in-
tegration; solar and wind generation intermittency and correction; microgrids; grid stability; energy storage and electric vehicles-simulation; monitoring; distribution and transmission grids; consumer-centric telecommunications; communications and computing; wireless, wireline, and powerline communica-
tions for smart grids; grid modeling, stability, and control; frequency and voltage regulation; ancillary services; wide-area situational awareness, phasor measurements; analytical methods and tools for monitoring and control. Concurrently scheduled with course C137. Letter grading. Mr. Gad (Not offered 2017-18) 237B. Fusion Plasma Physics and Analysis. (4) Same as Electrical and Computer Engineering M237B. Lecture and/or project study; eight hours. Fundamentals of plasmas at thermonuclear burning conditions. Fokker/Planck equation and ap-
plications to heating by neutral beams, RF, and fusion reaction products. Bremsstrahlung, synchrotron, and atomic radiation processes. Plasma-surface interac-
tions. Fluid description of burning plasma. Dynamics, stability, and control. Applications in tokamaks, tandem mirrors, and alternate concepts. Letter grading. Mr. Abdou (F) 237D. Fusion Engineering and Design. (4) Lecture; four hours; outside study, eight hours. Fusion reac-
tions and fuel cycles. Principles of inertial and mag-
netic fusion. Plasma requirements for controlled fu-
sion. Plasma-surface interactions. Fusion reactor concepts and technological components. Analysis and design of high heat flux components, energy conversion and tritium breeding components, radia-
tion shielding, magnets, and heating. Letter grading. Mr. Abdou (Not offered 2017-18) 239B. Seminar: Current Topics in Transport Phenom-
ena. (2 to 4) Seminar; two to four hours; outside study. Requisite: course 105D. Laboratory experiment on me-
chanical and aerospace engineering students. Lec-
tures, discussions, student presentations, and proj-
ects in areas of current interest in transport phe-
omena. May be repeated for credit with topic change. S/U grading. Mr. Carman (Sp) 239F. Special Topics in Transport Phenomena. (2 to 4) Lecture; two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced and cur-
rent study of heat and mass transfer, including the trans-
fer, such as turbulence, stability and transition, buoyancy effects, variational methods, and measure-
techniques. May be repeated for credit with topic change. S/U grading. 239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture; two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in nuclear engineering, such as reactor safety, risk-benefit trade-offs, nuclear ma-
terials, and reactor design. May be repeated for credit with topic change. S/U grading. 239H. Special Topics in Fusion Physics, Engineer-
ing, and Technology. (2 to 4) Seminar; two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Discussion 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, magnetic fusion, microgravity effects, and fu-
sion reactor safety. May be repeated for credit with topic change. S/U grading. CM240. Introduction to Biomechanics. (4) Same as Bioengineering CM240.) Lecture; four hours; dis-
cussion; two hours; outside study, six hours. Requi-
sites: courses 101, 102, and 156A or 166A. Introduc-
tion 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. Mr. Gupta (W) CM241. Mechanics of Cells. (4) Same as Bioengi-
neering CM241.) Lecture; four hours. Introduction to physical structures of cell biology and physical princi-
ples that govern how they function mechanically. Re-
view and application of continuum mechanics and statistical mechanics to develop quantitative mathe-
matical models of structural mechanics in cells. Structure of macromolecules, such as entropic springs, random walks and diffusion, mechanosensi-
tive proteins, single-molecule force-extension, DNA packing and transcriptional regulation, lipid bilayer membranes, mechanics of cytoskeleton, molecular motors, biological electricity, muscle mechanics, pat-
tern formation. Concurrently scheduled with course CM141. Letter grading. 242. Introduction to Multiﬁerroc材料s. (4) Lecture; four hours; outside study, eight hours. Overview of different types of multiﬁerroc材料s, including strain mediated. Basic crystal structure of single-
phase multiﬁerroc材料s, and multiﬁerroc材料s physics underlying ferroelectricity and ferromagnetism. Mate-
rial science description of these materials, with focus on linear and nonlinear behavior with associated mechanisms such as spin representation. Presentation of analytical tools necessary to predict material re-
sponse ranging from constitutive relations to gov-
erning equations, including elastodynamics and Max-
well. Analytical and physical implementations to explain several devices manufactured with multiﬁer-
roics, including magnetometers, memory devices, motors, and antennas. Letter grading. Mr. Carman (Sp) 250A. Foundations of Fluid Dynamics. (4) Lecture; four hours; outside study, eight hours. Requisite: course 150A. Corequisite: course 182B. Develop-
ment and application of fundamental principles of fluid dynamics at graduate level. Emphasis on incom-
pressible flow. Flow kinematics, basic equa-
tions, constitutive relations, exact solutions on the
Navier/Stokes equations, vorticity dynamics, decom-
position of potential flows, potential flow theory. Letter grading. Mr. Eldredge, Mr. J. Kim (W) 250B. Viscous and Turbulent Flows. (4) Lecture; four hours; outside study, eight hours. Requisite: course 150A. Fundamental principles of fluid dy-
namics applied to study of two-dimentional viscos-
ous media. Letter grading. 250C. Compressible Flows. (4) Lecture; four hours; outside study, eight hours. Requisites: courses 150A, 150B. Effects of compressibility in viscous and in-
viscid flows. Steady and unsteady inviscid supersonic and supersonic flows; method of characteristics; small disturbance theories (linearized and hyper-
sonic); shock dynamics. Letter grading. Mr. Karagozian, Mr. Zhong (F) 250D. Computational Aerodynamics. (4) Lecture; eight hours. Requisites: courses 150A, 150B, 182C. Introduction to useful methods for computation of aerodynamic flow fields. Coverage of potential, Euler, and Navier-Stokes equations for subsonic to super-
sonic speeds. Letter grading. Mr. Zhong (Not offered 2017-18) 250E. Spectral Methods in Fluid Dynamics. (4) Lecture; four hours; outside study, eight hours. Re-
forced requisites: course 182B, 182C, 250A, 250B. Introduction to basic concepts and techniques of various spectral methods applied to solving partial differential equations. Particular emphasis on tech-
niques of solving unsteady three-dimensional Navier-
Stokes equations. Topics include spectral represen-
tation of functions, discrete Fourier transform, etc. Letter grading. Mr. J. Kim (Not offered 2017-18) 250F. Hypersonic and High-Temperature Gas Dy-
namics. (4) Lecture; four hours; outside study, eight hours. Recommended requisite: course 250C. Mo-
olecular and chemical description of equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical ther-
modynamics for calculation gas properties, equilibri-
um 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 (Sp) 250G. Fluid Dynamics of Biological Systems. (4) Lecture; four hours; outside study, eight hours. Req-
quisite: course 103. Mechanics of aquatic locomotion; 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. Concurrently scheduled with course C150G. Letter grading. Mr. Eldredge (Sp)
250H. Numerical Methods for Incompressible Flows. (4) Lecture, four hours; outside study, eight hours. Designed for graduate mechanical and aerospace engineering students. Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Classical presentation of finite element methods to describe mechanics of materials and structures. May be repeated for credit. S/U grading. Mr. Ghoniem (Not offered 2017-18)

250M. Introduction to Microfluids/Nanofluids. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Thermodynamic properties of gases, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Concurrently scheduled with course C150P. Letter grading. Mr. Kavehpour (Not offered 2017-18)

C250P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 105A, 150A. Thermodynamic properties of gases, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Concurrently scheduled with course C150P. Letter grading. Ms. Karagozian (Not offered 2017-18)

C250R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. Rocket propulsion concepts, including chemical rockets (liquid, gas, and solid propellants), hybrid rockets, thrusters, plasma rocket, nuclear rockets, and solar-powered vehicles. Current issues in launch vehicle technologies. Concurrently scheduled with course C150R. Letter grading. Ms. Karagozian, Mr. Wiz (Sp) (Not offered 2017-18)

252A. Stability of Fluid Motion. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Mechanisms by which laminar flows can become unstable and lead to turbulence of secondary motions. Linear stability theory; thermal, centrifugal, and shear instabilities; boundary layer instability. Nonlinear aspects: sufficient criteria for stability, subcritical instabilities, supercritical states, transition to turbulence. Letter grading. Mr. Zhong (Not offered 2017-18)

252B. Turbulence. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250B. Classical presentation of turbulent flows, conservation and transport equations, statistical description of turbulent flows, scales of turbulent motion, simple turbulent flows, free-shear flows, wall-bounded flows, turbulence models, and simulations of turbulent flows, and turbulence control. Letter grading. Mr. J. Kim (Not offered 2017-18)


252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Basic concepts in chemical kinetics: molecular collisions, distribution functions and averaging, semiequilibrium and ab initio potential surfaces, trajectory calculations, statistical reaction rate theories. Practical examples of large-scale chain mechanisms from combustion chemistry of several elements, etc. Letter grading. Ms. Karagozian (Not offered 2017-18)

252P. Plasma and Ionized Gases. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 82, 102, 150A, 182B. Neutral and charged particle motion, magnetohydrodynamics, two-fluid plasma treatments, plasma in fusion, Child/Langmuir law, basic plasma devices, electron emission and work function, thermal distributions, vacuum and vacuum systems, space-charge, particle collisions and ionization, plasma discharges, sheaths, and electric arcs. Letter grading. Mr. Wiz (Not offered 2017-18)

254A. Special Topics in Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 82, 150A, 150B, 182B, 182C. Special topics in aerodynamics and fluid mechanics. Examples include transonic flow, hypersonic flow, sonic booms, and unsteady aerodynamics. Letter grading. Mr. Zhong (Not offered 2017-18)

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. Spearrin (Not offered 2017-18)

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Concepts of stability; state-space interpretation; stability determination by simulation, linearization, and Lyapunov direct method; the Hamiltonian as a Lyapunov function; nonautonomous systems; averaging and perturbation methods of nonlinear analysis; parametric excitation and nonlinear response. Application to mechanical systems. Letter grading. Mr. M. Closskey (Not offered 2017-18)

256A. Linear Elasticity. (4) Same as Civil Engineering M230A.) Lecture, four hours; outside study, eight hours. Reinforce or 168A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastic problems; boundary value problems, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Introduction to boundary integral equation methods. Letter grading. Mr. W. Ju, Mr. Mal (W)

256B. Nonlinear Elasticity. (4) Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course 256A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stresses, Cauchy equations of motion, balance of energy, stored energy; constitutive relations; stability, hyperelasticity, thermoplasticity, linearization of field equations; solution of selected problems. Letter grading. Mr. W. Ju, Mr. Mal (W)


256F. Analytical Fracture Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Review of modern fracture mechanics, elementary stress analyses; analytical and numerical methods for calculation of crack tip stress intensity factors; engineering applications in stiffened structures, pressure vessels, plates, and shells. Letter grading. Mr. Gupta (Sp)

257A. Elastodynamics. (4) Same as Earth, Planetary, and Space Sciences M232A.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity, Cauchy equation of motion, constitutive relations, boundary and initial conditions, plane and axisymmetric cases. Sources and waves in unbounded isotropic, anisotropic, and dissipative solids. Half-space problems. Guided waves in layered media. Applications to dynamic fracture, nondestructive evaluation (NDE), and mechanics of earthquakes. Letter grading. Mr. Mal (Not offered 2017-18)

258A. Nanomechanics and Micromechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Analytical and computational modeling methods to describe mechanics of materials at scales ranging from atomicistic through microstructure or transitional and up to continuum. Discusses topics of atomicistic simulation, molecular dynamics, Langevin dynamics, and kinetic Monte Carlo (KMC) and their applications at nanoscale. Developments and applications of dislocation dynamics and statistical mechanics methods in areas of nanostructure and microstructure self-organization, long-range plastic deformation, material instabilities, and failure phenomena. Presentation of technical applications of these emerging treatment to surfaces and interfaces, grain boundaries, dislocations and defects, surface growth, quantum dots, nanotubes, nanoclusters, thin films (e.g., optical thermal barrier coatings and ultrastrong nanolayer materials), nano-identification, smart (active) materials, nanobending and microbending, and torsion. Letter grading. Mr. Ghoniem (Not offered 2017-18)

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with intensive student participation involving assignments in research problems leading to term paper or oral presentation (proceedings and lectures). Letter grading. Mr. Kavehpour, Mr. Spearrin (F)

259B. Seminar: Advanced Topics in Solid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study in various fields of solid mechanics of topics which may vary from term to term. Topics include dynamics, elasticity, plasticity, and stability of solids. Letter grading. Mr. Mal

260. Current Topics in Mechanical Engineering. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, and student presentations and projects in areas of current interest in mechanical engineering. May be repeated for credit. S/U grading.


262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 168A. Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology. Micro/macroscale analysis, including classical laminate theory, concentric cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials. Active systems design, inch-worm, and bimorph. Letter grading. Mr. Carman (S)

263A. Kinematics of Robotic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 155, 171A. Kinematic analysis of serial robotic manipulators, including spatial descriptions and transformations (Euler angles, Denavit-Hartenberg/ DH parameters, equivalent angle vector), frame assignment procedure, direct kinematics, inverse kinematics (geometric and algebraic approaches), mechanical design topics. Letter grading. Mr. Hong (F)
263B. Dynamics of Robotic Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 263B, 263C. 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 propagation method, explicit formulation of Jacobian matrix, manipulator dynamics (Newtron/Euler formulation, Lagrangian formulation), trajectory generation, introduction to parallel and closed kinematic chains. Letter grading. Mr. Rosen (W)

253C. Control of Robotic Systems. (4) Lecture, four hours; outside study, eight 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 from nonlinear and adaptive control, hybrid control, nonholonomic systems, vision-based control, and perception. Letter grading. Ms. Santos (Sp)

263D. Advanced Topics in Robotics and Control. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 263B. Currently offers and advanced topics in robotics and control, including kinematics, dynamics, control, mechanical design, advanced sensors and actuators, flexible links, manipulability, actuators, switching, harmonic interaction, teleoperation, haptics. Letter grading. Mr. Rosen (Not offered 2017-18)

M280A. Dynamics of Structures. (4) (Same as Civil Engineering 237A) Lecture, four hours; outside study, eight hours. Enforced requisite: course 195P. Principles of dynamics. Determination of normal modes and frequencies by differential and integral equation solutions. Transient and steady state response. Emphasis on derivation and solution of governing equations using matrix formulation. Letter grading. Mr. Mal (W)

265B. Advanced Dynamics of Structures. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course M269A. Analysis of linear and nonlinear response of structures to dynamic loadings. Stresses and deflections in structures. Structural damping and self-induced vibrations. Letter grading. Mr. Mal (Sp)

269D. Aerodynamic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course M269A. Presentation of field of aerelasticity from unified viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aerelastic operators and unsteady airloads from governing variational principles. Flowinduced instability and mechanisms of structural resonance. Letter grading. Mr. Mal (Not offered 2017-18)

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering 228A and Electrical and Computer Engineering 224A.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 217A or Electrical and Computer Engineering 141. 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; observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle. Connections with transfer function techniques. Letter grading. Mr. M'Closkey (F)

270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 270A or Electrical Engineering 240A. Existence and uniqueness of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time systems, finite-time and infinite-time problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, stabilizability, observability, and detectability solutions. Letter grading. Mr. Gibson (W)

M270C. Optimal Control. (4) (Same as Chemical Engineering M280C and Electrical and Computer Engineering 237/237L.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 270B. Applications of variational methods, Pontryagin maximum principle, Hamilton/Jacobi/Bellman equation (dynamic programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading. Mr. Speyer (Not offered 2017-18)

C271A. Probability and Stochastic Processes in Dynamical Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 271A. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading. Mr. Speyer (W)

271C. Stochastic Optimal Control. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 271A. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading. Mr. Speyer (W)

M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical and Computer Engineering M242A.) Lecture, four hours; outside study, eight hours. Enforced requisite: course M270A or Chemical Engineering M280A or Electrical and Computer Engineering M240A. State-space techniques for studying solutions of time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Lyapunov theory (including converse theorems), invariant, center manifold theorem, and stable/ unstable manifold theorem. Letter grading. Mr. Speyer (Not offered 2017-18)

M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical and Computer Engineering M242A.) Lecture, four hours; outside study, eight hours. Enforced requisite: course M270A or Chemical Engineering M280A or Electrical and Computer Engineering M240A. State-space techniques for studying solutions of time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Lyapunov theory (including converse theorems), invariant, center manifold theorem, and stable/ unstable manifold theorem. Letter grading. Mr. Speyer (Not offered 2017-18)

271D. Seminar: Special Topics in Dynamic Systems. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer (Not offered 2017-18)

M273A. Probability and Stochastic Processes in Dynamic Systems. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer (Not offered 2017-18)

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 271A. Graduate-level introduction to analysis and design of multi-variable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representation, 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 2017-18)

275A. System Identification. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 275A. Various methods to identify transfer functions and state-space models. Discussion of applications in mechanical and aeroelastic engineering, including identification of flexible structures, micro-electro-mechanical systems (MEMS) devices, and acoustic ducts. Letter grading. Mr. Gibson (Not offered 2017-18)

M276. Dynamic Programming. (4) (Same as Electrical and Computer Engineering 237.) Lecture, four hours; outside study, eight hours. Enforced requisite: Electrical and Computer Engineering 232A or 236A. Introduction to mathematical analysis of sequential decision processes. Finite horizon model in both deterministic and Markovian cases. Finite-state infinite horizon model. Methods of solution. Examples from inventory theory, finance, optimal control and estimation, Markov decision processes, combinatorial optimization, communications. Letter grading. Mr. Cottle (Not offered 2017-18)

277. Advanced Digital Control for Mechatronic Systems. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisites: courses 171B, M270A. Digital signal processing and control algorithms for mechatronic systems. Introduction to real-time control systems. Letter grading. Mr. Tsao (W)

279. Dynamics and Control of Biological Oscillators. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 107, M270A. Analysis and design of dynamical mechanisms underlying biological control systems that generate coordinated oscillations. Topics include neuronal information processing through action potentials (spike train), central pattern generator, coupled nonlinear oscillators, optimal gait (periodic motion) for animal locomotion, and entrainment to natural oscillations via feedback control. Letter grading. Mr. Speyer (W)

M280B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Bioengineering M250B and Electrical and Computer Engineering M250B.) Lecture, four hours; outside study, eight hours. Enforced requisite: course M183B. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes as well as their computer-aided design integration. Materials issues such as chemical resis- tance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. C-Ch. Kim (Not offered 2017-18)

281. Microsciences. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 102, 103, 105D. Fundamentals of being in microscopic world and mechanical engineering micro devices. Topics include scale issues, surface tension, superhydrophobic surfaces and applications, and electrowetting and applications. Letter grading. Mr. C-Ch. Kim (Not offered 2017-18)

M282. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Bioengineering M252 and Electrical and Computer Engineering M252.) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 277, M270A. Design methods, design rules, sensing and actuation mech- anisms, microsensors, and microactuators. Design- ing MEMS to be produced with both foundry and monolithic processes. Letter grading. Mr. C-Ch. Kim (Not offered 2017-18)


285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 282, 103, 105A, 105D. Introduction to fundamental physi- cal phenomena occurring at interfaces and applica- tion of their knowledge to engineering problems. Fundamental concepts of interfacial phenomena, incl-uding surface tension, surfactants, interfacial ther- modynamics, interfacial forces, interfacial hydrodynam-ics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), fouling and emul- sions, microelectromechanical systems, and biolog- ical systems. Letter grading. Mr. Pilon (Not offered 2017-18)

C286. Applied Optics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: Physics 1C. Fundamental principles of optical systems. Geometric optics and aberration theory. Di-

Letter grading.

Mr. Chiou (F)

M287. Nanoscience and Technology. (4) (Same as Electrical and Computer Engineering M257.) Lecture, four hours; outside study, eight hours. Enforced requisites: course CM280A. Introduction to fundamentals of nanoscience and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanofabrication; nanomaterials, nanoelectronics, and nanobiotechnology. Introduction to new knowledge and future technology. Concurrently scheduled with course C186. Letter grading.

Mr. Y. Chen (W)

C207L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles related to these techniques. Top-down and bottom-up (self-assembly) nanofabrication, nanomaterial characterization (AEM, SEM, etc.), and optical and biological techniques. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C187L.

Letter grading.

Mr. Y. Chen (Sp)

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: Materials Science 104, Physics 17. Science and engineering of laser microfabrication of advanced materials, including semiconductors, metals, and insulators. Topics include fundamentals in laser interactions with advanced materials, transport issues (therma, mass, chemical, carrier, etc.), and laser micromachining, state-of-the-art techniques for laser microfabrication, applications such as rapid prototyping, surface modifications (physical/chemical), micromachining for three-dimensional MEMS (microelectromechanical systems), micro/nano-device development, up-to-date research activities. Student term projects. Letter grading.

(Note not offered 2017-18)

294A. Compliant Mechanism Design. (4) (Formerly numbered 294B.) Lecture, four hours; outside study, eight hours. Enforced requisites: linear algebra. Advanced compliant mechanism synthesis approaches, modeling techniques, and optimization tools. Fundamentals of flexible constraint theory, principles of constrained design: objective geometry, screw theory kinematics, and freedom and constraint topologies. Applications: precision motion stages, general purpose flexure bearings, microstructural architectures, MEMS, and nanoelectromechanical systems. Hands-on exercises include build-your-own flexure kits, CAD and FEA simulations, and term project. Letter grading.

Mr. Hopkins (W)

295A. Radio Frequency Identification Systems: Analysis, Design, and Applications. (4) (Formerly numbered 295C.) Lecture, four hours; outside study, eight hours. Designed for graduate engineering students. Examination of emerging discipline of radio-frequency identification (RFID), including basics of RFID, how RFID systems function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading.

Mr. Gadhi (Not offered 2017-18)

C296A. Mechanical Design for Power Transmis-
sion. (4) (Formerly numbered 296A.) Lecture, four hours; outside study, eight hours. Enforced 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 the finite element method. Shaft design. Design project involving computer-aided design (CAD) and finite element analysis (FEA) modeling. Concurrently scheduled with course C156B.

Letter grading.

Mr. Ghoniem (Sp)

296B. High-Temperature Mechanical Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: course 156A or equivalent. Review of elasticity and continuum thermodynamics, multiaxial plasticity, flow rules, cyclic plasticity, viscoplasticity, creep, creep damage in cyclic loading. Damage mechanics: thermodynamics, ductile, creep, fatigue, and fatigue-creep interaction damage. Fracture mechanics: elastic and elastoplastic analysis, J-integral, brittle fracture, ductile fracture, fatigue and creep crack propagation. Applications in design of high-temperature components such as turbine blades, pressure vessels, heat exchangers, connecting rods. Design project involving CAD and FEM modeling. Letter grading.

Mr. Ghoniem (Not offered 2017-18)

C297A. Rapid Prototyping and Manufacturing. (4) Lecture, four hours; outside study, six hours. Recommended requisites: level of knowledge in manufacturing equivalent to course 183A and CAD capability. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as popular manufacturing technology to accelerate product creation in last two decades. Machine for layered manufacturing builds parts directly from CAD models. This novel manufacturing technology enables building of parts that have traditionally been impossible to fabricate because of their complex shapes or of variety in materials. In analogy to photolithography and flexography, 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 micro-/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 297BA.) (Same as Materials Science M297B.) Lecture, four hours; outside study, eight hours. Enforced requisites: course 156C, Materials Science 151. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/compression molding, filament winding, pultrusion, resin transfer molding, autoclave, material removal and assembly, metal and ceramic matrix composites, quality assurance. Letter grading.

Mr. Ghoniem (Not offered 2017-18)

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate mechanical and aerospace engineering students. Presentations of research topics by leading academic researchers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.

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

Mr. Mal (F, W, Sp)

495. Teaching Assistant Training Seminar. (2 to 6) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. Supervised investigation of advanced technical problems. S/U grading.

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

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

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

599. Research for and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Usually taken after students have been advanced to candidacy. S/U grading.
Master of Science in Engineering Online Programs

Program Requirements for the year in which ucla.edu. Students are subject to the Requirements are available at https://grad

The following introductory information is based on the 2017-18 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at https://grad.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

M.S. in Engineering Online 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

Engineering Management Program

Leslie M. Lackman, Ph.D. (Mechanical and Aerospace Engineering), 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.

The program has a strong on-campus component to enhance social networking, communications, and team-building skills. 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. All on-campus events are held on Saturday mornings.

Environment and Water Resources Program

Jennifer A. Jay, Ph.D. (Civil and Environmental Engineering), Director; jay@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 providing access to clean water. Key elements in this degree program are surface and groundwater processes, hydroclimatoloy, 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), Director; ajit@seas.ucla.edu

The main objective of the mechanics of structures program is to provide students with the opportunity to develop the knowledge required for the analysis and synthesis of modern engineered structures. The fundamental concepts of linear and nonlinear elasticity, plasticity, fracture mechanics, finite element analysis, mechanics of composites, and structural vibrations are developed in a series of undergraduate and graduate courses.

These concepts are then applied in solving industry-relevant problems in a number of graduate-level courses. Students develop hands-on experience in using popular finite element packages for solving realistic structural analysis problems.

System Engineering Program

Christopher S. Lynch, Ph.D. (Mechanical and Aerospace Engineering), Director; clynch@seas.ucla.edu

System engineering has broad applications that include software, hardware, materials, and electrical and mechanical systems. A set of four core courses is offered that form the foundation of the system engineering program. The sequence of courses is designed for working professionals who are faced with design, development, support, and maintenance of complex systems.

For students who already hold an M.S. degree, a separate certificate of completion of the system engineering program can be earned by completing three of the core courses. See http://www.msol.ucla.edu/system-engineering/.

Data Science Engineering Program

Junghoo (John) Cho, Ph.D. (Computer Science), Director; cho@cs.ucla.edu

Vwani P. Roychowdhury, Ph.D. (Electrical and Computer Engineering), 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.

**M.S. in Engineering—Aerospace**
Xiaolin Zhong, Ph.D. (Mechanical and Aerospace Engineering), Director; xiaolin@seas.ucla.edu

The main objective of the program is to provide students with broad knowledge of the major technical areas of aerospace engineering to fulfill the current and future needs of the aerospace industry. Major technical areas include aerodynamics and computational fluid dynamics (CFD), systems and control, and structures and dynamics. Courses cover fundamental concepts of science and engineering of aerodynamics, compressible flow, computational aerodynamics, digital control of physical systems, linear dynamic systems, linear optimal control, design of aerospace structures, and dynamics of structures. Through a graduate course, students also gain skills in the development and application of CFD codes for solving practical aerospace problems.

If students have taken Mechanical and Aerospace Engineering 150B, 154B, and 171B or the equivalent at their undergraduate institution, they can take other online-offered courses, approved by the area director, as substitute courses. In addition, students are required to complete a project on a topic related to the three major areas of this program.

**M.S. in Engineering—Computer Networking**
Mario Gerla, Ph.D. (Computer Science), Director; gerla@cs.ucla.edu

Three undergraduate elective courses complement the basic background of the undergraduate electrical engineering or computer science degree with concepts in security, sensors, and wireless communications. The graduate courses expose students to key applications and research areas in the network and distributed systems field. Two required graduate courses cover the Internet and emerging sensor embedded systems. The electives probe different applications domains, including wireless mobile networks, security, network management, distributed P2P systems, and multimedia applications.

**M.S. in Engineering—Electrical**
Izhak Rubin, Ph.D. (Electrical and Computer Engineering), Director; rubin@ee.ucla.edu

The electrical engineering program covers a broad spectrum of specializations in communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering 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), 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), Director; dejan@ee.ucla.edu

The integrated circuits program includes analog integrated circuit (IC) design, design and modeling of VLSI circuits and systems, RF circuit and system design, signaling and synchronization, VLSI signal processing, and communication system design. Summer courses are not yet offered in this program; therefore it cannot currently be completed in two calendar years.

**M.S. in Engineering—Manufacturing and Design**
Nasr M. Ghoniem, Ph.D. (Mechanical and Aerospace Engineering), Director; ghoniem@ucla.edu

The manufacturing and design program covers a broad spectrum of fundamental and advanced topics, including mechanical systems, digital control systems, microdevices and nanodevices, wireless systems, failure of materials, composites, and computational geometry. The program prepares students with the higher educational background that is necessary for today’s rapidly changing technology needs.

**M.S. in Engineering—Materials Science**
Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Director; jyang@seas.ucla.edu

Materials engineering is concerned with the design, fabrication, and testing of engineering materials that must simultaneously fulfill dimensional properties, quality control, and economic requirements. Several manufacturing steps may be involved: (1) primary fabrication, such as solidification or vapor deposition of homogeneous or composite materials, (2) secondary fabrication, including shaping and microstructural control by operations such as mechanical working, machining, sintering, joining, and heat treatment, and (3) testing, which measures the degree of reliability of a processed part, destructively or nondestructively.

**M.S. in Engineering—Mechanical**
Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Director; ajit@seas.ucla.edu

The mechanical engineering program offers students advanced study in a number of areas, including mechanical behavior of materials, structures, fluids, controls, and manufacturing.

**M.S. in Engineering—Signal Processing and Communications**
Izhak Rubin, Ph.D. (Electrical and Computer Engineering), 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), Director; jyang@seas.ucla.edu

The program provides students with a broad knowledge of structural materials. Courses cover fundamental concepts of science and engineering of lightweight advanced metallic and composite materials, fracture mechanics, damage tolerance and durability, failure analysis and prevention, nondestructive evaluation, structural integrity and life prediction, and design of aerospace structures. Students are required to complete a project on a topic related to structural materials.
Schoolwide Programs, Courses, and Faculty

6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601

310-825-9580
http://engineer.ucla.edu

Professor Emeritus
Allen B. Rosenstein, Ph.D.

Graduate Study
For information on graduate admission to the schoolwide engineering programs and requirements for the Engineer degree and certificate of specialization, see Graduate Programs, page 25.

Faculty Areas of Thesis Guidance
Professor Emeritus
Allen B. Rosenstein, Ph.D. (UCLA, 1958)

Educational delivery systems, computer-aided design, design, automatic controls, magnetic controls, nonlinear electronics

Lower-Division Courses

10A. Introduction to Complex Systems Science. (3) Lecture, four hours; outside study, eight hours. How macroscopic patterns emerge dynamically from local interactions of large number of interdependent (often heterogeneous) entities, without global design or central control, such emergent order, whose explanation cannot be reduced to explanations at level of individual entities, is ubiquitous in biology and human social collectives, but also exists in certain physical processes such as earthquakes and some chemical reactions. Complexity also deals with how such systems undergo sudden changes, including catastrophic breakdowns, in absence of external force or central influence. Key aspect of biological and social collectives is their nature as complex adaptive systems, where individuals and groups adjust their behavior to external conditions. In biological and social systems, complexly structured beyond traditional mathematics and statistics in its use of multigent computational models that better capture these complex, adaptive, and self-organizing phenomena. Letter grading.

Mr. Bragin (Not offered 2017-18)

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Designed to immerse incoming students in foundation concepts and principles of computer science, with focus on fundamental principles, methodologies, and techniques. Basic concepts of programming and C++ computing language. Offered in summer only. P/NP grading.

20. First-Year Engineering Transition Bridge. (2) Seminar, 32 hours. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Designed to immerse incoming students in foundation concepts and principles of computer science, with focus on fundamental principles, methodologies, and techniques. Basic concepts of programming and C++ computing language. Offered in summer only. P/NP grading.

21. Computing Immersion Summer Experience. (2) Seminar, 32 hours. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Designed to immerse incoming students in foundation concepts and principles of computer science, with focus on fundamental principles, 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 Students. (2) Seminar, 32 hours. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Designed to immerse incoming students in foundation concepts and principles of computer science, with focus on fundamental principles, methodologies, and techniques. Basic concepts of programming and C++ computing language. Offered in summer only. P/NP grading.

87. Introduction to Engineering Disciplines. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Introduction to engineering as professional opportunity for freshman students by exploring difference between engineering disciplines and functions engineers perform. Development of skills and techniques for academic excellence through team process. Investigation of national need underlying current effort to increase participation of historically underrepresented groups in U.S. technological workforce. Letter grading. Lead or co-teacher: Allen B. Rosenstein, Ph.D.

95. Internship Studies in Engineering. (2 to 4) Tutorial, two to four hours. Limited to freshmen/sophomores. Internship studies course supervised by associate dean or designated faculty members. Further supervision to be provided by organization for which students are doing internship. Students may be required to meet on regular basis with instructor and provide periodic reports of their experience. May not be applied toward degree. May be repeated for credit. Individual contract with associate dean required. P/NP grading. Mr. Wesel (F,W,Sp)

96A. Introduction to Engineering Design. (2) Formerly numbered 96E. Lecture, one hour; laboratory, one hour; outside study, four hours. Introduction to engineering design while building teamwork and communication skills and examination of engineering majors offered at UCLA and of engineering careers. Completion of hands-on engineering design projects, preparation of short report describing projects, and presentation of results. Specific project details and relevant majors explored vary with instructor. Letter grading. Mr. Reifer (F,W,Sp)

96B. Introduction to Engineering Design: Digital Imaging. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Recommended for undergraduate Aerospace Engineering, Bioengineering, Computer Science, Electrical Engineering, and Mechanical Engineering majors. Introduction to engineering design while building teamwork and communication skills and examination of engineering majors offered at UCLA and of engineering careers. Hands-on experience with state-of-art solid-state imaging devices. How to focus, expose, record, and manipulate electronic image. Use of photographic technology from early chemical experiments to widespread use of cell phone camera. Completion of hands-on engineering design projects, preparation of short report describing projects, and presentation of results. Letter grading. Mr. Stafudd (W,Sp)

96C. Introduction to Engineering Design: Internet of Things. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Recommended for undergraduate Aerospace Engineering, Bioengineering, Computer Science, Electrical Engineering, and Mechanical Engineering majors. Introduction to engineering design while building teamwork and communication skills and examination of engineering majors offered at UCLA and of engineering careers. Hands-on experience with state-of-art Internet of Things (IoT) technology to rapidly develop innovative and inspiring systems that provide ideal introduction to computing systems and IoT applications specific to their major field. IoT technology has become one of most important advances in technology. Exploring difference between engineering design projects, preparation of short report describing projects, and presentation of results. Letter grading. Mr. Kaiser (F,Sp)

99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower-division students 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

M101. Principles of Nanoscience and Nanotechnology. (4) (Same as Materials Science M105.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, Physics 13, or Physics 13C. Introduction to modern aspects of nanoscience encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena that emerge in very small systems (typically with feature sizes below few hundred nanometers) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties, electron transport, structural stability, self-assembly, templated assembly and applications of various nanostructures such as quantum dots, nanoparticles, quantum wires, quantum wells and multilayers, carbon nanotubes. Letter grading. Mr. Ozolins (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 systems to integrate biosciences and nanosciences into synthetic systems, where biological components are reengineered and rewired to perform desirable functions in both intracellular and cell-free environments. Discussion of basic technologies and systems analysis that deal with dynamic behavior, noise, and uncertainties. Design project in which students are challenged to design novel biosystems and nanosystems for non-trivial task required. Letter grading. Mr. Liu (F,Sp)

M103. Environmental Nanotechnology: Implications and Applications. (4) (Same as Civil Engineering M165.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course M101, Introduction to potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental protection. Topics 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. Mr. Hoek (Sp)

Collaborative learning techniques and community-building activities are integral processes to both day and evening programs. Intensive classroom instruction and collaborative learning workshops. Offered in summer only. P/NP grading.

Schoolwide Programs, Courses, and Faculty

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110. Introduction to Technology Management and Economics for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Fundamental principles of micro-level (individual, firm, and industry) and macro-level (government, international) economics as they relate to technology management. How individuals, firms, and governments impact successful commercialization of both technology products and services. Letter grading.  
Mr. Monbuquet (FW)

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. Topics include market forecasting and external financial analysis (fin/kepalex) marketing and financing of high-technology innovation. Concepts include present value, future value, discounted cash flow, internal rate of return, return on assets, return on equity, return on investment, interest rates, cost of capital, and product, price, positioning, and promotion. Use of market research, segmentation, and forecasting in management of technological innovation. Letter grading.  
Mr. Monbuquet (WSp)

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of finance, marketing, and technology commercialization. Topics include intellectual property management, team building, forecasting, and capitalization of neural finance. Students work in small teams studying technology management plans to bring new technologies to market. Students select from set of available topics and, with guidance of faculty mentors, many generated at UCLA, that are in need of plans for movement from laboratory to market. Letter grading.  
Mr. Monbuquet (FSp)

113. Product Strategy. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Designed for juniors/seniors. Introduction to current management concept of product development. Topics include product strategy, strategy formulation, and product line; competitive strategy, vectors of differentiation, product pricing, first-to-market versus fast-follower; growth strategy, growth through acquisition, and new ventures; product portfolio management. Case studies, class projects, group discussions, and guest lectures by speakers from industry. Letter grading.  
Mr. Pao (F)

116. Statistics for Management Decisions. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or 3H or English as a Second Language 36. Not open for credit to students with credit for course 185EW. Designed for junior/senior engineering students. Non-technical skills and experiences necessary to engineer career success. Importance of group dynamics in engineering practice. Teamwork, team building, and effective group skills in engineering environments. Organization and control of multidisciplinary complex engineering projects. Forms of leadership and characteristics of effective leaders. How engineering, computer sciences, and technology relate to major ethical and social issues. Societal demands on practice of engineering. Emphasis on research and writing in engineering writing requirement. Letter grading.  
Mr. Wesel (F, W, Sp)

185. Art of Engineering Endeavors. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or 3H or English as a Second Language 36. Not open for credit to students with credit for course 185EW. Designed for junior/senior engineering students. Non-technical skills and experiences necessary to engineer career success. Importance of group dynamics in engineering practice. Teamwork, team building, and effective group skills in engineering environments. Organization and control of multidisciplinary complex engineering projects. Forms of leadership and characteristics of effective leaders. How engineering, computer sciences, and technology relate to major ethical and social issues. Societal demands on practice of engineering. Emphasis on research and writing in engineering writing requirement. Letter grading.  
Mr. Wesel (F, W, Sp)

188. Special Courses in Engineering. (4) Seminar, two hours; outside study, four hours. Prerequisites: course 201. Designed for graduate students with B.S. degrees in engineering or science and work experience in selected domain. Art and science of architecture, introduction to architectural methodology—paradigm and tools. Principles of architectural theory and practice of architecture. Review of necessary processes to successfully manage technology projects. Discussion of selected elements of architectural practices, such as representation modeling, design progress, and architectural frameworks. Examination of professional practice and system architecture. Letter grading.  
Mr. Lynch, Mr. Wesel

192. Fundamentals of Engineering Mentorship. (2) Seminar, two hours; outside study, four hours. Prerequisites: course 201. Designed for graduate students with B.S. degrees in engineering or science and work experience in selected domain. Art and science of architecture, introduction to architectural methodology—paradigm and tools. Principles of architectural theory and practice of architecture. Review of necessary processes to successfully manage technology projects. Discussion of selected elements of architectural practices, such as representation modeling, design progress, and architectural frameworks. Examination of professional practice and system architecture. Letter grading.  
Mr. Lynch, Mr. Wesel

200. Program Management Principles for Engineers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of necessary processes and procedures to successfully manage technology projects. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manager with necessary information to support decision making. Process through which project products are on time and within budget. Letter grading.  
Mr. Wesel

201. Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements: system requirements and flow down, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and documentation. Letter grading.  
(W)

202. Reliability, Maintainability, and Supportability. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements: system requirements and flow down, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and documentation. Letter grading.  
(W)

203. System Architecture. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements: system requirements and flow down, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and documentation. Letter grading.  
(W)

204. Trusted Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements: system requirements and flow down, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and documentation. Letter grading.  
(W)

205. Model-Based Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements: system requirements and flow down, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and documentation. Letter grading.  
(W)

Graduate Courses

200. Program Management Principles for Engineers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of necessary processes and procedures to successfully manage technology projects. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manager with necessary information to support decision making. Process through which project products are on time and within budget. Letter grading.  
Mr. Wesel

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obtained, as course covers Object Management Group ( OMG) Certified Systems Modeling Professional (CCSMP) courses, such as Model User and Model Builder Fundamentals and Model Builder Intermediate. Letter grading. Mr. Mosleh (F)

206. Engineering for Systems Assurance. (4) Lecture, four hours; outside study, eight hours. Recommended: 204, Computer Science 236. Systems are constructed to perform complex functions and services. How to understand needs of users, analysis of requirements and derived requirements, creation of system architecture products, and design and integration of various components into systems that perform these functions and services. System assurance addresses confidence that system operational requirements based on evidence provided by applying assurance techniques. Introduction, investigation, and analysis of framework of assurance to accomplish total system assurance. Development of secure, reliable, and dependable systems that range from commercial realm such as air traffic control, Supervisory Control and Data Acquisition (SCADA), and autonomous vehicles to military realm such as command, control, communication, intelligence, and cyber. Letter grading.

210. Operations and Supply Chain Management. (4) Lecture, four hours; outside study, eight hours. Introduction to strategic operating issues and decisions involved in managing enterprises. Operational processes use organization’s resources to transform inputs into goods and utilizes them to provide service, or set of organizational and set of analytical tools provided to enable students to better understand why processes behave as they do. Given this understanding, students are able to involve themselves in organization’s defining strategic decisions, those related to key processes affecting organizational unit’s performance. Letter grading.

211. Financial Management. (4) Lecture, four hours; outside study, eight hours. Introduction to concepts reflecting material generally covered in certain M.B.A. core and elective courses. Integration of both theory—to introduce essential conceptual building blocks in accounting and finance—and empirical practice—to emphasize how these theories are actually implemented in real world. Cases, comprehensive problems, and recent events presented to provide students with as much hands-on experience in applying material presented as possible. Letter grading. Mr. J.-M. Yang

212. Intellectual Property Law and Strategy. (4) Lecture, four hours; outside study, eight hours. Prior knowledge of legal doctrines or materials not required. Intellectual property law is not just topic for lawyers. Engineers who have design responsibilities must understand how legal system in some instances protects their designs and in other instances stands as obstacle to what would otherwise be most efficient design choice. Engineers with management responsibilities must understand intellectual property law implications for everything from pricing to strategic partnerships. Examination of intellectual property law, not only by learning fundamental rules associated with patent, copyright, trademark, and trade secret protection, but by studying business strategies that these rules support. Examples and case studies to be taken from across content, technology, and pharmaceuticals. Letter grading. Mr. Lichtman, Mr. J.-M. Yang (F)

213. Data and Business Analytics. (4) Lecture, four hours; outside study, eight hours. Coverage of wide variety of spreadsheet models that can be used to solve business and engineering problems, with emphasis on mastery of Excel spreadsheet modeling as integral part of analytic decision making. Managerial models include data modeling, regression and forecasting, linear programming, integer programming, and Monte Carlo simulation. Problems from operational, finance, and marketing taught by spreadsheet examples and describe general managerial situations from various industries and disciplines. Development of spreadsheet models to facilitate decision making. Letter grading. Mr. Mosleh (W)

214. Management Communication. (4) Lecture, four hours. Exploration of knowledge, attributes, skills, and strategies necessary to succeed communicatively in workplace, with focus on business problem solving, skills, visual and verbal persuasion, skills, and interpersonal communication skills. Letter grading. Mr. J.-M. Yang

215. Entrepreneurship for Engineers. (4) Lecture, four hours; outside study, eight hours. Limited to graduate engineering students. Topics in starting and developing high-tech enterprises and intended for students who wish to complement their technical education with introduction to entrepreneurship. Letter grading. Mr. Wiesel (F)

299. Capstone Project. (4) Activity, 10 hours. Preparation: completion of minimum of four 200-level courses in online M.S. program. Project course that satisfies UCLA final comprehensive examination requirement of M.S. online degree in Engineering. Project is completed under individual guidance from UCLA Engineering faculty member and incorporates advanced knowledge learned in M.S. program of study. Letter grading. Mr. Lynch (F,Sp)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel instruction 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)

407A-407D. Engineer in Technical Environment. (3 each) Lecture, three hours; outside study, six hours. Limited to Engineering Executive Program students. Theory and application of quantitative methods in decision making and synthesis of engineering systems for purpose of making management decisions. Optimization of outputs with respect to dollar costs, time, material, energy, information, and manpower. Case studies and individual projects. S/U or letter grading.

417A-417B-417C. Engineer in General Environment. (3-3-1.5) Lecture, three hours (courses 417A, 417B) and 90 minutes (course 417C). 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 grading (417A) or letter (417B, 417C) grading. In Progress (417B) and S/U or letter (417C) grading.

427A-427B-427C. Engineer in Business Environment. (3-3-1.5) Lecture, three hours (courses 427A, 427B, 427C) and 90 minutes (course 427D). Limited to Engineering Executive Program students. Language of business for engineering executive. Accounting, finance, business economics, business law, and marketing. Laboratory in organization and management problem solving. Analysis of actual business problems of firm, community, and nation, provided through cooperation and participation with California business corporations and government agencies. In Progress (427A, 427C, and S/U) letter grading (credit to be obtained on completion of courses 427B and 427D).

472A-473B. Analysis and Synthesis of Large-Scale Systems. (3-3) Lecture, two and one half hours; outside study, six hours. Limited to Engineering Executive Program students. Problem area of modern industry or government is selected as class project, and its solution is synthesized utilizing quantitative tools and methods. Project also serves as laboratory in organization for goal-oriented technical group. In Progress (472A) and S/U (473B) grading.

485A. Teaching Assistant Training Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: appointment as teaching assistant. Limited to graduate engineering students. Seminar on communication of engineering principles, concepts, and methods, preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading. (F)

M495I. Teaching Preparation Seminar: Writing for Engineers. (2) Formerly numbered M495B. (Same as English Composition M495I) Seminar, two hours; outside study, four hours. Limited to graduate students. Required of all teaching assistants for Engineering writing courses not exempt by appropriate departmental or program training. Training and mentoring, with focus on composition pedagogy, assessment of student writing, guidance of revision process, and specialized writing problems that may occur in engineering writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F,Sp)

M495J. Supervised Teaching of Writing for Engineers. (2) 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. Continued focus on composition pedagogy, assessment of student writing, guidance of revision process, and specialized writing problems that may occur in engineering writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F,W,Sp)

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of UCLA graduate adviser and graduate dean, and host campus instructor, department chair, and graduate dean. Used for enrollment of UCLA students in courses taken under cooperative arrangements with USC. S/U grading.
Center for Domain-Specific Computing

National Science Foundation (NSF) Expeditions in Computing Program and InTrans Program

Jason Cong, Ph.D. (Computer Science), Director; http://www.cdsc.ucla.edu

To meet ever-increasing computing needs and overcome power density limitations, the computing industry has entered the era of parallelization, with tens to hundreds of computing cores integrated into a single processor and hundreds to thousands of computing servers connected in warehouse-scale data centers. However, such highly parallel, general-purpose computing systems still face serious challenges in terms of performance, energy, heat dissipation, space, and cost. The Center for Domain-Specific Computing (CDSC) looks beyond parallelization and focuses on domain-specific customization as the next disruptive technology to bring orders-of-magnitude power-performance efficiency improvement to important application domains.

CDSC develops a general methodology for creating novel customizable computing platforms and the associated compilation tools and runtime management environment to support domain-specific computing. The recent focus is on design and implementation of accelerator-rich architectures, from single chips to data centers. It also includes highly automated compilation tools and runtime management software systems for customizable heterogeneous platforms, including multi-core CPUs, many-core GPUs, and FPGAs, as well as a general, reusable methodology for customizable computing applicable across different domains. By combining these critical capabilities, the goal is to deliver a supercomputer-in-a-box or supercomputer-in-a-cluster that can be customized to an application domain to enable disruptive innovations in that domain. This approach has been successfully demonstrated in the domain of medical image processing.

The CDSC team originally consisted of researchers from four universities: UCLA (lead institution), Rice University, UC Santa Barbara, and Ohio State University. Oregon Health and Science University joined as a research partner under the InTrans program. The research team consists of a group of highly accomplished researchers with diversified backgrounds, including computer science and engineering, electrical engineering, medicine, and applied mathematics. CDSC offers many research opportunities for graduate students, and also offers summer research fellowship programs for high school and undergraduate students.

CDSC was originally funded by the National Science Foundation with a $10 million award from the 2009 Expeditions in Computing program, which was among the largest single investments made by the NSF Computer and Information Science and Engineering (CISE) Directorate. In July 2014, CDSC was awarded an additional $3 million by Intel Corporation with matching support from NSF under its Innovation Transition (InTrans) program. This award supports follow-on research on accelerator-rich architectures with applications to health care, in which personalized cancer treatment was added as an application domain in addition to medical imaging. Currently, CDSC has a number of industrial sponsors worldwide including Baidu, Falcon Computing Solutions, Fujitsu, Google, Huawei, Mentor Graphics, and Intel.

Center for Encrypted Functionalities

National Science Foundation (NSF) Secure and Trustworthy Cyberspace FRONTIER Award

Amit Sahai, Ph.D. (Computer Science), Director; http://cs.ucla.edu/cef/

The Center for Encrypted Functionalities tackles the deep and far-reaching problem of general-purpose program obfuscation, which aims to make an arbitrary computer program unintelligible while preserving its functionality. Viewed in a different way, the goal of obfuscation is to enable software that can keep secrets: it makes use of secrets, but such that these secrets remain hidden even if an adversary can examine the software code in its entirety and analyze its behavior as it runs. Secure obfuscation could enable a host of applications, from hiding the existence of many vulnerabilities introduced by human error to hiding cryptographic keys within software.

The center’s primary mission is to transform program obfuscation from an art to a rigorous mathematical discipline. In addition to its direct research program, the center organizes retreats and workshops to bring together researchers to carry out its mission. The center also engages in high-impact outreach efforts, such as the development of free massive open online courses (MOOCs).

Center for Function Accelerated nanoMaterial Engineering

Semiconductor Research Corporation (SRC) STArnett and Defense Advanced Research Projects Agency (DARPA) Researcher Center

Jane P. Chang, Ph.D. (Chemical and Biomolecular Engineering), Director; http://fame-nano.org

The Center for Function Accelerated nanoMaterial Engineering (FAME) aims to incorporate nonconventional materials and nanostructures with their quantum properties for enabling analog, logic, and memory devices for beyond-Boolean computation. Its main focus is nonconventional material solutions ranging from semiconductors and dielectrics to metallic materials as well as their correlated quantum properties. FAME creates and investigates new, nonconventional, atomic-scale engineered materials and structures of multifunction oxides, metals, and semiconductors to accelerate innovations in analog, logic, and memory devices for revolutionary impact on the semiconductor and defense industries.

FAME is one of six university-based research centers established by SRC through its Semiconductor Technology Advanced Research Network (STARnet). Funded by DARPA and the U.S. semiconductor and supplier industries as a public-private partnership, STARnet projects help maintain U.S. leadership in semiconductor technology vital to U.S. prosperity, security, and intelligence. FAME expects to receive a total of $35 million in funding through 2018.

Center for Translational Applications of Nanoscale Multiferroic Systems

National Science Foundation (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.ucla.edu

The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) is a 10-year program focused on miniaturizing electromagnetic devices using a three-pillar strategy involving research, translation, and education. The research strategy engages the best researchers from the six TANMS campuses (UCLA, UC Berkeley, Cornell University, California State University, Northridge, Northeastern University, and Univer-
sity of Texas at Dallas) to understand and develop new nanoscale multifunctional devices. The fundamental research activities work synergistically with the center’s industrial partners to translate the concepts into applications such as memory, antennas, and motors. These research and translational efforts rely on a workforce of postgraduate, graduate, undergraduate, and K-12 students that also help educate the next generation of engineering leaders. TANMS promotes an inclusive atmosphere, producing a more innovative and diverse research environment compared to monolithic center cultures.

Center of Excellence for Green Nanotechnologies
Kang L. Wang, Ph.D. (Electrical and Computer Engineering), Director; http://www.cegn-kacst-ucla.org

The Center of Excellence for Green Nanotechnologies (CEGN) undertakes frontier research and development in the areas of nanotechnology in energy and nanoelectronics. It tackles major issues of scaling, energy efficiency, energy generation, and energy storage faced by the electronics industry. CEGN researchers are innovating novel solutions through a number of complementary efforts that minimize power usage and cost without compromising electronic device performance. The approach is based on the integration of magnetic, carbon-based, organic, and optoelectronic materials and devices.

King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia and the Henry Samueli School of Engineering and Applied Science collaborate in CEGN under KACST’s established Joint Center of Excellence Program (JCEP) to promote educational technology transfer and research exchanges. KACST has an agreement with UCLA for research in nanoelectronics and clean energy for the next 10 years. KACST is both Saudi Arabia’s national science agency and its premier national laboratory. CEGN was awarded an additional $11 million through 2019 in its recent renewal effort, expanding on the work that was originally funded at $3.7 million.

Named Data Networking Project
National Science Foundation (NSF) Future Internet Architecture (FIA) Program
Lixia Zhang, Ph.D. (Computer Science), Principal Investigator; http://named-data.net

While the Internet has far exceeded expectations, it has also stretched initial assumptions, often creating tussles that challenge its underlying communication model. The TCP/IP architecture was designed to create a communication network where packets named only communication endpoints. Sustained growth in e-commerce, digital media, social networking, and smartphone applications has led to dominant use of the Internet as a distribution network. Solving distribution problems through a point-to-point communication protocol is complex and error-prone.

This project investigates a new Internet architecture called Named Data Networking (NDN). NDN changes the host-centric TCP/IP architecture to a data-centric architecture. This conceptually simple shift has far-reaching implications for how we design, develop, deploy, and use networks and applications. Today’s TCP/IP architecture uses addresses to communicate; NDN directly uses application data names to fetch data. TCP/IP secures the data container and communication channels; NDN directly secures the data, decoupling trust in data from trust in hosts. The project takes an application-driven, experimental approach to design and build a variety of applications on NDN to drive the development and deployment of the architecture and its supporting modules, test prototype implementations, and encourage community use, experimentation, and feedback into the design.

The new Future Internet Architectures—Next Phase (FIA-NP) program began in May 2014. The Named Data Networking Project is now under FIA-NP funding.

Smart Grid Energy Research Center
Rajit Gadh, Ph.D. (Mechanical and Aerospace Engineering), Director; http://smartgrid.ucla.edu

The UCLA Smart Grid Energy Research Center (SMERC) performs research, develops technology, creates innovations, and demonstrates advanced technologies to enable the development of the next generation of the electric utility grid—the smart grid. SMERC is currently working on electric vehicle-to-grid integration (V1G and V2G), microgrids, distributed renewable integration including solar and wind, energy storage integration within microgrids, autonomous electric vehicles, distributed energy resources, automated demand response, cybersecurity, and consumer behavior. SMERC also furnishes thought leadership through partnership between utilities, renewable energy companies, technology providers, electric vehicle and electric appliance manufacturers, DOE research labs, and universities, so as to collectively work on vision, planning, and execution towards a grid of the future. The partnership recently launched the Energy for a Smart Grid (ESmart) Industry Consortium. It is expected that this smart grid would enable integration of renewable energy sources, allow for integration of electric vehicles and energy storage, improve grid efficiency and resilience, reduce power outages, allow for competitive energy pricing, and overall become more responsive to market, consumer, and societal needs.

SMERC is a participant in the Los Angeles Department of Water and Power (LADWP) Regional Smart Grid Demonstration Project, which has been funded by DOE at an estimated $60 million for LADWP and its partners combined. The SMERC microgrid demonstration project is funded by the California Energy Commission.

WIN Institute of Neurotronics
Nanoelectronics Research Initiative National Institute of Excellence
Kang L. Wang, Ph.D. (Electrical and Computer Engineering), Director; http://win-nano.org

Successor to the Western Institute of Nanoelectronics (WIN), the WIN Institute of Neurotronics (WINs) focuses on cutting-edge research including nanostructures for high-efficiency solar cells, patterned nanostructures for integrated active optoelectronics on silicon, and carbon nanotube circuits. Through the multidisciplinary research efforts of WINs, the National Institute of Standards and Technology (NIST) awarded UCLA $6 million to build the Western Institute of Nanotechnology on Green Engineering and Metrology (WIN-GEM) building as part of the Engineering Building I replacement, which broke ground in 2013.

Wireless Health Institute
Benjamin M. Wu, D.D.S, Ph.D. (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; http://www.wirelesshealth.ucla.edu

Advances in engineering and computer science are enabling the design of powerful home and mobile technologies that can augment functional independence and daily activities of people with physical impairments, disabilities, chronic diseases, and the cumulative impairments associated with aging. These wireless mobile-health technologies can serve as monitoring devices of health and activity, provide feedback to train more...
healthy behaviors and lessen risk factors for stroke and heart disease, and offer novel outcome measures for individual care and large clinical trials.

The Wireless Health Institute believes that tiny sensors—including accelerometers, gyroscopes, force transducers, and visual and sound recorders worn on the body and in clothing—will become essential components for the delivery of health care and health maintenance. Sensors created by micro- and nano-technologies will simplify communications with health providers seamlessly over 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 Curriculum

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<th>UNITS</th>
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<tr>
<td><strong>FRESHMAN YEAR</strong></td>
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<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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<tr>
<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<tr>
<td>Mathematics 31A—Differential and Integral Calculus</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<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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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables</td>
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<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td>HSSEAS GE Elective</td>
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<td><strong>SOPHOMORE YEAR</strong></td>
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<td><strong>1st Quarter</strong></td>
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<td>Mathematics 32B—Calculus of Several Variables</td>
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<td>Physics 1C/4BL—Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<td>Materials Science and Engineering 104—Science of Engineering Materials</td>
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<td>Mathematics 33A—Linear Algebra and Applications</td>
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<tr>
<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials</td>
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<tr>
<td>Mechanical and Aerospace Engineering 105A—Introduction to Engineering Thermodynamics</td>
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<tr>
<td>Mechanical and Aerospace Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I)</td>
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<td>Mechanical and Aerospace Engineering 82—Mathematics of Engineering</td>
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<td>Mechanical and Aerospace Engineering 102—Dynamics of Particles and Rigid Bodies</td>
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<td><strong>JUNIOR YEAR</strong></td>
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<tr>
<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits</td>
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<td>Mechanical and Aerospace Engineering 103—Elementary Fluid Mechanics</td>
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<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems</td>
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<td>Mechanical and Aerospace Engineering 150A—Intermediate Fluid Mechanics</td>
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<td>Mechanical and Aerospace Engineering 150B—Aerodynamics</td>
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<td>Mechanical and Aerospace Engineering C150R (Rocket Propulsion Systems) or 161A (Introduction to Astronautics)</td>
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<td>Mechanical and Aerospace Engineering C150P—Aircraft Propulsion Systems</td>
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<td>Mechanical and Aerospace Engineering 154S—Flight Mechanics, Stability, and Control of Aircraft</td>
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<td>Mechanical and Aerospace Engineering 166A—Analysis of Flight Structures</td>
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<td>Mechanical and Aerospace Engineering 154A—Preliminary Design of Aircraft</td>
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<td>Mechanical and Aerospace Engineering 157—Basic Mechanical and Aerospace Engineering Laboratory</td>
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<td>Mechanical and Aerospace Engineering 154B—Design of Aircraft Structures</td>
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<td>Mechanical and Aerospace Engineering 157A—Fluid Mechanics and Aerodynamics Laboratory</td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
4. See page 104 for list of electives.
B.S. in Bioengineering Curriculum

FRESHMAN YEAR

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<td>Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity</td>
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SOPHOMORE YEAR

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<td>Life Sciences 7C—Physiology and Human Biology</td>
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JUNIOR YEAR

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<td>Bioengineering 176—Principles of Biocompatibility</td>
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SENIOR YEAR

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TOTAL 185

1. Counts as Mathematics and Basic Sciences for ABET; total units Mathematics and Basic Sciences = 74.
2. Counts as Engineering Concepts for ABET; total units Engineering Concepts = 70.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
5. Restricted electives include Bioengineering C101, C106, C131, C155, M260 (a petition is required for M260).
## B.S. in Chemical Engineering

### Chemical Engineering Core Option Curriculum

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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 HSSEAS GE (see page 22 for details).
# B.S. in Chemical Engineering

## Biomedical Engineering Option Curriculum

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## SOPHOMORE YEAR

| **1st Quarter** |       |
| Chemical Engineering 100—Fundamentals of Chemical and Biomolecular Engineering | 4 |
| Chemistry and Biochemistry 30AL—General Chemistry Laboratory II | 4 |
| Mathematics 32B—Calculus of Several Variables | 4 |
| Physics 1C—Electrodynamics, Optics, and Special Relativity | 5 |
| **2nd Quarter** |       |
| Chemical Engineering 102A—Thermodynamics I | 4 |
| Chemistry and Biochemistry 30B—Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy | 4 |
| Mathematics 33A—Linear Algebra and Applications | 1 |
| HSSEAS GE Elective | 5 |
| **3rd Quarter** |       |
| Chemical Engineering 102B—Thermodynamics II | 4 |
| Civil and Environmental Engineering M20—Introduction to Computer Programming with MATLAB | 4 |
| Mathematics 33B—Differential Equations | 4 |
| HSSEAS Ethics Course | 4 |

## JUNIOR YEAR

| **1st Quarter** |       |
| Chemical Engineering 101A—Transport Phenomena I | 4 |
| Chemical Engineering 109—Numerical and Mathematical Methods in Chemical and Biological Engineering | 4 |
| HSSEAS GE Elective | 5 |
| **2nd Quarter** |       |
| Chemical Engineering 45—Biomolecular Engineering Fundamentals | 4 |
| Chemical Engineering 101B—Transport Phenomena II: Heat Transfer | 4 |
| Chemical Engineering 104A—Chemical and Biomolecular Engineering Laboratory I | 4 |
| **3rd Quarter** |       |
| Chemical Engineering 101C—Mass Transfer I | 4 |
| Chemical Engineering 103—Separation Processes | 4 |
| Technical Breadth Course | 4 |

## SENIOR YEAR

| **1st Quarter** |       |
| Chemical Engineering 104B—Chemical and Biomolecular Engineering Laboratory II | 6 |
| Chemical Engineering 106—Chemical Reaction Engineering | 4 |
| Chemical Engineering CM145—Molecular Biotechnology for Engineers | 4 |
| Chemical Engineering Elective | 4 |
| **2nd Quarter** |       |
| Chemical Engineering 107—Process Dynamics and Control | 4 |
| Chemical Engineering 108A—Process Economics and Analysis | 4 |
| HSSEAS GE Elective | 5 |
| Technical Breadth Course | 4 |
| **3rd Quarter** |       |
| Chemical Engineering 108B—Chemical Process Computer-Aided Design and Analysis | 4 |
| HSSEAS GE Elective | 5 |
| Technical Breadth Course | 4 |

**TOTAL** 180

1. Counts as Mathematics and Basic Sciences for ABET; total units Mathematics and Basic Sciences = 64.
2. Counts as Engineering Concepts for ABET; total units Engineering Concepts = 75.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
# B.S. in Chemical Engineering
## Biomolecular Engineering Option Curriculum

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**TOTAL** | 180 |

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 64.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
B.S. in Chemical Engineering
Environmental Engineering Option Curriculum

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<tr>
<td>3rd Quarter</td>
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<tr>
<td>Chemical Engineering 101C—Mass Transfer</td>
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<tr>
<td>Chemical Engineering 103—Separation Processes</td>
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</tr>
<tr>
<td>HSSEAS GE Elective</td>
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<table>
<thead>
<tr>
<th>SENIOR YEAR</th>
<th></th>
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<tbody>
<tr>
<td>1st Quarter</td>
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</tr>
<tr>
<td>Chemical Engineering 104B—Chemical and Biomolecular Engineering Laboratory II</td>
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<tr>
<td>Chemical Engineering 106—Chemical Reaction Engineering</td>
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<td>Chemical Engineering Elective</td>
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<tr>
<td>Technical Breadth Course</td>
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<tr>
<td>2nd Quarter</td>
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</tr>
<tr>
<td>Chemical Engineering 107—Process Dynamics and Control</td>
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<tr>
<td>Chemical Engineering 108A—Process Economics and Analysis</td>
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<tr>
<td>HSSEAS GE Elective</td>
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<td>Technical Breadth Course</td>
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<tr>
<td>3rd Quarter</td>
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<tr>
<td>Chemical Engineering 108B—Chemical Process Computer-Aided Design and Analysis</td>
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<td>Chemical Engineering Elective</td>
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<tr>
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</table>

**TOTAL** | **180**

1. Counts as Mathematics and Basic Sciences for ABET; total units Mathematics and Basic Sciences = 64.
2. Counts as Engineering Concepts for ABET; total units Engineering Concepts = 75.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
# B.S. in Chemical Engineering

## Semiconductor Manufacturing Engineering Option Curriculum

<table>
<thead>
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</tr>
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<tr>
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<tr>
<td>Chemical Engineering 20A—Chemical Structure^1</td>
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<tr>
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<tr>
<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory^1</td>
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<tr>
<td>Mathematics 31B—Integration and Infinite Series^1</td>
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<tr>
<td>Physics 1A—Mechanics^1</td>
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<td>3rd Quarter</td>
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<tr>
<td>Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity^1</td>
<td>4</td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables^1</td>
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<tr>
<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory^1</td>
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## SOPHOMORE YEAR

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<tbody>
<tr>
<td>Chemical Engineering 100—Fundamentals of Chemical and Biomolecular Engineering^2</td>
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<tr>
<td>Chemistry and Biochemistry 30AL—General Chemistry Laboratory^II</td>
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<td>Mathematics 32B—Calculus of Several Variables^1</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity^1</td>
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<tr>
<td>Chemical Engineering 102A—Thermodynamics ^I</td>
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<tr>
<td>Chemistry and Biochemistry 30B—Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy^I</td>
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<tr>
<td>Mathematics 33A—Linear Algebra and Applications^1</td>
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## JUNIOR YEAR

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<thead>
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<tbody>
<tr>
<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^2</td>
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<tr>
<td>Chemical Engineering 45—Biomolecular Engineering Fundamentals^2</td>
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<tr>
<td>Chemical Engineering 101B—Transport Phenomena II: Heat Transfer^2</td>
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<tr>
<td>Chemical Engineering 104A—Chemical and Biomolecular Engineering Laboratory ^I</td>
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<td>3rd Quarter</td>
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<tr>
<td>Chemical Engineering 101C—Mass Transfer^2</td>
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<tr>
<td>Chemical Engineering 103—Separation Processes^2</td>
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## SENIOR YEAR

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<tbody>
<tr>
<td>Chemical Engineering 106—Chemical Reaction Engineering^2</td>
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<tr>
<td>Chemical Engineering or Materials Science and Engineering Elective^2</td>
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<tr>
<td>Chemical Engineering 107—Process Dynamics and Control^2</td>
<td>4</td>
</tr>
<tr>
<td>Chemical Engineering 108A—Process Economics and Analysis^2</td>
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<tr>
<td>HSSEAS GE Elective^3</td>
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<tr>
<td>Technical Breadth Course^3</td>
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<tr>
<td>Chemical Engineering 104C/104CL—Semiconductor Processing/Laboratory^2</td>
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<td>Chemical Engineering 108B—Chemical Process Computer-Aided Design and Analysis^2</td>
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<td>Chemical Engineering C116—Surface and Interface Engineering^2</td>
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**TOTAL** ........................................................................... 180

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 64.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
# B.S. in Civil Engineering Curriculum

**FRESHMAN YEAR**

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<tr>
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<th>Course</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>Civil and Environmental Engineering 1 — Civil Engineering and Infrastructure</td>
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<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>
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<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<tr>
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<td>Physics 1A — Mechanics</td>
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<tr>
<td>3rd Quarter</td>
<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
<td></td>
<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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**SOPHOMORE YEAR**

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<tbody>
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<td>1st Quarter</td>
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<td>Physics 1G — Electrodynamics, Optics, and Special Relativity</td>
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<td>HSSEAS Ethics Course</td>
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<td>Civil and Environmental Engineering 102 — Dynamics of Particles and Bodies</td>
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<td>Civil and Environmental Engineering C104 (Structure, Processing, and Properties of Civil Engineering Materials)</td>
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<td>Civil and Engineering 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 I)</td>
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<td>Mathematics 33B (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</th>
<th>Units</th>
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<tr>
<td>1st Quarter</td>
<td>Civil and Environmental Engineering 120 — Principles of Soil Mechanics</td>
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<td>Civil and Environmental Engineering 135A — Elementary Structural Analysis</td>
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<td>Civil and Environmental Engineering 150 — Introduction to Hydrology</td>
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<td>Civil and Environmental Engineering 153 — Introduction to Environmental Engineering Science</td>
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<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<td>Civil and Environmental Engineering 103 — Applied Numerical Computing and Modeling in Civil and Environmental Engineering</td>
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<td>Civil and Environmental Engineering 110 — Introduction to Probability and Statistics for Engineers</td>
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**SENIOR YEAR**

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<th>Units</th>
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<tbody>
<tr>
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<td>Major Field Electives</td>
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<td>Major Field Electives</td>
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<td>Technical Breadth Course</td>
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<tr>
<td>3rd Quarter</td>
<td>HSSEAS GE Elective</td>
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<td>Major Field Elective</td>
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<tr>
<td></td>
<td>Technical Breadth Course</td>
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**TOTAL**                                                      | 181   |

1. Counts as Mathematics and Basic Sciences for ABET; total units Mathematics and Basic Sciences = 56.
2. Counts as Engineering Concepts for ABET; total units Engineering Concepts = 84.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
4. Must include required courses for two of the major field areas listed on page 49.
# B.S. in Computer Engineering Curriculum

## FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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</thead>
<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 31 — Introduction to Computer Science I</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<tr>
<td>2nd Quarter</td>
<td>Computer Science 32 — Introduction to Computer Science II</td>
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<tr>
<td></td>
<td>Engineering 96C — Introduction to Engineering Design: Internet of Things</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>Physics 1A — Mechanics</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science 33 — Introduction to Computer Organization</td>
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<tr>
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<td>Electrical and Computer Engineering 3 — Introduction to Electrical Engineering</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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## SOPHOMORE YEAR

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<td>Computer Science 35L — Software Construction Laboratory</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Physics 4AL — Mechanics Laboratory</td>
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<td>Computer Science M51A or Electrical and Computer Engineering M16 — Logic Design of Digital Systems</td>
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<td>Electrical and Computer Engineering 10 — Circuit Theory I</td>
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<td>Electrical and Computer Engineering 102 — Systems and Signals</td>
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<td>Mathematics 33B — Differential Equations</td>
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<td>Electrical and Computer Engineering 110 — Circuit Theory II</td>
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<td>Mathematics 61 — Introduction to Discrete Structures</td>
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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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## JUNIOR YEAR

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<thead>
<tr>
<th>Quarter</th>
<th>Course Description</th>
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<tr>
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<td>Computer Science 111 — Operating Systems Principles</td>
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<td>Probability Elective</td>
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<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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<tr>
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<td>Computer Science M152A or Electrical and Computer Engineering M116L — Introductory Digital Design Laboratory</td>
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<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science M151B or Electrical and Computer Engineering M116C — Computer Systems Architecture</td>
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<td>Electrical and Computer Engineering Elective</td>
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<td>HSSEAS GE Elective</td>
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## SENIOR YEAR

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<tr>
<th>Quarter</th>
<th>Course Description</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical and Computer Engineering 113</td>
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<td>Technical Breadth Course</td>
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<td>2nd Quarter</td>
<td>Computer Science Elective</td>
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<tr>
<td></td>
<td>Electrical and Computer Engineering Design Course</td>
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<td>HSSEAS GE Elective</td>
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<td>Technical Breadth Course</td>
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<tr>
<td>3rd Quarter</td>
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<td>HSSEAS GE Elective</td>
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<tr>
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<td>Technical Breadth Course</td>
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</tr>
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</table>

**TOTAL** 182

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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 HSSEAS GE (see page 22 for details).
4. See page 62 or 81 for list of electives.
## B.S. in Computer Science Curriculum

### FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Computer Science 1 — Freshman Computer Science Seminar</td>
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</tr>
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<td>Computer Science 31 — 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>
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<tr>
<td>2nd</td>
<td>Computer Science 32 — Introduction to Computer Science II</td>
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<tr>
<td></td>
<td>Mathematics 31B — Integration and Infinite Series</td>
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</tr>
<tr>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
<td>3rd</td>
<td>Computer Science 33 — Introduction to Computer Organization</td>
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<tr>
<td></td>
<td>Computer Science 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

<table>
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<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Computer Science 35L — Software Construction Laboratory</td>
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<tr>
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<td>Computer Science M51A or Electrical and Computer Engineering M16</td>
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<td>HSSEAS Ethics Course</td>
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<td></td>
<td>Mathematics 32B — Calculus of Several Variables</td>
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<tr>
<td>2nd</td>
<td>Mathematics 33A — Linear Algebra and Applications</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Mathematics 61 — Introduction to Discrete Structures</td>
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<td></td>
<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
<td>5</td>
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<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)</td>
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</tr>
<tr>
<td>3rd</td>
<td>Computer Science 111 — Operating Systems Principles</td>
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<tr>
<td></td>
<td>Computer Science M152A or Electrical and Computer Engineering M116L</td>
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<tr>
<td></td>
<td>HSSEAS GE Elective</td>
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### JUNIOR YEAR

<table>
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<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>1st</td>
<td>Computer Science 118 — Computer Network Fundamentals</td>
<td>4</td>
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<tr>
<td></td>
<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
<td>4</td>
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<td>HSSEAS GE Elective</td>
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<tr>
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<td>Science and Technology Elective</td>
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</tr>
<tr>
<td>2nd</td>
<td>Computer Science 131 — Programming Languages</td>
<td>4</td>
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<tr>
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<td>Computer Science M151B or Electrical and Computer Engineering M116C</td>
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<tr>
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<td>Probability Elective</td>
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<tr>
<td>3rd</td>
<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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### SENIOR YEAR

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<th>Course</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
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<td>Computer Science 130 (Software Engineering) or 152B (Digital Design Project Laboratory)</td>
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<td>HSSEAS GE Elective</td>
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<td>Science and Technology Elective</td>
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<tr>
<td>2nd</td>
<td>Computer Science Electives</td>
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<td>Technical Breadth Course</td>
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<tr>
<td>3rd</td>
<td>Computer Science Elective</td>
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</tr>
<tr>
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<td>Science and Technology Elective</td>
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<td>Technical Breadth Course</td>
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<td>Additional coursework to meet 180 unit requirement</td>
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**TOTAL**                                                                                                           **180**

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 HSSEAS GE (see page 22 for details).
4. See page 62 for list of electives.
5. Any excess or available units not already applied to another degree requirement will satisfy these units.
# B.S. in Computer Science and Engineering Curriculum

## Freshman Year

<table>
<thead>
<tr>
<th>Quarter</th>
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<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>Computer Science 31 — 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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<td></td>
<td>Mathematics 31B — Integration and Infinite Series</td>
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<tr>
<td></td>
<td>Physics 1A — Mechanics</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Computer Science 33 — Introduction to Computer Organization</td>
<td>5</td>
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<tr>
<td></td>
<td>Mathematics 32A — Calculus of Several Variables</td>
<td>4</td>
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<tr>
<td></td>
<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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## Sophomore Year

<table>
<thead>
<tr>
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<th>Course Code</th>
<th>Course Name</th>
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<tbody>
<tr>
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<td>Computer Science 35L — Software Construction Laboratory</td>
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<td>Computer Science M51A or Electrical and Computer Engineering M16 — Logic Design of Digital Systems</td>
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<tr>
<td></td>
<td>Mathematics 32B — Calculus of Several Variables</td>
<td>4</td>
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<tr>
<td></td>
<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Mathematics 33A — Linear Algebra and Applications</td>
<td>4</td>
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</tr>
<tr>
<td></td>
<td>Mathematics 61 — Introduction to Discrete Structures</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)</td>
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<tr>
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<td>HSSEAS GE Elective</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
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<td></td>
<td>Electrical and Computer Engineering 3 — Introduction to Electrical Engineering</td>
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<td>Mathematics 33B — Differential Equations</td>
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## Junior Year

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<thead>
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<th>Course Name</th>
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</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td>Computer Science 111 — Operating Systems Principles</td>
<td>5</td>
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<tr>
<td></td>
<td>Electrical and Computer Engineering 10 (Circuit Theory I) and 11L (Circuits Laboratory I)</td>
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<tr>
<td></td>
<td>HSSEAS GE Elective</td>
<td>5</td>
<td></td>
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<tr>
<td>2nd Quarter</td>
<td>Computer Science 131 — Programming Languages</td>
<td>4</td>
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<tr>
<td></td>
<td>Computer Science M152A or Electrical and Computer Engineering M116L — Introductory Digital Design Laboratory</td>
<td>2</td>
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<tr>
<td></td>
<td>Electrical and Computer Engineering 102 — Systems and Signals</td>
<td>4</td>
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<tr>
<td></td>
<td>HSSEAS GE Elective</td>
<td>5</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science 118 — Computer Network Fundamentals</td>
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<tr>
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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 110 (Circuit Theory II) and 111L (Circuits Laboratory II)</td>
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## Senior Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Code</th>
<th>Course Name</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td>Computer Science 152B — Digital Design Project Laboratory</td>
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<td>Computer Science 181 — Introduction to Formal Languages and Automata Theory</td>
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<td>Computer Science Elective</td>
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<tr>
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<td>HSSEAS GE Elective</td>
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<tr>
<td>2nd Quarter</td>
<td>Computer Science Elective</td>
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<td>Electrical and Computer Engineering Elective</td>
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<td>HSSEAS GE Elective</td>
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<td></td>
<td>Technical Breadth Course</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science Elective</td>
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<td>HSSEAS GE Elective</td>
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<tr>
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<td>Technical Breadth Course</td>
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<td></td>
<td>Additional coursework to meet 180 unit requirement</td>
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**Total:** 180

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 49.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
4. See page 61 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

<table>
<thead>
<tr>
<th>Quarter</th>
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<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Computer Science 31—Introduction to Computer Science</td>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<tr>
<td>2nd</td>
<td>Mathematics 31A—Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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<tr>
<td></td>
<td>Computer Science 32—Introduction to Computer Science</td>
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<tr>
<td></td>
<td>Mathematics 31B—Integration and Infinite Series</td>
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<td>Physics 1A—Mechanics</td>
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<tr>
<td>3rd</td>
<td>Electrical and Computer Engineering M16 (or Computer Science M51A)—Logic Design of Digital Systems</td>
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<td>Mathematics 32A—Calculus of Several Variables</td>
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<tr>
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<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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#### SOPHOMORE YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<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 32A—Linear Algebra and Applications</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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<td>Electrical and Computer Engineering 10 (Circuit Theory I) and 11L (Circuits Laboratory I)</td>
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<td>Electrical and Computer Engineering 102—Systems and Signals</td>
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<td>Mathematics 33B—Differential Equations</td>
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<td>Physics 4BL—Electricity and Magnetism Laboratory</td>
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<td>Electrical and Computer Engineering 2—Physics for Electrical Engineers</td>
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<td>Electrical and Computer Engineering 110 (Circuit Theory II) and 111L (Circuits Laboratory II)</td>
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#### JUNIOR YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
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<td>Electrical and Computer Engineering 131A—Probability and Statistics</td>
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<td>HSSEAS GE Elective</td>
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<td>Electrical and Computer Engineering 101A—Engineering Electromagnetics</td>
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<td>Electrical and Computer Engineering Core Course</td>
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<td>HSSEAS GE Elective</td>
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<td>3rd</td>
<td>Electrical and Computer Engineering Core Course</td>
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<td>Electrical and Computer Engineering Core Course or Computer Science 33 (Introduction to Computer Organization)</td>
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#### SENIOR YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
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<td>Electrical and Computer Engineering Design Course</td>
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<td>Electrical and Computer Engineering Elective</td>
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<td>Technical Breadth Course</td>
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<tr>
<td>2nd</td>
<td>Electrical and Computer Engineering Design Course</td>
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<td>Electrical and Computer Engineering Elective</td>
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<td>Technical Breadth Course</td>
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<td>Electrical and Computer Engineering or HSSEAS Elective</td>
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**TOTAL** ........................................................................................................................................... 182

1. Counts as Mathematics and Basic Sciences for ABET; total units Mathematics and Basic Sciences = 47.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
4. See page 80 for list of core courses.
# B.S. in Materials Engineering Curriculum

## Materials Engineering Option Curriculum

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<tr>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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</tr>
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<td>Mathematics 21A — Differential and Integral Calculus</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<tr>
<td>Mathematics 21B — Integration and Infinite Series</td>
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<td>Physics 1A — Mechanics</td>
<td>5</td>
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<td><strong>3rd Quarter</strong></td>
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</tr>
<tr>
<td>Mathematics 22A — Calculus of Several Variables</td>
<td>4</td>
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<tr>
<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td><strong>SUMMARY</strong></td>
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<thead>
<tr>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Civil and Environmental Engineering 101 (Statics) or Mechanical and Aerospace Engineering 101 (Statics and Strength of Materials)</td>
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<tr>
<td>Mathematics 22B — Calculus of Several Variables</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Materials Science and Engineering 90L — Physical Measurement in Materials Engineering</td>
<td>2</td>
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<tr>
<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I)</td>
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<td>Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)</td>
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<td>HSSEAS Ethics Course</td>
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<td>Technical Breadth Course</td>
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<td><strong>SUMMARY</strong></td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 54.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 22 for details).
4. See counselor in 6426 Boelter Hall for details.
5. See page 97 for list of approved mathematics courses.
6. Any excess or available units not already applied to another degree requirement will satisfy these units.
# B.S. in Materials Engineering

## Electronic Materials Option Curriculum

### FRESHMAN YEAR

#### 1st Quarter
- Chemistry and Biochemistry 20A—Chemical Structure
- English Composition 3—English Composition, Rhetoric, and Language
- Mathematics 31A—Differential and Integral Calculus
- Materials Science and Engineering 10—Freshman Seminar: New Materials

#### 2nd Quarter
- Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory
- Mathematics 31B—Integration and Infinite Series
- Physics 1A—Mechanics

#### 3rd Quarter
- Mathematics 32A—Calculus of Several Variables
- Physics 1B—Oscillations, Waves, Electric and Magnetic Fields
- HSSEAS GE Elective

### SOPHOMORE YEAR

#### 1st Quarter
- Materials Science and Engineering 104—Science of Engineering Materials
- Mathematics 32B—Calculus of Several Variables
- HSSEAS GE Elective

#### 2nd Quarter
- Materials Science and Engineering 90L—Physical Measurement in Materials Engineering
- Mathematics 32A—Linear Algebra and Applications
- Physics 1C—Electrodynamics, Optics, and Special Relativity
- HSSEAS GE Elective

#### 3rd Quarter
- Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science II)
- Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)
- Mechanical and Aerospace Engineering 101—Statics and Strength of Materials
- HSSEAS Ethics Course

### JUNIOR YEAR

#### 1st Quarter
- Electrical and Computer Engineering 100—Electrical and Electronic Circuits
- Materials Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory
- Materials Science and Engineering 130—Phase Relations in Solids
- HSSEAS GE Elective

#### 2nd Quarter
- Electrical and Computer Engineering 101A—Engineering Electromagnetics
- Materials Science and Engineering 120 (Physics of Materials) or Electrical and Computer Engineering/Electrical and Computer Engineering 2 (Physics for Electrical Engineers)
- Materials Science and Engineering 122—Principles of Electronic Materials Processing
- Materials Science and Engineering 131/131L—Diffusion and Diffusion-Controlled Reactions/Laboratory

#### 3rd Quarter
- Materials Science and Engineering 121/121L—Materials Science of Semiconductors/Laboratory
- Materials Science and Engineering 132—Structures and Properties of Metallic Alloys
- Electronic Materials Elective (Materials Science and Engineering 150—Introduction to Polymers or 160—Introduction to Ceramics and Glasses)
- Technical Breadth Course

### SENIOR YEAR

#### 1st Quarter
- Electrical and Computer Engineering 121B—Principles of Semiconductor Device Design
- Upper-Division Mathematics Course
- Technical Breadth Course

#### 2nd Quarter
- Electronic Materials Elective
- Electronic Materials Laboratory Course
- HSSEAS GE Elective
- Technical Breadth Course

#### 3rd Quarter
- Materials Science and Engineering 140—Materials Selection and Engineering Design
- Electronic Materials Elective
- Electronic Materials Laboratory Course

### TOTAL

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 HSSEAS GE (see page 22 for details).
4. See counselor in 6426 Boelter Hall for details.
5. See page 98 for list of approved mathematics courses.
# B.S. in Mechanical Engineering Curriculum

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**TOTAL** | 182

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 HSSEAS GE (see page 22 for details).
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