Contents

A Message from the Dean ........................................ 3
Henry Samueli School of Engineering and Applied Science ................................. 4
  Officers of Administration ........................................ 4
  The Campus ....................................................... 4
  The School ...................................................... 4
  Endowed Chairs .................................................. 5
  The Engineering Profession ....................................... 5
Correspondence Directory ........................................ 7
Calendars ........................................................... 8
General Information ................................................. 9
  Facilities and Services ......................................... 9
  Library Facilities ............................................... 9
  Services ......................................................... 9
  Continuing Education ......................................... 9
  Career Services ............................................... 10
  Arthur Ashe Student Health and Wellness Center ....................... 10
  Services for Students with Disabilities .......................... 10
  Dashew Center for International Students and Scholars .................... 10
Fees and Financial Support ....................................... 10
  Fees and Expenses ............................................ 10
  Living Accommodations ....................................... 11
  Financial Aid ................................................... 11
Special Programs, Activities, and Awards .................................................. 13
  Center for Excellence in Engineering and Diversity ..................... 13
  Student Organizations ......................................... 14
  Women in Engineering ......................................... 15
  Student and Honorary Societies ................................ 15
  Student Representation ........................................ 15
Prizes and Awards ................................................ 15
  Departmental Scholar Program ................................ 16
  Official Publications ........................................ 16
  Grading Policy ................................................ 16
  Grade Disputes ................................................ 16
  Nondiscrimination .............................................. 16
  Harassment ..................................................... 16
Undergraduate Programs .......................................... 18
  Admission ...................................................... 18
  Requirements for B.S. Degrees ................................ 21
  Honors ......................................................... 23
Graduate Programs ................................................. 24
  Admission ...................................................... 25
  Bioengineering .................................................. 26
  Chemical and Biomolecular Engineering ................................ 38
  Civil and Environmental Engineering .................. 47
  Computer Science ............................................. 59
  Electrical Engineering ........................................ 77
  Materials Science and Engineering ................................ 94
  Mechanical and Aerospace Engineering .......................... 101
  Master of Science in Engineering Online Programs .................... 116
  Schoolwide Programs, Courses, and Faculty ........................ 118
Externally Funded Research Centers and Institutes ............................... 121
Curricula Tables ................................................... 124
Index .............................................................. 138

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": name, address (local/mailing, permanent, and/or e-mail), 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 on 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.

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 the Dean of Students, 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 the Dean of Students, 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 https://grad.ucla.edu.

Cover: Students participate in Engineering Open House activities.
A Message from the Dean

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, semiconductors, biotechnology, and other areas are headquartered in Southern California or have a major presence here. The region also has a major startup scene in which so many UCLA engineers play a part. Los Angeles sets the agenda in design, arts and entertainment, sustainability, the environment, and more.

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

Finally, UCLA 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
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
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 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 School

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

UCLA engineering faculty members are active participants in many interdisciplinary research centers. The 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 Neuromorphic Engineering (WINes) 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 (CDSC) 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 Garrick 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 controls; advanced technologies for water reclamation; and new approaches and technologies for aerospace engineering.

And the school has established the Institute for Technology Advancement (ITA) dedicated to the effective transition of high-impact innovative research from UCLA to product development and commercialization. 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 39 academic and professional degree programs. The Bachelor of Science degree is offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil 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. Reamers 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
- Symantec Term Chair in Computer Science
- Carol and Lawrence E. Tannas, Jr., Endowed 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,

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 either in the computer science and engineering program or in the computer science 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 Engineering

The electrical engineering discipline deals primarily with the sensing, analysis, and processing of information. It develops circuits, devices, algorithms, and theories that can be used to sense data, analyze data, extrapolate data, communicate data, and take action in response to the data collected. The Electrical 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 engineering courses.

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

Mechanical Engineering

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

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

Mechanical engineers apply their knowledge to a wealth of systems, products, and processes, including energy generation, utilization and conservation, power and propulsion systems (power plants, engines), and commercial products found in the automotive, aerospace, chemical, or electronics industries.

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

Aerospace Engineering
Michel Moraga, 310-825-5760, michel@seas.ucla.edu; Vanessa Hernandez, 310-825-2757, vanessah@seas.ucla.edu

Bioengineering
Erkki Corpuz, 310-825-9442, erkki@seas.ucla.edu; Ashley Benson, 310-206-2891, abenson@seas.ucla.edu; Victoria Moraga, 310-825-9602, vikki@seas.ucla.edu

Chemical and Biomolecular Engineering
Ashley Benson, (310)206-2891, abenson@seas.ucla.edu; Erkki Corpuz, 310-825-9442, erkki@seas.ucla.edu; Julietta Torres, 310-206-6397, juliet@seas.ucla.edu

Civil Engineering
Vanessa Hernandez, 310-825-2757, vanessah@seas.ucla.edu; Jan J. LaBuda, 310-825-2514, jan@seas.ucla.edu; Erkki Corpuz, 310-825-9442, erkki@seas.ucla.edu; Ashley Benson, (310)206-2891, abenson@seas.ucla.edu

Computer Science
Alina Haas, 310-825-2889, ahaas@seas.ucla.edu; Michel Moraga, 310-825-5760, michel@seas.ucla.edu; Mary Anne Geber, 310-825-2036, maryanne@seas.ucla.edu; Jan J. LaBuda, 310-825-2514, jan@seas.ucla.edu; Victoria Moraga, 310-825-9602, vikki@seas.ucla.edu

Computer Science and Engineering
Alina Haas, 310-825-2889, ahaas@seas.ucla.edu; Michel Moraga, 310-825-5760, michel@seas.ucla.edu; Mary Anne Geber, 310-825-2036, maryanne@seas.ucla.edu; Jan J. LaBuda, 310-825-2514, jan@seas.ucla.edu; Victoria Moraga, 310-825-9602, vikki@seas.ucla.edu

Electrical Engineering
Mary Anne Geber, 310-825-2036, maryanne@seas.ucla.edu; Jan J. LaBuda, 310-825-2514, jan@seas.ucla.edu; James Washington, 310-825-1704, jaw@seas.ucla.edu; Alina Haas, 310-825-2889, ahaas@seas.ucla.edu; Victoria Moraga, 310-825-9602, vikki@seas.ucla.edu; Julietta Torres, 310-206-6397, juliet@seas.ucla.edu

Materials Engineering
James Washington, 310-825-1704, jaw@seas.ucla.edu; Jan J. LaBuda, 310-825-2514, jan@seas.ucla.edu; Erkki Corpuz, 310-825-9442, erkki@seas.ucla.edu

Mechanical Engineering
Michel Moraga, 310-825-5760, michel@seas.ucla.edu; Jan J. LaBuda, 310-825-2514, jan@seas.ucla.edu; Vanessa Hernandez, 310-825-2757, vanessah@seas.ucla.edu

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

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/applicat.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
# Academic Calendar

<table>
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<tr>
<th>Event</th>
<th>Fall 2016</th>
<th>Winter 2017</th>
<th>Spring 2017</th>
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<tr>
<td>First day for continuing students to check MyUCLA at</td>
<td>June 1</td>
<td>October 26</td>
<td>TBA</td>
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<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 13</td>
<td>November 9</td>
<td>February 6</td>
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<tr>
<td>Quarter begins</td>
<td>September 19</td>
<td>January 4, 2017</td>
<td>March 29</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>Instruction begins</td>
<td>September 22</td>
<td>January 9</td>
<td>April 3</td>
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<tr>
<td>Last day for undergraduates to add courses with per-course fee</td>
<td>October 14</td>
<td>January 27</td>
<td>April 21</td>
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<td>through MyUCLA</td>
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<td>Last day for undergraduates to drop nonimpacted courses</td>
<td>October 21</td>
<td>February 3</td>
<td>April 28</td>
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<td>without a transcript notation (with per-transaction fee</td>
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<td>through MyUCLA</td>
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<td>Last day for undergraduates to change grading basis (optional P/NP)</td>
<td>November 4</td>
<td>February 17</td>
<td>May 12</td>
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<td>with per-transaction fee through MyUCLA</td>
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<tr>
<td>Instruction ends</td>
<td>December 2</td>
<td>March 17</td>
<td>June 9</td>
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<tr>
<td>Final examinations</td>
<td>December 5–9</td>
<td>March 20–24</td>
<td>June 12–16</td>
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<td>Quarter ends</td>
<td>December 9</td>
<td>March 24</td>
<td>June 16</td>
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<td>HSSEAS Commencement</td>
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<td>June 17</td>
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<td>Academic and administrative holidays</td>
<td>November 11</td>
<td>January 16</td>
<td>March 31</td>
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<td>November 24-25</td>
<td>February 20</td>
<td>May 29</td>
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<td>December 23, 26</td>
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<td>December 30,  January 2</td>
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<tr>
<td>Winter campus closure (tentative)</td>
<td>December 27–29</td>
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# Admission Calendar

<table>
<thead>
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<th>Event</th>
<th>Fall 2016</th>
<th>Winter 2017</th>
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<td>Filing period for undergraduate applications (file online at <a href="http://admission.universityofcalifornia.edu/how-to-apply/apply-online/index.html">http://admission.universityofcalifornia.edu/how-to-apply/apply-online/index.html</a>)</td>
<td>November 1–30, 2015</td>
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<tr>
<td>Last day to file Application for Graduate Admission or readmission</td>
<td>Consult department</td>
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<td>with complete credentials and application fee, online at <a href="https://app.applyyourself.com/AYApplicantLogin/t_ApplicantConnectLogin.asp?id=ucla-grad">https://app.applyyourself.com/AYApplicantLogin/t_ApplicantConnectLogin.asp?id=ucla-grad</a> or with Graduate Diversity, Inclusion, and Admissions (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 1113 Murphy Hall (late applicants pay a late fee)</td>
<td>August 15</td>
<td>November 25</td>
<td>February 25</td>
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</table>
General Information

Facilities and Services

Teaching and research facilities at HSSEAS are in Boelter Hall, Engineering I, Engineering IV, Engineering V, and Engineering VI, located in the southern part of the UCLA campus. Boelter Hall houses classrooms and laboratories for undergraduate and graduate instruction, the Office of Academic and Student Affairs (http://www.seasoasa.ucla.edu), the SEASnet computer facility (http://www.seas.ucla.edu/seasnet/), specialized libraries, and offices of faculty and administration. The Shop Services Center and the Student and Faculty Shop are in the Engineering I building. 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, group study rooms, a learning commons, a research commons for collaborative projects, 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 backend 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 to off-site storage 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
Department of Engineering and Technology
Varaz Shahmirian, Ph.D., Director
Roman Fry, M.B.A., MSAE, Program Director
The UCLA Extension (UNEX) Department of Engineering and Technology (540 UNEX, 10995 Le Conte Avenue) provides 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 https://www.uclaextension.edu/shortcourses/. The acclaimed Technical Management Program has been offered for more than 60 years. See https://www.uclaextension.edu/tmp/.
The Information Systems program offers over 200 courses annually in applications programming, database management, information systems security, Linux/Unix, operating systems, systems analysis, data science, and Web technology. The engineering program offers over 250 courses annually, including 10 certificate programs in astronautical engineering, biotechnology engineering, communication systems, construction management, contract management, digital signal processing, government cost estimating and pricing, manufacturing engineering, medical device engineering, project management, recycling and solid waste management, and supply chain management. In addition, the department offers EIT and PE review courses in mechanical, civil, and chemical engineering. Most engineering and technical management courses are offered evenings on the UCLA campus, or are available online. See https://www.uclaextension.edu/eismv/.

Career Services
The UCLA Career Center assists HSSEAS undergraduate and graduate students and alumni in exploring career possibilities, preparing for graduate and professional school, obtaining employment and internship leads, and developing skills for conducting a successful job search. Services include career consulting and counseling, skills assessments, workshops, employer information sessions, and a multimedia collection of career planning and job search resources. BruinView™ furnishes undergraduate and graduate students with opportunities to meet one-on-one with employers seeking entry-level job candidates and offers 24-hour access to thousands of current full-time, part-time, seasonal, and internship positions. The annual engineering and technical fairs are held in fall and winter quarters, and HSSEAS students are also welcomed at all Career Center-sponsored job fairs. The Career Center staff also provides consultation services to HSSEAS student organizations. Career services are available at the UCLA Career Center, 501 Westwood Plaza, Strathmore Building, from 9 a.m. to 5 p.m. Monday through Friday, by appointment and for same-day counseling sessions. For more information call 310-206-1915 or see http://career.ucla.edu.

Arthur Ashe Student Health and Wellness Center
The Ashe Student Health and Wellness Center in Westwood Plaza (310-825-4073) 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 UCHIP 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 UCHIP benefits tier structure and coverage information, see the Ashe Center website and select Insurance, send e-mail to shsinsurance@ashe.ucla.edu, or call 310-825-4073.

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

Office hours during the academic year are 8 a.m. to 5:30 p.m. Monday through Friday, 9 a.m. to 4:30 p.m. Friday. Located at 221 Westwood Plaza (next to John Wooden Center), 310-825-4073; see http://www.studenthealth.ucla.edu.

Services for Students with Disabilities
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. Located at A255 Murphy Hall; voice 310-825-1501, TTY 310-206-6083; see http://www.cae.ucla.edu.

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

Fees and Financial Support

Fees and Expenses
Annual UCLA student fees shown for 2016-17 are current as of publication. See the Registrar's Office website for breakdown by term
at http://www.registrar.ucla.edu/ Fees-Residence/Overview/.

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

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

Living Accommodations

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.

The Community Housing Office, 360 De Neve Drive, Box 951495, Los Angeles, CA 90095-1495, 310-825-4491, https://housing.ucla.edu/community-housing, provides 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 a letter of acceptance and valid photo identification card are required for service.

Information about campus residence halls and suites is available from UCLA Housing Services, 360 De Neve Drive, Box 951381, Los Angeles, CA 90095-1381, 310-206-7011; see https://housing.ucla.edu/student-housing.

Financial Aid

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 2017-18 academic year is March 2, 2017. 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 service, extracurricular activities, and research achievement. The school works with alumni, industry, and individual donors to establish scholarships to benefit engineering students. In 2015-16, HSSEAS awarded more than 120 undergraduate scholarship awards totaling

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<tr>
<th>2016-17 ANNUAL UCLA UNDERGRADUATE AND GRADUATE STUDENT FEES</th>
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<tr>
<td><strong>Fees are subject to revision without notice.</strong></td>
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<tr>
<td><strong>Undergraduate Students</strong></td>
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<td><strong>Resident</strong></td>
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<td>Student Services Fee</td>
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<td>Tuition</td>
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<td>Instructional Enhancement Initiative (EI) Fee</td>
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<td>Undergraduate Students Association Fee</td>
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<td>Green Initiative Fee</td>
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<td>PLEDGE Fee</td>
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<td>Bruin Bash Fee</td>
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<td>Arts Restoring Community Fee</td>
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<tr>
<td>Graduate Students Association Fee</td>
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<td>Graduate Writing Center Fee</td>
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<td>Ackerman Student Union Fee</td>
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<td>Ackerman/Kerckhoff Seismic Fee</td>
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<td>Wooden Center Fee</td>
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<tr>
<td>Student Programs, Activities, and Resources Complex (SPARC) Fee</td>
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<tr>
<td>Student Health Insurance Plan (UCSHIP)</td>
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<tr>
<td>Course Materials and Services Fee</td>
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<tr>
<td>Nonresident Supplemental Tuition (NRTS)*</td>
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<tr>
<td>Continuing student total mandatory fees</td>
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<td>Document Fee</td>
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*Beginning with the first academic term following advancement to doctoral candidacy, nonresident supplemental tuition for graduate students is reduced by 100% for a maximum of three years including nonregistered time periods.

Information on UCLA financial aid programs is available at Financial Aid and Scholarships, A129J Murphy Hall, 310-206-0400; see http://www.financialaid.ucla.edu.
more than $620,000. 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 Grants are federal aid awards designed to provide financial assistance to U.S. citizens or eligible noncitizens undergraduate 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
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, A129J Murphy Hall, or at http://www.financialaid.ucla.edu.

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, visit Student Loan Services and Collections, A227 Murphy Hall, 310-825-9864; see http://www.loans.ucla.edu.

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

Students must be enrolled at least half-time (6 units for undergraduates, 4 for graduate students) and not be appointed at more than 50 percent 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.

GSR 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 2016-17 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 2016 for information on 2017-18 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. Boelter Fellowship. Supports study in engineering
Broadcom Fellowship. Electrical Engineering Department; supports doctoral students who have passed the preliminary examination and are doing research that explores new possibilities in state-of-the-art 22-nm CMOS technology
Broadcom Foundation First Year Fellowship. Supports first-year doctoral students in electrical engineering
Leon and Alyne Camp Fellowship. Supports graduate study in electrical and/or mechanical engineering, must be U.S. citizen
Deutsch Company Fellowship. Supports engineering research on problems that aid small business in Southern California
Electrical Engineering Graduate Fellowship. Supports master’s or doctoral study in electrical engineering
Venky Harinarayan Fellowship. Supports doctoral study in computer science
IBM Doctoral Fellowship. Supports doctoral study in computer science
Intel Fellowship. Computer Science Department; supports doctoral study in selected areas of computer science
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 Knessel Scholarship Fund. Materials Science and Engineering Department; supports master’s or doctoral study in ceramic engineering
Guru Krupa Foundation Fellowships in Electrical Engineering. Multiple fellowships to support graduate study with preference for those conducting research in integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering from the Indian Institutes of Technology (IIT) or the Indian Institute of Science, Bangalore
T.H. Lin Graduate Fellowship. Civil and Environmental Engineering Department; supports study by an international student in structural mechanics
Living Rocks Electrical Engineering Fellowship. Supports graduate study with preference for students conducting research in the areas of integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering from National Taiwan University, National Tsing Hua University, or National Chiao Tung University in Taiwan
Living Spring Fellowship. Electrical Engineering Department; supports graduate students with preference for those conducting research in integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering from National Taiwan University, National Tsing Hua University, or National Chiao Tung University in Taiwan
Microsoft Fellowship. Supports doctoral study in computer science
National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM) Fellowships. Support study in engineering and science to highly qualified individuals from communities where human capital is virtually untapped
H.J. Orchard Memorial Fellowship. Supports graduate study in electrical engineering
Qualcomm Innovation Fellowship. Supports doctoral students across a broad range of technical research areas based on Qualcomm core values of innovation, execution, and teamwork
Raytheon Fellowship. Supports graduate study in electrical engineering with preference for U.S. citizens
Martin Rubin Scholarship. Supports two undergraduate and/or graduate students pursuing degrees in civil engineering with an interest in transportation engineering
Henry Samueli Fellowship. Electrical 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 under-represented 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

Science and Mathematics Achievement and Research Training for Students (SMARTS). A six-week commuter summer program, SMARTS provides a diverse group of up to 50 10th and 11th graders with rigorous inquiry-based engineering, mathematics, and science enrichment. Students receive an introduction to the scientific process and to laboratory-based investigation through the Research Apprentice Program, sponsored by faculty and graduate research mentors in engineering.
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 2016.
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 917 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 260 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—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 multiferroics systems.

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

TANMS is a multi-university partnership between lead institution UCLA and partners California State University Northridge, Cornell University, UC Berkeley, and the Edgenossische Technische Hochschule in Switzerland.

CEED directs the TANMS program component, supports undergraduates placed in research laboratories, and coordinates recruitment of undergraduates from other universities. CEEP brings teacher-student teams to UCLA to conduct summer research and gain exposure to entrepreneurship.

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
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. See https://sites.google.com/site/uclansbe/.

Society of Latino Engineers and Scientists
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. See http://www.uclasoles.com.

Women in Engineering
Women make up about 23 percent of the HSSEAS undergraduate and 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
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 engineer-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. See http://www.seas.ucla.edu/swe/.

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.

AAAEE Arab American Association of Engineers and Architects
ACM Association for Computing Machinery
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
— Avengengineering
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

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 division student in good academic standing who has made outstanding contributions through service to the undergraduate student body.
student organizations, the school, and to the advancement of the undergraduate engineering program, through service and participation in extracurricular activities.

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

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.

Inquiries regarding the University’s student-related nondiscrimination policies may be directed to the UCLA Campus Counsel, 3149 Murphy Hall, Box 951405, Los Angeles, CA 90095-1405, 310-825-4042.

Inquiries regarding nondiscrimination on the basis of disability covered by the Americans with Disabilities Act (ADA) of 1990 or Section 504 of the Rehabilitation Act of 1973 may be directed to the ADA and 504 Compliance Coordinator, A239 Murphy Hall, UCLA, Box 951405, Los Angeles, CA 90095-1405, voice 310-825-1514, TTY 310-206-3349. See http://www.ada.ucla.edu.

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.

Students may grieve any action that they believe discriminates against them on the ground of race, color, national origin, marital status, sex, sexual orientation, disability, or age by contacting the Office of Student Conduct, 1206 Murphy Hall. Refer to UCLA Procedure 230.1 available in 1206 Murphy Hall or the University of California Policy on Student Grievance Procedures at http://policy.ucop.edu/doc/2710531/PACAO5-110 for further information and procedures.

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

Other Forms of Harassment

The University strives to create an environment that fosters the values of mutual respect and tolerance and is free from discrimination based on race, ethnicity, sex, religion, sexual orientation, disability, age, and other personal characteristics. Certainly harassment, in its many forms, works against those values and often corrodes a person’s sense of worth and interferes with one’s ability to participate in University programs or activities. While the University is committed to the free exchange of ideas and the full protection of free expression, the University also recognizes that words can be used in such a way that they no longer express an idea, but rather injure and intimidate, thus undermining the ability of individuals to participate in the University community. The University of California Policies Applying to Campus Activities, Organizations, and Students (hereafter referred to as Policies; 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 this Policy are available in the Office of Student Conduct, 1206 Murphy Hall, or in any of the Harassment Information Centers listed below:

1. Title IX Office, 2241 Murphy Hall, 310-206-3417, http://www.sexualharassment.ucla.edu
2. Counseling and Psychological Services, 221 Wooden Center West, 310-825-0768, http://www.counseling.ucla.edu

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 nine 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, B.S. A.E.
2. Bachelor of Science in Bioengineering, B.S. B.E.
3. Bachelor of Science in Chemical Engineering, B.S. Ch.E.
4. Bachelor of Science in Civil Engineering, B.S. C.E.
5. Bachelor of Science in Computer Science, B.S. C.S.
6. Bachelor of Science in Computer Science and Engineering, B.S. C.S.&E.
7. Bachelor of Science in Electrical Engineering, B.S. E.E.
8. Bachelor of Science in Materials Engineering, B.S. Mat.E.
9. Bachelor of Science in Mechanical Engineering, B.S. M.E.

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 selecting one of the majors within the school or the undeclared engineering option. In the selection process many elements are considered, including grades, test scores, and academic preparation.

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

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

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

Although applicants may qualify for admission to 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 this credit. AP Examination credit for freshmen entering fall quarter 2016 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:

1. Mathematics, including calculus I and II, calculus III (multivariable), differential equations, and linear algebra
2. Calculus-based physics courses in mechanics, electricity and magnetism, and waves, sound, heat, optics, and modern physics
3. Chemistry, including two terms of general chemistry, Bioengineering and Chemical Engineering majors are also required to complete two terms of organic chemistry. The Computer Science and Computer Science and Engineering majors do not require chemistry. Electrical Engineering majors must complete only one term of chemistry
4. Computer programming: applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors may take any C++, C, or Java course to meet the admission requirement, but to be competitive the applicant must take a C++ course equivalent to UCLA Computer Science 31. Applicants to Chemical Engineering may take any C++, C, Java, or MATLAB course to satisfy the admission requirement, but lack of a MATLAB course equivalent to UCLA Mechanical and Aerospace Engineering M20 or Civil and Environmental Engineering M20 will delay time to graduation. Applicants to all other engineering majors may take any C++, C, Java, or MATLAB course to satisfy the admission requirement, but the MATLAB course equivalent to Mechanical and Aerospace Engineering
## 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>3, 4, or 5</td>
<td>8 units maximum for all tests</td>
<td>No application</td>
</tr>
<tr>
<td>Drawing Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Biology</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may petition for Chemistry 20A) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science</td>
<td>3, 4, or 5</td>
<td>2 excess units</td>
<td>No application</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>3</td>
<td>8 units maximum for both tests</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>History</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>Chinese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Course</td>
<td>Units</td>
<td>Description</td>
<td>Application Notes</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>German Language</td>
<td>3</td>
<td>German 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>German 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Japanese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Latin</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Vergil</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Language</td>
<td>3</td>
<td>Spanish 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics (AB Test: Calculus)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 units</td>
<td>May be applied toward Mathematics 31A</td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units plus 4 units</td>
<td>4 units may be applied toward Mathematics 31A</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8 units</td>
<td>Mathematics 31A plus 4 units that may be applied toward Mathematics 31B</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td>8 units maximum for all tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics 1</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics 2</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (B Test)</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Mechanics)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may petition for Physics 1A)</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Electricity and Magnetism)</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Psychology 10 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Statistics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
</tbody>
</table>

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: Electricity and Magnetism (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 all 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’s 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 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 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 satisfy the Writing I requirement by completing English as a Second Language 36 with a grade of C or better (C– or a Passed grade is not acceptable). Admission into the course is determined by completion of English as a Second Language 35 with a passing grade or proficiency demonstrated on the English as a Second Language Placement Examination (ESLPE).

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 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 are enrolled in at least three and one-half courses (14 units) for the term. For details on P/NP grading, see Grading in the Academic Policies 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 M168/Environmental Health Sciences M168.

The course is automatically satisfied for the Natural Sciences requirement. 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 deal with all 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: (1) Preparation for the Major (lower division courses) and (2) 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.

**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 Unit Limit**
After students have completed 105 quarter units (regardless of where the units are completed), they do not receive unit credit or subject credit for courses completed at a community college.
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 Reporting System (DARS) and are able to view the credit they have received and determine which of their degree requirements are left to complete. See http://www.seasoasa.ucla.edu/dars/.

HSSEAS undergraduate students following a catalog year prior to 2005-06 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 2016-17 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 3.884 or better) for summa cum laude, the next five percent (GPA of 3.802 or better) for magna cum laude, and the next 10 percent (GPA of 3.642 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, engineering students must have a 3.884 grade-point average for summa cum laude, a 3.802 for magna cum laude, and a 3.642 for cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field upper division courses.
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, to the Master of Science in Engineering online degree, to the Master of Engineering degree, and to the 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 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 3.0. For further information, see http://msol.ucla.edu.

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 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

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 the Educational Testing Service, P.O. Box 6000, Princeton, NJ 08541-6000. See http://www.gre.org.
Bioengineering

UCLA
5121 Engineering V
Box 951600
Los Angeles, CA 90095-1600
tel: 310-267-4985
tax: 310-794-5956
e-mail: 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 Chiou, Ph.D.
Mark S. Cohen, Ph.D., in Residence
Ian A. Cook, M.D.
Linda L. Demer, M.D., Ph.D.
Timothy J. Deming, Ph.D.
Dino Di Carlo, Ph.D.
James C. Dunn, M.D., Ph.D.
Robin L. Garrett, Ph.D.
Warren S. Grundfest, M.D., FACS
Dean Ho, Ph.D.
Tzung Haiai, M.D., Ph.D., in Residence
Bahram Jalali, Ph.D.
Daniel T. Kamefi, Ph.D.
H. Pirouz Kavehpour, Ph.D.
Chang-Jin Kim, Ph.D.
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.
Tatiana Segura, Ph.D.
Kalyanam Shivkumar, M.D., Ph.D., in Residence
Ren Sun, Ph.D.
Yi Tang, Ph.D.
Michael A. Teitell, M.D., Ph.D.
Cun Yu Wang, D.D.S., Ph.D.
Benjamin M. Wu, D.D.S., Ph.D.
Yang Yang, Ph.D.

Professor Emeritus
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 Professor
Stephanie K. Seidills, Ph.D.

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

Adjunct Assistant Professors
Kayvan Niazi, 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. (Molecular and Medical Pharmacology)
Joseph L. Demer, M.D., Ph.D. (Neurology, Ophthalmology)
Katrina M. Dipplie, 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)
Robert P. Gunsalus, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Vijay Gupta, Ph.D. (Mechanical and Aerospace Engineering)
Y. Sungtaek Ju, Ph.D. (Mechanical and Aerospace Engineering)
H. Phillip Koefler, M.D., in Residence (Medicine)
Jody E. Kreiman, Ph.D., in Residence (Surgery)
Elliott M. Landay, M.D., Ph.D. (Biometrics, Biostatistics)
Karen M. Lyons, Ph.D. (Molecular, Cell, and Developmental Biology, Orthopaedic Surgery)
Dejan Markovic, Ph.D. (Electrical Engineering)
Thomas G. Mason, Ph.D. (Chemistry and Biochemistry, Physics and Astronomy)
Heather D. Maynard, Ph.D. (Chemistry and Biochemistry)
Harry McKellop, Ph.D., in Residence (Orthopaedic Surgery)
Istvan Mody, Ph.D. (Neurology, Physiology)
Harold G. Monbouquette, Ph.D. (Chemical and Biomolecular Engineering)
Samuel S. Murray, M.D., Ph.D., in Residence (Medicine)
Peter M. Narins, Ph.D. (Ecology and Evolutionary Biology, Integrative Biology and Physiology)
Ichiro Nishimura, D.D.S., M.D.Sc., D.M.D. (Dentistry)
Matteo Pellegrini, Ph.D. (Molecular, Cell, and Developmental Biology)
Laurent Piloln, Ph.D. (Mechanical and Aerospace Engineering)
Zhixin Qu, Ph.D., in Residence (Cardiology, Medicine)
Dario L. Ringach, Ph.D. (Neurobiology, Psychology)
Desmond Smith, Ph.D. (Molecular and Medical Pharmacology)

Michael V. Sofroniew, M.D., Ph.D. (Neurobiology)
Chia B. Soo, M.D. (Plastic Surgery)
Igor Spiegelman, Ph.D. (Dentistry)
Ricky Taiara, Ph.D., in Residence (Radiological Sciences)
Albert Thomas, Ph.D., in Residence (Radiological Sciences)
James G. Tidball, Ph.D. (Integrative Biology and Physiology)
Kang Ting, D.M.D., D.M.Sc. (Dentistry)
Hsian-Rong Tseng, Ph.D. (Molecular and Medical Pharmacology)
Jack Van Horn, Ph.D. (Neurology)
David Wong, Ph.D. (Dentistry)
Lily Wu, Ph.D., M.D. (Molecular and Medical Pharmacology, Urology)
Xinshu Grace Xiao, Ph.D. (Integrative Biology and Physiology)
Z. Hong Zhou, Ph.D. (Microbiology, Immunology, and Molecular Genetics)

Professor Emeritus
Tony F. Chan, Ph.D. (Mathematics)

Associate Professors
James W. Bisley, Ph.D. (Neurobiology)
Robert N. Candler, Ph.D. (Electrical Engineering)
Benjamin M. Ellington, Ph.D. (Radiology)
Thomas G. Graeber, Ph.D. (Molecular and Medical Pharmacology)
Jean-Pierre Hubshman, M.D., in Residence (Ophthalmology)
Min Lee, Ph.D. (Dentistry)
Daniel S. Levi, Ph.D. (Pediatrics)
Zili Liu, Ph.D. (Psychology)
Veronica J. Santos, Ph.D. (Mechanical and Aerospace Engineering)
Ladan Shams, Ph.D. (Psychology)
Michael R. van Dam, Ph.D. (Molecular and Medical Pharmacology)
Zhaoyan Zhang, Ph.D., in Residence (Head and Neck Surgery)

Assistant Professors
Louis S. Bouchard, Ph.D. (Chemistry and Biochemistry)
William Hsu, Ph.D. (Radiology)
Peng Hu, Ph.D. (Radiology)
Sotiris C. Masmanidis, Ph.D. (Neurobiology)
Nader Pouratian, Ph.D. (Neurosurgery)
Amy C. Rowat, Ph.D. (Integrative Biology and Physiology)
Dan Ruan, Ph.D. (Radiation Oncology)
Kyoung Hyun Sung, Ph.D. (Radiology)
Holden H. Wu, Ph.D. (Radiology)

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 suc-
cess 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 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), 3, 23L; 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 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, 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.

Biomedical Devices: Bioengineering C131, C172, 199 (8 units maximum), Electrical Engineering 102, Mechanical and Aerospace Engineering C187L. The electrical engineering or mechanical and aerospace engineering courses listed above may be used to satisfy the technical breadth requirement.

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

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www
Graduate Study
For information on graduate admission, see Graduate Programs, page 24.
The following introductory information is based on the 2016-17 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 underFields 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 Engineering M153 or Mechanical and Aerospace Engineering M153B), Electrical Engineering 100.
The outside member must be a qualified UCLA faculty member who does not appear on this list.

Group II: Field Elective Courses.
The remainder of the courses must be selected from one of the following three areas:


Microfluidics, Microelectromechanical Systems (MEMS), and Biosensors: Bioengineering M260, 282, Chemical Engineering C216, Chemistry and Biochemistry 118, 156, Elec-
Biomathematics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.


**Biosystems Science and Engineering**

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

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

**Course Requirements**

**Group I: Core Courses on General Concepts.** Three courses selected from Bioengineering C201 (or CM236) 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 Engineering 239AS, 266, Neurobiology M200C, Neuroscience CM272, M287, Physics and Biology in Medicine 205, M219, M248, and one course from Bioengineering 165EW, Biomathematics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207, 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 165EW, Biomathematics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

**Medical Imaging Informatics**

Medical imaging informatics (MII) is the rapidly evolving field that combines biomedical informatics and imaging, developing and adapting core methods in informatics to improve the usage and application of imaging in healthcare. Graduate study encompasses principles from across engineering, computer science, information sciences, and biomedicine. Imaging informatics research concerns itself with the full spectrum of low-level concepts (e.g., image standardization and processing, image feature extraction) to higher-level abstractions (e.g., associating semantic meaning to a region in an image, visualization and fusion of images with other biomedical data) and ultimately, applications and the derivation of new knowledge from imaging. Medical imaging informatics addresses not only the images themselves, but encompasses the associated (clinical) data to understand the context of the imaging study, to document observations, and to correlate and reach new conclusions about a disease and the course of a medical problem. Research foci include distributed medical information architectures and systems, medical image understanding and applications of image processing, medical natural language processing, knowledge engineering and medical decision-support, and medical data visualization. Coursework is geared toward 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 Engineering 211A, Physics and Biology in Medicine 210, 214, M213, M230, M266
- **Computer Understanding of Text and Medical Information Retrieval:** Computer Science 263A, Information Studies 228, 245, 246, 260, Linguistics 218, 232, Statistics M231
- **Information Networks and Data Access in Medical Environment:** Computer Science 240B, 244A, 246
- **Probabilistic Modeling and Visualization of Medical Data:** Biostatistics M209, M232, M234, M235, M236, Computer Science 241B, 262A, 262C, Information Studies 272, 277

**Group III: Field Ethics Course.** One course selected from Bioengineering 166EW, Biomathematics 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 others’ language and move comfortably among the intellectual domains of the two fields.

**Course Requirements**

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

**Group II: Field Specific Courses.** Bioengineering M260, M261A, M284, and one course from 165EW, Biomathematics 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 Chiou, Ph.D.** (UC Berkeley, 2006)
  - Optofludics 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 antidepressants on the brain, methods of treatment for mood disorders especially depression

- **Linda L. DeMer, M.D., Ph.D.** (Johns Hopkins, 1983)
  - Vascular biology, biomaterialization, vascular calcification, mesenchymal stem cells

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

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

- **James Dunn, M.D., Ph.D.** (Harvard, MIT, 1992)
  - Tissue engineering, stem cell therapy, regenerative medicine

- **Robin L. Garrett, 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, biological spectroscopy
Bioengineering / 31

Lower Division Courses

10. Introduction to Bioengineering. (2) Lecture, two hours; discussion, one hour; outside study, three hours. Preparation: high school biology, chemistry, mathematics, physics. Introduction to scientific and technological bases for established and emerging subfields of bioengineering, including biosensors, bioinstrumentation, and biosignal processing, biomechanics, biometrics, biomaterials, molecular biotechnology, biological imaging, biomedical optics and lasers, neuroengineering, and biomolecular machines. Letter grading. Mr. Deming (F)

18. Flat Lux Freshman Seminars. (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 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 32A, 32B, 115A; Physics 1B. Fundamental basis for analysis and design of biological and biomedical devices and systems. Classical and statistical thermodynamic analysis of biological systems. Material, energy, charge, and force balances. Introduction to network analysis. Letter grading. Mr. Kamei (W)

C101. Engineering Principles for Drug Delivery. (4) (Formerly numbered Biomedical Engineering C101.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 33B, Physics 1B. Application of engineering principles for designing and understanding delivery of therapeutics. Discussion of physics and mathematics required for understanding colloid stability. Analysis of concepts related to both modeling and experimentation of endocytosis and intracellular trafficking mechanisms. Analysis of diffusion of drugs, coupled with computational and engineering mathematics approaches. Concurrently scheduled with course C201. Letter grading. Mr. Kamei (F)

CM102. Human Physiological Systems for Bioengineering. I. (4) (Formerly numbered Biomedical Engineering CM102.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. broad overview of basic biological activities and organization of human body in system (organ/tissue) to system basis, with particular emphasis on molecular and cellular biology. Concurrently scheduled with course CM202. Letter grading. Mr. Grundfest (F)

CM103. Human Physiological Systems for Bioengineering II. (4) (Formerly numbered Biomedical Engineering CM103.) (Same as Physiological Science CM103.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Molecular-level understanding of human anatomy and physiology in selected organ systems (digestive, skin, muscleskeletal, endocrine, immune, urinary, reproductive). System-specific modeling/simulations (immunoregulation, wound healing, muscle mechanics and energetics, acid-base balance, excretion). Functional basis of biomedical instrumentation (diagnosis, artificial skin, pathogen detectors, ultrasound, birth-control drug delivery). Concurrently scheduled with course CM203. Letter grading. Mr. Grundfest (W)

C104. Physical Chemistry of Biomacromolecules. (4) (Formerly numbered M104) Lecture, three hours; discussion, two hours; outside study, seven hours. Preparation: Chemistry 20A, 20B, 30A, Life Sciences 2, 3, 23L. To understand biological materials and design synthetic replacements, it is imperative to under-
stand their physical chemistry. Biomacromolecules such as proteins are analyzed and characterized by applying fundamentals of polymer physics and chemistry. Investigation of polymer structure and conformation, bulk and solution thermodynamics and phase behavior of networks, and molecular 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 C204. Letter grading.

Mr. Wong (F)

C105. Engineering of Bioconjugates. (4) (Formerly numbered M105.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry is science of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of bioconjugates are used in delivery of pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including choice and design of conjugate linkers depending on type of biomolecule and desired application, such as degradable chemical linkers. Preparation and discussion of design and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C205. Letter grading.

Mr. Deming (W)

C106. Topics in Bioelectricity for Bioengineers. (4) (Formerly numbered M106.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20A, 20B, 23L. Mathematics 33B, Physics 1C. Coverage of different polymerization techniques, concepts of step-growth, chain-growth, ring-opening, with focus on factors that can be used to control chain length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in polymers. Presentation of application of different polymerization techniques. Concepts of step-growth, chain-growth, ring-opening, and coordination polymerization, and effects of synthesis route on polymer properties. Lectures include simple and practical issues demonstrated through examples. Concurrently scheduled with course C206. Letter grading.

Mr. Schmidt (F)

C107. Polymer Chemistry for Bioengineers. (4) (Formerly numbered M107.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course C104 or C105. Fundamental concepts of polymer synthesis, including step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control chain length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in polymers. Presentation of application of different polymerization techniques, concepts of step-growth, chain-growth, ring-opening, and coordination polymerization, and effects of synthesis route on polymer properties. Lectures include simple and practical issues demonstrated through examples. Concurrently scheduled with course C207. Letter grading.

Mr. Deming (W)

110. Biotransport and Bioreaction Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 100, Mathematics 33B. Introduction to analysis of fluid flow, heat transfer, mass transfer, binding events, and biochemical reactions in systems of interest to bioengineers, including cells, tissues, organs, human body, extracorporeal devices, tissue engineering systems, and bioartificial organs. Introduction to pharmacoki netic analysis.

Mr. Ng (W)

120. 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 troubleshooting. Emphasis on silicon-based microfabricated and nanofabricated sensors. Novel materials, biocompatibility, biostability, safety of electronic interfaces. Ac tuator design and integration, and data acquisition and processing. Mr. Grundfest, Mr. Schmidt (W)

C131. Nanopore Sensing. (4) (Formerly numbered M131.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 3, 23L. Physical origins of DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrical measurements in electrophoresis, nanopore fabrication, ionic conductance through pores and GHK equation, patch clamp and single channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions. 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, cell biology, and bioengineering. Understanding of different types of interactions between types of molecules, such as van der Waals interactions, entropically modulated electrostatic interactions, hydrophobic interactions, hydration and solvation interactions, polyelectrolyte solutions, de polyionization, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Students should be able to develop physical models and estimates 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 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, cell biology, and bioengineering. Understanding of different basic types of interactions, including various nucleic acids, proteins, and lipids. Study of how biological and biomimetic systems organize into their functional forms via self-assembly and how these structures impart biological function. Illustration of these ideas using examples from bioengineering and biomedical engineering. Case study on current topics, including drug delivery, gene therapy, cancer therapeutics, emerging pathogens, and relation of self-assembly to disease states. May be taken independently for credit. Concurrently scheduled with course C239B. Letter grading.

Mr. Wu (Sp)

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 96, 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. Biomechanics of soft tissues, including mechanical properties of cell biology and physical principles that govern how they function mechanically. Review and application of continuum mechanics and statistical mechanics to develop quantitative mathematical models of structural mechanics in cells. Structure of macromolecular frameworks and entropic walks and diffusion, mechanosensitive proteins, single-molecule force-extension, DNA packing and transcriptional regulation, lipid bilayer membranes, mechanics on single-molecule, polymer mechanics, muscle mechanics, pattern formation. Concurrently scheduled with course CM241. Letter grading.

(Not offered 2016-17)

CM145. Molecular Biotechnology for Engineers. (4) (Formerly numbered Bioengineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Life Sciences 1, 2, 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 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 CM245. Letter grading.

Mr. Liao (F)

C147. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) (Formerly numbered Bioengineering CM147.) Lecture, five hours; discussion, two hours; outside study, seven hours. Requisites: course CM102, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to bring biological tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological testing. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course C247. Letter grading.

Mr. Chiou (F)

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) (Same as Chemical Engineering M153, Electrical Engineering M153, and Mechanical and Aerospace Engineering M138B.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: courses 110, 111, 111A, 1B, 1C, 4A, 4AL, 4BL. Introduction to general manufacturing methods, mechanisms, constraints, and microfabrication and nanofabrication. Focus on concepts, physics, and instruments of various microfabrication and nanofabrication techniques that have been broadly applied in industry and academia, including various photolithography technologies, physical and chemical deposition methods, and physical and chemical etching methods. Hands-on experience for fabricating microstructures and nanostructures in modern cleanroom environment. Letter grading.

Mr. Chiu (Sp)


Mr. Wang (Sp)
microchannels over range of Reynolds numbers. Concurrently scheduled with course C272. Letter grading. Mr. Dunn, Mr. Wu (W)

C172. Design of Minimally Invasive Surgical Tools. (Formerly numbered M172.) Lecture, discussion, three hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, 23L. Mathematics 32A. Design of instruments and device and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of technology, regulatory policy and surgical procedures. Topics include: endoscopes and laparoscopes, biopsies devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instrumentation, and integration of devices with tools in the operation of complex surgical tools, design tool fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel devices. Concurrently scheduled with course C272. Letter grading. Mr. Dunn, Mr. Wu (W)

C183. Targeted Drug Delivery and Controlled Drug Release. (Formerly numbered Biomedical Engineering M184.) Lecture, discussion, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. New therapeutic approaches require comprehensive understanding of modern biotechnology, drug delivery, and engineering. Targeted delivery of genes and drugs and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug pharmacodynamics and clinical pharmacokinetics. Application of engineering principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of drug-delivery systems that can provide spatial and temporal control of drug release. Introduction to biomaterials with specialized structural and interfacial properties. Exploration of both chemistry of materials and physical presentation of devices and compounds used in delivery and release. Concurrently scheduled with course C283. Letter grading. Ms. Kasko (Sp)

M184. Introduction to Computational and Systems Biology. (2) (Formerly numbered Biomedical Engineering M184.) Lecture, laboratory, four hours; outside study, four hours. Emphasis on requisites: courses 30A, 30B, 30L, 180L. Introduction to engineering principles of selected medical device and therapeutic design, including topics such as need finding, intellectual property, entrepreneurship, regulation, and project management. Working in teams, students develop innovative solutions to address current problems in medicine and biology. Students conduct directed experiments and computational modeling, generate presentations, and participate in biomolecular design competition. Letter grading. Mr. Dunn, Mr. Wu (Sp)

CM178. Introduction to Biomaterials. (Formerly numbered Biomedical Engineering CM180.) Lecture, three hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L, or Materials Science 304. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM278. Letter grading. Ms. Kasko (W)

C179. Biomaterials-Tissue Interactions. (4) (Formerly numbered Biomedical Engineering C181.) Lecture, three hours; outside study, nine hours. Requisites: Chemistry 20A, 20B, 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 CM278. Letter grading. Ms. Kasko (W)

C180L. System Integration in Biology, Engineering, and Medicine I Laboratory. (4) Lecture, one hour; laboratory, four hours; clinical visits, four hours; outside study, four hours. Requisites: Chemistry 30A, 30B, 30L. Hand-on study of principles of internal medicine to various selected medical therapeutic devices associated with cardiovascular and pulmonary disorders. Letter grading. Mr. Dunn, Mr. Wu (Sp)

CM187. Research Communication in Computational and Systems Biology. (2) (Formerly numbered Biomedical Engineering CM187.) Lecture, laboratory, four hours; outside study, eight hours. Requisites: courses 330A, 330B, 33L. Hands-on study of principles of internal medicine to various selected medical therapeutic devices associated with cardiovascular and pulmonary disorders. Letter grading. Mr. Dunn, Mr. Wu (Sp)
Current interest in scientific community, appropriate to student needs and capabilities. Critical oral and written presentations and written progress reports explain how to proceed with search for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM287. Letter grading.

Mr. DiStefano (Sp)

188. Special Courses in Bioengineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Special topics in bioengineering for undergraduates. Concurrently scheduled with course CM287. Letter grading. May be repeated once for credit with topic or instructor change. Letter grading.

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

199. Directed Research in Bioengineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with school approval. Concurrently scheduled with course petitions available in Office of Academic and Student Affairs. Letter grading.

Graduate Courses

C201. Engineering Principles for Drug Delivery. (4) (Formerly numbered Biomedical Engineering C201.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 33B, Physics 1B. Application of engineering principles for designing and understanding delivery of therapeutics. Discussion of physics and mathematics required for understanding colloid stability. Analysis of concepts related to both modeling and experimentation of endocytosis and intracellular trafficking mechanisms. Analysis of diffusion of drugs, coupled with computational and engineering mathematics approaches. Concurrently scheduled with course C101. Letter grading.

Mr. Kamei (F)

CM202. Human Physiological Systems for Bioengineering I. (4) (Formerly numbered Biomedical Engineering CM202.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Broad overview of basic biological activities and organization of human body in system (organ/tissue) system basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM102. Letter grading.

Mr. Grundfest (F)


Mr. Grundfest (W)

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

C205. Engineering of Bioconjugates. (4) (Formerly numbered Biomedical Engineering C205.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: organic chemistry course. Bioconjugate chemistry is science of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one polymer to enhance its function. 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 chemical conjugate linkers, depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers. Presentation and discussion of design and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C105. Letter grading. Mr. Deming (F)

C206. Topics in Bioelectricity for Bioengineers. (4) (Formerly numbered Biomedical Engineering C206.) Lecture, three hours; outside study, eight hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 23L, Mathematics 33B, Physics 1C. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrostatics in dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Poisson/Boltzmann equations, Nerst potential, Donnan equilibrium, GHK equations, energy barriers in ion channels, activation potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course C106. Letter grading. Mr. Schmidt (F)

C207. Polymer Chemistry for Bioengineers. (4) (Formerly numbered Biomedical Engineering C207.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course C204 or C205. Fundamental concepts of polymer synthesis, including step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control chain length, chain with distinct functionality, chain copolymerization, and stereochemistry in polymerizations. Presentation of applications of use of different polymerization techniques. Concepts of step-growth, chain-growth, and coordination polymerization, and effects of synthesis route on polymer properties. Lectures include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C107. Letter grading.

Mr. Deming (W)


M215. Biochemical Reaction Engineering. (4) (Formerly numbered Biomedical Engineering M215.) (Same as Chemical Engineering CM215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: 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 biochemical reactors. Letter grading.

Mr. Liao (Sp)

M217. Biomedical Imaging. (4) (Formerly numbered Biomedical Engineering M217.) (Same as Electrical Engineering M217.) Lecture, outside study, nine hours. Enforced requisites: Electrical Engineering 114 or 211A. Optical imaging modalities in biomedicine. Other nonoptical imaging modalities discussed briefly for comparison purposes. Letter grading.

M219. Principles and Applications of Magnetic Resonance Imaging. (4) (Formerly numbered Biomedical Engineering M219.) (Same as Physics and Biology in Medicine M219.) Lecture, three hours; discussion, one hour. Emphasis on Fourier transforms, Fourier imaging, phase images, structure of pulse sequences, and various scanning parameters. Introduction to advanced techniques in rapid imaging, quantitative imaging, and spectroscopy. Letter grading.

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

Mr. Kangaroo (F)

221. Human Anatomy and Physiology for Medical and Imaging Informatics. (4) (Formerly numbered Biomedical Engineering 221.) Lecture, two hours; outside study, eight hours. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on understanding and visualizing imaging modality through medical images. Topics relevant to acquisition, representation, and dissemination of anatomical knowledge in computerized clinical applications. Topics include chest, cardiac, neurology, gastroentero-genitourinary, endocrine, and musculoskeletal systems. Introduction to basic imaging physics (magnetic resonance, computed tomography, ultrasound, computed radiography) to provide context for imaging modalities predominantly used to view human anatomy. Geared toward nonphysicians who require more formal understanding of human anatomy/physiology. Letter grading.

Mr. El-Saden (F)

M223A-223B-223C. Programming Laboratories for Medical and Imaging Informatics I, II, III. (4-4-4) (Formerly numbered Biomedical Engineering 223A-223B-223C.) Lecture, two hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Emphasis on understanding medical and imaging informatics core curriculum courses. Exposure to programming concepts for medical applications, emphasis on basic abstraction techniques used in image processing and medical information system infrastructures. Letter grading. M223A. Requisites: Computer Science 31, 32, Program in Computing 20A, 20B. Course 223A is requisite to 223B. Integrated with topics presented in course M227 to reinforce concepts presented with practical experience. Projects focus on understanding medical
networking issues and implementation of basic protocols between the components, with extensive hands-on use of DICOM. Introduction to basic tools and methods used within informatics. 223B. Requisite: course 223A. Integrated with topics presented in course M226 to reinforce concepts presented with practical experience. Projects focus on medical image manipulation and decision support systems. 223C. Requisite: course 223B. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used to extract meaningful features from medical text and imaging data and visualize results. Integrated with topics presented in courses 224A and M226 to reinforce concepts presented with practical experience. Projects focus on medical information retrieval, knowledge representation, and visualization.

Mr. Meng (F,W,Sp)

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

Mr. Morioka (W)

224B. Advances in Imaging Informatics. (4) (Formerly numbered Biomedical Engineering 224B) Lecture, four hours; outside study, eight hours. Requisites: course 224A. Overview of information retrieval techniques in medical imaging and informatics-based applications of imaging, with focus on various advances in field. Introduction to core concepts in information retrieval (IR), reviewing seminal papers on evaluating IR systems and their use in medicine (e.g., teaching files, case-based retrieval, etc.). Medical content-based image retrieval (CBIR) as motivating application, with examination of core works in this area. Techniques to realize medical CBIR, including image feature extraction and processing, feature representation, classification schemes (via machine learning), image indexing, and similarity-based retrieval and visualization of images (e.g., perception, presentation). Discussion of more advanced methods now being pursued by researchers. Letter grading. Mr. Morioka (Sp)

M225. Bioinformatics and Bioprocess Engineering. (4) (Formerly numbered Biomedical Engineering 225S) (Same as Chemical Engineering CM225S) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: Chemical Engineering 101G. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, enzmys, food additives, or pharmaceuticals that are products of biological reactors. Letter grading.

Mr. Monbouquette (W)

M226. Medical Knowledge Representation. (4) (Formerly numbered Biomedical Engineering 226M) (Same as Information Studies M226S) Seminar, four hours; outside study, eight hours. Designed for graduate students. Issues related to medical knowledge representation and its application in healthcare processes. Topics include data structures used for representing knowledge (conceptual graphs, frame-based models), different data models for representing spatio-temporal information, rule-based implementations, current statistical methods for discovery of knowledge (statistical classification 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 systems, and terminologies (e.g., SNOMED, UMLS). Letter grading.

Mr. Taira (Sp)

M227. Medical Information Infrastructures and Internet Technologies. (4) (Formerly numbered Bio- medical Engineering M227) (Same as Information Studies M227) Lecture, four hours; discussion, eight hours. Designed for graduate students. Introduction to networking, communications, and information infrastructures in medical environment. Exposure to technology related to several levels: low-level (TCP/IP services), medium-level (network topologies), and high-level (distributed computing, Web-based services) implementations. Common medical ontologies, current medical information systems (HIS, RIS, PACS). Advances in networking, such as wireless health systems, peer-to-peer topologies, grid/cloud computing. Introduction to security and encryption in networked environments. Letter grading.

Mr. Bui (F)

M228. Medical Decision Making. (4) (Formerly numbered Biomedical Engineering M228) (Same as Information Studies M228S) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concept of evidence-based medicine, introduction to process of care and outcomes. Basic probability and statistics to understand research results and evaluations, and algorithmic methods for decision-making processes (Bayes theorem, decision trees). Study design, hypothesis testing and estimation. Focus on current basic technical advances in medical decision support systems and expert systems, with review of classic and current systems. Introduction to common statistical and decision-making software packages to familiarize students with current tools. Letter grading.

Mr. Kangarloo (W)

C231. Nanopore Sensing. (Formerly numbered Biomedical Engineering M231) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 23L, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of fluctuating ionic conductance through artifical or protein nanopores. Physics of pore conductance. Applications to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of nanotechnology and instrumentation of electrical measurements in electrolytes, nanopore fabrication, ionic conductance through pores and GHK equation, patch clamp and single channel current measurement, ionic conductance, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C131. Letter grading.

Mr. Schmidt (F)

M233A. Medtech Innovation I: Entrepreneurial Opportunities in Medical Technology. (4) (Formerly numbered 233A) (Same as Management M271A) Lecture, three hours; discussion, three hours; outside study, six hours. Designed for graduate and professional students in engineering, dentistry, design, law, management, and medicine. Focus on understanding how to identify unmet clinical needs, properly filtering through these needs to determine potential markets, and then selecting promising needs for which poten- tial medtech solutions are explored. Students work in groups to expidite traditional research and develop- ment processes to invent and implement new med- tech devices that increase quality of clinical care and result in improved patient outcomes in hospital system. Introduction to intellectual properties basics and various medtech business models. Letter grading.

Mr. Liu, Mr. Shivkumar (W)

M233B. Medtech Innovation II: Prototyping and New Venture Development. (4) (Formerly numbered Biomedical Engineering M233B) Lecture, four hours; outside study, six hours. Enforced requisite: course M233A. Designed for graduate and professional students in engineering, dentistry, design, law, management, and medicine. Development of medtech solutions for unmet clinical needs previously identified in course M233A. Prototyping and business models to validate new concept. Exploration of concept selection, business plan development, intellectual property filing, financing strategies, and device prototyping. Letter grading.

Mr. Liu, Mr. Wu (Sp)

C239A. Biomolecular Materials Science I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different types of interactions that exist between bio- molecules, such as van der Waals interactions, en- tering atomistic and molecular types, hydrophobic interactions, hydration and solvation interactions, polymer-mediated interactions, depletion interactions, molecular recognition, and others. Illustration of these ideas using examples from bio- engineering and biomedical engineering. Students should be able to make simple calculations and esti- mates that allow them to engage broad spectrum of bioengineering problems, such as those in drug gene delivery and tissue engineering. May be taken independently for credit. Concurrently scheduled with course C139A. Letter grading.

Mr. Wong (W)

C239B. Biomolecular Materials Science II. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Course C239A is not requisite to C239B. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different types of biomolecules, with emphasis on nucleic acids, proteins, and lipids. Study of how biological and biomimetic systems organize into their functional forms via self-assembly and how these structures im- part biological function. Illustration of these ideas using examples from bioengineering and biomedical engineering. Case study on current topics, including drug delivery, antibody conjugates, emerging pathogens, and relation of self-assembly to disease states. May be taken independently for credit. Concurrently scheduled with course C139B. Letter grading.

CM240. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM240) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: Mechanical and Aerospace Engineering (M.E.) 105 or 106. Introduction to functional mechanisms of human body; skeletal adaptations to optimize load transfer, mo- bility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat transfer, mass transfer, Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading.

Mr. Gupta (W)


(Not offered 2016-17)

CM245. Molecular Biotechnology for Engineers. (4) (Formerly numbered Biomedical Engineering CM245) (Same as CM245) Lecture, four hours; discussion, one hour; outside study, seven hours. Selected topics in molecular bi- ology that form foundation of biotechnology and bio- medical industry today. DNA technology, molecular research tools, manipula- tion of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diag-
C247. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) Formerly numbered Biomedical Engineering C246. Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM202, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical testing. Case study includes skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course CM145. Letter grading.

M248. Introduction to Biomedical Imaging. (4) Formerly numbered Biomedical Engineering M248. (Same as Electrical Engineering M248 and Mechanical and Aerospace Engineering M280B.) Lecture, three hours; laboratory, one hour; outside study, seven hours. Exploration of role of biomedical imaging in modern biology and medicine, including imaging physics, instrumentation, image processing, and applications of imaging for range of modalities. Practical experience provided through series of imaging laboratories. Letter grading.

C250B. Microelectromechanical Systems (MEMS) Fabrication. (4) Formerly numbered Biomedical Engineering M250B and Mechanical and Aerospace Engineering M280B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course M153. Advanced 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 resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading.

C252. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) Formerly numbered Biomedical Engineering M252 and Mechanical and Aerospace Engineering M282.) Lecture, four hours; outside study, eight hours. Introduction to MEMS design. Methods, design rules, sensing and actuation of MEMS, sensors, and microfluidic systems. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. Wu (Sp)

C255. Fluid-Particle and Fluid-Structure Interactions in Microflows. (4) Lecture, four hours; laboratory, one hour; outside study, seven hours. Enforced requisite: course 110. Introduction to Navier-Stokes equations, assumptions, and simplifications. Analytical framework for calculating simple flows and numerical methods to solve and gain intuition for complex flows. Forces on particles in Stokes flow and finite-inertia finite-Reynolds number fluids. Induced vibrations and wake structures of a sphere, with and without finite inertia and implications for particle-particle interactions. Secondary flows induced by structures and particles in confined flows. Particle separation by fluid dynamic forces: fluid-flow fractionation, inertial focusing, structure-induced separations. Application concepts in internal biological flows and separations for biotechnology. Helps students understand and predict behavior of fluid flows in arbitrary microchannels. Surface interactions and models of fluidic microsystems to manipulate fluids, cells, and particles, and develop strong intuition for how fluid flows in arbitrarily sized microchannels. Microfluidic devices covered are micropumps, micromixers, microvalves, microchips, and microchannels over range of Reynolds numbers. Concurrently scheduled with course CM155. Letter grading. Mr. Di Carlo (Sp)


M260. Neuroanatomy: Structure and Function of Nervous System. (4) Formerly numbered Biomedical Engineering M260.) (Same as Electrical 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, electrophylography (action potentials, local field potentials, EEG. Emphasis on transduction, preamplification, signal processing, and physiology of neuronal circuits.) Letter grading. Mr. Liu (Sp)


M263. Neuroanatomy: Structure and Function of Nervous System. (4) Formerly numbered Biomedical Engineering M263.) Lecture, three hours; discussion/laboratory, three hours. Anatomy of central and peripheral nervous system at cellular histological and regional systems level, with emphasis on contemporary experimental approaches to morphological study of nervous system in discussions of circuitry and neurochemical anatomy of major brain regions. Consideration of representative vertebrate and invertebrate motor systems. Letter grading. Mr. Candler (Sp)

C270. Energy-Tissue Interactions. (4) Formerly numbered Biomedical Engineering C270.) Lecture, three hours; outside study, nine hours. Enforced requisite: Life Sciences 2, Physics 1C. Introduction to thermal effects in biological systems, techniques for characterizing structure and properties of biomaterial interfaces, and methods for investigating biomaterials with prescribed structure and properties in vitro and in vivo. Letter grading. Ms. Kasko (F)

C279. Biomaterials-Tissue Interactions. (4) Formerly numbered Biomedical Engineering C281.) Lecture, three hours; outside study, nine hours. Requisite: course CM278. In-depth exploration of host cellular response to biomaterials: vascular response, interface, and cloting, biocompatibility, animal models, inflammation, infection, extracellular matrix, cell adhesion, and role of mechanical forces. Concurrently scheduled with course CM178. Letter grading. Mr. Wu (Not offered 2016-17)

C282. Biomedical Interface and Tissue Engineering. (2) Formerly numbered Biomedical Engineering 282.) 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 morphology and composition of biomaterials and nanoscales, mesoscales, and macroscales, techniques for characterizing structure and properties of biomaterial interfaces, and methods for investigating 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) Formerly numbered Biomedical Engineering 283.) Lecture, laboratory, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. New therapeutic concepts require comprehensive understanding of modern biology, physiology, and engineering. Goals include understanding mechanisms by which delivery of genes and drugs and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug pharmacodynamics and clinical pharmacokinetics. Application of engineering principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of novel systems that can provide spatial and temporal control of drug release. Introduction to biomaterials with specialized structural and interfacial properties. Exploration of both chemical and physical presentation of devices and compounds used in delivery and release. Concurrently scheduled with course C183. Letter grading. Ms. Kasko (Sp)

M284. Functional Neuroimaging: Techniques and Applications. (3) Formerly numbered Biomedical Engineering M284.) (Same as Neuroscience 285, Physics and Biology in Medicine M285, Psychiatry M285, and Psychology M287.) Lecture, three hours. Examination of clinical applications of functional neuroimaging, including fMRI and electrophysiological methods, data acquisition and analysis, experimental design, and results obtained thus far in human systems. Focus on understanding technologies, how to design activation
M296A. Advanced Modeling Methodology for Dynamic Biological Systems. (4) (Formerly numbered Biomedical Engineering M296A.) (Same as Computer Science M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisite: course CM1102 or CM202, Chemistry 20A, 20B, 20L. Theory and applications of modeling methodologies for biological systems. Discussion of methods and their implementation in computer science, including nonlinear systems, biochemical kinetics, and physiology. Letter grading. Mr. Kamei (F,Sp)

M296B. Optimization Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Formerly numbered Biomedical Engineering M296B.) (Same as Computer Science M296B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biophysics 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 collecting and analyzing data. Letter grading. Mr. DiStefano (F)

M296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) (Formerly numbered Biomedical Engineering M296C.) (Same as Computer Science M296C and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course M296B. Advanced topics and research in systems biology and biomedicine. Topics include nonlinear systems, probabilistic analysis, stochastic systems, and advanced computing. Letter grading. Mr. DiStefano (W)

M296D. Introduction to Computational Cardiology. (4) (Formerly numbered Biomedical Engineering M296D.) (Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to biomedical mathematical modeling and computer simulation of cardiac electrophysiological processes. Ionic models of action potentials. Theory of AP propagation in one-dimensional and two-dimensional heart tissue. Letter grading. Mr. DiStefano (Sp)

295A-295Z. Seminars: Research Topics in Bioengineering. (2 to 4) (Formerly numbered Biomedical Engineering 295A-295Z.) (Same as Computer Science 295A-295Z.) Seminar, two hours; outside study, four hours. Requisite: course CM286. Directed research on special topics in bioengineering. Selection of research topic by student and advisor. Letter grading. Mr. Kogan (F,Sp)

296. Special Studies in Bioengineering. (4) (Formerly numbered Biomedical Engineering 296.) 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) (Formerly numbered Biomedical Engineering 299.) Seminar, two hours; outside study, four hours. Designed for graduate bioengineering students. Seminar by leading academic and industrial bioengineers from UCLA, other universities, and bioengineering companies such as Baxter, Amgen, Medtronics, 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 technology, and artificial organs. Letter grading. Mr. Wu (F,Sp)

375. Teaching Apprentice Practicum. (1 to 4) (Formerly numbered Biomedical Engineering 375.) Seminar, to be arranged. Preparation: appointment 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) (Formerly numbered Biomedical Engineering 495.) 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 in 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.
Chemical and Biomolecular Engineering

UCLA
5531 Boelter Hall
Box 951592
Los Angeles, CA 90095-1592

tel: 310-825-2046
fax: 310-206-4107
e-mail: chemeng@ucla.edu
http://chemeng.ucla.edu

Panagiotis D. Christofides, Ph.D., Chair
Tatiana Segura, Ph.D., Vice Chair

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

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

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

Scope and Objectives

The Department of Chemical and Biomolecular Engineering conducts undergraduate and graduate programs of teaching and research that focus on the areas of biomolecular engineering, systems engineering, and advanced materials processing and span the general themes of energy/environment and nanotechnology. 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 Mission and Program 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.
Chemical and Biomolecular Engineering

Biomedical Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109, Chemistry and Biochemistry 153A; 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 Chemical Engineering 108A, 108B; and one biomedical 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 UCLA Graduate Degrees. For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure.

Biomolecular Engineering Option

Preparation for the Major

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

The Major

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

For information on University and general education requirements, see Requirements for UCLA Graduate Degrees. For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure.

Environmental Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 105, 109, 113, 128, 135, 140, 142; four 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); one elective course (4 units) from Mechanical Engineering or Aerospace Engineering; and one elective course (4 units) from Computer Science or Electrical Engineering.

For information on University and general education requirements, see Requirements for UCLA Graduate Degrees. For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure. For information on graduate admission, see Graduate Programs, page 24.

Semiconductor Manufacturing Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 105, 109, 113, 128, 135, 140, 142; one technical breadth course (4 units) from Mechanical Engineering or Aerospace Engineering; and one elective course (4 units) from Computer Science or Electrical Engineering.

For information on University and general education requirements, see Requirements for UCLA Graduate Degrees. For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure. For information on graduate admission, see Graduate Programs, page 24.

Graduate Study

For information on graduate admission, see Graduate Programs, page 24.

For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure. The following introductory information is based on the 2016-17 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 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 Chemical Engineering 270 and 270R. Students also are required to take courses 104C, 104CL, Electrical Engineering 123A, and Materials Science and Engineering 121. In addition, two departmental elective courses and two electrical 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, 2240, Electrical 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 (PPE) 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 PPE is offered at the end of Winter Quarter of each academic year and is graded by a faculty committee. Students must take the PPE in their first year. If they fail the PPE for the first time, they may attempt it again for 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 PPE, 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 residency.

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, biochemical, and cellular engineering teaching and research. Facilities and equipment include bioreactors, fluorescence microscopy, real-time PCR thermocycler, UV-visible and fluorescence spectrophotometers, HPLC and LC-mass spectrometer, aerobic and anaerobic bioreactors from bench top to 100-liter pilot scale, protein purification facility, potentiostat/galvanostat and impedance analyzer for electroenzymology, membrane extruder and multiangle laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and phosphoinosfer for biochemical assays involving radiolabeled compounds.

Microbial cells are genetically and metabolically engineered to produce compounds that are used as fuel, chemicals, drugs, and food additives. Novel gene-metabolic circuits are designed and constructed in microbial cells to perform complex and non-native cellular behavior. These designer cells are cultured in bioreactors, and intracellular states are monitored. Such investigations are coupled with genomic and proteomic efforts, and mathematical modeling, to achieve system-wide understanding of the cell.

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

Chemical Kinetics, Catalysis, and Reaction Engineering Laboratory

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

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

Electrochemical Engineering and Catalysis Laboratories

With instrumentation such as rotating ring-disk electrodes, electrochemical packed-bed flow reactors, gas chromatographs, potentiostats, and function generators, the Electrochemical Engineering and Catalysis Laboratories are used to study metal, alloy, and semiconductor corrosion processes, electro-deposition and electroless deposition of metals, alloys, and semiconductors for GMR and MEMS applications, electrochemical energy conversion (fuel cells) and storage (batteries), and 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 quadrupole 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
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 hetero junction 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 Laboratory is equipped with instrumentation for online measurement of aerosols, including optical particle counters, electrical aerosol analyzers, and condensation particle counters. A novel low-pressure impactor designed in the laboratory is used to fractionate particles for morphological analysis in size ranges down to 50 nm (0.05 micron).

Also available is a high-volumetric flow rate impactor suitable for collecting particulate matter for chemical analysis. Several types of specially designed aerosol generators are also available, including a laser ablation chamber, tube furnaces, and a specially designed aerosol microreactor. Concern with nanoscale phenomena requires the use of advanced systems for particle observation and manipulation. Students have direct access to modern facilities for transmission and scanning electron microscopy. Located near the laboratory, the Electron Microscopy facilities staff provide instruction and assistance in the use of these instruments. Advanced electron microscopy has recently been used in the laboratory to make the first systematic studies of atmospheric nanoparticle chain aggregates. Such aggregate structures have been linked to public health effects and to the absorption of solar radiation. A novel nanostructure manipulation device, designed and built in the laboratory, makes it possible to probe the behavior of nanoparticle chain aggregates of a type produced commercially for use in nanocomposite materials; these aggregates are also released by sources of pollution such as diesel engines and incinerators.

Polymer and Separations Research Laboratory
The 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-structured ceramic and polymeric surfaces for a variety of applications that include membrane performance enhancement and chemical sensor arrays. Analytical equipment for polymer characterization includes several high-pressure liquid chromatographs for size exclusion chromatography equipped with different detectors, including refractive index, UV photodiode array, conductivity, and a photodiode array laser light scattering detector. The laboratory has a research-grade FTIR with a TGA interface, a thermogravimetric analysis system, and a dual column gas chromatograph. Equipment for viscometric analysis includes high- and low-pressure capillary viscometer, narrow gap cylindrical couette viscometer, cone-and-plate viscometer, intrinsic viscosity viscometer system and associated equipment.

Flow equipment is also available for studying fluid flow through channels of different geometries (e.g., capillary, slit, porous media). The evaluation of polymeric and novel ceramic-polymer membranes, developed in the laboratory, is made possible with reverse osmosis, pervaporation, and cross-flow ultrafiltration systems equipped with online detectors. Studies of high recovery membrane desalination are carried out in a membrane concentrator/crystallizer system. Resin sorption and regeneration studies can be carried out with a fully automated system.

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

Faculty Areas of Thesis Guidance
Professors
Jane P. Chang, Ph.D. (MIT, 1998) Materials processing, gas-phase and surface reaction, plasma enhanced chemistries, atomic layer deposition, chemical microelectromechanical systems, and computational surface chemistry
Panagiotis D. Christofides, Ph.D. (U. Minnesota, 1996) Process modeling, dynamics and control, computational and applied mathematics
James F. Davis, Ph.D. (Northwestern U., 1981) Intelligent systems in process, control operations and design, decision support, management of abnormal situations, data interpretation, knowledge databases, pattern recognition
Vijay K. Dhir, Ph.D. (U. Kentucky, 1972) Two-phase heat transfer, boiling and condensation, thermal hydraulics of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling
Robert F. Hicks, Ph.D. (UC Berkeley, 1984) Chemical vapor deposition and atmospheric plasma processing
Metabolic engineering, synthetic biology, bioenergy
Yunfeng Lu, Ph.D. (U. New Mexico, 1998)
Semiconductor manufacturing and nanotechnology
Vasilios I. Manousiouthakis, Ph.D. (Rensselaer, 1987)
Biocatalysis, bioengineering, biosensors, nano-technology
Computational science, image processing, stability and science
First principles atomic scale simulations; quantum chemistry; applications to heterogeneous catalysis: active sites and reaction mechanisms, nanomaterials for depollution and energy transformation, molecules at surfaces
Tatiana Segura, Ph.D. (Northwestern U., 2004)
Gene therapy, tissue engineering, substrate-mediated non-viral DNA delivery
Yi Tang, Ph.D. (Caltech, 2002)
Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel antibiotics/antitumor products

Professors Emeriti
Kendall N. Houk, Ph.D. (Harvard, 1968)
Computational chemistry, enzyme design, investigation of reaction mechanisms, design of materials and processes
Louis J. Igarro, Ph.D. (U. Minnesota, 1966)
Regulation and modulation of NO production
Eldon L. Knuth, Ph.D. (Caltech, 1953)
Molecular dynamics, thermodynamics, combustion, applications to air pollution control and combustion efficiency
Ken Nobe, Ph.D. (UCLA, 1956)
Electrochemistry, corrosion, electrochemical kinetics, electrochemical energy conversion, electrodeposition of metals and alloys, electrochemical treatment of toxic wastes, bioelectrochemistry
Sellm M. Senkcan, Ph.D. (MIT, 1977)
Reaction engineering, combinatorial catalysis, combustion, laser photoinitiation, real-time detection, quantum chemistry
A.R. Frank Wazzan, Ph.D. (UC Berkeley, 1963)
Fast reactors, nuclear fuel element modeling, stability and transition of boundary layers, heat transfer

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

Lower Division Courses
2. Technology and Environment. (4) Lecture, four hours; outside study, eight hours. Natural and anthropogenic flows of materials at global and regional scales. Case studies of natural cycles include global warming (CO2 cycles), stratospheric ozone depletion (chlorine and ozone cycles), and global nitrogen cycles. Flow of materials in industrial economies compared and contrasted with natural flows; presentation of lifecycle methods for evaluating environmental impact of processes and products. P/NP, letter grading. Mr. Manousiouthakis (Not offered 2016-17)
10. Introduction to Chemical and Biomolecular Engineering. (1) Lecture, one hour; outside study, two hours. General introduction to field of chemical and biomolecular engineering. Description of how chemical and biomolecular engineering analysis and design skills are applied for creative solution of current technological problems in production of micro-electronic devices. Phase equilibrium, chemical kinetics for minimum environmental impact, application of nanotechnology to chemical sensing, and genetic-level design of recombiant microbes for chemical synthesis. Letter grading. Mr. Tang (F)
19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.
45. Biomolecular Engineering Fundamentals. (4) Lecture, four hours; outside study, eight hours. Fundamentals of modern biomolecular engineering. Topics include structure and function of biomolecules, central dogma of molecular biology, molecular information and energy processing, and experimental methods, with strong emphasis on applications in medicine, industry, and bioenergy. Letter grading.
99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower division students under guidance of faculty mentor. Students will be in good standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses
100. Fundamentals of Chemical and Biomolecular Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20B, 20L (not enforced), Mathematics 32B (may be taken concurrently), Physics 1A. Introduction to analysis and design of industrial chemical processes. Material and energy balances. Introduction to programming in MATLAB. Letter grading. Mr. Manousiouthakis (F)
101C. Mass Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 101B. Introduction to analysis of mass transfer in systems of interest to chemical engineering practice. Fundamentals of mass species transport, Fick’s law of diffusion, diffusion in chemically reacting flows, interphase mass transfer, multicomponent systems. Letter grading.
Mr. Cohen (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, energy and exergy, and ideal and real gases, property evaluation, Thermodynamics of flow systems. Applications of first and second laws in biological processes and living organisms. Letter grading.
103. Separation Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 100, 101B. Application of principles of heat, mass, and momentum transport to design and operation of separation processes such as distillation, gas absorption, filtration, and reverse osmosis. Letter grading. Ms. Chen (Sp)
104A. Chemical and Biomolecular Engineering Laboratory I. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: course 100. Enforced corequisite 101B. Recommended: course 102B. Investigation of basic transport phenomena in 10 predetermined experiments, collection of data for statistical analysis and individually written technical reports and group presentations. Design and performance of one original experimental study involving separation, or another aspect of chemical and biomolecular engineering. Basic statistical mean, standard deviation, confidence limits, comparison of two means and of multiple means, single and multiple variable linear regression, and brief introduction to factorial design of experiments. Oral and written presentations. Technical writing of sections of technical reports and their contents; writing clearly, concisely, and consistently; importance of word choices and punctuation in multi-cultural engineering environments and following required formatting. Letter grading. Mr. Grasel (W,Sp)
104B. Chemical and Biomolecular Engineering Laboratory II. (6) Lecture, four hours; laboratory, eight hours; outside study, four hours; other, two hours. Enforced requisites: courses 100, 101A. Course consists of four experiments in chemical engineering unit operations, each of two weeks duration. Students present their results both written and orally. Written report includes sections on theory, experimental procedures, data analysis and process design, and error analysis. Letter grading. Mr. Grasel; Mr. Simonetti (F,Sp)
104C. Semiconductor Processing. (3) Lecture, four hours; outside study, five hours. Enforced requisites: course 101C. Enforced corequisite: course 104CL. Basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor devices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, metalization, and statistical design of experiments and error analysis. Presentation of student results in both written and oral form. Letter grading. Mr. Hicks (Not offered 2016-17)
104CL. Semiconductor Processing Laboratory. (3) Laboratory, four hours; outside study, five hours. Enforced requisites: course 104C. Lab exercises: characterization of semiconductor devices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, metalization. Hands-on device testing includes transistors, diodes, and capacitors. Letter grading. Mr. Hicks (Not offered 2016-17)
44 / Chemical and Biomolecular Engineering

104D. Molecular Biotechnology Laboratory: From Gene to Product. Four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101C, 102B. Fundamentals of genetics and molecular biology; isolation and characterization of purified protein; derivation of properties needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems; and understanding of chemical processes; concurrent with course C211. Letter grading.

Mr. Yuan (F)

C112. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101C, 102B. Fundamentals of kinetics and catalysis. Integration of computer software to chemical engineering design and reaction engineering and simple economic principles for design and evaluation of alternative technologies. Letter grading.

Mr. Simonetti (F)

107. Process Dynamics and Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101C, 103 (or C125), 106 (or C115), Principles of dynamics modeling and start-up behavior of chemical engineering processes. Chemical process control elements. Design and applications of chemical process computer control. Letter grading.

Mr. Christofides (W)

108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 104A, 106 (or C115). Integration of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation technologies, energy, and reaction engineering and simple economic principles for purposes of designing chemical processes and evaluating alternatives. Letter grading.

Mr. Pang (W)

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

Mr. Pang (Sp)

109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 106 (or C115), 108A, Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20. Introduction to numerical methods for solving system of linear or nonlinear algebraic equations, ordinary differential equations, and partial differential equations. Chemical and biomolecular engineering examples used throughout to illustrate application of these methods. Use of MATLAB as platform (programming environment) to write programs based on numerical methods to solve various problems arising in chemical engineering. Letter grading.

Mr. Christofides (F)

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

Mr. Christofides (F)


Mr. Cohen (Not offered 2016-17)

C111. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryogenic engineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems; and understanding of chemical processes; concurrent with course C211. Letter grading.

Mr. Manousiouthakis (Not offered 2016-17)

C121. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology, with emphasis on separations and membranes, and application to biochemical systems. Relationship between structure/mor- phology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective membranes. Concurrently scheduled with course C235. Letter grading.

Mr. Cohen (F)

C124. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 2, 3, 23L. Introduction to design and synthesis of biomaterials for regenerative medicine, in vitro cell culture, and drug delivery. Biological principles of cellular microenvironment and design of extracellular matrix analogs using biological and engineering principles. Biomaterials for growth factor, and DNA and siRNA delivery as therapeutics and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C224L. Letter grading.

Ms. Segura (Not offered 2016-17)

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

Ms. Segura (Sp)

CM127. Synthetic Biology for Biofuels. (4) Same as Chemistry CM127. 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 novel metabolic networks in cells. Such efforts require profound understanding of biochemistry, protein structure, and biological regulation and are aided by tools and techniques from systems biology, and molecular biology. Fundamentals of metabolic biochemistry, protein structure and function, and bioinformatics. Use of systems modeling for metabolic networks, understanding of organism for energy applications. Concurrently scheduled with course CM227. Letter grading.

Mr. Cohen (Not offered 2016-17)

C128. Hydrogen. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Chemistry 20A. Electronic, physical, and chemical properties of hydrogen. Various methods of production, including production through methane steam reforming, electrolysis, and thermochemical cycles. Description in depth of several uses of hydrogen, including hydrogen combustion and hydrogen fuel cells. Concurrently scheduled with course C224L. Letter grading.

Mr. Manousiouthakis (Sp)

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

Mr. Christofides (Sp)
C140. Fundamentals of Aerosol Technology. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course 101C. Phenomenology of aerosols and their effect on the environment. Chemical and biophysical aspects of aerosol formation and its role in atmospheric processes. Emphasis on molecular and particulate systems. (Same as Chemical Engineering M140.) Letter grading. (Not offered 2016–17)

C145. Molecular Biotechnology for Engineers. (4) (Same as Bioengineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Chemistry 20A. Introduction to biotechnology and modern genetics. Molecular biology, bioprocessing, and molecular technology. (Same as Chemical Engineering CM145.) Letter grading. (Not offered 2016–17)

C146A. Introduction to Bioreactor Engineering. (4) Lecture, four hours; discussion; outside study, seven hours. Requisite: Chemistry 20A. An introduction to the principles and applications of bioreactor design and operation. Topics include reactor configuration, mixing, phase separation, and reactor scale-up. Letter grading. (Not offered 2016–17)

C152. Molecular Biology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Principles of molecular biology and genetics. An introduction to the molecular mechanisms of life, from the genetic code to molecular structure and function of the cell. Letter grading. (Not offered 2016–17)

C155. Human Physiology. (4) Lecture, four hours; discussion; laboratory, two hours; outside study, eight hours. Requisite: course 101C. Integration of the many cellular and molecular events of living systems. Emphasis on the function and regulation of major body systems. Letter grading. (Not offered 2016–17)

C161A. Chemical Reaction Engineering I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Introduction to chemical reaction engineering and reaction modeling. Kinetics and equilibrium. Letter grading. (Not offered 2016–17)

C161B. Chemical Reaction Engineering II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Advanced chemical reaction engineering and reaction modeling. Heat transfer, mass transfer, and fluid dynamics. Letter grading. (Not offered 2016–17)

C161C. Chemical Reaction Engineering III. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Advanced chemical reaction engineering and reaction modeling. Advanced topics in chemical reaction engineering. Letter grading. (Not offered 2016–17)

C194. Research Participation Seminars: Chemical Engineering. (4) Seminar, four hours; outside study, eight hours. Design for undergraduate students who are part of research group. Research of current faculty member. May be repeated for credit. Letter grading. (Not offered 2016–17)

194C. Research Seminars: Chemical Engineering. (4) Seminar, four hours; outside study, eight hours. Design for undergraduate students who are part of research group. Research of current faculty member. May be repeated for credit. Letter grading. (Not offered 2016–17)

C210. Advanced Chemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: courses 101C, 106. Principles of chemical reaction analysis and design. Specific emphasis on simultaneous effects of chemical reaction and mass transport on catalytic reactions in fixed and fluidized beds. Letter grading. (Not offered 2016–17)

C211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryoengineering science pertaining to industrial low-temperature processes. Basic approach to analysis of cryogenic systems and processes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C111. Letter grading. (Not offered 2016–17)


C214. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: courses 102A, 102B (or Materials Science 130). Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes and metallic corrosion. Primary emphasis on fundamental approach to analysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semiconductors, electrochemical metal and semiconductor deposition, passivation, dielectrodeposition, electrolysis, electrochemistry, and biochemical processes. May be concurrently scheduled with course C114. Letter grading. (Not offered 2016–17)

C215. Biochemical Reaction Engineering. (4) (Same as Bioengineering M215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. May be concurrently scheduled with course C115. Letter grading. (Not offered 2016–17)

C216. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course 113A. Introduction to surfaces and interfaces of engineering materials, particularly catalytic surface and thin films for solid-state electronic devices. Topics include classification of crystals and surfaces, analysis of structure and composition of crystals and their surfaces and interfaces. Examination of engineering applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C116. Letter grading. (Not offered 2016–17)

C217. Electrochemical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course C114. Transport phenomena in electrochemical systems; relationships between molecular transport, convection, and electrode kinetics, along with applications to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading. (Not offered 2016–17)


C226. Design for Environment. (4) Lecture, four hours; discussion, one hour; 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 2016–17)

234. Plasma Chemistry and Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: for graduate chemistry or engineering students. Application of chemistry, physics, and engineering principles to design and operation of plasma and ion-beam processes. Analysis of physical, chemical, and cleaning of materials. Examination of atomic, molecular, and ionic phenomena involved in plasma and ion-beam processing of semiconductors, etc. Letter grading. Ms. Chang, Mr. Hicks (Not offered 2016-17)

235. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Sensitivity analysis and design strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, enzymes, food additives, or pharmaceutical products of biological reactors. Concurrently scheduled with course C125. Letter grading. Ms. Segura (Sp)

237. 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 novel metabolic networks in cells. Such efforts require profound understanding of biochemistry, protein structure, and biological regulations and are aided by tools in biostatistics, computer science, and molecular biology. Fundamentals of metabolic biochemistry, protein structure and function, and bioinformatics. Use of systems modeling to design and engineer microorganisms for energy applications. Concurrently scheduled with course C127. S/U or letter grading. (Not offered 2016-17)

228. Hydrogen. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Chemistry 20A. Electronic, physical, and chemical properties of hydrogen. Various methods of production, including production through methane steam reforming, electrolysis, and 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. Manoussiotakis (Sp)


231. Molecular Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 110. Analysis and design of molecular-beam systems. Molecular-beam sampling of reactive mixtures in combustion chambers or gas jets. Molecular-beam studies of gas-surface interactions, including energy accommodation and heterogeneous reactions. Applications to air pollution control and to catalysis. Letter grading. (Not offered 2016-17)

232. Combustion Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 110. Chemistry 200, or Mechanical and Aerospace Engineering C132A. Fundamentals: change equations for multicomponent reactive mixtures, rate laws. Applications: combustion, including burning of (1) premixed gases or (2) condensed fuels. Detonation, Sound absorption and dispersion. Letter grading. Mr. Senken (Not offered 2016-17)

233. Frontiers in Biotechnology. (2) (Formerly numbered M240A.) Lecture, four hours; discussion, one hour. Enforced requisite: course 101C. Life Sciences 3. Integration of science and business in biotechnology. Academic research leading to licensing and founding of companies that turn research breakthroughs into marketable products. 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 2016-17)


270. Principles of Reaction and Transport Phenomena. (4) Lecture, four hours; laboratory, eight hours. Fundamentals in transport phenomena, chemical reaction, kinetic, heat and mass transfer. Emphasis on problems related to state-of-art research areas in chemical engineering. Letter grading. Ms. Chang

270R. Advanced Research in Semiconductor Manufacturing. (8) Laboratory, nine hours; outside study, nine hours. Limited to graduate chemical engineering students in M.S. and doctoral manufacturing option. Supervised research in processing semiconductor materials and devices. Letter grading.

M280A. Linear Dynamic Systems. (4) (Same as Electrical Engineering M240A and Mechanical and Aerospace Engineering M270A.) Lecture, four hours; outside study, eight hours. Requisites: Electrical Engineering 141 or Mechanical and Aerospace Engineering 117A. State-space description of linear time-invariant (LTI) and time-variant (TV) systems. Linear systems theory, time-invariant 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 technology. Letter grading.


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

Mr. Christofides (Not offered 2016-17)


290. Special Topics. (2 to 4) Seminar, four hours. Requisites for each offering announced in advance 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 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 researchers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.

298A-298Z. Research Seminars. (2 to 4 each) Seminar, to be arranged. Requisites for each offering announced in advance by department. Lectures, 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 in discipline. May be repeated for credit. S/U grading. (F,W,Sp)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, 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, including use of grading, advising, and rapport with students. S/U grading. (F)

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

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

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

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

598. Research for and Preparation of M.S. Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate chemical engineering students. 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 chemical engineering students. Usually taken after students have been advanced to candidacy. S/U grading.
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 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, Environment 12, Life Sciences 1, 2, 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 101, 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, 155, 156, 164, M165, M166; laboratory courses: 156A, 156B; capstone design courses: 157B, 157C.
Geotechnical Engineering: Civil and Environmental Engineering 125; laboratory courses: 128L, 129L; design courses: 121, 123 (capstone).
Hydrology and Water Resources Engineering: Civil and Environmental Engineering 157A; laboratory course: 157L; design courses: 151, 152 (capstone).
Structural Engineering and Mechanics: Civil and Environmental Engineering 125, 130, 135B, M135C, 137, 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
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 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, 258A, 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; 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
Civil and Environmental 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 coursework 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 3.26 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 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.
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.

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.

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 hydroclimatology, watershed response to disturbance, remote sensing, data assimilation, hydrologic modeling and parameter estimation, multiobjective resources planning and management, numerical modeling of solute transport in groundwater, and optimization of conjunctive use of surface water and groundwater.

Structures (Structural Mechanics and Earthquake Engineering)

Research in structural mechanics is directed toward improving the ability of engineers to understand and interpret structural behavior through experiments and computer analyses. Areas of special interest include computer analysis using finite-element techniques, computational mechanics, structural dynamics, nonlinear behavior, plasticity, micromechanics of composites, damage and fracture mechanics, structural optimization, probabilistic static and dynamic analysis of structures, and experimental stress analysis. Designing structural systems capable of surviving major earthquakes is the goal of experimental studies on the strength of full-scale reinforced concrete structures, computer analysis of soils/structural systems, design of earthquake resistant masonry, and design of seismic-resistant buildings and bridges.

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

Facilities

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

Instructional Laboratories

Engineering Geomatics

Engineering Geomatics is a field laboratory that teaches basic and advanced geomatics techniques including light detection and 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 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 speci-
ments are made can be determined. It can also be used in fatigue-testing of small components.

Soil Mechanics Laboratory

The Soil Mechanics Laboratory is used for standard experiments and advanced research in geotechnical engineering, with equipment for static and dynamic triaxial and simple shear testing. Modern computer-controlled servo-hydraulic closed-loop system supports triaxial and simple shear devices. The system is connected to state-of-the-art data acquisition equipment. The laboratory also includes special simple shear apparatuses for small-strain cyclic and triaxial 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

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

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

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

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

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

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

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

Michael K. Stenstrom, Ph.D., P.E. (Clemson, 1976)
Earthquake engineering, design methodologies, seismic evaluation and retrofit, large-scale testing laboratory and field testing

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

Professors Emeriti

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

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

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

Gary C. Hatt, Ph.D., P.E. (Stanford, 1965)
Experimental engineering and analysis design of buildings for earthquake and wind loads, structural dynamics, and uncertainty and risk analysis of structures

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

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

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

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

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

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

Associate Professors

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

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

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

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

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

Assistant Professors

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

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

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

Sanjay Mohanrai, Ph.D. (U. Colorado Boulder, 2011)
Effect of water change on water quality and quantity; sustainable urban development at the water-energy nexus; transport of contaminants and colloids in the subsurface and groundwater; stormwater capture, treatment, and re-use; bioremediation

Adjunct Professors

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

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

George Mylonakis, Ph.D., P.E. (SUNY Buffalo, 2000)
Soil mechanics and dynamics, earthquake engineering, geomechanics, stress wave propagation, foundation engineering

Thomas Sabol, Ph.D., S.E. (UCLA, 1985)
Seismic performance and seismically designed 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.

Mr. Stewart (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.

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-ori-
101. Statics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 31A, 31B, Physics 1A. Newtonian mechanics, vector representation, and resultant forces and moments. Free-body diagrams and equilibrium, internal loads and equilibrium in trusses, frames, and beams. Planar and nonplanar systems, distributed forces, determinants and indeterminate force systems, moment diagrams, and axial force diagrams. Letter grading. Mr. Sant (F)

102. Dynamics of Particles and Bodies. (2) Lecture, two hours; discussion, two hours; outside study, two hours. Requisite: course 101, Physics 1B. Introduction to fundamentals of dynamics of single particles, system of particles, and rigid bodies. Topics include kinematics and kinetics of particles, work and energy, impulse and momentum, multiaxial 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 31. Mechanics 33B or Mechanical and Aerospace Engineering 82 (either may be taken concurrently). Introduction to numerical computing with specific applications in civil and environmental engineering. Topics include error and computer arithmetic, root finding, interpolation and differentiation, solution of systems of linear and nonlinear equations, numerical solution of ordinary and partial differential equations. Letter grading. Ms. Margulis, Mr. Taciroglu (Sp).


129L. Engineering Geomatics. (4) Formerly numbered 129.) Lecture, two hours; recitation, two hours; laboratory, four hours; outside study, four hours. Col- lection, processing, and interpretation of geospatial data. Ellipsoid and geod models of shape of Earth. Sea level, height, and geopotential surfaces. Elements and usage of topographic data and maps. Advanced global positioning systems (GPS) for high-precision mapping. Advanced laser-based light detection and ranging (LIDAR) mapping. Quantitative terrain analysis and change detection. Hydrogeomatics: seafloor mapping. Letter grading. Mr. Stewart (F).


110. Introduction to Probability and Statistics for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, 12 hours. Requisites: Mathematics 32A, 32A. Recommended: course M20. Introduction to fundamental concepts and applications of probability and statistics in civil engineering, with focus on how these concepts are used in experimental design and sampling, data analysis, risk and reliability analysis, and project design under uncertainty. Topics include basic probability concepts, random variables and analytical probability distributions, functions of random variables, estimating parameters from observational data, regression, hypothesis testing, and Bayesian concepts. Letter grading. Ms. Jay (Sp).

120. Principles of Soil Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 108. Soil as foundation for structures and as material of construction. Soil for- mation, classification, physical and mechanical prop- erties, soil compaction, earth pressures, consolida- tion, and shear strength. Letter grading. Mr. Vucetic (F).

125A. Elementary Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses M20 or Computer Science 31, 108. Introduction to structural analysis; classification of structural elements; anal- ysis of statically determinate trusses, beams, and frames; deflections in elementary structures; virtual work; analysis of structures using force method; introduction to displacement method and energy concepts. Letter grading. Mr. Vucetic (Sp).

115B. 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 method; matrix displacement method; analy- sis of statically determinate trusses, beams, and frames; deflections in elementary structures; virtual work; analysis of structures using force method; introduction to displacement method and energy concepts. Letter grading. Mr. Vucetic (Sp).

135C. Introduction to Finite Element Methods. (4) Same as Mechanical and Aerospace Engineering 168.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 130 or Mechanical and Aerospace Engineering 156A or permission. Introduction to basic principles of Finite Element Methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix
143. Design of Prestressed Concrete Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 135A, 142. Equivalency: load analyses, failure mechanisms in determinate and indeterminate systems. Flexural and shear strength design, including secondary effects in indeterminate systems. Design of indeterminate post-tensioned beam using both hand calculations and commercially available computer program. Design of external post-tensioning, one- and two-way slab systems. Letter grading. Mr. Wallace (Sp)

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

145. Design and Construction of Tall Buildings. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 135B, 141. Role of structural engineer and client in architectural design of tall buildings. Development of architectural design of tall buildings. Influence of building code, zoning, and finance. Advantages and limitations of different structural systems. Development of structural system design and computer model for architectural design. Letter grading. Mr. Sabol, Mr. Wallace (W)

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

151. Introduction to Water Resources Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 150, 151. Analysis and design of hydraulic and hydrologic systems, including stormwater management systems, potable and recycled water distribution systems, wastewater collection systems, and constructed wetlands. Emphasis on practical design components, including reading/interpreting professional drawings and documents, environmental impact reports, permitting, agency coordination, and engineering ethics. Project-based course includes analysis of alternative design methods, use of engineering economics, and preparation of written engineering reports. Letter grading. Mr. Margulis (F)

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

153. Introduction to Environmental Engineering. (4) Lecture, four hours; discussion, one hour (when scheduled); outside study, seven hours. Recommended requisite: Mechanical and Aerospace Engineering 103. Water, air, and soil pollution: natural processes and pollution sources; water and wastewater treatment, waste disposal, air pollution, global environmental problems. Field trip. Letter grading. Ms. Jay (F)

154. Chemical Fate and Transport in Aquatic Environments. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 153. Fundamental physical, chemical, and biological principles governing movement and fate of chemicals in natural systems. Topics include physical transport in various aquatic environments, air-water exchange, acid-base equilibria, oxidation-reduction chemistry, chemical sorption, biodegradation, and fate of persistent pharmaceuticals. Practical quantitative problems considered focusing both reaction and transport of chemicals in environment. Letter grading. Ms. Jay (W)

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

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

156B. Environmental Engineering Unit Operations and Processes Laboratory. (4) Laboratory, six hours; discussion, two hours; outside study, four hours. Requisites: Chemistry 20A, 20B. Characterization and analysis of typical natural waters and wastewaters for inorganic and organic constituents. Selected experiments include analysis of solids, nitrogen species, oxygen demand, and chlorine residual, that are used in unit operations experiments that include reactor dynamics, aerations, and molecular separation. Letter grading. Mr. Stensrom (W)

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

157B. Design of Water Treatment Plants. (4) Lecture, two hours; discussion, two hours; laboratory, four hours; outside study, four hours. Requisite: course 155. Water quality standards and regulations, overview of water treatment plants, design of unit operations, predesign of water treatment plants, hydraulics of plants, process control, and cost estimation. Letter grading. Mr. Stensrom (W)

157C. Design of Wastewater Treatment Plants. (4) Lecture, four hours; outside study, eight hours. Requisite: course 155. Process design of wastewater treatment plants, including primary and secondary treatment, design review of existing plants, process control, and economics. Letter grading. Mr. Stensrom (Not offered 2016-17)

157L. Hydrologic Analysis. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisite: course 150. Collection, compilation, and interpretation of data for quantification of components of hydrologic cycle, including precipitation, evaporation, infiltration, and runoff. Use of hydrologic variables and images/analyses/interpretation of hydrologic cycle. Letter grading. Mr. Gere (W)
157M. Hydrology of Mountain Watersheds. (4) Lecture, four hours; outside study, three; discussion, one. Requisite: course 150 or 157L. Development of field- and laboratory-based course with focus on study of hydrologic processes in mountain watersheds and understanding of nested and mountainous regions. Students measure and quantify snowpack properties, snowmelt, discharge, evaporation, infiltration, soil properties, and local meteorology. Investigate the hydrologic properties of surface and groundwater systems. Exploration of rating curves, stream classification, and flooding potential. Extended field trip required. Letter grading. Mr. Margulis (Not offered 2016–17)


M165. Environmental Nanotechnology: Implications and Applications. (4) Same as Engineering M103J. Lecture, discussion, two hours; outside study, six. Recommended requisite: Engineering 101. Exploration of potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental protection. Technical contents include three multidisciplinary areas: (1) physical, chemical, and biological properties of nanomaterials, (2) transport, reactivity, and toxicity of nanoscale materials in natural environmental systems, and (3) use of nanotechnology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading. Ms. Mahendra (Sp)

M166. Environmental Microbiology. (4) Same as Environmental Health Sciences M166J. Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 150. Course includes microbial cell and its metabolic capabilities, microbial genomics and its potentials, growth of microbes and kinetics of growth, microbial ecology and diversity, microbial processes 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 M166LJ. Lecture, two hours; outside study, two. Corequisite: course M166. General laboratory practice within environmental microbiology, sampling of environmental samples, classical and molecular techniques for enumeration of microbes from environmental samples, techniques for determination of microbial activity in environmental samples, laboratory reports and for studying environmental biotechnology. Letter grading. Ms. Mahendra (Not offered 2016–17)

180. Introduction to Transportation Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six. Recommended prereqs: courses 120, 121, 220. General characteristics of transportation systems, including streets and highways, rail, transit, air, and water. Capacity considerations including time-space diagrams and queueing. Components of transportation systems such as horizontal and vertical alignment, cross sections, earthwork, drainage, and pavements. Letter grading. Mr. Brandenberg (Sp)

181. Traffic Engineering Systems: Operations and Control. (4) Lecture, one hour; laboratory, two hours; outside study, six hours. Designed for juniors/seniors. Applications of traffic flow theories: data collection and analyses; intersection capacity, design, and signalization; pedestrian and bicycle facilities and design; traffic engineering 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 requisite: courses C104, 108, 120, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Recommended requisite: course 153. Microbiology, sampling of environmental samples, classical and modern molecular techniques for enumeration of microbes, with focus on practical examples and applications so students can independently run simulations at scale relevant to targeted problems. Letter grading. Ms. Bauchy (F)

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, groundwater, hydrology, and water resources engineering, materials engineering, structural engineering, and structural mechanics. May be repeated for credit. S/U grading. (F,W,Sp)

C205. Structure, Processing, and Properties of Amorphous Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 101, Chemistry 20A, 20B, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Corequisite: course 108. Nature and properties of amorphous civil engineering materials, with focus on practical examples and applications so students can independently run simulations at scale relevant to targeted problems. Letter grading. Mr. Brandenberg (F)

206. Modeling and Simulation of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: 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 at scale relevant to targeted problems. Letter grading. Mr. Bauchy (F)

220. Advanced Soil Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Recommended prerequisites: courses 220, 259B. Stress-strain properties of soils. In situ and laboratory methods for soil property evaluation. Letter grading. Mr. Brandenberg (F)


224. Advanced Cyclic and Monotonic Soil Behavior. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 121, 220. Basic concepts of stability of earth slopes, including shear strength, design charts, limit equilibrium analysis, seepage analysis, sliding on rigid and flexible foundations. Theory of earth pressures behind retaining structures, with special application to design of retaining walls, sheet piles, mechanically stabilized embankments, driven pile and drilled shaft foundations under vertical and lateral loading. Construction considerations. Letter grading. Mr. Brandenberg (Sp)

225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 220, 245 (may be taken concurrently). Analysis of earthquake-induced ground failure, liquefaction, cyclic stress-strain responses, residual shear strength, and seismic slope stability. Ground response effects on earthquake ground motions, soil-structure interaction, including dynamic and kinematic interaction and foundation deformations under seismic loading. Letter grading. Mr. Stewart (Sp)

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

227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of computer modeling of soils using finite element method, and to constitutive modeling based on elasticity and plasticity theories. Special emphasis on numerical applications and identification of modeling concerns such as instability, bifurcation, nonexistence, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vucetic (Not offered 2016-17)

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 ground surface, 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 such as tectonics, isostasy, and eustasy. 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. Rayen (W)

M230A. Linear Elasticity. (4) (Same as Mechanical and Aerospace Engineering M256A.) Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 156A or 166A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastostatic problems, holes, corners, inclusions, cracks; three-dimensional problems. Kirk, Ramin, Cerruti. 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; outside study, eight hours. Requisite: course M230A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor; nonlinear elasticity, strain energy functions, strain and displacement relations; balance laws, Cauchy and Piola stresses, Cauchy equations of motion, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoelasticity, linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mal (W)


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


234. Advanced Topics in Structural Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232. Limited to graduate engineering students. Current topics in composite materials, computational methods, finite element analysis, structural synthesis, nonlinear, and advanced methods for composite materials in general. Topics may vary from term to term. Letter grading. Mr. Ju (Not offered 2016-17)

235A. Advanced Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: 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 values of total and structural potential energy, minimum total potential energy, Maxwell/Willet 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: courses 130, 235A. Direct energy formulations for deformable systems; solution methods for linear equations; analysis of structural systems with both kinematic and geometric nonlinearity; and finite element analysis of structures of large deformation and geometric nonlinearity. Letter grading. Mr. Tacioglu (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 nonlinearity; Lagrangian, Eulerian description of motion; finite element methods in geometrically nonlinear problems; postbuckling behavior of structures; solution of nonlinear ordinary differential equations; iterative, programming methods. Letter grading. Mr. Tacioglu (W)


237A. Dynamics of Structures. (4) (Same as Mechanical and Aerospace Engineering M269A.) Lecture, four hours; outside study, eight hours. Requisites: course 137. Principles of dynamics. Determination of normal modes and frequencies by differential and integral equation solutions. Transfer functions and state space response. Empirical characteristic matrices and state space solution. Derivations of governing equations using matrix formulation. Letter grading. Mr. Madhavan, Mr. Ju, Mr. Tacioglu (W)


239. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 235B. Advanced finite element and meshfree methods for structural dynamics. Basic structural dynamics course for civil engineering students. Elastic free and forced vibrations of single degree of freedom systems, introduction to response history analysis techniques for single and multidegree of freedom systems. Axial, bending, and torsional vibration of beams. Consecutively scheduled with course C137. Letter grading. Mr. Tacioglu (F)


243A. Behavior and Design of Reinforced Concrete Structural Elements. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 142. Advanced topics on design of reinforced concrete structural elements, including stress-strain relationships for plain and confined concrete, moment-curvature analysis of sections, and design for shear. Design of slenderness and boundary conditions, problems of composite structural systems. Letter grading. Mr. Sabol, Mr. Wallace (Sp)

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

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

245. Earthquake Ground Motion Characterization. (4) Lecture, four hours; outside study, six hours. Corequisite: course C137 or 246. Earthquake fundamentals, including plate tectonics, fault types, seismic waves, and magnitude

Civil and Environmental Engineering / 57
246. Structural Response to Ground Motions. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses C137, 141, 142, 255A. Spectral analysis of ground motion; response time, and Fourier spectra. Response of structures to ground motions due to earthquakes. Computational methods to evaluate structural response. Response analysis, including evaluation of contemporary design standards. Limitations due to idealizations. Letter grading. Mr. Taciroglu, Mr. Wallace (W).

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


250A. Surface Water Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 150. In-depth study of sur- face water hydrology, including discussion and inter- relationship of major topics such as rainfall and evap- oration, 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. Gebermich (F).


251C. Remote Sensing with Hydrologic Applica- tions. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250C. Introduction to basic physical concepts of remote sensing as they relate to surface and atmospheric hydrologic pro- cesses. Emphasis on exchanges across phase boundaries: solid, liquid, and gas. Numerical models and computer programs to solve nonlinear partial differential equations and parameter estimation. Applications to digital imaging, remote sensing, and recent literature. Application to important environmental research topics in inverse problem of parameter estimation, experimental design, conjugate use of surface and ground water hydrology, lumped water re- sources planning, and optimization of water resource systems. Topics may vary from term to term. Letter grading. Ms. Yeh (Not offered 2016-17).

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


259A. Physical and Chemical Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requ- isites: courses 155, 254A. Review of momentum and mass transfer, chemical reaction engineering, co- agulation and flocculation, granular filtrations, sedi- mentation, carbon dioxide, gas transfer, disinfec- tion, oxidation, and water treatment processes. Letter grading. Mr. Hoek (W).

259B. Biological Processes for Water and Waste- water 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-bed processes, aer-obic and anaerobic digestion, sludge disposal, and biological nutrient removal. Letter grading. Mr. Stenstrom (Sp).

260. Advanced Topics in Hydrology and Water Re- sources. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Applications of membrane separation processes to desalination and seawater, brine disposal, and ultrapure water systems. Discussion of reverse osmosis, ultrafiltration, electrodialysis, and ion exchange technologies from both practical and theoretical standpoints. Letter grading. Mr. Hoek (Sp).

258B. Selected Topics in Water Resources. (2 to 4) Lecture, four hours; outside study, eight hours. Re- view of recent research and developments in water resources. Water supply and hydrology, global cli- mate change, economic planning, and optimization of water resources development. May be taken for max- imum of 4 units. Letter grading. Mr. Stenstrom (Not offered 2016-17).


261B. Advanced Biological Processes for Water and Wastewater Treatment. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255B. In-depth treatment of selected topics related to bio- logical treatment of waters and wastewaters, such as biodegradation of xenobiotics, pharmaceuticals, emerging pollutants, toxicity, and nutrients. Discus- sion of theoretical aspects, experimental observa- tions, and recent literature. Application to important and emerging environmental problems. Letter grading. Mr. Stenstrom (Not offered 2016-17).

262A. Introduction to Atmospheric Chemistry. (4) Same as Atmospheric and Oceanic Sciences M262A. Lecture, three hours. Under- graduates: Chemistry 20B. Principles of chemical ki- netics, chemodynamics, spectroscopy, and photo- chemistry; chemical composition and history of Earth’s atmosphere; biogeochemistry of key at- mospheric constituents; basic photochemistry of tro- posphere and stratosphere, upper atmosphere chemical processes; air pollution; chemistry and cli- mate. S/U or letter grading. (F).

262B. Atmospheric Diffusion and Air Pollution. (4) Same as Atmospheric and Oceanic Sciences M224B.) Lecture, three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban com- plexes; meteorological factors and air pollution po- tential; meteorological aspects of air pollution. S/U or letter grading. (Not offered 2016-17).

263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, six hours. Des- signed for graduate students. Transport processes in surface water, groundwater, and atmosphere. Em- phasis on exchanges across phase boundaries: sedi- ment/water interface; air/water interface; physical parti- cles, droplets, and bubbles; small-scale dispersion and mixing; effect of reactions on transport; linkages between physical, chemical, and biological pro- cesses. Letter grading. Ms. Jay (F).

263B. Advanced Topics in Transport at Environ- mental Interfaces. (4) Lecture, four hours; outside study, eight hours. Requisite: course 253A. In-depth treatment of selected topics involving transport phe- nomena 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 2016-17)

265A. Mass Transfer in Environmental Systems. (4) Lecture, four hours; computer applications, two hours; outside study, eight hours. Designed for graduate environmental engineering program students. Physical mass transfer and mass transfer fundamentals related to contaminant fate and transport in soil, air, and water systems, including soil/water sorption and desorption, contaminant retardation, vaporization and dissolution of nonaqueous phase liquids (NAPL), and other environmental systems. Letter grading.

Ms. Jay (Not offered 2016-17)

265B. Contaminant Transport in Soils and Groundwater. (4) Lecture, four hours; computer applications, two hours; outside study, six hours. Requisites: courses 250B, 265A. Principles of mass transfer as they apply in soil and groundwater, independent estimation of transport model parameters; remediation of hazardous waste sites. Letter grading.

Ms. Jay (Not offered 2016-17)

266. Environmental Biotechnology. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 15S, 254A. Environmental biotechnology — concept and potential, biotechnology of pollution control, bioremediation, biomass conversion: composting, biogas and bioethanol production. Letter grading.

Ms. Mahendra (F)

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

Ms. Jay (Not offered 2016-17)

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

Mr. Sant (Not offered 2016-17)

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

(FW,Sp)

297. Seminar: Current Topics in Civil Engineering. (2 to 4) Seminar, to be arranged. Lectures, discussions, and student presentations and projects in areas of current interest in civil engineering. May be repeated for credit. S/U grading.

(FW,Sp)

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

(FW,Sp)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: appointment 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.

(FW,Sp)

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

(F)

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

597A. Preparation for 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.

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Supervised independent research for Ph.D. preliminary examinations. S/U grading.

597C. 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.

598. Research for and 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 prospectus. S/U grading.

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

Computer Science

UCLA

4732 Boelter Hall
Box 951566
Los Angeles, CA 90095-1506

tel: 310-825-3886
fax: 310-825-2273
http://cs.ucla.edu

Mario Gerla, Ph.D., Chair
Glen D. Reinman, Ph.D., Vice Chair
Richard E. Korf, Ph.D., Vice Chair

Professors

Junhoo (John) Cho, Ph.D.
Jason (Jingsheng) Cong, Ph.D.
Adnan Y. Darwiche, Ph.D.
Joseph J. Di Stefano III, Ph.D.
Michael G. Dyer, Ph.D.
Milos D. Ercegovac, Ph.D.
Eliazar Eskin, Ph.D.
Eliezir M. Gafni, Ph.D.
Mario Gerla, Ph.D.
Richard E. Korf, Ph.D.
Christopher J. Lee, Ph.D.
Songwu Lu, Ph.D.
Todd D. Millerstein, Ph.D.
Stanley J. Osher, Ph.D.
Rafael Ostrovsky, Ph.D.
Jens Palsberg, Ph.D.
D. Stott Parker, Jr., Ph.D.
Miodrag Potkonjak, Ph.D.
Glenn D. Reinman, Ph.D.
Armit Sahai, Ph.D.
Majid Sarrafzadeh, Ph.D.
Stefano Soatto, Ph.D.
Mani B. Srivastava, Ph.D.
Demetri Terzopoulos, Ph.D. (Chancellor's Professor)
George Varghese, Ph.D.
Wei Wang, Ph.D.
Alan L. Yuille, Ph.D.
Carlo A. Zaniolo, Ph.D. (Norman E. Friedmann Professor of Knowledge Sciences)
Lixia Zhang, Ph.D. (Jonathan B. Postel Professor of Computer Systems)
Song-Chun Zhu, Ph.D.

Professors Emeriti

Algirdas A. Avizienis, Ph.D.
Rajive L. Bagrodia, Ph.D.
Alfonso F. Cardenas, Ph.D.
Jack W. Carlyle, Ph.D.
Wesley W. Chu, Ph.D.
Sheila A. Greibach, Ph.D.
Leonard Kleinrock, Ph.D.
Allan Klinger, Ph.D.
Lawrence P. McNamee, Ph.D.
Richard R. Muntz, Ph.D.
Julie Pearl, Ph.D.
David A. Rennels, Ph.D.
Miodrag Potkonjak, Ph.D.
Jens Palsberg, Ph.D.

Associate Professors

Miryung Kim, Ph.D.
Fei Sha, Ph.D.
Alexander Sherstov, Ph.D.
Yuval Tarni, Ph.D.

Assistant Professors

Tyson Condie, Ph.D.
Students in professor Jason Cong's VAST laboratory display a field-programmable gate array (FPGA) board.

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

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 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 Engineering 3, 10, 11L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Computer Science 111, 118, 131, M151B, M152A, 180, 181, Electrical Engineering 102, 110, 111L; one course from Civil and Environmental Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone design course (Computer Science 152B); 4 units of elective courses selected from Electrical Engineering 113, 115A, 115C, 132A, 141; 12 units of elective courses selected from Computer Science 111 through CM187 or Electrical Engineering 133A, at least one of which must be Computer Science CM121, CM122, CM124, 143, 161, or 174A; 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 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 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, principles of programming languages, data structures, computer architecture, theory of computation and formal languages, operating systems, distributed systems, computer modeling, computer networks, compiler construction, and artificial intelligence. Majors are prepared for employment in a wide range of industrial and business environments.

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, 4AL, 4BL.

The Major
Required: Computer Science 111, 118, 131, M151B, M152A, 180, 181; one course from Civil and Environmental Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone software engineering or design course from Computer Science 130 or 152B; 20 units of elective courses selected from Computer Science 111 through CM187 or Electrical Engineering 133A, at least one of which must be Computer Science 112 or 170A or Electrical Engineering 133A, and at least two of which must be selected from Computer Science CM121, CM122, CM124, 143, 161, or 174A, with at least one of the two courses from 143, 161, or 174A; 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 Engineering 133A unless at least one 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 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.

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

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

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

Required Upper Division Courses (18 units minimum): Computer Science 180 (or Mathematics 182), M184, and three courses selected from Civil and Environmental Engineering 110, Computer Science CM121, CM122, CM124, 170A, CM186, CM187, Ecology and Evolutionary Biology 135, Electrical Engineering 102, 131A, 141, Human Genetics C144, Mathematics 170A, Molecular Cell, and Developmental Biology 144, 172, Physiological Science 125, Statistics 100A, 100B. At least two of the courses must be selected from Computer Science CM121, CM122, and CM124. Eight units of either Bioinformatics 199 or Computer Science 194 or 199 may be applied as 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 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 24.

The following introductory information is based on the 2016-17 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 Engineering 100, 101A, 102, 110L, M116L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

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

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

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

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

**Comprehensive Examination Plan**

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

**Thesis Plan**

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

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

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

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

**Computer Science Ph.D.**

**Major Fields or Subdisciplines**

Artificial intelligence; computational systems biology; computer networks; computer sci-
ence 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 six courses, as well as the current literature in the area of specialization. In particular, students are required to take a minimum of four 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 three courses, at least two of which are graduate courses. 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 either be a research paper containing an original contribution or a focused critical survey paper. The paper should demonstrate that the student understands and can integrate and communicate ideas clearly and concisely. It should be approximately 10 pages single-spaced, and the style should be suitable for submission to a first-rate technical conference or journal. The paper must represent work that the student did as a graduate student at UCLA. Any contributions that are not the student's own, including those of the student's advisor, must be explicitly acknowledged in detail. Prior to submission, the paper must be approved by the student's advisor on a cover page with the advisor's signature indicating review. After submission, the paper must be reviewed and approved by at least two other members of the faculty. There are two deadlines a year for submission of papers.

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

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

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

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

1. Problem Solving. Analysis of tasks, such as playing chess or proving theorems, that require reasoning about relatively long sequences of primitive actions, deductions, or inferences
2. Knowledge representation and qualitative reasoning. Analysis of tasks such as commonsense reasoning and qualitative physics. Here the deductive chains are short, but the amount of knowledge that potentially may be brought to bear is very large
3. Expert systems. Study of large amounts of specialized or highly technical knowledge that is often probabilistic in nature. Typical domains include medical diagnosis and engineering design
4. Natural language processing. Symbolic, statistical, and artificial neural network
approaches to text comprehension and generation

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

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

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

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

### Computational Systems Biology

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

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

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

Typical research areas with a systems focus include molecular and cellular systems biology, organ systems physiology, medical, pharmacological, pharmacokinetic (PK), pharmacodynamic (PD), toxicokinetic (TK), physiologically based PBPK-PD, PBTK, and pharmacogenomic system studies; 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
5. Design methodology

### Resource Allocation

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

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

### Computer Science Theory

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

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

**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
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.

**Computer System Architecture**

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

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

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

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

1. **Novel architectures** encompass the study of computations that are performed in ways that are quite different than those used by conventional machines. Examples include various domain-specific architectures characterized by high computational rates, low power, and reconfigurable hardware used in a wide range of computing devices from smart phones to data centers.

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

3. The study of **computational algorithms and structures** deals with the relationship between computational algorithms and the physical structures that can be employed to carry them out. It includes the study of interconnection networks, and the way that algorithms can be formulated for efficient implementation where regularity of structure and simplicity of interconnections are required.

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

5. **VLSI architectures and implementation** is an area of current interest and collaboration between the Electrical 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
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. See http://reasoning.cs.ucla.edu.

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

Computational Systems Biology Laboratories
Biocybernetics Laboratory
Joseph J. DiStefano III, Director
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). See http://biocyb.cs.ucla.edu/research.html.

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

Computer Systems Architecture Laboratories
Concurrent Systems Laboratory
Yuval Tamir, Director
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. See http:// www.cs.ucla.edu/csd/research/labs/csl/.

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

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

VAST Laboratory
Jason Cong, Director
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), multiplex modules (MCMs), system-on-a-chip (SOCs), system-in-a-package (SIPs), and design for nanotechnologies. See http://vast.cs.ucla.edu.

Graphics and Vision Laboratories
Center for Vision, Cognition, Learning, and Art
Song-Chun Zhu, Director
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.). See http://vcla .stat.ucla.edu.

Computer Graphics and Vision Laboratory (MAGIX)
Demetri Terzopoulos, Director
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. See http://www .cs.ucla.edu/magix.

UCLA Collective on Vision and Image Sciences

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

Information and Data Management Laboratories

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

Web Information Systems Laboratory
Carlo A. Zaniolo, Director
This research group investigates Web-based information systems and seeks to develop enabling technology for such systems by integrating the Web with database systems. Current research efforts include the DeAL system, a next-generation data log system; SemScape, an NLP-based framework for mining unstructured or free text; EARL (Early Accurate Result Library) for Hadoop; Panta Rei, a study of support for schema evolution in the context of snapshot databases and transaction-time databases; StreamMill, a complete data stream management system; and ArchIS, a powerful archival information system. See http://www.cs.ucla.edu/wis/

Network Systems Laboratories

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

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

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

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

Software Systems Laboratories

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

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

Computer Science Centers

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

Center for Domain-Specific Computing (CDSC)
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 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. See http://www.cdsc.ucla.edu.

Center for Information and Computation Security (CICS)
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 pro-
vide 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 National 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. See http://www.cs.ucla.edu/security/.

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. Accordingly, the center focuses on big data, data mining bioinformatics, computational biology, knowledge-based systems, database systems, non-monotonic reasoning, and spatiotemporal reasoning.

Wireless Health Institute (WHI)
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 biomedically 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


Jason (Jingsheng) Cong, Ph.D. (U. Illinois, 1990) Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, computer architecture, reconfigurable computing, design for nanotechnologies

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

Joseph J. DiStefano III, Ph.D. (UCLA, 1966) Biocybernetics; computational systems biology; dynamic biosystems modeling, simulation, clinical therapy and experiment design optimization methodologies; pharmacokinetic (PK), pharmacodynamic (PD), and physiologically-based PK (PBPK) modeling; knowledge-based (expert) systems for life science research

Michael G. Dyer, Ph.D. (Yale, 1982) Artificial intelligence; natural language processing; connectionist, cognitive, and animat-based modeling

Milos D. Ercegovac, Ph.D. (U. Illinois, 1975) Application-specific architectures, digital computer arithmetic, digital design, low-power systems, reconfigurable systems

Eleazar Eskin, Ph.D. (Columbia, 2002) Bioinformatics, genetics, genomics, machine learning

Eliezer M. Gafni, Ph.D. (MIT, 1982) Computer communication, networks, mathematical programming algorithms

Mario Gerla, Ph.D. (UCLA, 1973) Wireless ad hoc networks; MAC, routing and transport protocols, vehicular communications, peer-to-peer mobile networks, personal-area networks (Bluetooth and Zigbee), underwater sensor networks, Internet transport protocols (TCP streaming), Internet path characterization, capacity and bandwidth estimates, analytic and simulation models for network and protocol performance evaluation

* Also Professor of Medicine
Problem solving, heuristic search, planning in artificial intelligence  
Christopher J. Lee, Ph.D. (Stanford, 1993)  
Bioinformatics and information theory of experiment planning, inference, and evolution  
Songwu Lu, Ph.D. (U. Illinois, 1999)  
Internet problems support over heterogeneous networks, e.g., mobile computing environments, Internet and ActiveNet: networking and computing, wireless communications and networks, computer communication networks, dynamic game theory, dynamic systems, neural networks, and information economics  
Programming language design, static type systems, formal methods, software model checking, compilers  
Scientific computing and applied mathematics  
†Rafael 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  
D. Stott Parker, Jr., Ph.D. (U. Illinois, 1978)  
Data mining, information modeling, scientific computing, bioinformatics, database and knowledge-based systems  
Miodrag Potkonjak, Ph.D. (U.C 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. (U.C 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, cryptology, computer security, algorithms, error-correcting codes and learning theory  
Majid Sarrafzadeh, Ph.D. (U. Illinois, 1987)  
Computer engineering, embedded systems, VLSI CAD, algorithm design  
Stefano Soatto, Ph.D. (Caltech, 1996)  
Computer vision: shape analysis, motion analysis, texture analysis, 3-D reconstruction, vision-based control, computer graphics: image-based modeling and rendering, medical imaging: registration, segmentation, statistical shape analysis; autonomous systems: sensor-based control, planning non-linear filtering, human-computer interaction: vision-based interfaces, visibility, visualization  
Mani B. Srivastava, Ph.D. (U.C Berkeley, 1992)  
Energy aware networking and computing, embedded networking 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 life/intelligence  
George Varghese, Ph.D. (MIT, 1993)  
Computer networks  
Wei Wang, Ph.D. (UCLA, 1999)  
Data mining, bioinformatics and computational biology, databases  
Computer vision, computational models of cognition, machine learning  
Carlo A. Zaniolo, Ph.D. (UCLA, 1976)  
Knowledge-based and deductive databases, parallel execution of PROLOG programs, formal software specifications, distributed systems, big data, artificial intelligence, and computational biology  
Lixia Zhang, Ph.D. (MIT, 1989)  
Computer network, Internet architecture, protocol designs, security and resiliency of large-scale systems  
Song-Chun Zhu, Ph.D. (Harvard, 1996)  
Computer vision, statistical modeling and computing, vision and visual arts, machine learning  
Professors Emeriti  
Alvarez A. Azizianis, Ph.D. (U. Illinois, 1960)  
Digital computer architecture and design, fault-tolerant computing, digital arithmetic  
Rajiv L. Bagrodia, Ph.D. (U. Texas, 1987)  
Wireless networks, nomadic computing, parallel programming, performance evaluation of computer and communication systems  
Alfonso F. Cardenas, Ph.D. (UCLA, 1969)  
Database management, distributed heterogeneous and multimedia (text, image/picture, video, voice) information systems, planning and development methodologies, software engineering, medical informatics, legal and intellectual property issues  
Communication theory and practice, algorithms and complexity, discrete system theory, developmental and probabilistic systems  
Wesley W. Chu, Ph.D. (Stanford, 1966)  
Distributed computing, distributed database, memory management, computer communications, performance measurement and evaluation for distributed systems and multiaccess packet-switched systems  
Shelia A. Greibach, Ph.D. (Harvard, 1963)  
Theoretical computer science, computational complexity, program schemes and semantics, formal languages, automata, computability  
Leonard Kleinrock, Ph.D. (MIT, 1963)  
Computer networks, computer-communication systems, resource sharing and allocation, computer systems modeling analysis and design, queueing systems and applications, performance evaluation of congestion-prone systems, performance evaluation and design of distributed multiaccess packet-switching systems, wireless networks, mobile computing, nomadic computing, and distributed and parallel processing systems  
Allen King, Ph.D. (U.C Berkeley, 1966)  
Pattern recognition, picture processing, biomedical applications, mathematical modeling  
Lawrence P. McNamee, Ph.D. (U. Pittsburgh, 1964)  
Computer graphics, discrete simulation, digital filtering, computer-aided design, LSI fabrication techniques, printed circuit board design  
Multimedia systems, database systems, data mining  
Judea Pearl, Ph.D. (Polytechnic Institute of Brooklyn, 1965)  
Artificial intelligence, philosophy of science, reasoning under uncertainty, causal inference, causal and counterfactual analysis  
David A. Rennels, Ph.D. (UCLA, 1973)  
Digital computer architecture and design, fault-tolerant computing, digital arithmetic  
Jacques J. Vidal, Ph.D. (U. Paris-Sorbonne, France 1961)  
Information processing in biological systems, with emphasis on neuroscience, cybernetics, online laboratory computer systems, and pattern recognition, analog and hybrid systems/ signal processing  
Associate Professors  
Minyoung Kim, Ph.D. (U. Washington, 2008)  
Software engineering specifically on software evolution  
Fei Sha, Ph.D. (U. Pennsylvania, 2007)  
Statistical machine learning, developing principled probabilistic models and algorithms for problems arising in scientific applications  
Alexander Sherstov, Ph.D. (U. Texas Austin, 2003)  
Complexity theory with a focus on communication and circuit complexity, computational learning theory, quantum computing  
Yuvu Tamir, Ph.D. (U.C Berkeley, 1986)  
Computer systems, computer architecture, software systems, parallel and distributed systems, dependable systems, cluster computing, reliable network services, interconnection networks and switches, multi-core architectures, reconfigurable systems  
Assistant Professors  
Tylanc Coudre, Ph.D. (U.C Berkeley, 2010)  
Large-scale distributed data management, declarative languages, systems for machine learning and big data analysis  
Jason Ernst, Ph.D. (UCLA, 2008)  
Computational biology, bioinformatics, machine learning  
Raghu Meka, Ph.D. (U. Texas Austin, 2011)  
Complexity theory, pseudorandomness, algorithms, learning probability and data mining  
Sriram Sankaranarayanan, Ph.D. (U.C Berkeley, 2010)  
Computational biology, computational/statistical genomics, statistical machine learning probabilistic graphical models, Bayesian statistics  
Yizhou Sun, Ph.D. (U. Illinois, 2012)  
Information and social network analysis, data mining, database systems, statistics, information retrieval, machine learning and network science  
Ameet Talwalkar, Ph.D. (New York U., 2010)  
Statistical machine learning, scalable data analytics, computational genomics  
Guy Van den Broeck, Ph.D. (Katholieke U. Leuven, Belgium, 2013)  
Machine learning (statistical relational learning), knowledge representation and reasoning (graphical models, probabilistic inference), applications of probabilistic reasoning and learning (probabilistic programming, probabilistic databases), artificial intelligence  
Senior Lecturers S.O.E.  
Paul R. Eggert, Ph.D. (UCLA, 1980)  
Programming languages, operating systems principles, compilers, Internet  
David A. Smallberg, M.S. (UCLA, 1978)  
Programming languages, software development  
Senior Lecturer S.O.E. Emeritus  
Leon Levine, M.S. (MIT, 1949)  
Computer methodology  
Adjunct Professors  
Deborah L. Estrin, Ph.D. (MIT, 1985)  
Sensor networks, embedded network sensing, environmental monitoring, computer networks  
David E. Heckerman, Ph.D. (UCLA, 1979)  
Models and methods used for statistics and data analysis, machine learning, probability theory, decision theory, information retrieval, and genome-wide association studies  
Van Jacobson, M.S. (U. Arizona, 1972)  
Named data network (NDA), content-centric networking  
Alan Kay, Ph.D. (U. Utah, 1969)  
Object-oriented programming, personal computing, graphical user interfaces
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


M. Yahya Sanadidi, Ph.D. (UCLA, 1982) Computer networking, path characteristics estimation and applications in flow control, adaptive streaming and overlays design, probability models of computing systems, algorithms and networks

Adjunct Associate Professors

Edward W. Kohler, Ph.D. (MIT, 2001) Operating systems, software architecture, network measurement, network protocol design, programming language techniques for improving systems software


Bioinformatics

Lower Division Courses

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

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

Upper Division Course

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

Computer Science

Lower Division Courses

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

2. Great Ideas in Computer Science. (4) Lecture, four hours; discussion, two hours. Broad coverage for liberal arts and social sciences students of computer science theory, technology, and implications, including artificial and neural machine intelligence, computational logic, cellular automata, artificial life, programming languages survey, and philosophical and societal implications. P/NP or letter grading. Mr. Dyer

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. Paisberg, Mr. Smallberg (F,WSp)


Mr. Nakanishi, Mr. Smallberg (WSp)

33. Introduction to Computer Organization. (5) Lecture, four hours; discussion, two hours; outside study, nine hours. Enforced requisite: course 32. Introductory course on computer architecture, assembly language, and operating systems fundamentals. Number systems, machine language, and assembly language. Procedure calls, stacks, interrupts, and traps. Assemblers, linkers, and loaders. Operating systems concepts: processes and process management, input/output (I/O) programming, memory management, file systems. Letter grading.

Mr. Eggert, Mr. Reimann (F,WSp)

35L. Software Construction Laboratory. (2) Laboratory, four hours per week. 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 (F,WSp)

M51A. Logic Design of Digital Systems. (4) (Same as Electrical 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: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading.

Mr. Ercegovac, Mr. Potkonjak (F,WSp)

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


Mr. Kampe, Mr. Reiher (F,WSp)

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 junior/senior. Probability and stochastic process models as applied in computer science. Basic mathematical tools include random variables, conditional probability, expectation and higher moments, Bayes’ Theorem, Markov chains. Applications include probabilistic algorithms, evidential reasoning, analysis of algorithms and data structures, reliability, communication protocol and queueing models. Letter grading.

Mr. Sanadidi, Mr. Soatto (WSp)

114. Peer-to-Peer Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 118. Optional: course 218. Peer-to-peer concepts with real-world networks, such as distributed hash-tables, routing, searching, and related network management protocols (Join, Leave, death management, routing, table repair). Video streaming and Internet television (IPTV) applications, with emphasis on thin clients 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 metrics and illustration of common optimization techniques (peer capacity, network delay). Hands-on approach to guide students to development and testing of actual experimental system on PlanetLab. Letter grading.

Mr. Gerla (Not offered 2016-17)

M117. Computer Networks: Physical Layer. (4) (Same as Electrical Engineering M117) Lecture, two hours; discussion, two hours; outside study, six hours. Designed for credit for course M117L. 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 health, positioning, and environmental monitoring, and experimental laboratory sessions included. Letter grading.

Mr. Dzhkindze (F,WSp)

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

Mr. Afanasiev, Mr. Lu (F,WSp)

CM121, Introduction to Bioinformatics. (4) (Same as Chemistry CM160A) Lecture, four hours; discussion, two hours. Enforced requisite: course 32 or Program in Computing 10C with grade of C– or
Computer Science / 71

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 CM221. P/N or letter grading. Mr. Lee (F)

CM122. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Chemistry CM160B.) 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. Course CM121 is not required to CM122. Designed for engineering students as well as students from biological sciences and medical school. Development and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM222. Letter grading. Mr. Eskin (W)

CM124. Computational Genetics. (4) (Same as Computer Science 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 techniques for obtaining genetic information, and genetic sequencing. Focus on formulating interdisciplinary problems as computational problems and then solving these problems using computational techniques. Emphasis on statistics and computer science. Concurrently scheduled with course CM224. Letter grading. Mr. Sankararaman (Sp)

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisites: course 111. Recommended: Engineering 183EW or 185EW. Structured programming, program specification, program proving, modularity, abstract data types, composite design, software tools, software control systems, program testing, team programming, Letter grading. Mr. Eggett, 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 abstraction, modularity, control mechanisms, types, declarations, syntax, and semantics. Study of several different programming paradigms, including functional, object-oriented, and logic programming. Letter grading. Mr. Eggett, Mr. Millstein (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. Mr. Falsberg (F)

133. Parallel and Distributed Computer Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 111 (may be taken concurrently), 131. Distributed memory and shared memory parallel architectures; asynchronous parallel systems; programming models for parallel computation: specification of parallelism, interprocess communication and synchronization; design of parallel algorithms and software for communicating and distributed systems. Letter grading. Mr. Cong (W)

136. Introduction to Computer Security. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 116. Introduction to computer security, necessary for students to understand risks and mitigations associated with protection of systems and data. Topics include security models and architectures, security threats and attacks, access control, authentication/authorization, cryptography, network security, secure application design, and ethics and law. Letter grading. Mr. Reiter (W)

C137A. Prototyping Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 131. How different programming language paradigms provide dramatically different ways of thinking about computation and offer trade-offs on many dimensions, such as modularity, extensibility, expressiveness, and safety. Concrete exploration of three major programming paradigms—functional, object-oriented, and logic programming—by prototyping implementations of languages in each. Analysis of prototypes to shed light on design and structural properties of each language and paradigm and to allow easy comparison against earlier experience in implementing new abstractions, both as stand-alone languages and as libraries in existing languages. Concurrently scheduled with course C237A. Letter grading. Mr. Millstein (Not offered 2016-17)

C137B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced requisites: course C137A. Study of various programming language designs, from computing history and research literature, that attempt to address problems of software systems that are bloated, buggy, and difficult to maintain and extend despite trend in computing toward ever higher levels of abstraction for programming languages. Alternative designs, prototyping, and evaluating new languages, language abstractions, and/or programming environments. Concurrently scheduled with course C237B. Letter grading. Mr. Menon (Not offered 2016-17)


144. Web Applications. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: 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 databases, information retrieval model and theory, search engines and user models, Web services and distributed transactions. Letter grading. Mr. Cho (W)

145. Introduction to Data Mining. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 130. Introductory survey of data mining (process of automatic discovery of patterns, changes, associations, and anomalies in massive databases), knowledge engineering, for applications in information retrieval, marketing, and network analysis. Topics include basic building blocks of mining techniques and ideas for applications in bioinformatics, e-commerce, environmental studies, financial markets, multimedia data processing, and pattern recognition. Letter grading. Ms. Wang (F)

M151B. Computer Systems Architecture. (4) (Same as Electrical Engineering M116C.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 33, and M151A or Electrical Engineering M16. Recommended: courses 111, and M152A or Electrical Engineering M16L.

Computer system organization and design, implementation of CPU and DMA architecture, system design, memory hierarchy (caches, main memory, virtual memory) organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation of developed programs. Letter grading.

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

151C. Design of Digital Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses M151B, M152A. Design of combinational and sequential logic circuits, logic design for digital systems, and introduction to VLSI. Emphasis on design of small chips, gate-level design techniques, and regular structures. Combinational, sequential, and algorithmic systems. Microprogramming and firmware engineering. Cost/performance measures and technology trends in the design of digital systems. Design project. Letter grading. Mr. Ercogevc (Not offered 2016-17)

M152A. Introductory Digital Design Laboratory. (4) (Same as Electrical Engineering M118L) Laboratory, four hours; outside study, two hours. Enforced requisites: course M51A or Electrical Engineering M16. Hands-on design, implementation, and debugging of digital logic circuits, use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits using programmed array logic, design projects. Letter grading. Mr. Potkonjak (F,W,Sp)

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


Mr. Cerviche, Mr. Korf, Mr. Van den Broeck (F,W,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 methods for numeric and symbolic computation, matrix algebra, statistics, floating point, optimization, and spectral analysis. Emphasis on applications in simulation of physical systems. Letter grading. Mr. Parker (F)

M171L. Data Communication Systems Laboratory. (2 to 4) (Same as Electrical 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 and digital aspects of data and communication systems through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse generators, logic analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modern and terminal characteristics, and interfaces. Letter grading. Mr. Gerla (Sp)
17A. Real-Time Three-Dimensional Animation. (4) Lecture, four hours; two hours of outside study, six hours. Enforced requisite: course 32. Introduction to handling of geometry, appearance, and motion specifically for real-time virtual environments, both on real-time hardware levels, with emphasis on techniques, algorithms, and prototyping of one quality real-time three-dimensional animation by following through from preproduction to postproduction. End products expected to be game demonstrations, or machinima. Focus on novel ways to utilize real-time graphics engines to create cinematic productions. Focus on achieving highest quality productions to qualify and submit products to Student Awards competition. Use of Unity Engine to make technical decisions to adapt stories to games. Introduction to interaction concepts, enabling students to create low-fidelity real-time three-dimensional animation and to create in artificial intelligence, enabling them to refine their interactions to create high-fidelity real-time three-dimensional animation. Letter grading.

Ms. Ford (W)

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

Mr. Terzopoulos (W,Sp)

174B. Introduction to Computer Graphics: Three-Dimensional Photography and Rendering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. State of art in three-dimensional photography and image-based rendering. How to use cameras and light to capture shape and appearance of real objects and scenes. Process provides simple way to acquire three-dimensional models of unparalleled detail and realism. Applications of techniques from entertainment (reverse engineering and post processing of movies, generation of realistic synthetic objects and characters) to medicine (modeling of biological structures from imaging data), mixed reality (augmentation of video), and security (visual surveillance). Fundamental analytical tools for modeling and inferring geometric, photometric, and radiometric properties to objects and scenes, and for rendering and manipulating novel views. Letter grading.

Mr. Terzopoulos (W,Sp)


Mr. Sarrafzadeh (F)

183D. Introduction to Cryptography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Preparation: knowledge of basic probability theory, and understanding of computer science and mathematics. Introduction to cryptography, computer security, and basic concepts and techniques. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom permutations, semantic security, public-key and private-key encryption, key-agreement, homomorphic encryption, private information retrieval, and broadcast encryption. Letter grading.

Mr. Ostrovsky (Not offered 2016-17)

183E. Introduction to the Theory of Computation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Preparation: knowledge of basic probability theory, and understanding of computer science and mathematics. Introduction to cryptography, computer security, and basic concepts and techniques. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom permutations, semantic security, public-key and private-key encryption, key-agreement, homomorphic encryption, private information retrieval, and broadcast encryption. Letter grading.

Mr. Ostrovsky (Not offered 2016-17)

185A. Introduction to Computer Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 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 contributions in computational biocinematics and aiming for more informed basis for focused studies by students with computational and systems biology interests. Presentations by individual UCLA researchers discussing their active computational and systems biology research. P/NP grading.

Mr. DiStefano (F)

185B. Introduction to Computational and Systems Biology. (2) (Same as Bioengineering M184 and Computational and Systems Biology M184.) Lecture, four hours; discussion, two hours. Enforced requisite: 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 contributions in computational biocinematics and aiming for more informed basis for focused studies by students with computational and systems biology interests. Presentations by individual UCLA researchers discussing their active computational and systems biology research. P/NP grading.

Mr. DiStefano (F)

185L. Research Opportunities in Computational and Systems Biology. (4) (Same as Computational and Systems Biology M185.) Lecture, two hours; discussion, two hours; outside study, six hours. Requisite: course 185M. Mathematics 32B, 33A, 33B, Life Sciences 4. Introduction to interdisciplinary laboratory research methods and research opportunities in computational and systems biology, preparation and initiation for active engagement in research. Presentation of potential projects by faculty members and student visits to individual laboratories and participation in ongoing projects. P or letter grading.

Mr. DiStefano (W)

186. Introduction to Cryptography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 185L. Letter grading.

Mr. Ostrovsky (Not offered 2016-17)

194. Research Group Seminars: Computer Science. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field or oral presentations and written progress reports explain how to proceed with search for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM287. Letter grading.

Mr. DiStefano (Sp)

198. Special Courses in Computer Science. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Special topics in computer science for undergraduates taught on a semesters-on- 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.

199. Directed Research in Computer Science. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual 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

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

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 computer and applications of information processing systems. Each member completes one tutorial and one or more original pieces of work in one specialized area. May be repeated for credit. Letter grading.

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

Mr. Sarrafzadeh

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

Mr. Lu (F)

212A. Queueing Systems Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: course 112, Electrical Engineering 131A, Resource sharing issues and theory of queuing (waiting-line) systems.
CM221. Introduction to Bioinformatics. (Same as Bioinformatics M226 and Human Genetics M260A.) Lecture, four hours; discussion, two hours. Enforced prerequisites: 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 computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using computational techniques. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM122. Letter grading. Mr. Lee (F)

CM222. Algorithms in Bioinformatics and Systems Biology. (Same as Bioinformatics M226B and Chemistry M260B.) Lecture, four hours; discussion, two hours. Enforced prerequisites: 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 CM221 is not requisite to CM222. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational approaches to biological questions, with focus on combining techniques from statistics and computer science. Concurrently scheduled with course CM122. Letter grading. Mr. Li (F)

CM223. Experimental Physical Biology. (4) Lecture, four hours; discussion, two hours. Enforced prerequisites: 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 CM221 is not requisite to CM222. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational approaches to biological questions, with focus on combining techniques from statistics and computer science. Concurrently scheduled with course CM122. Letter grading. Mr. Okamoto (F)

CM224. Computational Genetcs. (4) Lecture, four hours; discussion, two hours. Enforced prerequisites: 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 approaches to biological questions, with focus on combining techniques from statistics and computer science. Concurrently scheduled with course CM124. Letter grading. Mr. Sankaraman (Sp)

CM225. Computational Methods in Genomics. (Same as Biological Chemistry M225 and Human Genetics M265.) Lecture, two hours and one half; discussion, two one half hours; outside study, seven hours. Limited to bioinformatics, computer science, human genetics, and molecular biology graduate students. Introduction to computational approaches in bioinformatics, genomics, and computational genetics and preparation for computational interdisciplinary research. Course topics include genome analysis, regulatory genomics, association analysis, association study design, isolated and admixed populations, population substructure, human structural variation, model organisms, and genomic technologies. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM125. Letter grading. Mr. Sankaraman (Sp)

CM226. Machine Learning in Bioinformatics. (Same as Bioinformatics M226 and Human Genetics M226.) Lecture, four hours; outside study, eight hours. Enforced prerequisites: 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. Familiarity with probability, statistics, linear algebra, and data analysis is expected. Designed for engineering students as well as students from biological sciences and medical school. Introduction to machine learning provides important toolkit in this endeavor. Biological datasets offer new challenges to field of machine learning. Examination of statistical and computational aspects of machine learning and their application to key biological questions. Letter grading. Mr. Sankaraman (F)

M229S. Seminar: Current Topics in Bioinformatics. (4) (Same as Biological Chemistry M229S and Human Genetics M229S.) Lecture, four hours; outside study, eight hours. Enforced prerequisites: 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 current topics in bioinformatics, genomics, and computational genetics and preparation for computational interdisciplinary research in genetics and genomics. Topics include genome analysis, regulatory genomics, association analysis, association study design, isolated and admixed populations, population substructure, human structural variation, model organisms, and genomic technologies. Computational techniques include those from statistics and computer science. May be repeated for credit with topic change. Letter grading. Mr. Eskin (Not offered 2016-17)
tributed systems; primitives for parallel computation; specifications of concurrent communication and synchronization, atomic actions, binary and multiway rendezvous; synchronous and asynchronous languages: CSP, Ada, Linda, Maisie, UC, and others; introduction to parallel program analysis and verification. Letter grading.

Mr. Cong

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

Mr. Bagrodia

234. Computer-Aided Verification. (4) Lecture, four hours; outside study, eight hours. Requires: course 181. Introduction to theory and practice of formal methods for design and analysis of concurrent and embedded systems, with focus on algorithmic techniques for checking logical properties of hardware and software systems. Topics include semantics of reactive systems, invariant verification, 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 or C++ programming experience. Requires: 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, processes, interprocess communication, preemptive multitasking, file systems. Virtualization, networking, profiling, research operating systems. Series of laboratory projects, including extra challenge work. Letter grading. Mr. Eggert

236. Computer Security. (4) Lecture, four hours; outside study, eight hours. Requires: courses 111, 118. Basic and research material on computer security. Topics include basic principles and goals of computer security, common security tools, use of cryptographic protocols for security, security tools (firewalls, virtual private networks, honeypots), virus and worm protection, security assurance and testing, design of secure programs, privacy, applying security principles to realistic problems, and new and emerging threats and security tools. Letter grading.

Mr. Palsberg, Mr. Reihner

C237A. Prototyping Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 131. How different programming language paradigms can lead to dramatically different ways of thinking about computation and offer trade-offs on many dimensions, such as modularity, extensibility, expressiveness, and safety. Concrete exploration of three major programming paradigms—functional, object-oriented, and logic programming—by prototyping implementations of languages in each. Analysis of prototypes to shed light on design and structural properties of each language and paradigm and to allow easy comparison against one another. Hands-on experience implementing new abstractions, both as stand-alone languages and as libraries in existing languages. Concurrency scheduled with course C153A. Letter grading.

Mr. Millstein

C237B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced requisite: course C237A. Study of various programming language designs, from computing history and research literature, that attempt to address problems of software systems that are bloated, buggy, and difficult to maintain and extend. Despite trends in computing toward ever higher levels of abstraction for programming, hands-on experience designing, prototyping, and evaluating new languages, language abstractions, and/or programming environments. Concurrently scheduled with course C215A. Letter grading.

Mr. Millstein

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

Mr. Millstein


Mr. Zaniolo (Not offered 2016-17)

240B. Advanced Data and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requires: courses 143, 240A. Logical models for data and knowledge representation. Databases, trigger, event, temporal reasoning, and logic-based declarative querying/pro- gramming are salient features of this technology. Other topics include object-relational systems and data mining techniques. Letter grading.

Mr. Zaniolo

242B. Pictorial and Multimedia Database Management. (4) Lecture, three and one half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requires: course 143. Multimedia data: alphanumeric, long text, images/pictures, video, and voice. Multimedia information systems requirements. Data models. Searching and accessing databases and across Internet by alphanumeric, image, video, and audio content. Querying, visual languages, and communication. Media organization, logical and physical. Indexing methods. Internet multimedia streaming. Other topics at discretion of instructor. Letter grading.

Mr. Parker, Mr. Zaniolo

244A. Distributed Database Systems. (4) Lecture, four hours; outside study, eight hours. File allocation, intelligent directory design, transaction management, deadlock, strong and weak concurrency control, commit protocols, semantic query answering, multitable database systems, discovery techniques, network partitioning, experiments, trade-offs, and design experiences. Letter grading.

Mr. Condie (F)

246. Web Information Management. (4) Lecture, four hours; outside study, eight hours. Requires: courses 143, 147. Basic and research material on computer security. Topics include Web technologies. XML, HTML, HTTP, and their use in the Web. Search engines, URL hierarchies, and query processing. Current research areas. Letter grading.

Mr. Cardenas

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

Mr. Cho (Sp)

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

Mr. Ercogevac, Mr. Tamir

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

Mr. Ercogevac, Mr. Tamir (Not offered 2016-17)


Mr. Ercogevac

252A. Advanced Scalable Architectures. (4) Lecture, four hours; outside study, eight hours. Requires: course M151B. Recommended: course 251A. State-of-art scalable multiprocessors. Interdependency and implementation techniques. Dedicated shared-memory processors, multiprocessor interconnection networks, system architecture. High-performance building blocks, such as chip multiprocessors (CMPs). On-chip and off-chip communication. Mechanisms for exploiting parallelism at multiple levels. Current research areas. Examples of chips and systems. Letter grading. Mr. Tamir (Not offered 2016-17)

M258A. Design of VLSI Circuits and Systems. (4) (Same as Electrical Engineering M216A.) Lecture, four hours; discussion, two hours; outside study, four hours; outside study, two hours. Requires: courses M51A or Electrical Engineering M16, and Electrical Engineering 115A. Recommended: Electrical Engineering 115C. VLSI/LSI design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on chips. Letter grading.

M258C. LSI in Computer System Design. (4) (Same as Electrical Engineering M130C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Requires: course M258A. LSI/VLSI design and application in computer systems. In-depth study of VLSI architectures and VLSI design tools. Letter grading.

258F. Physical Design Automation of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Detailed study of various physical design automation problems of VLSI circuits, including logic partitioning, floorplanning, placement, global routing, channel and switchbox routing, planar routing and via minimization, compaction and performance-driven placement and pin assignment. Use of state-of-the-art design tools and software. Letter grading.

Mr. Cong

258G. Logic Synthesis of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Detailed study of various logic synthesis problems in digital circuit design. Logic synthesis technology mapping for standard cell designs and field-programmable gate-array (FPGA) designs; retiming for sequential circuits; and applications of binary decision diagrams (BDDs). Letter grading.

Mr. Cong

258H. Analysis and Design of High-Speed VLSI Interconnects. (4) Lecture, four hours; outside study, eight hours. Requires: courses M258A, 258F. Detailed study of various problems in analysis and design of high-speed VLSI interconnects at both integrated circuit (IC) and packing levels, including inter-
connect capacitance and resistance, lossless and loss transmission lines, crosstalk and power dissipation models, interconnect topology and geometry optimization, and clocking for high-speed systems. Letter grading.  

259. Current Topics in Computer Science: System Design/Architecture. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer science system design in which instructor has developed special preference or consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading. (F,W,Sp)  


261A. Problem Solving and Search. (4) Lecture, four hours; outside study, eight hours. Requisite: course 262A. Introduction to problem-solving search algorithms in artificial intelligence, including problem spaces, brute-force search, heuristic search, linear-space algorithms, real-time search, heuristic evaluation functions, two-player games, and constraint-satisfaction problems. Letter grading.  

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


263A. Language and Thought. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Introduction to natural language processing, emphasis on semantics. Examination of representation models for processing tasks of various kinds, including question answering, paraphrasing, machine translation, word-sense disambiguation, narrative and expository. Examination of both symbolic and statistical approaches to language processing and acquisition. Letter grading.  

263B. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Designed for students undertaking thesis research. Discussion of current and recent research in computational neuroscience. Letter grading.  

263C. Animats-Based Modeling. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Animats are mobile/sensing animals modeled-like software agents embodied in simulated dynamical systems. We explore agent-level goal-oriented behavior via neurocontrollers, adaptation via reinforcement learning, evolutionary programming. Animat-based tasks include foraging, mate finding, predator navigation, including cooperative nest construction, communication, and parent. Letter grading.  

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


268S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Designed for students undertaking thesis research. Discussion of current and recent 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 with topic change. Letter grading.  

269. Seminar: Current Topics in Artificial Intelligence. (4) Seminar, to be arranged. Review of current literature and research practicum in area of artificial intelligence. Topics include specialized software for expert system projects, special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading.  

274C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. Introduction to computer animation, including basic principles of character modeling, forward and inverse kinematics, forward and inverse dynamics, capture animation techniques, physics-based animation of particles and systems, and motor control. Concurrency scheduled with course C174C. Letter grading.  

275. Artificial Life for Computer Graphics and Vision. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 174A. Recommended: course 161. Investigation of important role that concepts from artificial intelligence play in discipline that spans computational and biological sciences, can play in construction of advanced computer graphics and vision models for virtual reality, animating interactive game-like virtual scenes, visual sensor networks, medical image analysis, etc. Focus on comprehensive models that can realistically emulate variety of living things (plants and animals) from lower order to humans. Exposure to effective computational modeling of natural phenomena of life and their incorporation into sophisticated, self-animating graphical entities. Specific topics include modeling plants using L-systems, biomechanical simulation and control, behaviors of growth and neural-network learning of locomotion, cognitive modeling, artificial animals and humans, human facial animation, and artificial evolution. Letter grading.  

M267A. Pattern Recognition and Machine Learning. (4) (Same as Statistics M231.) Lecture, three hours. Designed for graduate students. Fundamental concepts, theories, and algorithms for pattern recognition and machine learning that are used in computer vision, image processing, speech recognition, data mining, statistics, and computational biology. Topics include Bayesian decision theory, parametric and nonparametric learning, clustering, complexity and VC-dimension, MDL, AIC, PCA/LCA/TCA, MDS, SVM, boosting. S/U or letter grading.  

280A-280ZZ. Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. Additional requisite for each offering announced in advance by department. Selections from design, analysis, optimization, and implementation of algorithms; computational complexity and general theory of algorithms; application of algorithms to particular application areas. Substitutes of some current sections: Principles of Design and Analysis (280A); Distributed Algorithms (280B); Graphs and Networks (280G). May be repeated for credit with instructor and topic change. Letter grading.  

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

281A. Computability and Complexity. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181 or compatible background. Concepts fundamental to study of discrete information systems and theory of computation, with emphasis on regular sets of strings, Turing-recognizable (recursively enumerable) sets, closure properties, machine characterizations, nondeterminism, decidability, unsolvable problems, "easy" and "hard" problems, PTIME/NP-TIME. Letter grading.  

M282A. Cryptography. (4) (Same as Mathematics M209A.) Lecture, four hours; outside study, eight hours. Requisite: introduction to computer graphics, stressing rigorous definitions and proofs of security. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators,
pseudorandom functions and pseudorandom permut-
ations, secure-key and pre-distribution encryption, secret-sharing, message authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, zero-knowledge arguments, one-way functions, and two-party secure computation with static security. Letter grading.

Mr. Ostrovsky (F)

M292B. Cryptographic Protocols. (4) (Same as Mathematics M209B) Lecture, four hours; outside study, eight hours. Requisite: course M292A. Consideration of advanced cryptographic protocol design and analysis. Topics include noninteractive zero-knowledge proofs; zero-knowledge arguments; concurrent zero-knowledge; IP=PSPACE proof, stronger notions of security for public-key encryption, including chosen-ciphertext security; secure multi-party computation; dealing with dynamic network and link connectivity and possibility of secure protocols; software protection; threshold cryptography; identity-based cryptography; private information retrieval; protection against man-in-the-middle attacks; voting protocols; identification protocols: digital cash schemes; lower bounds on use of cryptographic primitives, software obfuscation. May be repeated for credit with topic change. Letter grading.

Mr. Ostrovsky (Sp)

M283A-M283B. Topics in Applied Number Theory. (4-4) (Same as Mathematics M208A-M208B) Lecture, three hours. Basic number theory, including congruences and prime numbers. Cryptography: public-key and discrete log cryptosystems. Attacks on cryptosystems. Primality testing and factorization methods. Elliptic curve methods. Topics from coding theory in which instructor has developed special proficiency as consequence of research inter-
ests. Students report on selected topics. Letter grading.

Mr. Sahai (F)

M284A-284ZZ. Topics in Automata and Languages. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 181. Additional requisites for each offering are announced as they advance by department. Selections from families of formal languages, grammars, machines, operators; pushdown automata, context-free languages and their generalizations, parsing; multidimensional grammars, developmental systems; machine-based complexity. Subtopics of some current and planned sections: Context-Free Languages (284A), Parsing Algorithms (284P). May be repeated for credit with consent of instructor and topic change. Letter grading.

Mr. Sahai (Not offered 2016-17)

CM286. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Formerly numbered CM286.) (Same as Bioengineering CM296) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 102. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multicompartmental, predator-prey, pharmacokinetic (PK), pharmacody-
namic (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 mod-
eling, with focus on translating biomodeling goals and data acquisition into models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exer-
cises in class and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading.

Mr. DiStefano (Not offered 2016-17)

CM287. Research Communication in Computational and Systems Biology. (2 to 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 labora-
tory. Direction on how to focus on topics of current interest in scientific community, appropriate to the student's interests and capabilities. Critiques of oral pre-
sentations and written progress reports explain how to proceed with research for success. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM187. Letter grading.

Mr. DiStefano (Not offered 2016-17)

288S. Seminar: Theoretical Computer Science. (2) Seminar, two hours; outside study, six hours. Requir-
ces: courses 280A, 281A. Intended for students un-
terstanding of current research in advanced topics and current research in such areas as algo-
rithms and complexity models for parallel and current computation, and formal language and au-
tomata theory. May be repeated for credit. S/U grading.

289A-289ZZ. Current Topics in Computer Theory. (2 to 12 each) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer theory in which instructor has developed special proficiency as consequence of research inter-
est. Students report on selected topics. Letter grading.

289CO. Complexity Theory. (4) Lecture, four hours; outside study, eight hours. Diagonalization, poly-
mensitive-time hierarchy, PSPACE theorem, randomness and de-randomization, circuit complexity, attempts and limitations to proving P does not equal NP, average-
case complexity, hardness amplifica-
tion. Problem sets and presentation of previous and original research related to course topics. Letter grading.

289OA. Online Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. In-
troduction to decision making under uncertainty and competitive analysis. Review of current research in online algorithms for problems arising in many areas, such as data and memory management, searching and navigating in unknown terrains, and server sys-
tems. Letter grading.

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

M296A. Advanced Modeling Methodology for Dy-
namic Biomedical Systems. (4) (Same as Bioen-
gineering M296A and Medicine M270C) Lecture, four hours; outside study, eight hours. Requisite: Elec-
trical Engineering 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Devel-
opment of dynamic systems modeling methodology for physiological, biochemical, and biomedical systems, and related systems. Control system, multi-
compartamental, noncompartamental, and input/ output models, linear and nonlinear. Emphasis on model validation, sensitivity analysis, and relevance in bio-
medical sciences and other limited data environ-

Mr. DiStefano

M296B. Optimal Parameter Estimation and Exper-
iment 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. Introduction to optimization method-
ology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algo-
rithms for designing optimal experiments for de-
veloping 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 and applications in physi-
ology and pharmacology. Letter grading.

Mr. DiStefano

M296C. Advanced Topics and Research in Bio-
medical Systems Modeling and Computing. (4) (Same as Bioengineering and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course M296B. Research tech-
niques 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 formu-
lation. Approaches to Ph.D.-to-M.S. and Ph.D-level project training. Letter grading.

Mr. DiStefano

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

Mr. DiStefano

288. Research Seminar: Computer Science. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate computer science students. Discussion of advanced topics and current research in algorithmic processes that describe and transform information: theory, analysis, design, effi-
ciency, implementation, and application. May be re-
peate4 for credit. S/U grading.

289. Teaching Apprentice Practicum. (1 to 4) Sem-
inar, to be arranged. Preparation: apprentice per-
sonnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guid-
ce and supervision of regular faculty member re-
ponsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading.

375. Tutorial, to be arranged. Limited to graduate computer science students. Petition forms to request en-
rollment may be obtained from assistant dean, Grad-
uate Students. Supervised investigation of advanced topics and current research in algorithmic processes that describe and transform information: theory, analysis, design, effi-
ciency, implementation, and application. May be re-
peate4 for credit. S/U grading.

495. Tutorial, to be arranged. Limited to graduate computer science students. Petition forms to request en-
rollment may be obtained from assistant dean, Grad-
uate Students. Supervised investigation of advanced topics and current research in algorithmic processes that describe and transform information: theory, analysis, design, effi-
ciency, implementation, and application. May be re-
peate4 for credit. S/U grading.

596. Directed Individual or Tutorial Studies. (1 to 8) Tutorial, to be arranged. Limited to graduate computer science students. Petition forms to request en-
rollment may be obtained from assistant dean, Grad-

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

597B. Preparation for Ph.D. Preliminary Examina-
tions. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Reading and preparation for Ph.D. preliminary examinations. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Exam-
ination. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for oral qualifying examination, including preliminary re-

598. Research for and Preparation of M.S. Thesis. (1 to 12) Tutorial, to be arranged. Limited to graduate computer science students. Supervised independ-
ent research for M.S. candidates, including thesis prospects. S/U grading.
Electrical Engineering

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.

Scope and Objectives

Electrical engineers are responsible for societal revolutionary inventions such as the electrical grid, telecommunications, and automated computing and control. The profession continues to make vital contributions in many domains. To further these ends, the Department of Electrical Engineering fosters a dynamic academic environment that is committed to a tradition of excellence in teaching, research, and service and has state-of-the-art research programs and facilities in a variety of fields. Departmental faculty members are engaged in research efforts across several disciplines in order to serve the needs of industry, government, society, and the scientific community. Interactions
with other disciplines are strong. Faculty members regularly conduct collaborative research projects with colleagues in the Geffen School of Medicine, Graduate School of Education and Information Studies, School of Theater, Film, and Television, and College of Letters and Science.

There are three primary research areas in the department: circuits and embedded systems, physical and wave electronics, and signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, control systems, 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.

The program grants one undergraduate degree (Bachelor of Science in Electrical 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 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 governmental agencies, (4) achieve visibility by active participation in conferences and technical and community activities, and (5) publish enduring scientific articles and books.

Undergraduate Program 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.

Undergraduate Study
The Electrical Engineering major is a designated capstone major. Undergraduate students complete a design course in which they integrate their knowledge of the discipline and engage in creative design within realistic and professional constraints. Students apply their knowledge and expertise gained in previous mathematics, science, and engineering coursework. Within a multidisciplinary team structure, students identify, formulate, and solve engineering problems and present their projects to the class.
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 discipline in 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 the electrical grid, integrated circuits, photonic devices, automatic computation and control, and telecommunication devices and systems.

Students are encouraged to make use of their electrical 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 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 Engineering 101A, 102, 110, 111L, 113, 131A; six core courses selected from Computer Science 33, Electrical Engineering 101B, 115A, 121B, 132A, 133A, 141, 170A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 12 units of major field elective courses, at least 8 of which must be upper division electrical engineering courses—the remaining 4 units may be from upper division electrical engineering courses or from another HSSEAS department; and one two-term electrical 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 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 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 Engineering 101B, 162A, 163A, and 163C and 8 capstone design units from 163DA/163DB or 164DA/164DB.

Embedded Computing: The study of compact systems that include collections of integrated circuits that interact with the physical world for purposes such as sensing and control in applications as diverse as appliances, automobiles, and medicine. Students might take 12 units selected from Electrical Engineering 115A, 115C, M116C, M116L, M117, and 142 and 8 capstone design units from 180DA/180DB or 183DA/183DB.

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

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

Signal Processing: The study of how to derive meaningful inferences from measured data, such as speech, images, or other data, after conversion from analog to digital form. Students might take 12 units selected from Electrical Engineering 114, 133A, 133B, and 134 and 8 capstone design units from 113DA/113DB.

Simulation and Data Analysis: Studies focus on applications related to the processing of big data for both analog/ multimedia and digital sources. Students might take 12 units selected from Electrical Engineering 114, 131B, 132A, 133A, 133B, and 134 and 8 capstone design units from 113DA/113DB or 180DA/180DB.

Solid-State and Microelectromechanical Systems (MEMS) Devices: The study of the nanoscale and microscale devices that are the base of modern computation and sensing systems. Students might take 12 units selected from Electrical Engineering 121B, 123A, 123B, 128, and M153 and 8 capstone design units from 121DA/121DB.

Suggested Tracks

The technical breadth area requirement provides an opportunity to combine elective courses in the Electrical Engineering major with those from another 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, C102, and 110 and/or 12 units from Computer Science CM121, Electrical 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 Engineering 115C, M116C, M116L, M117, and 132B 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 Engineering M116C, 132B, and 142 and 8 capstone design units from 183DA/183DB.

Graduate Study

For information on graduate admission see Graduate Programs, page 24.

The following introductory information is based on the 2016-17 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 Pro-
gram Requirements for the year in which they enter the program.

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

**Electrical Engineering M.S.**

**Areas of Study**

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

**Course Requirements**

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

The minimum requirements for the M.S. degree are as follows:

1. **Requisite.** B.S. degree in Electrical Engineering or a related field
2. All M.S. program requirements should be completed within two academic years from admission into the M.S. graduate program in the Henry Samueli School of Engineering and Applied Science
3. Students must maintain a minimum cumulative grade-point average of 3.0 every term and 3.0 in all graduate courses
4. **Thesis Option.** Students selecting the thesis option must complete at least the following requirements: (a) five formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical Engineering 297, (d) two Electrical Engineering 598 courses involving work on the M.S. thesis, (e) no other 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements, and (f) an M.S. thesis completed under the direction of the faculty adviser to a standard that is approved by a committee comprised of three faculty members. The thesis research must be conducted concurrently with the coursework

5. **Non-Thesis Option.** Students selecting the non-thesis option must complete at least the following requirements: (a) six formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical Engineering 297, (d) Electrical Engineering 299 to serve as the M.S. comprehensive examination, which is evaluated by a committee of three faculty members appointed by the department. In case of failure, students may be reexamined only once with consent of the departmental graduate adviser, and (e) no 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements

6. Students must select a number of formal graduate courses to serve as their major and minor fields of study according to the requirements listed above for the thesis (seven courses) and non-thesis (eight courses) options. The selection of the major and minor sequences of courses must be from different established tracks, or approved ad hoc tracks, or combinations thereof. The selected courses must be approved by the faculty adviser

7. For the thesis option at least four, and for the non-thesis option five, of the formal graduate courses used to satisfy the M.S. program requirements listed above must be in the Electrical Engineering Department

8. A formal graduate course is defined as any 200-level course, excluding seminar or tutorial courses

9. At most one upper division undergraduate course is allowed to replace one of the formal graduate courses covering the major and minor fields of study provided that (a) the undergraduate course is not required of undergraduate students in the Electrical Engineering Department and (b) the undergraduate course is approved by the faculty adviser

10. A track is a coherent set of courses in some general field of study. The department suggests lists of established tracks as a means to assist students in selecting their courses. Students are not required to adhere to the suggested courses in any specific track

**Circuits and Embedded Systems Area Tracks**

1. **Embedded Computing Track.** Courses deal with the engineering of computer systems as may be applied to embedded devices used for communications, multimedia, or other such restricted purposes. Courses include Computer Science 251A, Electrical Engineering 201A, 201C, M202A, M202B, 213A, M216A

2. **Integrated Circuits Track.** Courses deal with the analysis and design of analog and digital integrated circuits; architecture and integrated circuit implementations of large-scale digital processors for communications and signal processing; hardware-software co-design; and computer-aided design methodologies. Courses include Computer Science 251A, 252A, Electrical Engineering 213A, 215A through 215E, M216A, 221A, 221B

**Physical and Wave Electronics Area Tracks**

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

2. **Photonics and Plasma Electronics Track.** Courses deal with laser physics, optical amplification, electro-optics, acousto-optics, magneto-optics, nonlinear optics, photonic switching and modulation, ultrafast phenomena, optical fibers, integrated waveguides, photodetection, optoelectronic integrated circuits, optical microelectromechanical systems (MEMS), analog and digital signal transmission, photonics sensors, lasers in biomedicine, fundamental plasma waves and instability; interaction of microwaves and laser radiation with plasmas; plasma diagnostics; and controlled nuclear fusion. Courses include Electrical Engineering
Courses deal with solid-state physical electronics, semiconductor device physics and design, and microelectromechanical systems (MEMS) design and fabrication. Courses include Electrical 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 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 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 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 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 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 Engineering 297, (c) one technical communications course such as Electrical Engineering 295, (d) no 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements, (e) pass the Ph.D. preliminary examination which is administered by the department and takes place once every year. In case of failure, students may be reexamined only once with consent of the departmental graduate adviser, (f) pass the University Oral Qualifying Examination which is administered by the doctoral committee, (g) complete a Ph.D. dissertation under the direction of the faculty adviser, and (h) defend the Ph.D. dissertation in a public seminar with the doctoral committee.

5. A formal graduate course is defined as any 200-level course, excluding seminar or tutorial courses. Formal graduate courses taken to meet the M.S. degree requirements may not be applied toward the Ph.D. course requirements.

6. At least two of the formal graduate courses must be in electrical engineering.

7. Within two academic years from admission into the Ph.D. program, all courses should be completed and the Ph.D. preliminary examination should be passed. It
8. The University Oral Qualifying Examination must be taken when all required courses are complete, and within one year after passing the Ph.D. preliminary examination.

9. Students admitted originally to the M.S. program in the Electrical Engineering Department must complete all M.S. program requirements with a grade-point average of at least 3.5 to be considered for admission into the Ph.D. program. Only after admission into the program can students take the Ph.D. preliminary examination.

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

Written and Oral Qualifying Examinations

The written qualifying examination is known as the Ph.D. preliminary examination in the department. The purpose of the examination is to assess student competency in the discipline, knowledge of the fundamentals, and potential for independent research. Students admitted originally to the M.S. program in the Electrical Engineering Department must complete all M.S. program requirements with a grade-point average of at least 3.5 to be considered for admission into the Ph.D. program. Only after admission into the program can students take the Ph.D. preliminary examination, which is held once every year. Students are examined independently by a group of faculty members in their general area of study. The examination by each faculty member typically includes both oral and written components, and students pass the entire Ph.D. preliminary examination and not in parts. Students who fail the examination may repeat it once only with consent of the departmental graduate adviser. The preliminary examination, together with the course requirements for the Ph.D. program, should be completed within two years from admission into the program.

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)

UCLA Engineering has established the Center for Heterogeneous Integration and Performance Scaling (CHIPS) to address the dramatic changes taking place in the electronic hardware arena. CHIPS is an interdisciplinary, University-led consortium of industrial partners, universities, and government agencies that addresses limitations of the current application space and design environment, including integration schemes of new materials and components.

CHIPS develops new methodologies, tools, and manufacturing infrastructure for fracturing complex subsystems and dies into small, primitive dies and then re-integrating them at pitches comparable to on-chip wiring levels, enabling both latencies and bandwidth at on-chip levels. CHIPS also applies monolithic 3D integration using wafer-to-wafer bonding for memory scaling and neuromorphic cognitive applications. The ability to hardware-synthesize extremely large and complex systems from prefabricated hard IP will reduce turnaround times from years to weeks, and costs from tens of millions to a few hundred thousand dollars. This paradigm shift will change the way systems are integrated, spur innovation, and deliver new products significantly faster, with an associated reduced cost and extending this concept to biocompatible and flexible substrates. CHIPS also addresses issues associated with supply-chain integrity, security novel CHIPS-enabled architectures, and novel devices that can be leveraged by its methodology. CHIPS is multidisciplinary, integrating specialties and students in diverse areas including electrical engineering, computer science, materials science, mechanical engineering, and the biosciences, with strong industry participation.
eral 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 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 Engineering 163DA and 164DB, special projects classes such as Electrical Engineering 199, and/or research projects, have the opportunity to obtain experimental and design experience in the following technology areas: integrated microwave circuits and antennas, integrated millimeter wave circuits and antennas, numerical visualization of electromagnetic waves, electromagnetic scattering and radar cross-section measurements, and antenna near field and diagnostics measurements.

Integrated Modeling Process and Computation for Technology (IMPACT+) Center
The Integrated Modeling Process and Computation for Technology (IMPACT+) Center research team—with its strengths spanning patterning, devices, algorithms, modeling, and design automation—plans to address future semiconductor technology challenges through two intertwined themes: process and device, and design interface. This industry-supported, cross-university center involves more than 12 semiconductor companies and three University of California campuses.

Nanoelectronics Research Facility
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/class 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. For more information, see http://www.nanolab.ucla.edu.

Photonics and Optoelectronics Laboratories
Students in the Laser Laboratory study the properties of lasers and gain an understanding of the application of this modern technology to optics, communication, and holography.

The Photonics and Optoelectronics Laboratories include facilities for research in all of the basic areas of quantum electronics. Specific areas of experimental investigation include high-powered lasers, nonlinear optical processes, ultrastar lasers, parametric frequency conversion, electro-optics, infrared detection, and semiconductor lasers and detectors. Operating lasers include mode-locked and Q-switched Nd:YAG and Nd:YLF lasers, Ti:Al2O3 lasers, ultraviolet and visible wavelength argon lasers, wavelength-tunable dye lasers, as well as gallium arsenide, helium-neon, excimer, and high-powered continuous and pulsed carbon dioxide laser systems. Also available are equipment and facilities for research on semiconductor lasers, fiber optics, nonlinear optics, and ultrashort laser pulses. These laboratories are open to undergraduate and graduate students who have faculty sponsorship for their thesis projects or special studies.

Plasma Electronics Facilities
Two laboratories are dedicated to the study of the effects of intense laser radiation on matter in the plasma state. One, located in Engineering IV, houses a state-of-the-art table top terawatt (T3) 400fs laser system that can be operated in either a single or dual frequency mode for laser-plasma interaction studies. Diagnostic equipment includes a ruby laser scattering system, a streak camera, and optical spectrographs and multi-channel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing.

The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, focusable to 1016 W/cm2. The laser is used for testing new ideas for laser-driven particle accelerators and free-electron lasers. Several high-pressure, short-pulse drivers can be used on the MARS; other equipment includes a theta-pinch plasma generator, an electron linac injector, and electron detectors and analyzers.

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

There is also a large computing cluster called DAWSON 2 that is dedicated to the study of plasma-based acceleration, inertial fusion energy, and high energy density plasma science. DAWSON 2 consists of 96 HP L390 nodes each with 12 Intel X5650 CPUs and...
48 GB of RAM, and three Nvidia M2070s GPUs and 18 GB of Global Memory (for a total of 1152 CPUs and 288 GPUs) connected by a non-blocking QDR Infiniband network with 160TB of parallel storage from Panasas. Peak system performance is approximately 300TF/150TF (single/double precision) with a measured Linpack performance of 68.1TF (double precision). DAWSON 2 is housed within the UCLA Institute for Digital Research Engineering data center.

**Solid-State Electronics Facilities**

Solid-state electronics equipment and facilities include a modern integrated semiconductor device processing laboratory, complete new Si and III-V compound molecular beam epitaxy systems, CAD and mask-making facilities, lasers for beam crystallization study, thin film and characterization equipment, deep-level transient spectroscopy instruments, computerized capacitance-voltage and other characterization equipment, including doping density profiling systems, low-temperature facilities for material and device physics studies in cryogenic temperatures, optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices, and characterization equipment for high-speed devices, including high magnetic field facilities for magnetotransport measurement of heterostructures. The laboratory facilities are available to faculty, staff, and graduate students for their research.

**Wireless Health Institute (WHI)**

Benjamin M. Wu, *Director*
Bruce Dobkin, William Kaiser, Majid Sarrafzadeh, *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.

**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 Architectonics Focus Center (FENA)
- Plasma Science and Technology Institute
- Translational Applications of Nanoscale Multiferroic Systems (TANMS)
- WN Institute of Neurotronics (WINs)

**Faculty Groups and Laboratories**

Department faculty members also lead a broad range of research groups and laboratories that cover a wide spectrum of specialties, including:

- Actuated Sensing and Coordinated Embedded Networked Technologies (ASCENT) Laboratory (Kaiser)
- Adaptive Systems Laboratory (Sayed)
- Algorithmic Research in Network Information Laboratory (Fragouli)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
- Autonomic Intelligent Networked Systems (Razavi)
- BioPhotonics Laboratory (Ozcan)
- CMOS Research Laboratory (Woo)
- Communication Circuits Laboratory (Roychowdhury)
- Complex Networks Group (Stafsudd)
- 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)
- Laboratory for Embedded Machines and Ubiquitous Robotics (Mehta)
- Laser-Plasma Group (Joshi)
- Mesoscopic Optics and Quantum Electronics Laboratory (Wong)
- Microwave Electronics Laboratory (Joshi)
- Nanoelectronics Research Center (Candler)
- Nanostructure Devices and Technology Laboratory (Chui)
- Nanosystems Computer-Aided Design Laboratory (Gupta)
- Networks, Economics, Communication Systems, Informatics, and Multimedia Research Lab Focus (van der Schara)
- Neuroengineering Group (Markovic)
- Optoelectronics Circuits and Systems Laboratory (Jalali)
- Optoelectronics Group (Yablokonovitch)
- Public Safety Network Systems Laboratory (Yao, Rubin)
- Quantum Electronics Laboratory (Stafsudd)
Faculty Areas of Thesis Guidance

Professors

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

Abeer A.H. Alwan, Ph.D. (MIT, 1992)
Speech processing, acoustic properties of speech sounds with applications to speech synthesis, recognition by machine and coding, hearing-aid design, and digital signal processing

Katsushi Arisaka, Ph.D. (U. Tokyo, Japan, 1985)
High energy and astro-particle experiments

M.-C. Frank Chang, Ph.D. (National Chiao-Tung U., Taiwan, 1978)
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 nano-technologies

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. Grundfest, M.D., FACS (Columbia, 1980)
Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopy, spectroscopy, photodynamic therapy (PDT), optical technology, biologic feedback control mechanisms

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, MIR optoelectronic devices, solar cells, Si photonics, 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 metamaterials 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 subsystems integration and neuromorphic computing

Bahram Jalali, Ph.D. (Columbia, 1989)
RF photonics, integrated optics, fiber optic integrated circuits

Laser fusion, laser acceleration of particles, nonlinear optics, high-power lasers, plasma physics

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

Kuo-Nan Liu, Ph.D. (New York U., 1971)
Radiative transfer 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. Chicago, 2006)
Power/area-efficient 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 computation, applied mathematics

Aryogzan Oznan, Ph.D. (Stanford, 2005)
Blomaging, nano-photonic, nonlinear optics

Gregory J. Pottie, Ph.D. (McMaster U., Canada, 1988)
Communication systems and theory with applications to wireless sensor networks

Yahya Rahmat-Samii, Ph.D. (U. Illinois, 1975)
Satellite communications antennas, personal communication antennas including human interactions, antennas for remote sensing and radio astronomy applications, advanced numerical and genetic optimization techniques in electromagnetics, frequency selective surfaces and photonic band gap structures, novel integrated and fractal antennas, near-field antenna measurements and diagnostic techniques, electromagnetic theory

Behzad Razavi, Ph.D. (Stanford, 1992)
Analog, RF, and mixed-signal integrated circuit design, dual-slope transducers, phase-locked systems and frequency synthesizers, A/D and D/A converters, high-speed data communication circuits

Ivan 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, nonparametric 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/UGV-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, interpolates between signal processing and control methodologies, fast algorithms for large-scale systems

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. Spyer, Ph.D. (Harvard, 1968)
Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics

Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)
Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems

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

Pauo 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/categorial methods

Lieve 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 networking, multimedia compression, multimedia networking, multimedia communications, 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, MSB and superlattices, microwave and millimeter electronics, quantum information

Richard D. Wesel, Ph.D. (Stanford, 1996)
Communication theory and signal processing with particular interests in channel coding, including turbo codes and trellis codes, joint algorithms for distributed communication and detection

Chee Wei Wong, Sc.D. (MIT, 2002)
Ultrafast and ubiquitous communications, quantum communications and computing, chip-scale optoelectronics, precision measurements and sensing
Associate Professors

Daniijela Catic, Ph.D. (UC Berkeley, 2007) Wireless communications system design, cognitive radio networks, VLSI architectures of signal processing and digital communication algorithms, performance analysis and experiments on embedded system platforms.

Robert N. Candler, Ph.D. (Stanford, 2006) MEMS and nanoscale devices, fundamental limitations of sensors, packaging, biological and chemical sensing.


Lara Dolecek, Ph.D. (UC Berkeley, 2007) Information and coding theory, graphical models, statistical algorithms and computational methods with applications to large-scale and complex systems for data processing, communication and storage.

Puneet Gupta, Ph.D. (UC San Diego, 2007) CAD for VLSI design and manufacturing, physical design, manufacturing-aware circuits and layouts, design-aware manufacturing.

Mona Jaraahi, Ph.D. (Stanford, 2007) Radio frequency (RF), microwave, millimeter-wave, and terahertz circuits, high-frequency devices and circuits, integrated photonics and optoelectronics.

Sudhakar Pamarthi, Ph.D. (UC San Diego, 2003) Mixed-signal IC design, signal processing and communication theory.

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.


Assistant Professors

Samko Coogan, Ph.D. (UC Berkeley, 2015) Control theory and dynamical systems, formal methods, cyber-physical systems.

Sam Ermannejad, Ph.D. (Stanford, 2014) Biological and chemical sensors, wearable and flexible electronics, MEMS and NEMS fabrication, microfluidics, internet of things devices, technology development for personalized precision medicine.

Ankur Mehta, Ph.D. (UC Berkeley, 2012) Robotics and electronic systems design, fabrication, and control; wireless sensor networks hardware and applications; systems integration.

Yi-Chi Shih, Ph.D. (U. Texas Austin, 1982) Device/circuit optimization, novel device design.

Asad M. Marki, Ph.D. (California Coast U., 1987) Development and commercialization of intelligent sensors and systems, RF and microwave instrumentation, signal processing.

Yi-Chi Shih, Ph.D. (U. Texas Austin, 1982) Microwave/millimeter-wave active and passive devices, characterization and modeling, integrated circuits, components and subsystems for sensors and communications applications.

Ingrid M. Verbaanvode, Ph.D. (Katholieke U. Leuven, Belgium, 1991) Embedded systems, VLSI, architecture and circuit design and design methodologies for applications in security, wireless communications and signal processing.

Bi Yablokowitch, Ph.D. (Harvard, 1972) Optoelectronic and optothermal communications, photonic integrated circuits, photonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication.

Adjunct Associate Professor


Adjunct Assistant Professors


Zachary Taylor, Ph.D. (UCSB, 2009) Biomedical optics, imaging system design, novel contrast-generation mechanisms.

Lower Division Courses

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. Mr. Pottie, Mr. Williams (F,W,Sp)

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

3. Introduction to Electrical Engineering. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Requisite: Physics 1B. Introduction to field of electrical engineering. Basic circuits techniques with application to explanation of electrical engineering inventions such as telecommunications, electrical grid, automatic computing and control, and enabling device technology. Research frontiers of electrical engineering. Introduction to measurement and design of electrical circuits. Letter grading. Mr. Pottie (F,Sp)

10. Circuit Theory I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 3 (or Computer Science 1 or Materials Science 10), Mathematics 33A, Physics 1B. Corequisites: course 11L (enforced only for Com-
111A. Analog Electronic Circuits I. (4, Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 110. Review of physics and operation of diodes and bipolar and MOS transistors. Equivalent circuits and models of semiconductor devices, design of single-stage amplifiers, DC biasing circuits. Small-signal analysis. Operational amplifier systems. Letter grading.

Mr. Abidi, Mr. Daneshrad (F,Sp)

115A. Analog Electronic Circuits II. (4, Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 115A. Analysis and design of differential amplifiers in bipolar and MOS technologies. Current mirrors and active loads. Frequency response of amplifiers. Feedback and its properties. Stability issues and frequency compensa-

115AN. Analog Electronic Circuits Laboratory I. (2, Laboratory, four hours; outside study, two hours. Enforced requisites: courses 110L or 111L, 115A. Experimental determination of device characteristics, resistive diode circuits, single-stage amplifiers, compound transistor stages, effect of feedback on single-stage amplifiers, operational amplifiers, and operational amplifier circuits. Introduction to hands-on design experience based on individual student hardware design and implementation platforms. Letter grading.

Mr. Abidi (F,Sp)

115B. Analog Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115A. Digital Signal Processing Design. Use of computer-aided design tools for the design of digital filter design techniques. Letter grading.

Mr. Markovic (F, W)


Mr. Markovic (F, W)

115G. Design Studies in Electronic Circuits. (4) Formerly numbered 115D.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115A. Digital Signal Processing Design. Use of computer-aided design tools for the design of digital filter design techniques. Letter grading.

Mr. Markovic (F, W)


Mr. Markovic (F, W)


Mr. Abidi (Sp)


Mr. Abidi (Sp)

116L. Introductory Digital Design Laboratory. (2) (Same as Computer Science M115A) Laboratory, in four hours; discussion, outside study, two hours. Enforced requisite: course M115A or Computer Science M31A. Students must be in good academic standing and enrolled in one of the following courses: Computer Engineering 33, Computer Engineering 34, or Computer Engineering 115B. Recommended: course M116L or Computer Science M31A. Computer Science 115A. 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. Abidi (Sp)

117. Computer Networks: Physical Layer. (Same as Computer Science M117.) Lecture, two hours; discussion, one hour; outside study, six hours. Not open to students with credit for course M171L. Introduction to fundamental computer communication concepts underlying and supporting modern networked wireless communications and media access layers of network protocol stack. Systems include wireless LANs

Mr. He (F,Sp)


Mr. Gupta, Mr. Pamarti (F, W, Sp)

119. Fiat Lux Freshman Seminars. (1) Seminar, three hours. Limited to 20 students. Designed as a supplement to lower division courses. 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.

120. 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. Development of approximate models for interconnected systems and learning how to perform power flow, economic dispatch, and short circuit analysis. Introduction to power system transient dynamics. Letter grading.

Mr. Tabuada (Not offered 2016–17)

121. Analog Circuit Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 111C. Design of analog integrated circuits. Frequency response principles, op-amp-based circuit synthesis, and two-port network principles. Letter grading.

Mr. Gupta, Mr. Pamarti (Sp)

122. Digital Signal Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 110. Digital signal processing techniques and applications. Letter grading.

Mr. Ray (W)

123A. Digital Signal Processing Laboratory. (2) Laboratory, in four hours; discussion, one hour; outside study, six hours. Enforced requisite: course 112A. Laboratory component of course 112A. Lab reports, computer-aided simulation of digital circuits. Letter grading.

Mr. Abidi, Mr. Razavi (F, W, Sp)

125A. Digital Systems Laboratory. (2) Laboratory, in four hours; discussion, one hour; outside study, six hours. Enforced requisite: course 115A. Digital Signal Processing Design. Use of computer-aided design tools for the design of digital filter design techniques. Letter grading.

Mr. Markovic (F, W)

126. 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. Development of approximate models for interconnected systems and learning how to perform power flow, economic dispatch, and short circuit analysis. Introduction to power system transient dynamics. Letter grading.

Mr. Tabuada (Not offered 2016–17)


Mr. Gupta, Mr. Pamarti (Sp)

128. 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. Development of approximate models for interconnected systems and learning how to perform power flow, economic dispatch, and short circuit analysis. Introduction to power system transient dynamics. Letter grading.

Mr. Tabuada (Not offered 2016–17)
131B. Principles of Semiconductor Device Design. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 121. Introduction to principles of operation of bipolar and MOS transistors, equivalent circuits, high-frequency behavior, voltage limitations. Letter grading.

Mr. Chiu (F,Sp)

121DA-121DB. Semiconductor Processing and Device Design. (4-8) Design fabrication and characterization of p-n junction and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metalization, and photolithography. Introduction to CAD tools used in integrated circuit processing and device design. Development of optimization tool based on MEDICI, process integration tool based on SUPREM, four hours. Enforced requisite or corequisite: course 121B. In progress grading (credit to be given only on completion of course 121DB). Letter grading.

Mr. Huffaker (F,Sp)

123A. Fundamentals of Solid-State I. (4) Lecture, three hours; discussion, one hour; outside study, four hours. Eight requisite: course 2 or Physics 1C. Limited to junior/senior engineering majors. Fundamentals of solid-state, introduction to quantum mechanics and quantum statistical mechanics related to solid-state Crystal structure, energy levels in solids, and band theory and semiconductor properties. Letter grading.

Ms. Huffaker (F)

123B. Fundamentals of Solid-State II. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Eight requisite: Physics 1C. Introduction to fundamentals of nanoscale for electronics nanosystems. Principles of nanoscale devices and circuits, including various photolithography technologies, physical and chemical deposition methods, and physical and chemical etching methods. Hands-on experience with nanofabrication and nanofabrication in modern cleanroom environment. Letter grading.

Mr. Rahmat-Samii (Sp)


Mr. Rubin (F)

133B. Simulation, Optimization, and Data Analysis. (4) Formerly numbered 136.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 133A. Simulation of dynamical systems. Random number generators. Evaluation of stochastic systems, Monte Carlo methods. Error analysis, statistical applications. Letter grading.

Mr. Vandenberghe (FSp)

134. Graph Theory in Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Basics of graph theory, including trees, bipartite graphs and matching, vertex and edge coloring, planar graphs and networks. Emphasis on reducing real-world engineering problems to graph theory formulations. Letter grading.

Mr. Fragouli (Not offered 2016-17)


Mr. Tabuada (WSp)

142. Linear Systems: State-Space Approach. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 122. State-space methods of linear system analysis and synthesis, with application to problems in networks, control, and system modeling. Letter grading.

Mr. Tabuada (Not offered 2016-17)

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) Same as Bioengineering M153, Chemical Engineering M153, and Mechanical Engineering M183B.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisite: Chemistry 20A, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to general manufacuring 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 methods. Hands-on experiments for fabricating microstructures and nanofstructures in modern cleanroom environment. Letter grading.

Mr. Chiou (FSp)

162A. Wireless Communication Links and Antennas. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 101B. Basic properties of transmitting and receiving antennas and antenna arrays. Array synthesis. Adaptive arrays. Friis transmission formula, radar equations, antenna design, cell-site and microwave budget. Noise in communication systems (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading.

Mr. 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 communication systems, radar systems, wireless sensors, and biological applications of microwaves. Letter grading.

Mr. Itoh, Mr. Jalali (Not offered 2016-17)

163DA. Microwave and Wireless Design I. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisite: courses 101A, 101B. Course 163DA is enforced requisite for 163DB. Limited to senior Electrical Engineering majors. Capstone design course, with emphasis on design, analysis, fabrication and testing of microwave circuits and components to address need in industry and research community for students with microwave and wireless circuit design experiences. Standard design procedure for waveguide and transmission 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 these designs, In Progress grading (credit to be given only on completion of course 163DB). Letter grading.

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

163DB. Microwave and Wireless Design II. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisite: courses 101A, 101B, 101C. Course 163DA is enforced requisite for 163DB. Limited to senior Electrical Engineering majors. Design of radio frequency circuits and systems, with emphasis on both theoretical foundations and hands-on experience. Design of radio frequency transceivers and their building blocks according to given specifications or in form of open-ended problems. Introduction to advanced topics related to project through lecture and laboratory by students of end-to-end systems in application context, managing trade-offs across subsystems while meeting constraints and optimizing metrics related to cost, performance, ease of use, manufacturability, testing, and other real-world considerations. Oral and written presentations of project results required. Letter grading.

Mr. Itoh, Y.E. Wang (Sp)
184DA-184DB. Radio Frequency Design Project I, II (4-4) (F, W) Laboratory, one hour; lecture, three hours; outside study, eight hours. Enforced requisite: course 170A. Course 184DA is enforced requisite to 184DB. Limited to senior Electrical Engineering majors. Design of radio frequency circuits and systems, with emphasis on both theoretical foundations and hands-on experience. Design of radio frequency transceivers and their building blocks 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 performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations. Limited to 75 students. In Progress (184DA) and letter (184DB) grading.

Mr. Chang, Mr. Itoh, Mr. Razavi

(Not offered 2016-17)

170A. Principles of Photonics. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: courses 2, 101A. Development of solid foundation on essential principles of photonics from ground up with minimum prior knowledge of quantum mechanics. Topics include optical properties of materials, optical wave propagation and modes, optical interferometers and resonators, optical coupling and modulation, optical absorption and emission, principles of lasers and light-emitting diodes, and optical detection. Letter grading.

Mr. Liu (F, W)

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 photonics devices and circuits. Topics include optical waveguides, optical fibers, optical couplers, optical modulators, lasers and light-emitting diode detectors, and integrated photonics 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. Recommended requisite: course 2, 170A. Fundamentals of detection of light for communication and sensing, as well as conversion of light to electrical energy in solar cells. Design by analogy 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, (2-4) (Same as Computer Science M171L) Laboratory, four to eight hours; outside study, two to four hours. Recommended prerequisite: course M171L. Exploration of key concepts and practical aspects of modern data communication systems and the laboratory exercises are designed to give students hands-on 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 frame relay protocols. Discussion of principles of modeling and optimization codevelopment effects, reliability, and manufacturability. Discussion of principles of modeling and optimization codevelopment effects, reliability, and manufacturability. Letter grading.

Mr. Ozcan (Sp)

(For M180DA in F, W; 180DB in W, Sp)

M182L. Science, Technology, and Public Policy. (4) Same as Public Policy CM182. Lecture, three hours. Another course required. Examination of the roles played by science and technology in society, and on-policy form or in projects required. May be repeated for credit with instructor change. Letter grading.

Mr. Briggs (Not offered 2016-17)

183DA-183DB. Design of Specialized Digital Hardware I, II (4-4) (F, W) Limited to senior Electrical Engineering majors. Design of specialized hardware functions in system-on-chip application processor context with integration of diverse processing technologies such as general-purpose processors, graphics processors, and energy-efficient domain-specific accelerators. Design of logic gates, their size and voltage optimization for energy-delay trade-offs, operation of clocked-storage elements and their timing parameters, timing analysis of digital data-path logic, architecture parallelism and time multiplexing, clock and power. Introduction to advanced project-related topics. Open-ended projects with enhanced project performance required. Student teams create hardware accelerator engines for various applications. 183DA. Lecture, one hour; laboratory, four hours; outside study, eight hours. Enforced requisite: course 183DA. Recommended: course 115B. In Progress grading (credit to be given only on completion of course 183DB). 183DB. Laboratory, four hours; outside study, eight hours. Enforced requisite: course 183DA. Recommended: course 115B. Letter grading.

Mr. Markovic (183DA in W; 183DB in Sp)

184DA-184DB. Independent Group Project Design, (2-2) Laboratory, five hours; discussion, one hour; outside study, eight hours. Course 184DA is enforced requisite to 184DB. Courses centered on project group that runs year long to give students intensive experience on hardware design, microcontroller programming, and project coordination. Several projects based on autonomous robots that traverse small mazes and course offers yearly and target regional competition; Enforced requisite: courses M16, 110, 110L. Course 184DA is enforced requisite to 184DB. Designed for graduate computer science and electrical engineering students. 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-aware system design, timing synchronization, fault tolerance and debugging, and techniques for hardware and software ar-
architecture optimization. Theoretical foundations as well as practical design methods. Enforced requisite: course 215A. (Same as Computer Science M213B.) Lecture, four hours; laboratory, four hours; outside study, four hours. Designed for graduate computer science and electrical engineering students. Topics in combination of 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. Four 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-art embedded hardware platform. Letter grading.

Mr. Kaiser (F)

205A. Matrix Analysis for Scientists and Engineers. (4) Lecture, four hours; discussion, one hour; outside study, four hours. Designed for graduate computer science and electrical engineering students. Topics include two-dimensional linear system theory, image processing theory and techniques. Topics in current and advanced topics in one or more aspects of circuits and embedded systems, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication circuits and systems; embedded processor architectures; embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. S/U or letter grading.

Ms. Cabric (FSP)


M. Srivastava (F)


M. Privitera (F)


M. Privitera (F)

208AS. 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, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication circuits and systems; embedded processor architectures; embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. S/U or letter grading.

Mr. Sayed (Not offered 2016-17)

209A. Analysis of Linear Circuits and Systems. (4) Lecture, four hours; discussion, four hours; laboratory, four hours; outside study, eight hours. Preparation: prior training in probability theory, random processes, and linear algebra. Recommended requisites: courses 205A, 241A. Mean-square-error estimation and filters, least-squares estimation and filters, steepest-descent algorithms, stochastic-gradient algorithms, convergence, stability, tracking, and performance analysis. Algorithms for learning and classification, optimization. Letter grading.

Mr. Sayed (W)


M. Srivastava (F)

211A. Digital Image Processing I. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Preparation: computer programming experience. Requisite: course 113. Fundamentals of digital image processing theory and techniques. Topics include two-dimensional linear system theory, image transformation, and edge detection. Emphasis is placed on lecture applied in computer laboratory assignments. Letter grading.

Mr. Villasenor (W)


Mr. Pamarti (F)

212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Fundamentals of multirate systems and filter banks; implementation; applications of multirate systems; maximally decimated filter banks; perfect reconstruction systems; paralytic filter banks; wavelet transform and its relation to multirate filter banks. Letter grading.

Mr. Pamarti (Not offered 2016-17)

213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Digital filter design and optimization tools, analog/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 speech and image processing circuits. Letter grading.

M. Ataria (F)


Mr. Majumdar (W)

215A. Analog Integrated Circuit Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 115B. Analysis and design of analog integrated circuits. MOS and bipolar device structures and models, single-stage and differential amplifiers, noise, gain and frequency response, offset and distortion, sampling devices and discrete-time circuits, bandgap references. Letter grading.

Mr. Abidi, Mr. Razavi (F)


M. Ayaz (W)

215C. Analysis and Design of RF Circuits and Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 215A, Principles of RF circuits and system design, with emphasis on monolithic implementation in VLSI technologies. Basic concepts, communications background, transceiver architectures, low-noise amplifiers, oscillators, oscillator stability, waveforms, power amplifiers. Letter grading.

Mr. Abidi, Mr. Razavi (Sp)

215D. Analog Microsystem Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 215A. Principles of RF circuits and system design, with emphasis on monolithic implementation in VLSI technologies. Basic concepts, communications background, transceiver architectures, low-noise amplifiers, oscillators, oscillator stability, waveforms, power amplifiers. Letter grading.

Mr. Abidi, Mr. Razavi (Sp)

215E. Symbolic and Iconic Representations in Process Design. (4) Lecture, four hours; computer assignments, two hours; outside study, seven hours. Requisite: course 214A. Advanced techniques used in various speech-processing applications, with focus on speech recognition by humans and machine. Physiology and psychoacoustics of human perception. Dynamic Time Warping (DTW) and Hidden Markov Models (HMM) for automatic speech recognition systems, pattern classification, and search algorithms. Aids for hearing impaired. Letter grading.

Mr. Alwan (Sp)

216A. Advanced Digital Signal Processing. (4) Same as Bioengineering M216A.) Lecture, three hours; computer assignments, two hours; outside study, seven hours. Requisite: course 214A. Advanced techniques used in various speech-processing applications, with focus on speech recognition by humans and machine. Physiology and psychoacoustics of human perception. Dynamic Time Warping (DTW) and Hidden Markov Models (HMM) for automatic speech recognition systems, pattern classification, and search algorithms. Aids for hearing impaired. Letter grading.

Mr. Alwan (Sp)

217A. 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 architectures; embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change.Letter grading.
systems. Use of both digital and analog design techniques to improve data rate of electronic devices, functional blocks, chips, and systems. Advanced clocking methodologies, phase-locked loop design for clock generation, and high-performance wire-line transmitters, receivers, and timing recovery circuits. Letter grading.

Mr. Pamarti (Sp)

M216A. Design of VLSI Circuits and Systems. (4) (Same as Computer Science M258A.) Lecture, four hours; discussion, two hours; laboratory, four hours; outside study, seven 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 digital systems on chips. Letter grading. Mr. Markovic (Not offered 2016-17)

M216B. 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 from digital signal processing (DSP) theory, architecture, and circuit design applied to complex DSP algorithms in emerging applications for personal communications and healthcare. Letter grading.

Mr. Markovic (Not offered 2016-17)

M216C. LSI in Computer System Design. (4) (Same as Computer Science M258C.) Lecture, four hours; outside study, seven hours. Requisites: course M216A. LSI/VLSI design and application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. Letter grading.

(Not offered 2016-17)

M217. Biomedical Imaging. (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 constructed to model, analyze, optimize, and shape emerging interactions among users in different networks and system settings. How strategic agents can successfully compete with each other for limited and time-varying resources by optimizing their decision process and learning from their past interaction with other agents. To determine their optimal actions in these situations, agents in dynamically decentralized environments, agents need to learn and model directly or implicitly other agents’ responses to their actions. Discussion of existing multilayer learning techniques and implications including adjustment processes for learning equilibrium, fictitious play, regret-learning, and more. Letter grading.

Ms. van der Schaar (Not offered 2016-17)

221A. Physics of Semiconductor Devices I. (4) Lecture, four hours; outside study, eight hours. Physical principles and design considerations of junction devices. Letter grading.

Mr. K.L. Wang, Mr. Woo (F)

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

Mr. Woo (Sp)

221C. Microwave Semiconductor Devices. (4) Lecture, four hours; outside study, eight hours. Physical principles and design considerations of microwave solid-state devices: Schottky barrier mixer diodes, IMPATT diodes, transferred electron devices, tunnel diodes, microwave transistors. Letter grading.

Mr. K.L. Wang, Mr. Woo (Not offered 2016-17)


Mr. Woo (W)


Mr. Chui (F)

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 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)

229. Seminar: Advanced Topics in Solid-State Electronics. (4) Seminar, four hours; outside study, eight hours. Requisite: course 224. Eight hours. Recent 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 2016-17)

229S. 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 report on tutorial topic and on research topic in their dissertation area. May be repeated for credit. S/U grading. (Not offered 2016-17)

230A. Detection and Estimation in Communication. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Applications of estimation and detection concepts in communication and signal processing; random signal and noise characterizations by analysis and simulations; mean square (MS) and maximum likelihood (ML) estimations and algorithms. Additional topics: Blasewicz and Neyman/Pearson (NP) criteria; signal-to-noise ratio (SNR) and error probability evaluations. Introduction to Monte Carlo simulations. Letter grading.

Mr. Y. Yao (F)


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. Application to beamforming for SNIR enhancement, smart antenna, and source separation and localization. Introduction to compressive sampling and applications. Letter grading. (Not offered 2016-17)


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 and rate distortion in lossy data compression; basics of network information flow over general noisy networks. Letter grading.

Mr. Diggavi (W)

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: course 231A. Fundamentals of error control codes and decoding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading.

Mr. Wessel (Sp)


Mr. Rubin (W)

232B. Telecommunication Switching and Queueing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Modeling, analysis, and design of queuing systems; 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 systems. Queuing networks with applications to computer communications, Internet, and management networks. Letter grading.

Mr. Rubin (Not offered 2016-17)

232C. Telecommunication Architecture and Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232B. Analysis and design of integrated-service communication networks and multiple-access protocols; queuing analysis of priority-based queueing system models. Queuing networks; network protocol architectures; error control; routing, flow, and access control. Applications to local-area, packet-radio, satellite, and computer communication networks. Letter grading.

Mr. Wessel (Not offered 2016-17)

232D. Telecommunication Networks and Multiple Access Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Performance analysis and design of telecommunication networks, mobile wireless networks, and multiple-access communication systems. Network architecture, multiple-access protocols, medium access control, error propagation, error control, and flow control. Letter grading.

Mr. Wessel (Not offered 2016-17)
works, heterogeneous large/small cell networks, WiFi mesh network, mobile ad hoc and sensor networks, vehicular highway networks, autonomous transportation networks, smart grid networks, adaptive multimedia streaming over mobile wireless networks, sensor fusion, or wireless sensor networks.

M248. System, Dynamics, and Control Topics. (2) (Same as Chemical Engineering M297 and Mechanical and Aerospace Engineering M299A.) Seminar course hours; outside study required; limited to graduate engineering students. Presentations of research topics by leading academic researchers from fields of systems, dynamics, and control. Students will work in these fields, review the relevant literature, and present the results in a seminar format. Letter grading. Mr. Tabuada (W)

M248S. Seminar: Systems, Dynamics, and Control Topics. (2) (Same as Chemical Engineering M297 and Mechanical and Aerospace Engineering M299A.) Seminar course hours. Presentations of research topics by leading academic researchers from fields of systems, dynamics, and control. Students will work in these fields, review the relevant literature, and present the results in a seminar format. Letter grading. Mr. Tabuada (W)

M250B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Bioengineering M252B and Mechanical and Aerospace Engineering M282B.) Lecture, four hours; outside study, eight hours. Enforced requisites: course M252A and Chemical Engineering M280B. Prerequisite: course M250A or equivalent. Design, development, and implementation of MEMS devices. Topics include device fabrication, materials, and applications. Credit cannot be awarded for both M250B and M252B. Letter or S/U grading. Mr. Candler (Sp)

M252. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Bioengineering M252 and Mechanical and Aerospace Engineering M282.) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 141, 162A. Introduction to MEMS design. Design of MEMS and MEMS fabrication processes. Credit cannot be awarded for both M252 and M252B. Letter grading. Mr. Perelman (Sp)

M259A. Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course 240B. Introduction to optimal control, with emphasis on detailed study of LQR, or linear regulators modeling methods. Letter grading. Mr. Tabuada (F)

M260A. Advanced Engineering Electrodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 101A, 101B. Advanced treatment of concepts in electrodynamics and their applications to modern engineering problems. Vector calculus in generalized coordinate system. Solutions of vector potentials by direct integration, transmission, and polarization. Vector potential, duality, reciprocity, and equivalence theorems. Scattering from cylinder, half-plane, wedge, and sphere, including the radar cross-section. Green’s functions in electromagnetics and dyadic calculus. Letter grading. Mr. Rahmat-Samii (F)

Mr. Rahmat-Samii (W) 261. Microwave and Millimeter Wave Circuits. (4) Lecture, four hours; outside study, eight hours. Requisite: course 162A. Design of active microwave and millimeter wave circuits, substrates, and surface wave phenomena. Analytical methods for discontinuity effects. Design of passive microwave and millimeter wave circuits. Letter grading. 


Mr. Rahmat-Samii (Not offered 2016-17) 266. Computational Methods for Electromagnetics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 162A, 163A. Computational techniques for partial differential and integral equations: finite-difference, finite-element, method of moments. Applications include transmission lines, resonators, integrated circuits, solid-state device modeling, electromagnetics, scattering, and antennas. Letter grading. 


Mr. Liu (W) 274. Fiber Optic System Design. (4) Lecture, three hours; outside study, 173D and/or 174. Top-down introduction to physical layer design in fiber optic communication systems, including Telecom, Datacom, and CATV. Fundamentals of optical technologies, modulation systems, fiber transmission characteristics, and optical modulation techniques, including direct and external modulation and computer-aided design. Architectures of optical and microwave waveguide circuits, including preamplifier, quantizer, clock and data recovery, laser driver, and predistortion circuits. Letter grading. 

Mr. Jalali (W) 278AS. Special Topics in Physical and Wave Electronics. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of physical and wave electronics, such as electromagnetics, microwave and millimeter wave circuits, photonics and optoelectronics, antennas, 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 electromagnetics, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading. 

(Not offered 2016-17) 279CS. Clean Green IGERT Brown-Bag Seminar. (1) Seminar, one hour. Required of students in Clean Energy for Green Industry (IGERT) Research. Literature seminar presented by graduate students and experts from around country who conduct research in energy harvest, storage, and conservation. S/U grading. 

Mr. Williams (Not offered 2016-17) CM282. Science, Technology, and Public Policy. (4) (Same as Public Policy CM282.) Lecture, three hours. Recent and continuing advances in science and technology are raising profoundly important public policy issues. Consideration of selection of critical policy issues, each of which has substantial ethical, social, economic, political, and technological aspects. Concurrently scheduled with course CM182. Letter grading. 

Mr. Villasenor (W) 285A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 201A, 201B, 201C, and 212. 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 streaming instabilities. Application to experiments in fully and partially ionized gases. Letter grading. 


(Not offered 2016-17) 293. Intellectual Property for Technology Entrepreneurs and Managers. (2) Seminar, two hours; outside study, four hours. Introduction to intellectual property (IP) in context of technology products and markets. Topics include basic practices to put in place before product development starts, how to develop high-value patent portfolios, patent licensing, offensive and defensive IP litigation considerations, trade secrets, opportunities and pitfalls of open source software, trademarks, managing copyright in increasingly complex content ecosystems, and adopting IP strategies to globalized marketplaces. Includes case studies inspired by complex IP questions facing technology companies today. S/U or letter grading. 

Mr. Villasenor (Sp) 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 reviewing conference and journal papers, and practice writing for and speaking to various audiences, including professional students 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. 

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, two to four hours; outside study, four to eight hours. Seminars and discussions on 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. 

299. M.S. Project Seminar. (4) Seminar, to be arranged. Limited to graduate electrical engineering students. Topics in current and future technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. S/U or letter grading. 

(Not offered 2016-17) 305. Corporate Intellectual Property. (1) Seminar, one hour. Required of all students. Topics include best practices to put in place before product development starts, how to develop high-value patent portfolios, patent licensing, offensive and defensive IP litigation considerations, trade secrets, opportunities and pitfalls of open source software, trademarks, managing copyright in increasingly complex content ecosystems, and adopting IP strategies to globalized marketplaces. Includes case studies inspired by complex IP questions facing technology companies today. S/U or letter grading. 

375. Teaching Apprentice Practicum. (1 to 4) Seminar, one hour; outside study, two hours. Limited to graduate electrical engineering students. Required of all departmental teaching assistants (TAs). May be taken concurrently while holding TA appointment. Seminar on departmental TA expectations, responsibilities, basic assignments, ethics, ABET reporting, online resources, and electrical engineering web. S/U grading. 

Ms. Alwan (F)
Materials Science and Engineering

UCLA
3111 Engineering V
Box 851595
Los Angeles, CA 90095-1595
tel: 310-825-5534
fax: 310-206-7353
http://www.mse.ucla.edu

Dwight C. Streit, Ph.D., Chair
Mark S. Goorsky, Ph.D., Vice Chair

Professors
Russel E. Callisch, Ph.D.
Gregory P. Cannell, 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)
Nar M. Gheewala, Ph.D.
Mark S. Goorsky, Ph.D.
Vijay Gupta, Ph.D.
Robert F. Hicks, Ph.D.
Yu Huang, Ph.D.
Ioanna Kakoulli, D.Phil.
Richard B. Kaner, Ph.D.
Ali莫斯利, Ph.D., NAE ( Evalyn Knight Professor of Engineering)
Vidvuds Ozelins, Ph.D.
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.
William Clement, Jr., 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.

Adjunct Associate Professors
Eric P. Bescher, Ph.D.
Esther H. Lan, Ph.D.
Sergey Prihodko, 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 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 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; Physics 1A, 1B, 1C.

The Major
Required: Civil and Environmental Engineering 101 (or Mechanical and Aerospace Engineering 96), 108, Electrical Engineering 100, Materials Science and Engineering 104, 110, 110L, 120, 130, 131, 131L, 132, 143A, 150, 160, Mechanical and Aerospace Engineering 82 or 181A; 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 (8 units) from Chemical Engineering C114, Civil and Environmental Engineering 130, 135A, Electrical 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 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; Physics 1A, 1B, 1C.

The Major
Required: Electrical Engineering 100, 101A, 121B, Materials Science and Engineering 104, 110, 110L, 120 (or Electrical Engineering 2), 121, 121L, 122, 130, 131, 131L, 132, 150, Mechanical and Aerospace Engineering 82, 96, 181A; either Materials Science and Engineering 150 or 160, and one course (4 units) from Electrical Engineering 123A or 123B or Materials Science and Engineering 150 or 160; four 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 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 24.
The following introductory information is based on the 2016-17 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program...

The research efforts of professor Suneel Kodambaka’s In situ Microscopy Lab are focused on synthesis and characterization of low-dimensional structures such as quantum dots, nanowires, and graphene thin films. Research students include (left to right) Dean Cheikh, Jeung Hun Park, Chilan Ngo, Filiberto Colon, and Yuya Murata.
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.

Structural materials: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, 211, 243A, 243C, 250B, 298.

As long as a majority of the courses taken are offered by the department, substitutions may be made with the consent of the departmental graduate adviser.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical 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 multilayer) for electronic and optoelectronic applications.

Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications that include growth, processing, and characterization techniques. Active research programs address the relationship between
Structural Materials
The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.

Facilities
Facilities in the Materials Science and Engineering Department include:
- Ceramic Processing Laboratory
- Glass and Ceramics Research Laboratories
- Mechanical Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Microscopy Laboratories with a transmission electron microscope (100 keV), access to several field-emission transmission electron microscopes (80–300 keV), and a scanning electron microscope equipped with a quantitative chemical/compositional analyzer, a stereo microscope, micro-cameras, and metallurgical microscopes
- Nano-Materials Laboratory
- Nondestructive Testing Laboratory
- Organic Electronic Materials Processing Laboratory
- Semiconductor and Optical Characterization Laboratory
- Thin Film Deposition Laboratory, including molecular beam epitaxy and wafer bonders
- X-Ray Diffraction Laboratory
- X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility

Faculty Areas of Thesis Guidance

Professors
Russel E. Cahn, Ph.D. (New York U., 1978)
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. Carman, Ph.D. (Virginia Tech, 1991)
Electromagnetoelasticity models and characterization, thin film shape memory, nanoscale multiferroics, magnetoelectrics and piezoelectric materials

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

Yong Chen, Ph.D. (UC Berkeley, 1996)
Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits and systems

Bruce S. Dunn, Ph.D. (UCLA, 1974)
Synthesis and characterization of electromechanical materials, energy storage, sol-gel materials and chemistry

Mark S. Goorsky, Ph.D. (MIT, 1989)
Electronic materials processing, strain relaxation in epitaxial and nanostructures 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

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

Yi Juan Huang, Ph.D. (Harvard, 2003)
Nanomaterial fabrication and development, bio-nano structures and applications of superhard metals, conducting polymers, thermoelectrics and graphene

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

Vidvuds Ozolins, Ph.D. (Kungliga Tekniska Högskolan, Sweden, 1998)
Materials theory, computational materials design, materials for energy storage and generation, magnets and optical materials, thermoelectrics, mathematical models for atomistic simulation and quantum mechanics, machine learning, knowledge extraction

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

Dwight C. Streit, Ph.D. (UCLA, 1986)
Properties of electronic materials, characterization techniques, correlation of material and device performance

Sarah H. Tolbert, Ph.D. (UC Berkeley, 1996)
Self-organized nanostructured materials for energy storage, energy harvesting, nanomagnetics and nanoelectronics

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoscale physics, materials and devices nanoelectronics, magnets and photonics, nonlinear interactions of correlated devices and nanosystems

Paul S. Weiss, Ph.D. (UC Berkeley, 1986)
Atomic-scale surface chemistry and physics, molecular devices, nanolithography, biophysics and neuroscience, nanometer-scale electronics and storage, surface interactions, surface dynamics, and direct manipulation, extending capabilities of scanning tunneling microscope, molecular-scale control and measurement of composition and properties in membranes

Processing, characterization, and controlled delivery of biological molecules of bioerodible polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

Ya-Hong Xie, Ph.D. (UCLA, 1986)
Physical properties and device application of graphene and other van der Waals materials; semiconductor physics, heterostructures, and devices; epitaxial growth of semiconductor thin films; nanofabrication

Jenn-Ming Yang, Ph.D. (U. Delaware, 1986)
Nanomechanical testing, nanostructured materials, ceramic and ceramic matrix composites, hybrid materials and composites, materials synthesis and processing

Yang Yang, Ph.D. (U. Massachusetts Lowell, 1992)
Organic and inorganic semiconductor materials and devices with emphasis on solution processes; fundamental understanding of material properties; optoelectronic devices (LEDs, PVs, TFT, sensors)

Professors Emeriti
Alan J. Ardell, Ph.D. (Stanford, 1964)
Irradiation-induced precipitation, high-temperature deformation of solids, electronic microscopy, physical metallurgy of aluminum/lithium alloys, precipitation hardening

David L. Douglass, Ph.D. (Ohio State, 1958)
Oxidation and sulfidation kinetics and mechanisms, materials compatibility, defect structures, diffusion

William Klement, Jr., Ph.D. (Caltech, 1962)
Phase transformations in solids, high-pressure effects on solids

Glass science, ceramics, electrical properties of amorphous materials, materials recycling

Kanji Ono, Ph.D. (Northwestern U., 1964)
Mechanical behavior and nondestructive testing of structural materials, acoustic emission, dislocations and strengthening mechanisms, microstructural effects, and ultrasonics

Aly H. Shabaik, Ph.D. (UC Berkeley, 1966)
Metal forming, metal cutting, mechanical properties, friction and wear, biomaterials, manufacturing processes

King-Ning Tu, Ph.D. (Harvard, 1968)
Kinetic processes in thin films, metal-silicon interfaces, electromigration, Pb-free interconnects, 3D IC packaging

Associate Professors
Suneel Kodambaka, Ph.D. (U. Illinois Urbana-Champaign, 2002)
In situ microscopy, surface thermodynamics, kinetics of crystal growth, phase transformations and chemical reactions, thin film physics

Jaime Marian, Ph.D. (UC Berkeley, 2002)
Computational materials modeling and simulation in solid mechanics, irradiation damage, plasticity, phase transformations, thermodynamics
Lower Division Courses

10. Freshman Seminar: New Materials. (1) Seminar, one hour; outside study, two hours. Preparation: high school chemistry and physics. Not open to students with credit for course 104. Introduction to basic concepts of materials science and new materials vital to advanced technology. Microstructural analysis and various material properties discussed in conjunction with such applications as medical sensors, pollution control, and microelectronics. Letter grading. Mr. Tu (W)

11. Introduction to Materials Characterization B (Electronic Microscopy). (4) Formerly numbered C111L. Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projections; electron backscatter, scanning electron microscopy; high-resolution X-ray diffraction methods, and special projects. Letter grading. Mr. Goorsky (F)

12. Structure and Properties of Metallic Alloys. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 104. Structure and properties of metallic alloys. Strengthening mechanisms, microstructural terminations of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray spectroscopy; design of materials characterization procedures. Letter grading. Mr. Ron (W)

13. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; outside study, eight hours. Requisites: course 130. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decomposition, design of heat treatment processes of alloys, growth of intermetallic phases, stress corrosion cracking, oxidation-resistant alloys, recrystallization, and grain growth. Letter grading. Mr. Tu (W)

14. Materials Selection and Engineering Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131. Practical relevance emphasized as part of successful design. Design projects. Letter grading. Mr. J-M. Yang (Sp)

Upper Division Courses

104. Science of Engineering Materials. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20B, Physics 1C. General introduction to 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 (F/W/Sp)

M105. Principles of Nanoscience and Nanotechnology. (4) (Same as Engineering M101.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: 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 of a 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, X-ray scattering; powder method, Laue method; determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray spectroscopy; design of materials characterization procedures. Letter grading. Mr. Goorsky (F)

110L. Introduction to Materials Characterization A Laboratory. (2) Laboratory, four hours; outside study, two hours. Experimentation in analytical techniques and analysis of materials through X-ray scattering techniques; powder method, crystal structure determination, high-resolution X-ray diffraction methods, and special projects. Letter grading. Mr. Goorsky (F)

111. Introduction to Materials Characterization B (Electron Microscopy). (4) Formerly numbered C111L. Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projections; electron backscatter, scanning electron microscopy; emissive and reflective modes; chemical analysis; electron optics of both instruments. Letter grading. Mr. Kodambaka (W)


120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: 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. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectrical properties, and ferromagnetism. Letter grading. Ms. Huang (Sp)

121L. Materials Science of Semiconductors. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 120. Structure and properties of elemental and compound semiconductors. Electrical and optical properties, defect chemistry, and doping. Electronic materials analysis and characterization, including electrical, optical, and ion-beam techniques. Heterostructures, band-gap engineering, development of new materials for optoelectronic applications. Letter grading. Ms. Huang (Sp)

121L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes; discussion, 30 minutes; laboratory, two hours; outside study, three hours. Corequisite: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and the film biaxial modulus using CITE. Letter grading. Mr. Goorsky (Sp)

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 compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading. Mr. Goorsky (W)

130. Phase Relations in Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 104, and Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A. Summary of thermodynamic laws, equilibrium criteria, solution thermodynamics, mass action law, binary and ternary phase diagrams, glass transitions. Letter grading. Mr. Xie (F)

131. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decomposition, design of heat treatment processes of alloys, growth of intermetallic phases, stress corrosion cracking, oxidation-resistant alloys, recrystallization, and grain growth. Letter grading. Mr. Tu (W)

131L. Diffusion and Diffusion-Controlled Reactions Laboratory. (2) Laboratory, two hours; outside study, four hours. Enforced requisite: 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 theory. Letter grading. Mr. Tu (W)


140. Materials Selection and Engineering Design. (4) Lecture, four hours; discussion; one hour; outside study, seven hours. Enforced requisite: at least two courses from 132, 150, 160. Explicit guidance among myriad materials available for design in engineering. Preparation and applications of steels, nonferrous al- loys, polymeric, ceramic, and composite materials, coatings. Materials selection, treatment, and service-ability emphasized as part of successful design. Design projects. Letter grading. Mr. J-M. Yang (Sp)

141L. Computer Methods and Instrumentation in Materials Science. (2) Laboratory, four hours. Preparation: knowledge of BASIC or C or assembly language. Limited to junior/senior Materials Science and Engineering majors. Interface and control techni- ques, real-time data acquisition and processing, computer-aided testing. Letter grading.

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, dislocations, fracture, micro- structural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading. Mr. Dunn (F/W/Sp)

143L. Mechanical Behavior Laboratory. (2) Labo- ratory, four hours. Requisites: courses 90L, 143A (may be taken concurrently). Methods of characteri- zing mechanical behavior of various materials and plastic deformation, fracture toughness, fatigue, and creep. Letter grading. Mr. Ono (Not offered 2016-17)

150. Introduction to Polymers. (4) Lecture, four hours; discussion; one hour; outside study, seven hours. Polymerization mechanisms, molecular weight and distribution, chemical structure and bonding, structure crystallinity, and morphology and their ef- fects on physical properties. Glassy polymers, amorphous polymers, elastomers, thermosets, thermoplastic polymers, and composites. Fiber forming polymers, polymer processing technology, plasticization. Letter grading. Mr. Pei (W)

151. Structure and Properties of Composite Mate- rials. (4) Lecture, four hours; outside study, eight hours. Preparation: at least two courses from 132, 143A, 150, 160. Requisite: course 104. Relationship between structure and mechanical properties of composite materials with fiber and particulate rein-
forcement, Properties of fiber, matrix, and interfaces. Selection of microstructures and macroscopic properties of materials.

Letter grading.

Mr. J-M. Yang (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, including modern techniques of powder synthesis, greenware forming, sintering, glass melting. Microstructure and property relations in ceramics. Fracture analysis and design with ceramics. Letter grading.

Mr. Dunn (Not offered 2016-17)

161L. Laboratory in Ceramics. (2) Laboratory, four hours. Requisite: course 160. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and processing operations. Letter grading.

Mr. Dunn (Sp)

162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 104, Physics 20B, 20C, 20E. Introduction to electronic ceramics and packaging; magnetic ceramics; ferroelectric ceramics and electro-optic devices; optical wave guide applications and designs. Letter grading.

Mr. Dunn (Not offered 2016-17)

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 gain experiential effectiveness of their communica-tion and presentation skills. Letter grading.

Mr. Xie (Not offered 2016-17)

171. Engaging Elements of Communication: Writing for Technical Community. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive technical writing skills on subjects specific to field of materials science and engineering. Students write review term paper in selected subject field of materials science and engineering from given set of journal publications. Instruction leads students through several crucial steps, including brain-storming, choosing title, coming up with outline, concise writing of abstract, conclusion, and final polishing. Other subjects include writing style, word choices, and grammar. Letter grading.

Mr. Xie (Not offered 2016-17)

CM180. Introduction to Biomaterials. (4) Same as Bioengineering CM118. Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompati-bility. Concurrently scheduled with course CM180L. Letter grading.

Mr. Wu (Not offered 2016-17)

188. Special Courses in Materials Science and Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in materials science and engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated for credit with a new project or study. Letter grading. (Not offered 2016-17)

194. Research Group Seminars: Materials Science and Engineering. (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 of or research of faculty members or students. May be repeated for credit. Letter grading.

199. Directed Research in Materials Science and Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. Occasional field trips. Letter grading. (Not offered 2016-17)

Graduate Courses


211. Introduction to Materials Characterization B (Electron Microscopy). (4) Formerly numbered C211L. Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and micro-chemistry of materials; transmission electron micros-copy; reflection and transmission electron micros-copy, 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)


M213. Cultural Materials Science I: Analytical Im- ages and Documenting the Conservation of Ma- terials. (4) Same as Conservation M215L. Lecture, two hours; laboratory, two hours. Basic and ad- vanced techniques on digital photography, com- puterized recording techniques to determine and document condition (defects) and technological features of archaeological and ethnographic materials. Development of basic theoretical knowledge on imaging, photo-documentation, and practical skills on conservation photo-documentation, analytical (forensic) photography, and advanced imaging technology. Letter grading.


M214. Structure, Properties, and Degradation of Materials: Rock Art, Wall Paintings, Mosaics. (2) (Same as Conservation M264.) Lecture, three hours. Recommended preparation: basic knowledge of general chemistry and materials science. Introduction to materials and techniques of rock art, wall paintings (including painted surfaces on cement and composite decorative architectural surfaces), and mosaics. Archaeological and ethnographic context, techniques and methods, and historical, and binding media. Chemical, optical, and structural properties. Relationship between composition (chemistry), structure (crystals, molecular arrange- ment, and microstructure), and properties explained using basic concepts from physics and chemistry. In- trinsic attributes and resistance to weathering. Causes, sources, and mechanisms of deterioration (physical, chemical, and biochemical). Letter grading. Ms. Kakoulli (F)


221. Science of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Study of major physical and chemical principles affecting properties and performance of semiconductor materials. Topics include bonding,
22. Growth and Processing of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 130, 131. Thermodynamics of materials. Deposition techniques by reactive and nonreactive vapor deposition methods. Examination of material properties through structural and electrical characterization. Letter grading. Mr. Goorsky (Sp)

223. Science of Thin Films. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 131, 137. Thermodynamics of materials. Deposition techniques by reactive and nonreactive vapor deposition methods. Examination of material properties through structural and electrical characterization. Letter grading. Mr. Goorsky (AW)

224. Deposition Technologies and Their Applications. (4) Lecture, four hours; outside study, eight hours. Examination of physics behind majority of modern thin film deposition technologies based on vapor phase transport. Basic vacuum technology and gas chemistry. Deposition techniques as used in technology applications. Theory and experimental details of physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition (PECVD). Techniques for deposition of metals, dielectrics, and insulating layers. Letter grading. Mr. Xie


226. Si-CMOS Technology: Selected Topics in Materials Science. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Recommended preparation: Electrical Engineering 221B. Requisites: courses 130, 131, 200, 221, 222. Selected topics in materials science from modern Si-CMOS technology, including dopant diffusion in high-k/metal gate stacks, strained Si FETs, SOI and three-dimensional FETs, source/drain engineering including transient-enhanced diffusion, nonvolatile memory, and metallization for chronic contacts. Letter grading. Mr. Xie

243A. Fracture of Structural Materials. (4) Lecture, four hours; laboratory, two hours; outside study, four hours. Requisite: course 143A. Engineering and scientific aspects of crack nucleation, slow crack growth, and unstable fracture. Fracture mechanics, dislocation models, fatigue, fracture in reactive environments, alloy development, fracture-safe design. Letter grading. Mr. J-M. Yang (W, even years)

243C. Dislocations and Strengthening Mechanisms in Solids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143A. Elastic and plastic behavior of crystals, geometry, mechanics, and interaction of dislocations, mechanisms of yielding, work hardening, and other strengthening. Letter grading. Mr. Xie (F; odd years)

246A. Mechanical Properties of Nonmetallic Crystalline Solids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Materials and environmental factors affecting mechanical properties of nonmetallic crystalline solids, including atomic bonding and structure, atomic-scale defects, microstructural features, residual stresses, temperature stress state, strain rate, size and surface conditions. Letter grading. Mr. Dunn (W)

246B. Structure and Properties of Glass. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Structure of amorphous solids and glasses. Conditions of glass formation and theories of glass transition. Optical properties of glass and relationship to structure. Letter grading. Mr. Dunn (W, even years)

246D. Electronic and Optical Properties of Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Mechanics of Nanomaterials. Magnetic, infrared, visible, and ultraviolet transmission. Unique applications of ceramics. Letter grading. Mr. Dunn (Sp, even years)

247. Nanoscale Materials: Challenges and Opportunities. (4) Lecture, three hours; discussion, six 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. Mr. Huang (W)

248. Materials and Physics of Solar Cells. (4) Lecture, four hours; outside study, eight hours. Preparations: B.S. in Materials Science and Engineering, Requisite: course 151. Fabrication methods, structure, and properties of thin-film solar cells, microcrystalline silicon solar cells, thin-film solids, and multiple junction solar cells. Provided to increase student knowledge. Tour of research 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 composite materials, Fibers, resin-, metal-, and ceramic-matrix composites. Physical, mechanical, and nondestructive characterization techniques. Letter grading. Mr. Y. Yang (Sp)

251. Chemistry of Soft Materials. (4) Lecture, four hours. Introduction to organic soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft materials: organic molecules, synthetic polymers, and biomolecules and biomaterials. Extensive description and discussion of structure-property relationship, spectroscopic and experimental techniques, and preparation methods for various soft materials. Letter grading. Mr. Pei (F)

252. Organic Polymer Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to organic electronic materials on materials chemistry and processing. Topics include conjugated polymers; heavily doped, highly conducting polymers; 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 techniques 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 research literature for these methods can be used to study interesting phenomena in material science. Hands-on computer experiments. Letter grading. Mr. Ozolins (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, crystals, and liquids, with emphasis on practical applications in solving energy levels and using it to calculate physical properties such as elastic constants, equilibrium structures, binding energies, vibrational frequencies, electronic band gaps, band structures, properties of surfaces, interfaces, and magnetism. Extensive hands-on experience with modern density-functional theory code. Letter grading. Mr. Ozolins (W)

272. Theory of Nanomaterials. (4) Lecture, four hours; outside study, eight hours. Preparation: course 143A, four hours. Recommended requisite: course 200. Introduction to properties and applications of nanoscale materials, with emphasis on understanding of basic principles that distinguish nanomaterials. Study of behavior of nanoscale materials (with feature size below 100 nm) from more common microstructured materials. Explanation of new phenomena that emerge only in very small systems, using simple concepts from quantum mechanics and thermodynamics. Topics include structure and electronic properties of quantum dots, wires, nanotubes, and multilayers, self-assembly on surfaces and in liquid solutions, mechanical properties of nanostructured materials, mechanical and thermal properties of photovoltaic cell, covering basic principles of photovoltaic devices, physical models of cell operation, characteristics and design of common types of solar cells, and approaches to increasing solar cell efficiency. Recent progress in solar cell technology, microcrystalline solar cell, thin-film solar cells, and multiple junction solar cells provided to increase student knowledge. Tour of research laboratory included. Letter grading. Mr. Y. Yang (Sp)

282. Exploration of Advanced Topics in Materials Science and Engineering. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Preparation: course 104, or Chemistry 20A, 20B, and 20L Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties and suitability to task, surface chemistry, processing and treatment methods, and bioocompatibility. Concurrently scheduled with course CM180. Letter grading. Mr. Wu (Not offered 2016–17)

297B. Material Processing in Manufacturing. (4) (Same as Mechanical and Aerospace Engineering 297B.) Lecture, four hours; outside study, eight hours. Preparation: required: 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, metallic and nonmetallic, sintering, welding, plastic forming, and chemical vapor deposition, infiltration, composites. Letter grading.

297C. Composites Manufacturing. (4) (Same as Mechanical and Aerospace Engineering 297C.) Lecture, four hours; outside study, eight hours. Preparation: course 151, Mechanical and Aerospace Engineering 166C. Matrix materials, fibers, preforms, elements of processing, autoclave/compression molding, deposition 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.
Mechanical and Aerospace Engineering

UCLA
48-121 Engineering IV
Box 951597
Los Angeles, CA 90095-1597
tel: 310-825-7793
tax: 310-206-4830
e-mail: maeapp@seas.ucla.edu
http://mae.ucla.edu

Christopher S. Lynch, Ph.D., Chair
H. Pirouz Kavehpour, Ph.D., Vice Chair
Ajit K. Mal, Ph.D., Vice Chair

Professors
Mohamed A. Abdou, Ph.D.
Oddvar O. Bendiksen, Ph.D.
Gregory P. Carman, Ph.D.
Yong Chen, Ph.D.
Pei-Yu Chiu, Ph.D.
Vijay K. Dhir, Ph.D.
Jeffrey D. Eldredge, Ph.D.
Rajit Gadh, Ph.D.
Nasr M. Gholiemi, Ph.D.
James S. Gibson, Ph.D.
Vijay Gupta, Ph.D.
Dennis W. Hong, Ph.D.
Tetsuya Iwasaki, Ph.D.
Y. Sungtaek Ju, Ph.D.
Ann R. Karagözian, Ph.D. (Interim Vice Chancellor, Research)
H. Pirouz Kavehpour, Ph.D.
Chang-Jin (C-J) Kim, Ph.D.
J. John Kim, Ph.D. (Rockwell Collins Professor of Engineering)
Adrienne G. Lavine, Ph.D.
Xiaochun Li, Ph.D. (Raytheon Company Professor of Manufacturing Engineering)
Kuo-Nan Liu, Ph.D.
Christopher S. Lynch, Ph.D.
Ajit K. Mal, Ph.D.
Robert T. M’Closkey, Ph.D.
Ali Mosleh, Ph.D., NAE (Evalyn Knight Professor of Engineering)
Jayathi Y. Murthy, Ph.D., Dean
Laurent G. Pilon, Ph.D.
Jacob Rosen, Ph.D.
Jason L. Speyer, Ph.D. (Ronald and Valerie Sproul Professor of Engineering)
Tsu-Chin Tsao, Ph.D.
Xiaolin Zhong, Ph.D.

Professors Emeriti
Ivan Catton, Ph.D. (Research Professor)
Peretz P. Friedmann, Sc.D.
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor Emeritus of Aeronautics)
Walter C. Hurty, M.S.
Robert E. Kelly, Sc.D.
Anthony F. Mills, Ph.D.
D. Lewis Mingori, Ph.D.
Peter A. Monkewitz, Ph.D.
Philip F. O’Brien, M.S.
Lucien A. Schmit, Jr., M.S.
Owen I. Smith, Ph.D.
Richard Stern, Ph.D.
Russell A. Westmann, Ph.D.
Daniel C.H. Yang, Ph.D.

Associate Professors
Veronica J. Santos, Ph.D.
Richard E. Wirz, Ph.D.

Assistant Professors
Jonathan B. Hopkins, Ph.D.
Yongjie Hu, Ph.D.
Lihua Jin, Ph.D.
Raymond M. Spearin, Ph.D.

Lecturers
Ravnessh C. Amar, Ph.D.
Amiya K. Chatterjee, Ph.D.
Robert J. Kinsey, Ph.D.
Damian M. Tooley, M.S.

Adjunct Professors
Dan M. Goebel, Ph.D.
Leslie M. Lackman, Ph.D.
Wilbur J. Marner, Ph.D.
Neil B. Morley, Ph.D.
Neil G. Siegel, Ph.D.

Adjunct Assistant Professor
Abdon E. Sepulveda, Ph.D.

Scope and Objectives

The Department of Mechanical and Aerospace Engineering offers curricula in aerospace engineering and mechanical engineering at both the undergraduate and graduate levels. The scope of the departmental research and teaching program is broad, encompassing dynamics, fluid mechanics, heat and mass transfer, manufacturing and design, nanoelectromechanical and microelectromechanical systems, structural and solid mechanics, and systems and control. The applications of mechanical and aerospace engineering are quite diverse, including aircraft, spacecraft, automobiles, energy and propulsion systems, robotics, machinery, manufacturing and materials processing, microelectronics, biological systems, and more.

At the undergraduate level, the department offers accredited programs leading to B.S. degrees in Aerospace Engineering and in Mechanical Engineering. At the graduate level, the department offers programs leading to M.S. and Ph.D. degrees in Mechanical Engineering and in Aerospace Engineering. An M.S. in Manufacturing Engineering is also offered.

Department Mission

The mission of the Mechanical and Aerospace Engineering Department is to educate the nation’s future leaders in the science and art of mechanical and aerospace engineering. Further, the department seeks to expand the frontiers of engineering science and to encourage technological innovation while fostering academic excellence and scholarly learning in a collegial environment.
Undergraduate Program Objectives

The aerospace engineering and mechanical engineering programs are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

In consultation with its constituents, the Mechanical and Aerospace Engineering Department has set its educational objectives as follows: within a few years after graduation, the students will be successful in careers in aerospace or mechanical or other engineering fields, and/or in graduate studies in aerospace or mechanical or other engineering fields, and/or in further studies in other fields such as medicine, business, and law.

Undergraduate Study

The Aerospace Engineering and Mechanical Engineering majors are designated capstone majors. Within their capstone courses, Aerospace Engineering students are exposed to the conceptual and design phases for aircraft development and produce a structural design of a component, such as a lightweight aircraft wing. Mechanical Engineering students work in teams in their capstone courses to propose, design, analyze, and build a mechanical or electromechanical device. Graduates of both programs should be able to apply their knowledge of mathematics, science, and engineering in technical systems; design a system, component, or process to meet desired needs; function as productive members of a team; identify, formulate, and solve engineering problems; and communicate effectively, both orally and in writing.

Aerospace Engineering B.S.

Capstone Major

The aerospace engineering program is concerned with the design and construction of various types of fixed-wing and rotary-wing (helicopters) aircraft used for air transportation and national defense. It is also concerned with the design and construction of spacecraft, the exploration and utilization of space, and related technological fields. Aerospace engineering is characterized by a very high level of technology. The aerospace engineer is likely to operate at the forefront of scientific discoveries, often stimulating these discoveries and providing the inspiration for the creation of new scientific concepts. Meeting these demands requires the imaginative use of many disciplines, including fluid mechanics and aerodynamics, structural mechanics, materials and aeroelasticity, dynamics, control and guidance, propulsion, and energy conversion.

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 96, 102, 103, 105A, 107, 150A, 150B, 150P, 150R or 161A, 154S, 157A, 157S, 166A, 171A; two departmental breadth courses (Electrical Engineering 100 and Materials Science and Engineering 104) —if one or both of these courses are taken as part of the technical breadth requirement, students must select a replacement upper division course or courses from the department —except for Mechanical and Aerospace Engineering 156A—or, by petition, from outside the department); three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (9 units) from 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 Engineering M20 (or Computer Science 31), 82, 94; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Electrical Engineering 110L, Mechanical and Aerospace Engineering 96, 102, 103, 105A, 105D, 107, 131A or 133A,
156A, 157, 162A, 171A, 183A (or M183B); two departmental breadth courses (Electrical 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 24.

The following introductory information is based on the 2016-17 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, 152B, M171L, 199, Electrical 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 96, 102, 103, 105A, 105D, 107, 188, 194, 199.

Aerospace Engineering

Breadth Requirements. Students are required to take at least three courses from the following four categories: (1) Mechanical and Aerospace Engineering 154A or 154B or 154S, (2) 150B or C150P, (3) 155 or 166A or 169A, (4) 161A or 171A.

Mechanical Engineering

Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162D or 183A.

Comprehensive Examination Plan
The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, or (3) take and pass three comprehensive examination questions offered in association with three mechanical and aerospace engineering graduate courses. Contact the department Student Affairs Office for more information.

Thesis Plan
The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Manufacturing Engineering M.S.

Areas of Study
Consult the department.

Course Requirements
Students may select either the thesis plan or comprehensive examination plan. At least nine courses (and 36 units) are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor’s degree may not be applied toward a graduate degree at UCLA. Choices may be made from the following major areas:

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical 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 96, 102, 103, 105A, 105D, 107, 188, 194, 199.

Aerospace Engineering

Breadth Requirements. Students are required to take at least three courses from the following four categories: (1) Mechanical and Aerospace Engineering 154A or 154B or 154S, (2) 150B or C150P, (3) 155 or 166A or 169A, (4) 161A or 171A.

Mechanical Engineering

Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162D or 183A.

Comprehensive Examination Plan
The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, or (3) take and pass three comprehensive examination questions offered in association with three mechanical and aerospace engineering graduate courses. Contact the department Student Affairs Office for more information.
Upper Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 96, 102, 103, 105A, 105D, 107, 188, 194, 199.

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, 242B, 243B, 243C, 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.

Major Fields or Subdisciplines
Dynamics; fluid mechanics; heat and mass transfer; manufacturing and design (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 minor field examination may be taken (once only).

Written and Oral Qualifying Examinations
After mastering the body of knowledge defined in the major field, students take a written qualifying (preliminary) examination covering this knowledge. Students must have been formally admitted to the Ph.D. program or admitted subject to completion of the M.S. degree by the end of the term following the term in which the examination is given. The examination must be taken within the first two calendar years from the time of admission into the Ph.D. program. Students must be registered during the term in which the examination is given and be in good academic standing (minimum GPA of 3.25). The student’s major field proposal must be completed prior to taking the examination. Students may not take an examination more than twice. Students in an ad hoc major field must pass a written qualifying examination that is approximately equivalent in scope, length, and level to the written qualifying examination for an established major field.

After passing the written qualifying examination, students take the University Oral Qualifying Examination within four calendar years from the time of admission into the Ph.D. program. The nature and content of the examination are at the discretion of the doctoral committee but include a review of the dissertation prospectus and may include a broad inquiry into the student’s preparation for research.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department.

Fields of Study
Design, Robotics, and Manufacturing
The program is developed around an integrated approach to design, robotics, and manufacturing. It includes research on manufacturing and design aspects of mechanical systems, material behavior and processing, robotics and manufacturing systems, CAD/CAM theory and applications, computational geometry and geometrical modeling, composite materials and structures, automation and digital control systems, microdevices...
and nanodevices, radio frequency identification (RFID), and wireless systems.

**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, aeracoustics, bio fluid mechanics, chemically reactive flows, chemical reaction kinetics, numerical methods for computational fluid dynamics (CFD), and experimental methods. The educational program for graduate students provides a strong foundational background in classical incompressible and compressible flows, while providing elective breadth courses in advanced specialty topics such as computational fluid dynamics, microfluidics, bio fluid 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 microscopy, 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 electromagneto-thermomechanical material systems, and ferroelectric materials. The structural mechanics program includes structural dynamics with applications to aircraft and spacecraft, fixed-wing and rotary-wing aerelasticity, fluid structure interaction, computational transonic aerelasticity, biomechanics with applications ranging from whole organs to molecular and cellular structures, structural optimization, finite element methods and related computational techniques, structural mechanics of composite material components, structural health monitoring, and analysis of adaptive structures.

**Systems and Control**
The program features systems engineering principles and applied mathematical methods of modeling, analysis, and design of continuous- and discrete-time control systems. Emphasis is on modern applications in engineering, systems concepts, feedback and control principles, stability concepts, applied optimal control, differential games, computational methods, simulation, and computer process control. Systems and control research and education in the department cover a broad spectrum of topics primarily based in aerospace and mechanical engineering applications. However, the Chemical and Biomolecular Engineering and Electrical 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.

**Facilities**
The Mechanical and Aerospace Engineering Department has a number of experimental facilities at which both fundamental and applied research is being conducted. More information is at http://www.mae.ucla.edu.

**Active Materials Laboratory**
Gregory P. Carman, Director
The Active Materials Laboratory contains equipment to evaluate the coupled response of materials such as piezoelectric, magnetostrictive, shape memory alloys, and fiber optic sensors. The laboratory has manufacturing facilities to fabricate magnetostrictive composites and thin film shape memory alloys. Testing active material systems is performed on one of four servo-hydraulic load frames in the lab. All of the load frames are equipped with thermal chambers, 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 modem communication.

**Beam Control Laboratory**
James S. Gibson, Director
The Beam Control Laboratory involves students, faculty, and postdoctoral scholars to develop novel methods for laser-beam control in applications including directed energy systems and laser communications. Algorithms developed at UCLA for adaptive and optimal control and filtering, as well as system identification, are being used in adaptive optics and beam steering. UCLA high-bandwidth controllers correct both higher-order wavefront errors and tilt jitter to levels not achievable by classical beam control methods.

**Biomechatronics Laboratory**
Veronica J. Santos, Director
The Biomechatronics Laboratory is dedicated to improving quality of life by enhancing the functionality of artificial hands and their control in human-machine systems.
The research is advancing the design and control of human-machine systems as well as autonomous robotic systems.

**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.

**Cybernetic Control Laboratory**
Tetsuya Iwasaki, **Director**
The Cybernetic Control Laboratory (CyCLab) aims to develop biologically inspired control theories for rhythmic movements and dynamic pattern formation with applications to robotic vehicles, devices for human assist, and rehabilitation.

**Design and Manufacturing Laboratory**
The Design and Manufacturing Laboratory offers an environment for synergistic integration of design and manufacturing. Available equipment includes four CNC machines, two rapid prototyping systems, coordinate measuring, X-ray radiography, robots with vision systems, audiovisual equipment, and a distributed network of more than 30 workstations.

**Energy and Propulsion Research Laboratory**
Ann R. Karagozian, **Director**
The Energy and Propulsion Research Laboratory involves the application of modern diagnostic methods and computational tools to the development of improved combustion, propulsion, and fluid flow systems. Research includes aspects of fluid mechanics, chemistry, optics, and numerical methods, as well as thermodynamics and heat transfer.

**Energy Innovation Laboratory**
Richard E. Wirz, **Director**
The Energy Innovation Laboratory investigates high-impact renewable energy science and technology. Its current work primarily focuses on large-scale thermal energy storage for grid-scale applications and advanced wind energy capture.

**Flexible Research Group**
Jonathan B. Hopkins, **Director**
The Flexible Research Group is dedicated to the design and fabrication of flexible structures, mechanisms, and materials that achieve extraordinary capabilities. The laboratory is equipped with state-of-the-art synthesis tools, optimization software, and a number of commercial and custom-developed additive fabrication technologies for fabricating complex flexible structures at the macro- to nano-scale.

**Fusion Science and Technology Center**
Mohamed A. Abdou, **Director**
The Fusion Science and Technology Center includes experimental facilities for conducting research in fusion science and engineering, and multiple scientific disciplines in thermofluids, thermomechanics, heat/mass transfer, and materials interactions. The center includes experimental facilities for liquid metal magnetohydrodynamic fluid flow, thick and thin liquid metal systems exposed to intense particle and heat flux loads, and metallic and ceramic material thermomechanics.

**Laser Spectroscopy and Gas Dynamics Laboratory**
Raymond M. Spearin, **Director**
The Laser Spectroscopy and Gas Dynamics Laboratory conducts research driven by applications in propulsion and energy, with extensions to health and environment. Lab activities are united by a core focus in experimental thermofluids and applied spectroscopy. Projects commonly span fundamental spectroscopy science to design and deployment of prototype sensors to investigate dynamic flow-fields.

**Materials Degradation Characterization Laboratory**
Ajit K. Mal, **Director**
The Materials Degradation Characterization Laboratory is used for the 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 for research on fracture mechanics and ultrasonic nondestructive evaluation.

**Materials in Extreme Environments (MATRIX) Laboratory**
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? Knowing such behavior, can we design engineering materials to be more resilient?

**Mechatronics and Controls Laboratory**
Tsu-Chin Tsao, **Director**
The Mechatronics and Controls Laboratory focuses on servo control with applications in precision machining, engine control, and nanosizing. The lab is a key part of the interdisciplinary UCLA Center for Systems, Dynamics, and Control.

**Micro-Manufacturing Laboratory**
Chang-Jin (C-J) Kim, **Director**
The Micro-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 micromanufacturing 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**

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.

**Plasma and Beam Assisted Manufacturing Laboratory**

The Plasma and Beam Assisted Manufacturing Laboratory is an experimental facility for processing and manufacturing advanced materials by high-energy means (plasma and beam sources). It is equipped with plasma diagnostics, two vortex gas tunnel plasma guns, powder feeder and exhaust systems, vacuum and cooling equipment, high-power DC supplies (400kW), vacuum chambers, and large electromagnets. Current research is focused on ceramic coatings and nano-phase clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

**Plasma and Space Propulsion Laboratory**

Richard E. Wirz, **Director**

The Plasma and Space Propulsion Laboratory investigates 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 micro-plasmas, 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.

**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, polishing and imaging equipment for microstructural characterization, for measurement and control study of thin film interface strength.

**Faculty Areas of Thesis Guidance**

**Professors**

Mohamed A. Abdou, Ph.D. (U. Wisconsin, 1973)

Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermomechanics, thermal hydraulics, fluid dynamics, heat, and mass transfer in the presence of magnetic fields (MHD flows), neutronics, radiation transport, plasma-material interactions, blankets and high heat flux components, experiments, modeling and analysis

Gregory P. Carman, Ph.D. (Virginia Tech, 1991)

Electromagnetocaloric effects, fatigue characterization of piezoelectric ceramics, magnetostrictive composites, characterizing shape memory alloys, fiber-optic sensors, design of damage detection systems, micromechanical analysis of composite materials, experimentally evaluating damage in composites

Yong Chen, Ph.D. (U.C Berkeley, 1996)

Nanoscale science and engineering, micro- and nanofabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits and systems

Pei-Yu Chiou, Ph.D. (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 hydraulic 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, bioinspired locomotion in fluids, transition and turbulence of high-speed flows, aerodynamically generated sound, vortex-based numerical methods, simulations of biomedical flows


Mobile Internet, web-based product design, wireless and collaborative engineering, CAD/visualization

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
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 multi-legged mobile robots
Tetsuya Iwasaki, Ph.D. (Purdue, 1993)
Dynamical systems, robust and optimal controls, nonlinear oscillators, resonance entrainment, modeling and analysis of neural control circuits for animal locomotion, central pattern generators, body-fluid interaction during undulatory and oscillatory swimming
Y. Sungtaek Ju, Ph.D. (Stanford, 1999)
Heat transfer, thermodynamics, microelectromechanical and nanoelectromechanical systems (MEMS/NEMS), magnetism, nano-bio technology
Ann R. Karagozian, Ph.D. (Caltech, 1982)
Dynamical systems, real-time implementation
Nanofluid transfer, fluid transfer, computational fluid dynamics, simulation of fluid flow and heat transfer for industrial applications, sub-micron thermal transport, multiscalar multiphysics simulations and uncertainty quantifications
Laurent G. Pilon, Ph.D. (Purdue, 2002)
Interfacial and transport phenomena, radiation transfer, materials synthesis, multi-phase flow, heterogeneous media
Jason L. Speyer, Ph.D. (Harvard, 1968)
Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics
Tsu-Chin Tsao, Ph.D. (UC Berkeley, 1988)
Modeling and control of dynamical systems with applications in mechanical systems, manufacturing processes, automotive systems, and energy systems, digital control, repetitive and learning control, adaptive and optimal control, mechatronics
Xiaolin Zhong, Ph.D. (Stanford, 1991)
Computational fluid dynamics, hypersonic flow, rarefied gas dynamics, numerical simulation of transient hypersonic flow with nonequilibrium real gas effects, instability of hypersonic boundary layers

Professors Emeriti
Ivan Catton, Ph.D. (UCLA, 1968)
Heat transfer and fluid mechanics, transport phenomena in porous media, nucleonics heat transfer and thermal hydraulics, natural and forced convection, thermal/hydraulic stability, turbulence
Aeroelasticity of helicopters and fixed-wing aircraft, structural dynamics of rotating systems, rotor dynamics, unsteady aerodynamics, active control of structural dynamics, structural optimization with aeroelastic constraints
Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular fluidic phenomena, microelectromechanical systems (MEMS), bionanotechnolo­gies, 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 Mingori, 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 luminous engineering systems
Lucien A. Schmit, Jr., M.S. (MIT, 1950)
Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and optimization methods for fiber composite structural components

Owen I. Smith, Ph.D. (UC Berkeley, 1977)
Combustion and combustion-generated air pollutants, hydromechanics 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. Wernick, Ph.D. (UC Berkeley, 1962)
Mechanics of solid bodies, fracture mechanics, adhesive mechanics, composite materials, the cerebrospinal fluid, mixed boundary value problems
Daniel C.H. Yang, Ph.D. (Rutgers, 1982)
Robotics and mechanisms; CAD/CAM systems, computer-controlled machines

Associate Professors
Veronica S. Santis, Ph.D. (Cornell, 2007)
Bayesian approach to biomechanical modeling, treatise on human thumb
Richard E. Wirt, Ph.D. (Caltech, 2005)
Space and plasma propulsion, partially ionized plasma discharges, behavior of miniature plasma devices, spaceflight and space mission design, wind energy, solar thermal energy

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 nano-fabrication processes; MEMS
Yongjie Hu, Ph.D. (Harvard, 2011)
Heat transfer and electron transport in nanostructures; interfaces and packaging; thermal, electrical, optoelectronic, and thermoelectric devices and systems; energy conversion, storage, and thermal management; ultrafast optical spectroscopy and high-frequency electronics; nanomaterials design, processing, and manufacturing
Linhua Jin, Ph.D. (Harvard, 2014)
Mechanics of soft materials; continuum mechanics and applications in technologies; additive manufacturing, soft robotics and stretchable electronics, nanomechanics, and multiscale modeling
Raymond M. Spearrin, Ph.D. (Stanford, 2015)
Spectroscopy and gas dynamics, advanced optical sensors including laser absorption and fluorescence with experimental application to propulsion, energy systems and other reacting flow fields

Lecturers
Ravesh C. Amar, Ph.D. (UCLA, 1974)
Heat transfer and thermal science
Amiya K. Chatterjee, Ph.D. (UCLA, 1976)
Elastic wave propagation and penetration dynamics
Modeling, simulation, and analysis of spacecraft dynamics and pointing control systems; nonlinear dynamics of spinning bodies; concurrent engineering methods for space mission conceptual design
Damian M. Tooley, M.S. (MIT, 2004)
Guidance, navigation, and control for autonomous aircraft, launch vehicles, and missile systems, adaptive controls, automatic control reallocation for aircraft and reentry vehicles

Adjunct Professors
Dan M. Goebel, Ph.D. (UCLA, 1981)
Hollow cathode, magnetic-multiple ion sources for neutral beam injection
Lower Division Courses

1. Undergraduate Seminar. (1) Seminar, one hour; outside study, two hours. Introduction by faculty members and industrial lecturers to mechanical and aerospace engineering disciplines through current and emerging applications in aerospace, medical instrumentation, automotive, entertainment, energy, and manufacturing industries. P/NP grading.

Mr. Mal (F,W)


Ms. Lavine (Not offered 2016-17)

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current concern and non-course work. Requires: enrollment and standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Adjunct Assistant Professor Abdon E. Sepulveda, Ph.D. (UCLA, 1990)

Upper Division Courses

102. Dynamics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: course 96 (enforced), Physics 45A, Physics 8A. Fundamental concepts of Newtonian mechanics. Kinematics and kinetics of particles and rigid bodies in one and two dimensions. Impulse-momentum and work-energy relationships. Applications. Letter grading.

Mr. Lynch (F,W,Sp)

103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: Mathematics 32B, 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading.

Mr. Kavehpoor, Mr. Kim (F,W)

105A. Introduction to Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: Chemistry 20B, Mathematics 32B. Phenomenological thermodynamics. Concepts of equilibrium, temperature, and reversibility. First law and concept of energy; second law and concept of entropy. Equations of state and thermodynamic properties. Engineering applications of these principles in analysis and design of closed and open systems. Letter grading.

Mr. Pilon (F,W,Sp)

105D. Transport Phenomena. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: Mathematics 32B, 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading.

Mr. Ju, Ms. Lavine (F,W)

107. Introduction to Modeling and Analysis of Dynamic Systems. (4) Lecture, four hours; discussion, two hours; laboratory outside study, one hour; outside study, five hours. Enforced requires: courses M20 (or Computer Science 31), 82, Electrical Engineering 100. Introduction to modeling of physical systems, with examples of mechanical, fluid, thermal, and electrical systems. Description of these systems with coverage of impulse response, convolution, frequency response, first- and second-order systems transient response analysis, and convolution solution. Nonlinear differential equations and equilibria of system behavior, solution of differential equations, small signal linearization, large signal response. Block diagram representation and function of interconnections of systems. Hands-on experiments reinforce lecture material. Letter grading.

Mr. M’Closkey, Mr. Tsao (F,W)


Mr. Gupta (W)

CM141. Mechanics of Cells. (4) (Same as Bioengineering CM141.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requires: courses 96, 102, and 156A or 166A. Introduction to mechanisms of 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.

CM140. Introduction to Biomechanics. (4) (Same as Bioengineering CM140.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requires: courses 96, 102, and 156A or 166A. Introduction to mechanisms of 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. Gadh (F)


Mr. Pilon (Not offered 2016-17)

133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: course 82. Chemistry 20A. Review of nuclear physics, radioactivity and decay, and radiation interaction with matter. Nuclear fission and fusion processes and mass defect, chain reactions, criticality, neutron diffusion and multiplication, and applications. Introduction to nuclear power plants for commercial electricity production, space power, spacecraft propulsion, nuclear fusion, and nuclear science for medical uses. Letter grading.

Mr. Abdou (Not offered 2016-17)

135. Fundamentals of Nuclear Science and Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: course 82. Chemistry 20A. Review of nuclear physics, radioactivity and decay, and radiation interaction with matter. Nuclear fission and fusion processes and mass defect, chain reactions, criticality, neutron diffusion and multiplication, and applications. Introduction to nuclear power plants for commercial electricity production, space power, spacecraft propulsion, nuclear fusion, and nuclear science for medical uses. Letter grading.
110 / Mechanical and Aerospace Engineering
tern form. Concurrently scheduled with course CM241. Letter grading. Mr. Lynch (Not offered 2016-17)

150A. Intermediate Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 103, 105A, Thermodynamic properties of gases, aircraft engine jet cycle analysis, and component performance, component matching, advanced aircraft engine topics. Concurrently scheduled with course C250P. Letter grading. Mr. Eldredge, Ms. Karagozian (FW)

150B. Aerodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. 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. Karagozian (Not offered 2016-17)

150C. Combustion Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 103, 105A, 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. Mr. Eldredge, Mr. Ghoniem, Mr. Ju (FW,Sp)

1510G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 105A, Thermodynamic properties of gases, aircraft engine jet cycle analysis, and component performance, component matching, advanced aircraft engine topics. Concurrently scheduled with course C250P. Letter grading. Mr. Eldredge (Sp)

1510P. Aircraft Propulsion Systems. (4) Formerly numbered 150P) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. Rocket propulsion concepts, introduction of 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. Karagozian, Mr. Wirz (Sp)

1515A. Engineering Acoustics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Described for junior/senior engineering majors. Fundamental concepts of acoustics, propagation of sound, and sources of sound. Design of field measurements. Estimation of jet and blade noise with design aspects. Letter grading. Mr. Eldredge (Not offered 2016-17)

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; discussion, two hours; outside study, seven hours. Enforced requisite: course 154S. Classical preliminary design of aircraft, including weight estimation, performance and stability, and control consideration. Team assignment consists of preliminary design of low-speed aircraft. Letter grading. Mr. Bendiksen (W)


154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, one hour; outside study, seven hours. Requisites: courses 150A, 150B. Aircraft performance, flight mechanics, stability, and control; some basic ingredients needed for design of aircraft performance and control; aerodynamics of rough flow; or stability derivatives. Letter grading. Mr. Bendiksen (F)

155. Intermediate Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 102. Axioms of Newtonian mechanics, generalized coordinates, Lagrangian formulation, 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. Gibson (F)

156A. Advanced Strength of Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: courses 82, 96. Not open to students with credit for course 166A. Concepts of stress, strain, and material behavior. Stresses in loaded beams with symmetric and asymmetric cross sections. Torsion of cylinders and thin-walled structures; shear flow; press-fit and shrink-fit problems, rotating shafts. Curved beams. Contact stresses. Strength and failure, plastic deformation, fatigue, elastic instability. Letter grading. Mr. Maal (Sp)

156B. Material Failure in Mechanical Design I: Power Transmission. (4) Lecture, four hours; outside study, eight hours. Enforced 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. Statistical considerations in design. Applications of failure prevention in design power transmission shafting. Design project involving computer-aided design (CAD) and finite element analysis (FEA) modeling. Concurrently scheduled with course C296A. Letter grading. Mr. Ghoniem, Mr. Tsao (Sp)

157. Basic Mechanical and Aerospace Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 96, 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 (FW,Sp)

157A. Fluid Mechanics and Aerodynamics Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 150A, 150B, and 157 or 157P. Laboratory is in preparation of conceptual fluid mechanical phenomena in area of fluid mechanics/aerodynamics, as well as hands-on experience with design of experimental programs and use of modern experimental tools and techniques in field. Letter grading. Mr. Ghoniem, Mr. Ju (FW,Sp)

157S. 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 basic physical principles and characteristics of structures/systems to relevance of aerospace engineering. Letter grading. Mr. Ghoniem, Mr. Ju (Not offered 2016-17)

161A. Introduction to Astronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 102. Recommended: course 150A. Study of space vehicles, including spacecraft power, instruments, communications, structures, materials, thermal control, and attitude/orbit determination and control. Space mission development, launch vehicles/considerations, propulsion system. Letter grading. Mr. Wirz (W)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 161B. Preliminary design and analysis by students of Earth-orbiting or interplanetary vehicles and spacecraft. Students work in groups of three or four, with each student responsible primarily for one subsystem and for integration with whole. Letter grading. Mr. Wirz (Sp)

161D. Space Technology Hardware Design. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Enforced requisite: course 161B. Design by students of hardware with applications to space technology. Design for manufacture of SEASSE professional machine shop and tested by students. Letter grading. Mr. Wirz (Not offered 2016-17)


162D. Mechanical Engineering Design I. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisites: courses 94, 156A (or 163A or M183B), 162A (or 171A). Limited to seniors. First of two mechanical engineering capstone design courses. Lectures on engineering project management, design of thermal systems, mechatronics, mechanical systems, and mechanical components. Students work in teams to begin their two-term design project. Laboratory modules include CAD design, 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 design projects started in course 162D, making use of CAD design laboratory, CAD analysis laboratory, and mechatronics laboratory. Design theory, design tools, economics, marketing, manufacturability, quality, intellectual property, design for manufacture and assembly, design for safety and reliability, and engineering ethics. Students conduct hands-on design, fabrication, and testing. Culfinating project demonstrations or competition. Preparation of design project presentations in both oral and written formats. Letter grading. Mr. Ghoniem, Mr. Tsao (Sp)

166A. Analysis of Flight Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 82, 96. Not open to students with credit for course 166A. Introduction to two-dimensional elasticity, stress-strain laws, yield and failure; bending 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 166A or 166A. History of composites, stress-strain relations for composite materials, bending and extension of symmetric
laminates, failure analysis, design examples and design
simulations; composite consolidation; nonsymmetric laminates, micromechanics of com-
posites. Letter grading. Mr. Carman (W)

M168. Introduction to Finite Element Methods. (4)
(Same as Civil Engineering M133C) Lecture, four hours; dis-
tussion, one hour; outside study, six hours. Enforced requi-
tes: 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 elements; and elasticity and
shell elements. Practical use of FEM software; geometric
and analytical modeling; preprocessing and postpro-
cessing techniques; term projects with computers.
Letter grading. Mr. M. Khaleghi (F)

169A. Introduction to Mechanical Vibrations. (4)
Lecture, four hours; discussion, two hours; outside study,
Free, forced, and transient vibration of one and two
degrees of freedom systems, including damping.
Normal modes, coupling, and normal coordinates.
Vibr ation isolation devices, vibrations of continuous systems, and vehicle suspensions.
Letter grading. Mr. M. Saha (W)

171A. Introduction to Feedback and Control Sys-
tems: Dynamic Systems Control I. (4) Lecture, four
hours; discussion, two hours; outside study, six
hours. Enforced requisite: course 107. Introduction to
feedback and control systems design and system
stability. Modeling of physical systems in en-
gineering 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 (FW,Sp)

171B. Digital Control of Physical Systems. (4)
Lecture, four hours; discussion, two hours; outside study,
six hours. Enforced requisite: course 171A or Elec-
trical Engineering 141. Feedback control systems design and
digital control systems. Sampling theory. Z-transformation.
Discrete-time system representation. Design using
classical methods: performance specifications, root
locus, frequency response, loop-shaping compensa-
tion. Design using state-space methods: state feed-
back, state estimator, state estimator feedback con-
trol. Simulation of sampled data systems and prac-
tical aspects: roundoff errors, sampling rate selection, commutation delay. Letter grading.
Mr. Tiao (Sp)

172. Control System Design Laboratory. (4)
Lecture, four hours; laboratory, two hours; outside study,
six hours. Enforced requisite: course 171A. In-
duction to loop shaping controller design with application
to laboratory electromechanical systems. Power
spectrum models of noise and disturbances, and
performance trade-offs imposed by conflicting re-
quirements. Constraints on sensitivity function and
complementary sensitivity function imposed by non-
minimum phase plants. Lecture topics supported by
weekly hands-on laboratory work. Letter grading.
Mr. M. Closkey ( Not offered 2016–17)

174. Probability and Its Applications to Risk, Reli-
ability, and Quality Control. (4) Lecture, four hours;
discussion, two hours; outside study, six hours. Requi-
sites: Mathematics 33A. Introduction to probability
theory; random variables, distributions, functions of
random variables, models of failure of components,
reliability, redundancy, complex systems, stress-
strength models, fault tree analysis, statistical quality control. Dis-
cussion, one hour; outside study, seven
sampling. Letter grading. Mr. Mosleh (F)

C175A. Probability and Stochastic Processes in
Dynamical Systems. (4) Lecture, four hours; out-
side study, eight hours. Enforced requisite: course
82, 107. Probability spaces, random variables, sto-
chastic processes and processes, expectation, con-
titional expectation, Gauss/Markov sequences, and
minimum variance filter (Kalman filter) with appli-
cations. Concurrently scheduled with course
C271A. Letter grading. Mr. Speyer (F)

181A. Complex Analysis and Integral Transforms. (4)
Lecture, four hours; laboratory, one hour; outside study,
six hours. Enforced requisite: course 82. Complex variables, analytic functions, conformal mapping, contour inte-
grales, singularities, residues. Cauchy integrals; La-
place transforms; Fourier transforms; properties, convolution, FFT, appli-
cations in dynamics, vibrations, structures, and heat
conduction. Letter grading. Mr. Eldredge (W)

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 science. Eigen-
value problems, Sturm/Liouville theory. Development
and use of special functions. Representation by
means of orthogonal functions; Galerkin method.
Improper Green's function and transform methods.
Letter grading.

Mr. Eldredge, Mr. J. Kim (Not offered 2016–17)

182C. Numerical Methods for Engineering Ap-
plications. (4) Lecture, four hours; discussion, one
hour, outside study, seven hours. Enforced requi-
ts; courses 202 (or Civil Engineering 202 or Com-
puter Science 31), 82. Basic topics from numerical
analysis having wide application in solution of prac-
tical engineering problems: roundoff error, accuracy,
and errors. Solution of linear and nonlinear systems. Alge-
bric eigenvalue problem. Least-square methods,
numerical quadrature, and finite difference approximations.
Numerical solution of initial and boundary value
problems for ordinary and partial differential
 equations. Letter grading.

Mr. Zhong (F)

183A. Introduction to Manufacturing Processes. (4)
(Fomerly numbered 183.) Lecture, three hours;
laboratory, four hours; outside study, five hours. En-
forced requisite: Materials Science 104. Manufac-
turing fundamentals. Materials in manufacturing. So-
idization processes. Metal forming processes. Ma-
terial removal processes. Welding/joining.
Letter grading. Mr. C-J. Kim (FW,Sp)

M183B. Introduction to Microscale and Nanoscale
Manufacturing. (4) Same as Bioengineering M153,
Chemical Engineering M153, and Electrical Engi-
neering M153.) Lecture, three hours; laboratory,
four hours; outside study, five hours. Enforced requi-
ts: Chemistry 20A, 20B, 4AL, 4BL. Introdu-
to general manufacturing methods, mecha-
nisms, constraints, and microfabrication and nano-
fabrication. Focus on concepts, physics, and instru-
ments of various fabrication and microfabrication
and nanofabrication techniques that have been broadly
applied in industry and academia, including various
photolithography technologies, physical and chem-
ical deposition methods, and physical and chemical
electching methods. Hands-on experience for fabri-
cating microstructures and nanostuctures in modern
cleanroom environment. Letter grading.

Mr. Chiu (F,Sp)

C183C. Rapid Prototyping and Manufacturing. (4)
Lecture, four hours; laboratory, two hours; outside
study, six hours. Enforced requisite: course 183A.
Rapid prototyping (RP), solid freeform fabrication, or
additive manufacturing has emerged as popular
techniques of nanoscale fabrication, characterization,
and biodetection laboratory. Design, fabrication, and
use of special functions. Representation by
means of orthogonal functions; Galerkin method.
Improper Green's function and transform methods.
Letter grading. Mr. Li (W)

184. Introduction to Geometry Modeling. (4)
Lecture, four hours; laboratory, one hour; outside study,
four hours. Enforced requisite: courses M20 (or Civil
Engineering M20 or Computer Science 31), 94. Fun-
damentals in parametric curve and surface modeling, parametric spaces, splines, Bezier curve, coordinate transformations,
and geometric and finite form of surfaces, analytical
properties of curve and surface, hands-on experi-
ence with CAD/CAM designs and implementa-
tions. Letter grading.

Mr. Gadh (Not offered 2016–17)

185. Introduction to Radio Frequency Identifica-
tion and Its Application in Manufacturing and
Supply Chain. (4) Lecture, four hours; discussion,
two hours; outside study, six hours. Enforced requi-
ts: course M20 or Civil Engineering M20 or Com-
puter Science 31. Manufacturing today requires as-
ssembling of individual components into assembled
products, shipping of such products, and eventually
use, maintenance, and recycling of such products.
Radio frequency identification (RFID) chips installed on
components, subassemblies, and final assemblies of
products allows them to be tracked automatically as
they move and transform through manufacturing
and inventory. RFID tags have memory and small CPU
that allows information about product status to be
written, read, and transferred. Tag data can then be
forwarded by reader to enterprise software
by way of RFID middleware. Study of how
RFID is being utilized in manufacturing, with focus on
automotive and aerospace. Letter grading.

Mr. Gadh (Sp)

C186. Applied Optics. (4) Lecture, four hours;
discussion, two hours; outside study, six hours. Requi-
ts: Engineering 11C. Fundamentals of optical systems. Geometric optics and aberration theory. Dis-
fract and interference. Fourier optics, beam op-
tics. Propagation of light, Snell's law, and Huygen
principle. Refraction and reflection. Plane waves,
spherical waves, and wave-front aberration. Total internal reflection. Polarization, polarizers, and wave-plates.
Lenses and aberrations, lens laws and formation of
images, resolution and primary aberrations. Simple
optical instruments, still cameras, shutters, apertures.
Design of telescopes, microscope design, projection
system design. Interference, Young's slit experiment
and fringe visibility. Michelson interferometer, mul-
tiple-beam interference and thin film coatings. Diff-
raction theory, Fraunhofer and Fresnel diffraction,
Fresnel zone plate. Fiber optics, waveguides and
tubes, fiber coupling, types of fiber: single and multim-
time. Concurrency scheduled with course C287L. Letter grading.

Mr. Chiu (F)

C187L. 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 bio-
logical principles related to these techniques, top-
down, and bottom-up nanofabrication - nanocharacterization (AEM, SEM, etc.), and
optical and electrochemical biosensors. Students en-
couraged to create their own ideas in self-designed experiments. Concurrently scheduled with course
C287L. Letter grading.

Mr. Y. Chen (Sp)

188. Special Courses in Mechanical and Aero-
ospace Engineering. (2 to 4) Lecture, two to four
hours; outside study, four to eight hours. Special
topics in mechanical and aerospace engineering for
undergraduate students taught on experimental or
permanent basis, such as those taught by resident
and visiting faculty members. May be repeated once
for credit with topic or instructor change. P/NP or
letter grading.

194. Research Group Seminars: Mechanical and
Aerospace Engineering. (2 to 4) Seminar, two hours.
Designed for undergraduate students who are part of
research groups. Disciplinary seminars on currents
in field. Student presentation of proj-
ects in research area. May be repeated for
credit. P/NP or letter grading.

Mechanical and Aerospace Engineering / 111
Graduate Courses

231A. Convective Heat Transfer Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: course 150D. Fluid mechanics, heat, and mass transfer. Discussion of convection in laminar and turbulent flow. Interpretation of theoretical results. Numerical analysis. Fluids. Letter grading. Mr. Eldredge (Sp)


233A. Nuclear Reactor Theory. (4) Lecture, four hours; outside study, eight hours. Underlying physics and mathematics of nuclear reactor (fission) core design. Diffusion theory, reactor kinetics, slowing down and thermalization, multigroup methods, introduction to transport theory. Letter grading. Mr. Eldredge (Sp)

237D. Design and Testing of Small Satellites. (4) Lecture, four hours; outside study, eight hours. Demand response; transactive/price-based load control; home-area network, smart energy profile; advanced metering infrastructure; renewable energy integration; solar and wind generation intermittency and correction; microgrids; grid stability; energy storage and electric vehicles-simulation; monitoring; distribution and transmission grids; consumer-centric technologies, sensors, communications, electrical computing; wireless, wireline, and powerline communications for smart grids; grid modeling, stability, and control; frequency and voltage regulation; ancillary services; wide-area situational awareness, phasor measurements; analytical methods and tools for modeling and analysis. Concurrently scheduled with course C137. Letter grading. Mr. Gadh (F)

252B. Clustered Data Analysis and Information Retrieval (3) Lecture, four hours; outside study, eight hours. Fundamental concepts in data mining and statistical learning. Applications to various domains such as bioinformatics, social media, and informatics. Letter grading. Mr. Lynch (Not offered 2016-17)

242D. Introduction to Multifield Materials. (4) Lecture, four hours; outside study, eight hours. Overview of different types of multifield materials, including strain mediated. Basic crystal structure of single-phase multifilms, as well as fundamental physics underlying ferroelectricity and ferromagnetism. Material science description of thin film growth, in isolation and on linear and nonlinear behavior with associated mechanisms such as spin reorientation. Presentation of analytical tools necessary to predict material response to an applied electric field. Passive devices. Letter grading. Ms. Karagozian, Mr. J. Kim (W)

250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250A. Fundamental principles of fluid dynamics applied to the study of fluid mechanics. Focus on the interplay of fluid mechanics and thermal sciences. Letter grading. Mr. Carman (Sp)

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250A. Focus on the Navier-Stokes equations, vorticity dynamics, decomposition of flow fields, potential flow. Letter grading. Mr. Eldredge, Mr. J. Kim (W)

250C. Compressible Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250A, 156B. Focus on the Navier-Stokes equations, vortex dynamics, decomposition of flow fields, potential flow. Letter grading. Ms. Karagozian, Mr. J. Kim (Sp)


250E. Spectral Methods in Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. En- forces requisites: courses 250A, 250B. Introduction to basic concepts and techniques of various spectral methods applied to solving partial differential equations. Particular emphasis on techniques of solving unsteady three-dimensional Navier-Stokes equations. Topics include spectral representation of functions, discrete Fourier transform, etc. Letter grading. Mr. J. Kim (Not offered 2016-17)

250F. Hypersonic and High-Temperature Gas Dynamics. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 250C. Molecular and chemical description of equilibrium and nonequilibrium hypersonic and high-temperature gas flows. Chemical thermodynamics and statistical thermodynamics for calculation gas properties, equilibrium flows of real gases, vibrational and chemical rate processes, nonequilibrium flows of real gases, and computational fluid dynamics for noneq- uilibrium hypersonic flows. Letter grading. Mr. Zhong (Not offered 2016-17)

250G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 103. Mechanics of 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)

Mr. Edredge (F)


Mr. Kavehpour (Not offered 2016-17)

C250P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 105A, 150A. Thermodynamic properties, turbines, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Concurrently scheduled with course C150P. Letter grading.

Ms. Karagozian, Mr. Wirz (Sp)

C250R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 103, 105A. Rocket propulsion concepts, including chemical rockets, liquid propellant, gas- and solid-propellant rocket engines, electric ion (plasma) rockets, nuclear rockets, and solar-powered vehicles. Current issues in launch vehicle technologies. Concurrently scheduled with course C150R. Letter grading.

Mr. Karagozian, Mr. Wirz (Sp)

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 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 2016-17)


Mr. J. Kim (Not offered 2016-17)


Ms. Karagozian (Not offered 2016-17)

252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Basic concepts in chemical kinetics: molecular collisions, distribution functions and averaging, semiempirical and ab initio potential surfaces, trajectory calculations, statistical reaction rate theories. Practical topics: large-scale chemical mechanisms from combustion chemistry of several elements, etc. Letter grading.

Ms. Karagozian (Not offered 2016-17)

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, ion and electron diffusion, gas diffusion, Child/Langmuir law, basic plasma devices, electron emission and work function, thermal distributions, vacuum and vacuum systems, space-charge, particle collisions and ionization, plasma discharges, sheaths, and electric arcs. Letter grading.

Mr. Wirz (Not offered 2016-17)

254A. Special Topics in Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 150A, 150B. Special topics of current interest in advanced aerodynamics. Examples include transonic flow, hypersonic flow, sonic booms, and unsteady aerodynamics. Letter grading. (May be repeated for credit. S/U grading.)

Mr. Zhong (Not offered 2016-17)

255A. Advanced Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 169A. Variational principles and Lagrange equations. Kinematics and dynamics of rigid bodies; procession and nutation of spinning bodies. Letter grading.

Mr. Gibson (Sp)

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. 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; bifurcation and non-linear resonance. Application to mechanical systems. Letter grading.

Mr. M’Closkey (Not offered 2016-17)

M256A. Linear Elasticity. (4) (Same as Civil Engineering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Linear elasticstics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastostatic problems; elastic waves, elasstics, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Introduction to boundary integral equation method. Letter grading.

Mr. W. Ju, Mr. Mal (F)

M256B. Nonlinear Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stresses, Cauchy equations of motion, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoelasticity; linearization of field equations; solution of selected problems. Letter grading.

Mr. W. Ju, Mr. Mal (W)

M256C. Plasticity. (4) (Same as Civil Engineering M230C.) Lecture, four hours; outside study, eight hours. Requisite: course M256B. Classical rate-independent plasticity theory, yield functions, flow rules and thermodynamics. Classical rate-de- pending viscoplasticity, Perzyna and Duvaut/Lions types of viscoplasticity and creep, Return mapping algorithms for plasticity and visco-plasticity. Finite element implementations. Letter grading.

Mr. Gupta (Not offered 2016-17)

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, solutions in non-linearly elastic materials at scales ranging from atomistic through micro-structure or transitional and up to continuum. Discussion of atomistic simulation methods (e.g., molecular dynamics, Langevin dynamics, and kinetic Monte Carlo) and their applications at nanoscale. Development of applications in atomic and statistical mechanics methods in areas of nanostructure and microstructure self-organization, heterogeneous plastic deformation, material instabilities, and failure mechanisms. Prerequisite: applications of these emerging modeling techniques to surfaces and interfaces, grain boundaries, dislocations and defects, surface growth, quantum dots, nano-tubes, nanoclusters, thin films (e.g., optical thermal barrier coatings and ultra-thin materials), nano-identification, smart (active) materials, nanotubing and microbending, and torsion. Letter grading.

Mr. Gholien (Not offered 2016-17)

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 (possible help from graduate students). Letter grading.

Mr. Kavehpour

259B. Seminar: Advanced Topics in Solid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in solid mechanics on 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.


Mr. Klug (F)


Mr. Mal (Not offered 2016-17)

262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisites: course 165C. Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology. Micro/macroscale analysis, including classical laminate theory, shear lag theories, and hexagonal honeycomb models, and homogenization techniques as they apply to active materials. Active systems design, incl-worm, and bimorph. Letter grading.

Mr. Carman (Sp)

263A. Kinematics of Robotic Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisites: courses 155, 171A. Kinematic models of serial robotic manipulators, including spatial descriptions and transformations (Euler angles, Denavit-Hartenberg/DFH 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; discussion, one hour; outside study, eight hours. Enforced requisite: course 255B. Dynamics models of serial and parallel robotic manipulators, including review of spatial descriptions and transformation matrices. Kinematics, linear and angular velocities, Jacobian matrix (velocity and force), velocity propagation method, force propagation method, explicit formulation of Jacobian (Newton-Euler formulation, Lagrangian formulation), trajectory generation, introduction to parallel manipulators. Letter grading. Mr. Rosen (W)

263C. 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 topics from nonlinear and adaptive control, hybrid control, nonholonomic systems, vision-based control, and perception. Letter grading. Mr. Santos (Sp)

263D. Advanced Topics in Robotics and Control. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 263C. Current and advanced topics in robotics and control, including kinematics, dynamics, control, mechanical design, advanced sensor integration, flexible-link manipulators, redundant manipulators, human-robot interaction, teleoperation, haptics. Letter grading. Mr. Ghoniem (W)


M269B. Advanced Dynamics of Structures. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course M269A. Classical point of field of aerodynamics from Euler's equation, zeroth-order approximations, geometrical derivation of lift and drag, stall, shock waves, boundary layer separation. Letter grading. Mr. Bendiksen (Sp)

M269C. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course M269B. Presentation of field of aeroelasticity with emphasis on stability. Lyapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theory. Letter grading. Mr. M'Closkey (W)

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical Engineering M240A.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 171A or Electrical 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 governing the single-input single-output (SISO) and multi-input multi-output (MIMO) performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading. Mr. M'Cluskey (F)

M270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course M270A or Electrical Engineering M240A. Existence and uniqueness of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time systems, finite-time and infinite-time problems; Hamilton-Jacobi-Bellman equations; discrete-time Riccati equations; implications of controllability, stabilizability, observability, and detectability solutions. Letter grading. Mr. Gibson (W)

M270C. Optimal Control. (4) (Same as Chemical Engineering M290C and Electrical Engineering M240C.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 270B. Applications of variational methods, Pontryagin maximum principle, Hamilton-Jacobi-Bellman equations; (dynamic programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading. Mr. Speyer (Not offered 2016-17)

C271A. Probability and Stochastic Processes in Dynamical Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: courses 82, 107. Probability spaces, random variables, stochastic sequences and processes, expectation, conditionally expectations, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C175A. Letter grading. Mr. Speyer (F)

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 271A. Stochastic dynamic programming, certainty equivalence principle, separation theorem, information states. Linear-quadratic-Gaussian problem, linear-exponential-Gaussian problem. Relationship between stochastic control and robust control. Letter grading. Mr. Speyer (Not offered 2016-17)

271D. Seminar: Special Topics in Dynamical Systems Control. (4) Lecture, four hours; outside study, eight hours. Seminar on current research topics in dynamical 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 2016-17)

272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical Engineering M242A.) Lecture, four hours; outside study, eight hours. Enforced requisite: course M270A or Chemical Engineering M280A or Electrical 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), invariance, center manifold theorem, input-to-state stability and small-gain theory. Letter grading. Mr. Chiou (F)

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: courses 171A, M270A. Graduate-level introduction to analysis and design of multivariable control systems: loop-shaping, performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading. Mr. M'Cluskey (Not offered 2016-17)

275A. System Identification. (4) Lecture, four hours; outside study, eight hours. Methods for identification of dynamical systems from input/output data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of conversion to continuous-time models. Models identified include transfer functions and state-space models. Discussion of applications to control, signal processing, and aero-space engineering, including identification of flexible structures, microelectromechanical systems (MEMS) devices, and acoustic ducts. Letter grading.

M276. Dynamic Programming. (4) (Same as Electrical Engineering M237L) Lecture, four hours; outside study, eight hours. Enforced requisite: Electrical Engineering 232A or 236A or 238B. Introduction to numerical analysis of sequential decision processes. Finite horizon model in both deterministic and stochastic cases. Finite-state infinite horizon model. Methods of solution. Examples from inventory theory, finance, optimal control and estimation, sampling, optimization, and material optimization, communications. Letter grading.

277. Advanced Digital Control for Mechatronic Systems. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: courses 117S, M270A. Digital signal processing and control analysis of mechatronic systems. System inversion-based digital control algorithms and robustness properties, Youla parameterization of stabilizing controller design, repetitive and learning control, and adaptive control. Real-time control investigation of topics to selected mechatronic systems. Letter grading. Mr. Iwasaki (Not offered 2016-17)

279. Dynamics and Control of Biological Oscillations. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: courses 107, M270A. Analysis and design of dynamical mechanisms underlying biological control systems that generate coordinate oscillations. Topics include neuronal information processing through action potentials (spike train), central pattern generator, coupled nonlinear oscillators, optimal gaits (periodic locomotion). Letter grading. Mr. Ho, Mr. C-J. Kim (W)

281. Microsystems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: courses 102, 103, 105D. Fundamental issues of being in microscopic world and mechanical and electronic devices. Topics include scale issues, surface tension, superhydrophobic surfaces and applications, and electrowetting and applications. Letter grading. Mr. Ho, Mr. C-J. Kim (F)

M282. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Bioengineering M252B and Electrical Engineering M252.) Lecture, four hours; outside study, eight hours. Enforced requisite: course M183B. Advanced discussion of micromachining processes used to fabricate MEMS. Coverage of photolithography, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. C-J. Kim (F)

284. Sensors, Actuators, and Signal Processing. (4) Lecture, four hours; outside study, eight hours. Principles and performance of micro transducers. Applications of unique properties of micro transducers for distributed and real-time control of engineering problems. Associated signal processing requirements for these applications. Letter grading. Mr. Chiou (Sp)

285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course M52. Introduction to MEMS design methods, device models, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. Chiu (Sp)

286. Applied Optics. (4) Lecture, four hours; outside study, six hours. Enforced requisite: Physics 1C. Fundamental principles of optical systems, Geometric optics and aberration theory, Diffraction and interference. Fourier optics, beam op-
M287. Nanoscience and Technology. (4) Same as Chemical Engineering M287.) Lecture, four hours; outside study, eight hours. Enforced requisite: course CM280A. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanofabrication, nanocharacterization, nanomaterials, nanoelectronics, and nanobiotechnology. Technology. Introduction to new knowledge and techniques in nano areas to understand scientific principles related to these techniques, top-down and bottom-up (self-assembly) nanofabrication, nanocharacterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create new ideas in multidisciplinary nano areas. Letter grading. Mr. Chiou

C287L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory practicum, 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, nanocharacterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create new 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. Requisites: Materials Science 104, Physics 17. Science and engineering of laser microscopic fabrication of advanced materials, including semiconductors, metals, and insulators. Topics include fundamentals in laser interactions with advanced materials, laser safety issues (thermal, chemical, carrier, etc.) in laser microfabrication, state-of-art optics and instrumentation for laser microfabrication, applications such as rapid prototyping, surface modifications (physical/chemical), micro-and nanochannels for three-dimensional MEMS (microelectromechanical systems) and data storage, up-to-date research activities. Student term projects. Letter term grading.

294A. Compliant Mechanism Design. (4) Formerly numbered 294B.) Lecture, four hours; outside study, eight hours. Requisite: linear algebra. Advanced compliant mechanism synthesis approaches, modeling techniques, and optimization tools. Fundamentals of flexible constraint theory, principles of constraint-based design, projective geometry, screw theory kinematics, and freedom and constraint topologies. Applications: topological analysis of compliant mechanisms, general purpose flexure bearings, microstructural architectures, MEMs, optical mounts, and nanoscale positioning systems. Hands-on exercises include build-your-own flexure, CAD and FEAs 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. Requisites: Graduate engineering student (2 to 12). Examination of emerging discipline of radio frequency identification (RFID), including basics of RFID, how RFID systems function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading. Mr. Gadh (Not offered 2016-17)

C296A. Material Failure in Mechanical Design I: Power Transmission. (4) Formerly numbered 296A.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 156A or 166A. Material selection in mechanical design. Load and stress analysis. Design and stiffness. Failure due to static loading. Fatigue failure. Design for safety factors and reliability. Statistical considerations in design. Applications of failure prevention in design of power transmission shafting. Design project involving computer aided design (CAD) and finite element analysis (FEA) modeling. Concurrently scheduled with course C156B. Letter grading. Mr. Ghoniem (Sp)

296B. Material Failure in Mechanical Design II: High-Temperature Components. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 156A, C296A. 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 2016-17)

C297A. Rapid Prototyping and Manufacturing. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Recommended requisite: level of knowledge in manufacturing equivalent to course 183A and CAD capability. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as popular manufacturing technology to accelerate product creation in last two decades. Machine for layered manufacturing builds parts directly from CAD models. This novel manufacturing technology enables building of parts that have traditional impossible internal structures, including those with complex shapes or of variety in materials. In analogy to speed and flexibility of desktop publishing, rapid prototyping is also called desktop manufacturing, with actual three-dimensional solid objects instead of mere two-dimensional images. Methodology of rapid prototyping has also been extended into meso-/micro-nano-scale to produce three-dimensional functional microstructures. Concurrently scheduled with course C183C. Letter grading. Mr. Li (W)

M297B. Material Processing in Manufacturing. (4) Formerly numbered 297A.) (Same as Materials Science M297B.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 183A. Thermodynamics, principles of material processing: phase equilibria and transitions, transport mechanisms of heat and mass, nucleation and growth of microstructure. Applications in casting/solidification, welding, consolidation, chemical vapor deposition, infiltration, composites. Letter grading. Mr. Ghoniem (Sp)

M297C. Composites Manufacturing. (4) Formerly numbered 297D.) (Formerly numbered 297A.) (Same as Materials Science M297C.) Lecture, four hours; outside study, eight hours. Requisites: course 186C, Materials Science 151. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/compression molding, filament winding, pultrusion, resin transfer molding, automation, material removal and assembly, metal and ceramic matrix composites, quality assurance. Letter grading. Mr. Ghoniem (Not offered 2016-17)

298. Seminar: Engineering. (2 to 12) 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

UCLA
7440 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601

310-825-6542
fax: 310-825-3081
http://www.msol.ucla.edu

Jenn-Ming Yang, Ph.D., Associate Dean

Scope and Objectives

The primary purpose of the Master of Science in Engineering online degree programs is to enable employed engineers and computer scientists to augment their technical education beyond the Bachelor of Science degree and to enhance their value to the technical organizations in which they are employed. The training and education that the programs offer are of significant importance and usefulness to engineers, their employers, California, and the nation. It is at the M.S. level that engineers have the opportunity to learn a specialization in depth, and those engineers with advanced degrees may also renew and update their knowledge of the technology advances that continue to occur at an accelerating rate.

The M.S. programs are addressed to those highly qualified employed engineers who, for various reasons, do not attend the on-campus M.S. programs and who are keenly interested in developing up-to-date knowledge of cutting-edge engineering and technology.

Graduate Study

For information on graduate admission, see Graduate Programs, page 24.

The following introductory information is based on the 2016-17 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. The directed study 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; ilackman@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 lectures 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.

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; cslynch@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/ for further information.

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 institutions, 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 Engineering), Director; rubin@ee.ucla.edu
The electrical engineering program covers a broad spectrum of specializations in communications and telecommuncations, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, micro-electromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

M.S. in Engineering—Electronic Materials
Ya-Hong Xie, Ph.D. (Materials Science and Engineering), 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 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 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

UCLA
6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
310-825-9580
http://engineer.ucla.edu

Professors Emeriti
Allen B. Rosenstein, Ph.D.
Bonham Spence-Campbell, E.E.

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 24.

Faculty Areas of Thesis Guidance
Professors Emeriti
Allen B. Rosenstein, Ph.D. (UCLA, 1958)
Bonham Spence-Campbell, E.E. (Cornell, 1939)

Development of interdisciplinary engineering/social science teams and their use in planning and management of projects and systems

Lower Division Courses
10A. Introduction to Complex Systems Science. (5) Lecture, four hours; outside study, eight hours. How macroscopic patterns emerge dynamically from local interactions of large number of interdependent (often heterogeneous) entities, without global design or central control. Such emergent order, whose explanation cannot be reduced to explanations at level of individual entities, is ubiquitous in biology and human social 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 adapt their behavior to external conditions. In biological and social systems, complexity science goes beyond traditional mathematics and statistics in its use of multilayer computational models that better capture these complex, adaptive, and self-organizing phenomena. Letter grading.

Mr. Bragin (Not offered 2016-17)

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

20. First-Year Engineering Transition Bridge. (2) Seminar, three hours. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Designed to immerse incoming computing students in foundation concepts and principles of computer science, with focus on fundamental computer programming principles, methodologies, and techniques. Basic concepts of programming and C++ computing language. Offered in summer only. P/NP grading.

21. Computing Immersion Summer Experience. (2) Seminar, three hours. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Designed to immerse incoming computing students in foundation concepts and principles of computer science, with focus on fundamental computer programming principles, methodologies, and techniques. Basic concepts of programming and C++ computing language. Offered in summer only. P/NP grading.

22. Summer Bridge Review for Enhancing Engineering Students. (2) Seminar, three hours. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Designed to immerse incoming computing students in foundation concepts and principles of computer science, with focus on fundamental computer programming principles, methodologies, and techniques. Basic concepts of programming and C++ computing language. Offered in summer only. P/NP grading.

96C. Introduction to Engineering Design: Internet of Things. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Recommended for students pursuing Aerospace Engineering, Bioengineering, Computer Science, Electrical Engineering, and Mechanical Engineering majors. Introduction to engineering design while building teamwork and communication skills and examination of engineering majors offered at UCLA and of engineering careers. Hands-on experience with state-of-art Internet of things (IoT) technology to offer students opportunity to rapidly develop innovative and impactful projects that provide ideal introduction to computing systems and IoT applications specific to their major field. IoT technology has become one of most important advanced technology history with applications ranging from wearable devices for healthcare to residential monitoring systems, natural resource protection and management, intelligent vehicles and transportation systems, robotics systems, and energy conservation. Completion of hands-on engineering design projects, preparation of short report describing projects, and presentation of results. Letter grading.

Mr. Stafanuddi (FW)

101. Principles of Nanoscience and Nanotechnology. (4) (Same as Materials Science M101S) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, Physics 1C. Introduction to underlying science encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena that emerge in very small systems (typically with feature sizes below few hundred nanometers) explained using basic concepts from physics and chemistry. Chemical, physical, and electronic properties, electron transport, structural stability, self-assembly, templated assembly and applications of various nanostructures such as quantum dots, nanoparticles, quantum dots, metal and metal oxides, carbon nanotubes. Letter grading.

Mr. Ozolins (F)

102. Synthetic Biosystems and Nanosystems Design. (4) (Same as Materials Science M102S) Lecture, four hours; discussion, one hour; outside study, eight hours. Required: course M101, Life Sciences 3. Introduction to current progress in engineering to integrate biosciences and nanosciences into synthetic systems, where biological components are reengineered and recombined 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 encouraged to design novel biosystems and nanosystems for non-trivial task required. Letter grading.

Mr. Liao

M103. Environmental Nanotechnology: Implications and Applications. (4) (Same as Civil Engineering M103S) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: course M101. Introduction to potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental protection. Technical contents include three multidisciplinary areas: (1) physical, chemical, and biological properties of nanomaterials, (2) transduction, reactivity, and toxicology of materials in natural environmental systems, and (3) use of nanotechnology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading.

Mr. Hoek (Sp)
110. Introduction to Technology Management and Economics (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) decision processes and their effect on technology management. How individuals, firms, and governments impact successful commercialization of high-technology products and services. Letter grading. Mr. Monbouquette (F,W)

111. Introduction to Finance and Marketing for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of finance and marketing research and practice as they relate to technology commercialization. Internal (within firm) and external (in marketplace) marketing and financing of high-technology innovation. Concepts include present value, future value, discounting, 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. Monbouquette (F,W)

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Designed for seniors and graduate students. Holistic view of engineering discipline, covering lifecycle of engineering, processes, and techniques used in industry today. Multidisciplinary systems engineering perspective in which aspects of electrical, mechanical, and computer software engineering are incorporated. Three specific case studies in communication, sensor, and processing systems included to help students understand these concepts. Special attention paid to link material covered to engineering curriculum offered by UCLA to help students integrate and enhance their understanding of knowledge already acquired. Motivation of students to continue their learning and reinforce lifelong learning habits. Letter grading. Mr. Monbouquette (Sp)

183EW. Engineering and Society. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or English as a Second Language 36. Not open for credit to students with credit for course 183EW. Limited to sophomore/junior engineering students. Professional and ethical considerations in practice of engineering. Impact of technology on society and on development of moral and ethical values. Contemporary environmental, biological, legal, and other issues created by new technologies. Emphasis on research and writing within engineering environments. Writing and revision of about 20 pages total, including two individual technical essays and one team-written research report. Readings address technical issues and written form. Satisfies engineering writing requirement. Letter grading. Mr. Wesel (F,Sp)

185EW. Art of Engineering Endeavors. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or English as a Second Language 36. Not open for credit to students with credit for course 183EW. Designed for junior/senior engineering students. Nontechnical skills and experiences necessary for engineering career success. Importance of group dynamics in engineering practice. Teamwork and effective group skills in engineering environments. Organizations and control of multidisciplinary complex engineering projects. Forms of leadership and qualities and characteristics of effective leaders. 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 environments. Satisfies engineering writing requirement. Letter grading. Mr. Wesel (F,Sp)

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

192. Fundamentals of Engineering Mentorship. (2) Seminar, two hours; outside study, four hours. Prerequisites: completion of at least one year of engineering or science and one to two years work experience in selected domain. Art and science of mentoring. Introduction toarchitecting methodology—paradigm and tools. Principles of archiecting through analysis of architecture designs of major existing systems. Discussion of selected elements of architectural practices, such as representation models, design progression, and architecture framework. Examination of professionalization of system architecting. Letter grading. Mr. Lynch, Mr. Wesel

203. System Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course 201. Designed for graduate students with B.S. degrees in engineering or science and one to two years work experience in selected domain. Art and science of architeccting. Introduction to archiecting methodology—paradigm and tools. Principles of architecting through analysis of architecture designs of major existing systems. Discussion of selected elements of architectural practices, such as representation models, design progression, and architecture framework. Examination of professionalization of system architecting. Letter grading. Mr. Lynch, Mr. Wesel

204. Trusted Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Trusted systems engineering principles, and using them as guide to formulate and construct trusted development processes. Ensuring the security, confidentiality, and integrity of systems, while understanding the threat environment in which systems operate. Emphasis on research and writing in engineering environments.Letter grading. Mr. Pottie (Sp)

205. Model-Based Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Model-based systems engineering (MBSE) and systems modeling language (SysML) taught through lectures and hands-on, project-based assignments. A systems engineer must be able to articulate complex system architectures and technologies within a systems context, and to communicate with domain experts, both inside and outside the organization. Lecture and hands-on coursework provides students with experience in leveraging SysML to guide a team in the architectural design of complex systems. Students will learn the roles and responsibilities of different stakeholders in the systems development process. Letter grading.
obtained, as course covers Object Management Group (OMG) Certified Systems Modeling Professional (OCSSMP) tests, 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 requisites: course 204, Computer Science 236. Systems are constructed to perform complex functions and services. How to understand needs of users, analysis of requirements, design of systems, creation of various system architecture products, and design and integration of various components into systems that perform these functions and services. System assurance addresses confidence that systems meet specified operational requirements based on evidence provided by applying 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 and operating issues and decision making in managing enterprises. Applications use organization’s resources to transform inputs into goods and utilizes them to provide service, or does both. Conceptual framework and set of analytical tools provided to enable students to better understand why processes behave as they do. Given this understanding, students are able to involve themselves in organization’s defining strategic decisions, those related to key processes affecting organizational unit’s performance. Letter grading. Mr. Vandenberghe (Sp)

211. Financial Management. (4) Lecture, four hours; outside study, eight hours. Introduction to concepts reflecting material generally covered in certain 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 pharmaceutical industries. Letter grading. Mr. Lichtman, Mr. J-M. Yang (F)

213. Data and Business Analytics. (4) Lecture, four hours; outside study, eight hours. Coverage of wide variety of spreadsheet models that can be used to solve business and engineering problems, with emphasis on mastery of Excel spreadsheet modeling as integral part of analytic decision making. Managerial models include data modeling, regression and forecasting, linear programming, network and distribution models, integer programming, nonlinear programming, and Monte Carlo simulation. Problems from operations, finance, and marketing taught by spreadsheet example and describe general managerial situations from various industries and disciplines. Development of spreadsheet models to facilitate decision making. Letter grading. Mr. Mosleh (F)

214. Management Communication. (4) Lecture, four hours. Exploration of knowledge, attributes, skills, and strategies necessary to succeed communicatively in workplace, with focus on business presentation skills, visual and verbal persuasion skills, and interpersonal communication skills. Letter grading. Mr. J-M. Yang

215. Entrepreneurship for Engineers. (4) Lecture, four hours; outside study, eight hours. Limited to graduating engineering students. Topics in starting and developing high-tech enterprises and intended for students who wish to complement their technical education with introduction to entrepreneurship. Letter grading. Mr. Abe, Mr. Cong, Mr. Wesel (W)

299. Capstone Project. (4) Activity, 10 hours. Preparation: completion of minimum of four 200-level courses in online M.S. program. Project course that satisfies UCLA complete comprehension 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,W,Sp)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, four hours; outside study, five hours. Enforced requisite: course 472C (credit to be given on completion of courses 472B and 472C) and 90 minutes (course 471C). Limited to Engineering Executive Program students. Language of instruction with introduction to entrepreneurship. Letter grading. Mr. J-M. Yang (F)

472A-472D. Engineer in Business Environment. (3-3-1.5) Lecture, three hours (courses 472A, 472B, and 90 minutes (course 471C). Limited to Engineering Executive Program students. Influences of human relations, laws, social sciences, humanities, and fine arts on development and utilization of natural and human resources. Interaction of technology and society, past, present, and future. Change agents and resistance to change. S/U or letter (471A) grading; in Progress (471B) and S/U or letter (471C) grading.

472A-472D. Engineer in Business Environment. (3-3-1.5) Lecture, three hours (courses 472A, 472B, and 90 minutes (course 471C). Limited to Engineering Executive Program students. Language of business for engineering executive. Accounting, finance, business economics, business law, and marketing. Laboratory in organization and management problem solving. Analysis of actual business problems of firm, community, and nation, provided through cooperation and participation with California business corporations and government agencies. In Progress (472A, 472C) and S/U or letter grading (credit to be given on completion of courses 472B and 472D).

473A-473B. Analysis and Synthesis of Large-Scale System. (3-3-3) Lecture, two and one half hours; outside study, six hours. Limited to Engineering Executive Program students. Problem area of modern industry or government is selected as class project, and its solution is synthesized using quantitative tools and methods. Project also serves as laboratory in organization for goal-oriented technical group. In Progress (473A) and S/U (473B) grading.

495A. Teaching Assistant Training Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: appointment as teaching assistant. Limited to graduate engineering students. Seminar on communication of engineering principles, concepts, and methods, preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading. (F)

M495I. Teaching Preparation Seminar: Writing for Engineers. (2) (Formerly numbered M495I.) (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,W,Sp)

M495J. Supervised Teaching of Writing for Engineers. (2) (Formerly numbered M495J.) (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 to record enrollment of UCLA graduate 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) STARnet 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 multiferroic devices. The fundamental research activities work synergistically with the center’s industrial partners to translate the concepts into applications such as memory, antennae, 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 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 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 Engineering), Majid Sarrafzadeh, Ph.D. (Computer Science), Co-Directors; http://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

### Freshman Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>English Composition 3—English Composition, Rhetoric, and Language</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mathematics 31A—Differential and Integral Calculus</td>
<td>4</td>
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<tr>
<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>
<td></td>
<td>Physics 1A—Mechanics</td>
<td>5</td>
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<tr>
<td>3rd Quarter</td>
<td>Mathematics 32A—Calculus of Several Variables</td>
<td>4</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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<td>HSSEAS GE Elective</td>
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### Sophomore Year

<table>
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<tr>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Mathematics 32B—Calculus of Several Variables</td>
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<tr>
<td></td>
<td>Physics 1C/4BL—Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td>2nd Quarter</td>
<td>Materials Science and Engineering 104—Science of Engineering Materials</td>
<td>4</td>
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<tr>
<td></td>
<td>Mathematics 33A—Linear Algebra and Applications</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 96—Static and Strength of Materials</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 105A—Introduction to Engineering Thermodynamics</td>
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<tr>
<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31</td>
<td>4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 82—Mathematics of Engineering</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 102—Dynamics of Particles and Rigid Bodies</td>
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<td>HSSEAS GE Elective</td>
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### Junior Year

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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 100—Electrical and Electronic Circuits</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 103—Elementary Fluid Mechanics</td>
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<tr>
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<td>HSSEAS Ethics Course</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td>2nd Quarter</td>
<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems</td>
<td>4</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 150A—Intermediate Fluid Mechanics</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering 150B—Aerodynamics</td>
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<td></td>
<td>Mechanical and Aerospace Engineering C150R (Rocket Propulsion Systems) or 161A (Introduction to Astronautics)</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 171A—Introduction to Feedback and Control Systems</td>
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<td>Technical Breadth Course</td>
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### Senior Year

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<th>Quarter</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Mechanical and Aerospace Engineering C150P—Aircraft Propulsion Systems</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 154S—Flight Mechanics, Stability, and Control of Aircraft</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 166A—Analysis of Flight Structures</td>
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<td>Technical Breadth Course</td>
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<tr>
<td>2nd Quarter</td>
<td>Mechanical and Aerospace Engineering 154A—Preliminary Design of Aircraft</td>
<td>4</td>
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<td>Mechanical and Aerospace Engineering 157—Basic Mechanical and Aerospace Engineering Laboratory</td>
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<td>Aerospace Engineering Elective</td>
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<td></td>
<td>Technical Breadth Course</td>
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<tr>
<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering 154B—Design of Aerospace Structures</td>
<td>4</td>
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<td></td>
<td>Mechanical and Aerospace Engineering 157A—Fluid Mechanics and Aerodynamics Laboratory</td>
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<td>Aerospace Engineering Elective</td>
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<tr>
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<td>TOTAL</td>
<td>184</td>
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</table>

1. Counts as Mathematics and Basic Sciences for ABET; total units Mathematics and Basic Sciences = 50.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 21 for details).
4. See page 102 for a list of electives.
# B.S. in Bioengineering Curriculum

## FRESHMAN YEAR

### 1st Quarter

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>Bioengineering 10 — Introduction to Bioengineering^2</td>
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<tr>
<td>Chemistry and Biochemistry 20A — Chemical Structure^1</td>
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<tr>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A — Differential and Integral Calculus^1</td>
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### 2nd Quarter

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<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>Bioengineering 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory^1</td>
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</tr>
<tr>
<td>Mathematics 31B — Integration and Infinite Series^1</td>
<td>4</td>
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<tr>
<td>Physics 1A — Mechanics^1</td>
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### 3rd Quarter

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<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity^1</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

### 1st Quarter

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<tbody>
<tr>
<td>Chemistry and Biochemistry 30AL — General Chemistry Laboratory II^1</td>
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<tr>
<td>Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy^3</td>
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<tr>
<td>Mathematics 32B — Calculus of Several Variables^1</td>
<td>4</td>
</tr>
<tr>
<td>Physics 1C — Electrodynamics, Optics, and Special Relativity^1</td>
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### 2nd Quarter

<table>
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<tr>
<th>Course</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>Bioengineering 100 — Bioengineering Fundamentals^2</td>
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</tr>
<tr>
<td>Life Sciences 2 — Cells, Tissues, and Organs^1</td>
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<tr>
<td>Mathematics 33A — Linear Algebra and Applications^3</td>
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<td>HSSEAS GE Elective^3</td>
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### 3rd Quarter

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Bioengineering 167L — Bioengineering Laboratory^2</td>
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<tr>
<td>Computer Science 31 (Introduction to Computer Science I) or Mechanical and Aerospace Engineering M20 (Introduction to Computer Programming with MATLAB)^2</td>
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<tr>
<td>Mathematics 33B — Differential Equations^1</td>
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## JUNIOR YEAR

### 1st Quarter

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Bioengineering 165EW — Bioengineering Ethics</td>
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<tr>
<td>Electrical Engineering 100 — Electrical and Electronic Circuits^2</td>
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<tr>
<td>Life Sciences 3 — Introduction to Molecular Biology^1</td>
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<tr>
<td>Life Sciences 23L — Introduction to Laboratory and Scientific Methodology^1</td>
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### 2nd Quarter

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<thead>
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<tbody>
<tr>
<td>Bioengineering 120 — Biomedical Transducers^2</td>
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<td>Bioengineering Elective^2,4</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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### 3rd Quarter

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>Bioengineering 110 — Biotransport and Bioreaction Processes^2</td>
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<tr>
<td>Bioengineering 176 — Principles of Biocompatibility^2</td>
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<td>Bioengineering Elective^2,4</td>
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<tr>
<td>Technical Breadth Course^3</td>
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## SENIOR YEAR

### 1st Quarter

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<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Bioengineering 177A — Bioengineering Capstone Design I^2</td>
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<td>Bioengineering Elective^2,4</td>
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<tr>
<td>Restricted Elective^2,5</td>
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### 2nd Quarter

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<tbody>
<tr>
<td>Bioengineering 177B — Bioengineering Capstone Design II^2</td>
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<tr>
<td>Bioengineering 180 — System Integration in Biology, Engineering, and Medicine^2</td>
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### 3rd Quarter

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<tr>
<td>Bioengineering Electives (2)^2,4</td>
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<td>Restricted Elective^2,5</td>
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### TOTAL

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 74.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 21 for details).
5. Restricted electives include Bioengineering C101, C106, C131, C155, M260 (a petition is required for M260).
# B.S. in Chemical Engineering Curriculum

## FRESHMAN YEAR

### 1st Quarter
- Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering
  - Units: 1
- Chemistry and Biochemistry 20A — Chemical Structure
  - Units: 4
- English Composition 3 — English Composition, Rhetoric, and Language
  - Units: 5
- Mathematics 31A — Differential and Integral Calculus
  - Units: 4

### 2nd Quarter
- Chemical Engineering 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory
  - Units: 7
- Mathematics 31B — Integration and Infinite Series
  - Units: 4
- Physics 1A — Mechanics
  - Units: 5

### 3rd Quarter
- Chemical Engineering 30A — Organic Chemistry I: Structure and Reactivity
  - Units: 4
- Mathematics 32A — Calculus of Several Variables
  - Units: 4
- Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory
  - Units: 7

## SOPHOMORE YEAR

### 1st Quarter
- Chemical Engineering 100 — Fundamentals of Chemical and Biomolecular Engineering
  - Units: 4
- Chemistry and Biochemistry 30AL — General Chemistry Laboratory II
  - Units: 4
- Mathematics 32B — Calculus of Several Variables
  - Units: 4
- Physics 1C — Electrodynamics, Optics, and Special Relativity
  - Units: 5

### 2nd Quarter
- Chemical Engineering 102A — Thermodynamics
  - Units: 4
- Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy
  - Units: 4
- Mathematics 33A — Linear Algebra and Applications
  - Units: 4
- HSSEAS GE Elective
  - Units: 5

### 3rd Quarter
- Chemical Engineering 102B — Thermodynamics
  - Units: 4
- Civil and Environmental Engineering M20 — Introduction to Computer Programming with MATLAB
  - Units: 4
- Mathematics 33B — Differential Equations
  - Units: 4
- HSSEAS Ethics Course
  - Units: 4

## JUNIOR YEAR

### 1st Quarter
- Chemical Engineering 101A — Transport Phenomena
  - Units: 4
- Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering
  - Units: 4
- HSSEAS GE Elective
  - Units: 5

### 2nd Quarter
- Chemical Engineering 45 — Biomolecular Engineering Fundamentals
  - Units: 4
- Chemical Engineering 101B — Transport Phenomena II: Heat Transfer
  - Units: 4
- Chemical Engineering 104A — Chemical and Biomolecular Engineering Laboratory
  - Units: 4

### 3rd Quarter
- Chemical Engineering 101C — Mass Transfer
  - Units: 4
- Chemical Engineering 103 — Separation Processes
  - Units: 4
- HSSEAS GE Elective
  - Units: 5

## SENIOR YEAR

### 1st Quarter
- Chemical Engineering 104B — Chemical and Biomolecular Engineering Laboratory II
  - Units: 6
- Chemical Engineering 106 — Chemical Reaction Engineering
  - Units: 4
- Chemical Engineering Elective
  - Units: 4
- Technical Breadth Course
  - Units: 4

### 2nd Quarter
- Chemical Engineering 107 — Process Dynamics and Control
  - Units: 4
- Chemical Engineering 108A — Process Economics and Analysis
  - Units: 4
- HSSEAS GE Elective
  - Units: 5
- Technical Breadth Course
  - Units: 4

### 3rd Quarter
- Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis
  - Units: 4
- Chemical Engineering Elective
  - Units: 4
- Technical Breadth Course
  - Units: 4

**TOTAL**

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 64.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 21 for details).
## B.S. in Chemical Engineering

**Biomedical Engineering Option Curriculum**

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
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<tbody>
<tr>
<td>Chemical Engineering 10—Introduction to Chemical and Biomolecular Engineering</td>
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<tr>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
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<tr>
<td>Mathematics 31B—Integration and Infinite Series</td>
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<tr>
<td>Physics 1A—Mechanics</td>
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<thead>
<tr>
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<tbody>
<tr>
<td>Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity</td>
</tr>
<tr>
<td>Mathematics 32A—Calculus of Several Variables</td>
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<tr>
<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<tr>
<td>Chemical Engineering 100—Fundamentals of Chemical and Biomolecular Engineering</td>
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<td>Chemistry and Biochemistry 30AL—General Chemistry Laboratory II</td>
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<tr>
<td>Mathematics 32B—Calculus of Several Variables</td>
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<tr>
<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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<table>
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<tr>
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<tbody>
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<td>Chemical Engineering 102A—Thermodynamics I</td>
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<tr>
<td>Chemistry and Biochemistry 30B—Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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<tr>
<td>Mathematics 33A—Linear Algebra and Applications</td>
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<tr>
<td>HSSEAS GE Elective</td>
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<table>
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<tr>
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<tbody>
<tr>
<td>Chemical Engineering 102B—Thermodynamics II</td>
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<tr>
<td>Civil and Environmental Engineering M20—Introduction to Computer Programming with MATLAB</td>
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<tr>
<td>Mathematics 33B—Differential Equations</td>
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<tr>
<td>HSSEAS Ethics Course</td>
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<table>
<thead>
<tr>
<th>JUNIOR YEAR</th>
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<tbody>
<tr>
<td>Chemical Engineering 101A—Transport Phenomena</td>
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<tr>
<td>Chemical Engineering 109—Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<tr>
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<table>
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<tbody>
<tr>
<td>Chemical Engineering 45—Biomolecular Engineering Fundamentals</td>
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<tr>
<td>Chemical Engineering 101B—Transport Phenomena II: Heat Transfer</td>
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<tr>
<td>Chemical Engineering 104A—Chemical and Biomolecular Engineering Laboratory I</td>
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<table>
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<tr>
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<tbody>
<tr>
<td>Chemical Engineering 101C—Mass Transfer</td>
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<tr>
<td>Chemical Engineering 103—Separation Processes</td>
</tr>
<tr>
<td>Chemistry and Biochemistry 153A—Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>SENIOR YEAR</th>
<th>1st Quarter</th>
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</thead>
<tbody>
<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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<table>
<thead>
<tr>
<th>2nd Quarter</th>
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<tbody>
<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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<tr>
<td>Technical Breadth Course</td>
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<tr>
<th>3rd Quarter</th>
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<tbody>
<tr>
<td>Chemical Engineering 108B—Chemical Process Computer-Aided Design and Analysis</td>
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<tr>
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<tr>
<td>Technical Breadth Course</td>
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</table>

**TOTAL** | 180 |

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 88.
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 21 for details).
### B.S. in Chemical Engineering

#### Biomolecular 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>Chemical Engineering 10—Introduction to Chemical and Biomolecular Engineering</td>
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<tr>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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</tr>
<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>Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity</td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables</td>
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</tr>
<tr>
<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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</table>

**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 | 4 |
| Chemistry and Biochemistry 30B—Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy | 4 |
| Mathematics 33A—Linear Algebra and Applications | 4 |
| 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 | 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 | 4 |
| **3rd Quarter** |       |
| Chemical Engineering 101C—Mass Transfer | 4 |
| Chemical Engineering C125—Bioseparations and Bioprocess Engineering | 4 |
| Chemistry and Biochemistry 153A—Biochemistry: Introduction to Structure, Enzymes, and Metabolism | 4 |

**SENIOR YEAR**

| **1st Quarter** |       |
| Chemical Engineering 104D—Molecular Biotechnology Laboratory: From Gene to Product | 6 |
| Chemical Engineering C115—Biochemical Reaction Engineering | 4 |
| Chemical Engineering Elective | 4 |
| Technical Breadth Course | 4 |
| **2nd Quarter** |       |
| Chemical Engineering 107—Process Dynamics and Control | 4 |
| Chemical Engineering 108A—Process Economics and Analysis | 4 |
| 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 = 68.
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 21 for details).
## B.S. in Chemical Engineering

### Environmental Engineering Option Curriculum

<table>
<thead>
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<tbody>
<tr>
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<tr>
<td>Chemical Engineering 10—Introduction to Chemical and Biomolecular Engineering</td>
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<td>Chemistry and Biochemistry 20A—Chemical Structure</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>Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity</td>
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<tbody>
<tr>
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<tr>
<td>Chemical Engineering 100—Fundamentals of Chemical and Biomolecular Engineering</td>
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<td>Mathematics 32B—Calculus of Several Variables</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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<td>Chemical Engineering 102B—Thermodynamics II</td>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemical Engineering 101A—Transport Phenomena</td>
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<tr>
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<tr>
<td>Chemical Engineering 101B—Transport Phenomena II: Heat Transfer</td>
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</tr>
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<td>Chemical Engineering 104A—Chemical and Biomolecular Engineering Laboratory I</td>
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<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Chemical Engineering 101C—Mass Transfer</td>
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<tr>
<td><strong>1st Quarter</strong></td>
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<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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</table>

**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 21 for details).
# B.S. in Chemical Engineering

## Semiconductor Manufacturing Engineering Option Curriculum

### FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
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<td>Chemical Engineering 10—Introduction to Chemical and Biomolecular Engineering</td>
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<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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<td>Mathematics 31A—Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B—Integration and Infinite Series</td>
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<td>Physics 1A—Mechanics</td>
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<td>Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity</td>
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<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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### SOPHOMORE YEAR

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<td>Chemical Engineering 100—Fundamentals of Chemical and Biomolecular Engineering</td>
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<td>Chemical Engineering 102A—Thermodynamics</td>
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<td>Chemistry and Biochemistry 30B—Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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<td>Mathematics 33A—Linear Algebra and Applications</td>
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<td>Chemical Engineering 102B—Thermodynamics II</td>
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<td>Civil and Environmental Engineering M20—Introduction to Computer Programming with MATLAB</td>
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### JUNIOR YEAR

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<td>Chemical Engineering 109—Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemical Engineering 101C—Mass Transfer</td>
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### SENIOR YEAR

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<td>Chemical Engineering 107—Process Dynamics and Control</td>
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<td>Chemical Engineering 108A—Process Economics and Analysis</td>
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<td>3rd Quarter</td>
<td>Chemical Engineering 104C/104CL—Semiconductor Processing/Laboratory</td>
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<td>Chemical Engineering 108B—Chemical Process Computer-Aided Design and Analysis</td>
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<td>Chemical Engineering C116—Surface and Interface Engineering</td>
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</table>

**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 21 for details).
## B.S. in Civil Engineering Curriculum

### FRESHMAN YEAR  

**1st Quarter**

- Chemistry and Biochemistry 20A—Chemical Structure\(^1\) ................................................................. 4  
- Civil and Environmental Engineering 1—Civil Engineering and Infrastructure\(^2\)  
- English Composition 3—English Composition, Rhetoric, and Language ........................................... 5  
- Mathematics 31A—Differential and Integral Calculus\(^3\) .................................................................. 4  

**2nd Quarter**

- Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory\(^1\) ................................................................. 7  
- Mathematics 31B—Integration and Infinite Series\(^1\) ................................................................. 4  
- Physics 1A—Mechanics\(^1\)  
- Mathematics 32A—Calculus of Several Variables\(^1\) ................................................................. 4  
- Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory\(^1\)  
- HSSEAS GE Elective\(^3\)  

### SOPHOMORE YEAR  

**1st Quarter**

- Civil and Environmental Engineering 101—Statics\(^2\) ................................................................. 4  
- Mathematics 32B—Calculus of Several Variables\(^1\) ................................................................. 4  
- Physics 1C—Electrodynamics, Optics, and Special Relativity\(^1\) ................................................................. 5  
- HSSEAS Ethics Course.  

**2nd Quarter**

- Civil and Environmental Engineering 102—Dynamics of Particles and Bodies\(^2\) ................................................................. 2  
- Civil and Environmental Engineering C104 (Structure, Processing, and Properties of Civil Engineering Materials) or Materials Science and Engineering 104 (Science of Engineering Materials)\(^2\) ................................................................. 4  
- Civil and Environmental Engineering 108—Introduction to Mechanics of Deformable Solids\(^2\) ................................................................. 4  
- Mathematics 33A—Linear Algebra and Applications\(^1\) ................................................................. 4  

**3rd Quarter**

- Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I)\(^2\) ................................................................. 4  
- Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)\(^1\) ................................................................. 4  
- Mechanical and Aerospace Engineering 103—Elementary Fluid Mechanics\(^2\) ................................................................. 4  

### JUNIOR YEAR  

**1st Quarter**

- Civil and Environmental Engineering 120—Principles of Soil Mechanics\(^2\) ................................................................. 4  
- Civil and Environmental Engineering 135A—Elementary Structural Analysis\(^2\) ................................................................. 4  
- Civil and Environmental Engineering 150—Introduction to Hydrology\(^2\) ................................................................. 4  
- Civil and Environmental Engineering 153—Introduction to Environmental Engineering Science\(^2\) ................................................................. 4  

**2nd Quarter**

- Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)\(^2\) ................................................................. 4  
- Major Field Elective\(^2,4\) ................................................................. 4  
- Natural Science Course\(^1\) ................................................................. 4  

**3rd Quarter**

- Civil and Environmental Engineering 103—Applied Numerical Computing and Modeling in Civil and Environmental Engineering\(^2\) ................................................................. 4  
- Civil and Environmental Engineering 110—Introduction to Probability and Statistics for Engineers\(^2\) ................................................................. 4  
- Major Field Electives (2)\(^2,4\) ................................................................. 8

### SENIOR YEAR  

**1st Quarter**

- HSSEAS GE Elective\(^3\) ................................................................. 5  
- Major Field Electives (2)\(^2,4\) ................................................................. 8  
- Technical Breadth Course\(^3\) ................................................................. 4  

**2nd Quarter**

- HSSEAS GE Elective\(^3\) ................................................................. 5  
- Major Field Electives (2)\(^2,4\) ................................................................. 8  
- Technical Breadth Course\(^3\) ................................................................. 4  

**3rd Quarter**

- HSSEAS GE Elective\(^3\) ................................................................. 5  
- Major Field Elective\(^2,4\) ................................................................. 4  
- Technical Breadth Course\(^3\) ................................................................. 4  

**TOTAL** ................................................................................................................................. 181

---

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 56.  
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 21 for details).  
4. Must include required courses for two of the major field areas listed on page 48.
# B.S. in Computer Science Curriculum

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<th>UNITS</th>
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<td><strong>1st Quarter</strong></td>
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<tr>
<td>Computer Science 1 — Freshman Computer Science Seminar (^2)</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<tr>
<td>Mathematics 31A — Differential and Integral Calculus (^1)</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Computer Science 32 — Introduction to Computer Science II (^2)</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><strong>3rd Quarter</strong></td>
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<tr>
<td>Computer Science 33 — Introduction to Computer Organization (^2)</td>
<td>5</td>
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<tr>
<td>Mathematics 32A — Calculus of Several Variables (^1)</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory (^1)</td>
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<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Computer Science 35L — Software Construction Laboratory (^2)</td>
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<td>Computer Science M51A or Electrical Engineering M16 — Logic Design of Digital Systems (^2)</td>
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<td>Mathematics 32B — Calculus of Several Variables (^1)</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory (^1)</td>
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<tr>
<td>Mathematics 33A — Linear Algebra and Applications (^1)</td>
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<tr>
<td>Mathematics 61 — Introduction to Discrete Structures (^1)</td>
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<tr>
<td>Physics 1C — Electrodynamics, Optics, and Special Relativity (^1)</td>
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<tr>
<td>HSSEAS Ethics Course</td>
<td>4</td>
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<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Computer Science 111 — Operating Systems Principles (^2)</td>
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<td>Computer Science M152A or Electrical Engineering M116L — Introductory Digital Design Laboratory (^2)</td>
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<td>Mathematics 33B — Differential Equations (^3)</td>
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<tbody>
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<td><strong>1st Quarter</strong></td>
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<tr>
<td>Computer Science 118 — Computer Network Fundamentals (^2)</td>
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<td>Computer Science 180 — Introduction to Algorithms and Complexity (^2)</td>
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<td>Science and Technology Elective (^2)</td>
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<tr>
<td>Computer Science 131 — Programming Languages (^2)</td>
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<tr>
<td>Computer Science M151B or Electrical Engineering M116C — Computer Systems Architecture (^2)</td>
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<td>HSSEAS GE Elective (^3)</td>
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<td>Computer Science 181 — Introduction to Formal Languages and Automata Theory (^2)</td>
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<tr>
<td>Computer Science 130 (Software Engineering) or 152B (Digital Design Project Laboratory) (^2)</td>
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**TOTAL** | 179

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 51.
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 21 for details).
4. See page 61 for a list of electives.
5. Must complete a minimum of 180 units.
## B.S. in Computer Science and Engineering Curriculum

### FRESHMAN YEAR

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### SOPHOMORE YEAR

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<td>3rd</td>
<td>Computer Science 190 — Introduction to Algorithms and Complexity</td>
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### JUNIOR YEAR

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<td>Computer Science 131 — Programming Languages</td>
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<td>Electrical Engineering 102 — Systems and Signals</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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<td>Technical Breadth Course</td>
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<tr>
<td>3rd</td>
<td>Computer Science Elective</td>
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<tr>
<td></td>
<td>HSSEAS GE Elective</td>
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</tr>
<tr>
<td></td>
<td>Technical Breadth Course</td>
<td>4</td>
</tr>
</tbody>
</table>

**TOTAL**                                               | **181** |

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 51.
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 21 for details).
4. See page 61 for a list of electives.
B.S. in Electrical Engineering 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>Computer Science 31—Introduction to Computer Science</td>
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<tr>
<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<tr>
<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 20A—Chemical Structure</td>
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<tr>
<td>Computer Science 32—Introduction to Computer Science II</td>
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<tr>
<td>Mathematics 31B—Integration and Infinite Series</td>
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<td>Physics 1A—Mechanics</td>
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<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Electrical Engineering M16 (or Computer Science M51A)—Logic Design of Digital Systems</td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables</td>
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</tr>
<tr>
<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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**SOPHOMORE YEAR**

| **1st Quarter** | |
| Electrical Engineering 3—Introduction to Electrical Engineering | 4 |
| Mathematics 32B—Calculus of Several Variables | 4 |
| Mathematics 33A—Linear Algebra and Applications | 4 |
| Physics 1C—Electrodynamics, Optics, and Special Relativity | 5 |
| **2nd Quarter** | |
| Electrical Engineering 10 (Circuit Theory I) and 11L (Circuits Laboratory I) | 5 |
| Electrical Engineering 102—Systems and Signals | 4 |
| Mathematics 33B—Differential Equations | 4 |
| Physics 4BL—Electricity and Magnetism Laboratory | 2 |
| **3rd Quarter** | |
| Electrical Engineering 2—Physics for Electrical Engineers | 4 |
| Electrical Engineering 110 (Circuit Theory II) and 111L (Circuits Laboratory II) | 5 |
| HSSEAS Ethics Course | 4 |
| HSSEAS GE Elective | 4 |

**JUNIOR YEAR**

| **1st Quarter** | |
| Electrical Engineering 113—Digital Signal Processing | 4 |
| Electrical Engineering 131A—Probability and Statistics | 4 |
| HSSEAS GE Elective | 5 |
| **2nd Quarter** | |
| Electrical Engineering 101A—Engineering Electromagnetics | 4 |
| Electrical Engineering Core Course | 4 |
| HSSEAS GE Elective | 5 |
| **3rd Quarter** | |
| Electrical Engineering Core Course | 4 |
| Electrical Engineering Core Course | 4 |
| Electrical Engineering Core Course | 4 |
| Electrical Engineering Core Course or Computer Science 33 (Introduction to Computer Organization) | 4 |

**SENIOR YEAR**

| **1st Quarter** | |
| Electrical Engineering Core Course | 4 |
| Electrical Engineering Design Course | 4 |
| Electrical Engineering Elective | 4 |
| Technical Breadth Course | 4 |
| **2nd Quarter** | |
| Electrical Engineering Design Course | 4 |
| Electrical Engineering Elective | 4 |
| HSSEAS GE Elective | 5 |
| Technical Breadth Course | 4 |
| **3rd Quarter** | |
| Electrical Engineering or HSSEAS Elective | 4 |
| HSSEAS GE Elective | 5 |
| Technical Breadth Course | 4 |

**TOTAL** | 182

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 47.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 21 for details).
4. See page 79 for the list of core courses.
# B.S. in Materials Engineering Curriculum

## FRESHMAN YEAR

### 1st Quarter
- Chemistry and Biochemistry 20A—Chemical Structure\(^1\) .................................................. 4
- English Composition 3—English Composition, Rhetoric, and Language ........................................ 5
- Materials Science and Engineering 10—Freshman Seminar: New Materials\(^2\) ......................... 1
- Mathematics 31A—Differential and Integral Calculus\(^3\) .......................................................... 4

### 2nd Quarter
- Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory\(^1\) ........................................ 7
- Mathematics 31B—Integration and Infinite Series\(^3\) .............................................................. 4
- Physics 1A—Mechanics\(^3\) ........................................................................................................ 5

### 3rd Quarter
- Mathematics 32A—Calculus of Several Variables\(^1\) ............................................................ 4
- Physics 1B—Oscillations, Waves, Electric and Magnetic Fields\(^1\) ............................................. 5
- HSSEAS GE Elective\(^3\) .......................................................................................................... 5

## SOPHOMORE YEAR

### 1st Quarter
- Civil and Environmental Engineering 101 (Statics) or Mechanical and Aerospace Engineering 96 (Statics and Strength of Materials)\(^2\) .................................................. 4
- Materials Science and Engineering 104—Science of Engineering Materials\(^2\) ......................... 4
- Mathematics 32B—Calculus of Several Variables\(^1\) ............................................................ 4

### 2nd Quarter
- Materials Science and Engineering 90L—Physical Measurement in Materials Engineering\(^2\) .................. 2
- Mathematics 33A—Linear Algebra and Applications\(^3\) ......................................................... 4
- Physics 1C—Electrodynamics, Optics, and Special Relativity\(^1\) ................................................ 5
- HSSEAS GE Elective\(^3\) .......................................................................................................... 5

### 3rd Quarter
- Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science)\(^2\) .......................................................... 4
- Mathematics 33B—Differential Equations\(^3\) ........................................................................... 4
- HSSEAS Ethics Course\(^4\) ...................................................................................................... 4
- Technical Breadth Course\(^3\) ................................................................................................ 4

## JUNIOR YEAR

### 1st Quarter
- Materials Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory\(^2\) .......................................................... 6
- Materials Science and Engineering 130—Phase Relations in Solids\(^2\) ........................................ 4
- Technical Breadth Course\(^3\) ................................................................................................ 4

### 2nd Quarter
- Materials Science and Engineering 120—Physics of Materials\(^2\) .............................................. 4
- Materials Science and Engineering 131/131L—Diffusion and Diffusion-Controlled Reactions/Laboratory\(^2\) .......................................................... 6
- Materials Science and Engineering 143A—Mechanical Behavior of Materials\(^2\) .................. 4
- Materials Engineering Elective\(^2,4\) ................................................................................... 4

### 3rd Quarter
- Civil and Environmental Engineering 108—Introduction to Mechanics of Deformable Solids\(^2\) .......................................................... 4
- Materials Science and Engineering 132—Structures and Properties of Metallic Alloys\(^2\) ........ 4
- HSSEAS GE Elective\(^3\) .......................................................................................................... 5

## SENIOR YEAR

### 1st Quarter
- Electrical Engineering 100—Electrical and Electronic Circuits\(^2\) .............................................. 4
- Materials Science and Engineering 160—Introduction to Ceramics and Glasses\(^2\) ................. 4
- Mechanical and Aerospace Engineering 82 (Mathematics of Engineering) or 181A (Complex Analysis and Integral Transforms)\(^2\) .................... 4
- Materials Engineering Elective\(^2,4\) ................................................................................... 4

### 2nd Quarter
- Materials Science and Engineering 150—Introduction to Polymers\(^2\) ....................................... 4
- Materials Engineering Elective\(^2,4\) ................................................................................... 4
- Materials Engineering Laboratory Course\(^2,4\) ................................................................... 2
- HSSEAS GE Elective\(^3\) ...................................................................................................... 5

### 3rd Quarter
- Materials Science and Engineering 140—Materials Selection and Engineering Design\(^2\) ........ 4
- Materials Engineering Laboratory Course\(^2,4\) ................................................................... 2
- HSSEAS GE Elective\(^3\) ...................................................................................................... 5
- Technical Breadth Course\(^3\) ............................................................................................. 4

## TOTAL\(^5\) ........................................................................................................................................ 179

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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 21 for details).
4. Must complete a minimum of 180 units.
# B.S. in Materials Engineering

## Electronic Materials Option Curriculum

### FRESHMAN YEAR

**1st Quarter**
- Chemistry and Biochemistry 20A — Chemical Structure\(^1\) .......................................................... 4
- English Composition 3 — English Composition, Rhetoric, and Language ........................................... 5
- Materials Science and Engineering 10 — Freshman Seminar: New Materials\(^2\) ................................. 1
- Mathematics 31A — Differential and Integral Calculus\(^1\) ................................................................. 4

**2nd Quarter**
- Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory\(^1\) ................................................................. 7
- Mathematics 31B — Integration and Infinite Series\(^1\) ........................................................................... 4
- Physics 1A — Mechanics\(^1\) .................................................................................................................. 5

**3rd Quarter**
- Mathematics 32A — Calculus of Several Variables\(^1\) ................................................................. 4
- Physics 1B — Oscillations, Waves, Electric and Magnetic Fields\(^1\) ...................................................... 5
- HSSEAS GE Elective\(^3\) ...................................................................................................................... 4

### SOPHOMORE YEAR

**1st Quarter**
- Materials Science and Engineering 104 — Science of Engineering Materials\(^2\) ................................. 4
- Mathematics 32B — Calculus of Several Variables\(^1\) ........................................................................... 4
- HSSEAS GE Elective\(^3\) ...................................................................................................................... 5

**2nd Quarter**
- Materials Science and Engineering 90L — Physical Measurement in Materials Engineering\(^2\) ............. 2
- Mathematics 33A — Linear Algebra and Applications\(^1\) ................................................................. 4
- Physics 1C — Electrodynamics, Optics, and Special Relativity\(^1\) ....................................................... 5
- HSSEAS GE Elective\(^3\) ...................................................................................................................... 5

**3rd Quarter**
- Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I)\(^2\) .................. 4
- Mathematics 33B — Differential Equations\(^1\) .................................................................................... 4
- Mechanical and Aerospace Engineering 96 — Statics and Strength of Materials\(^2\) ......................... 4
- HSSEAS Ethics Course\(^3\) .................................................................................................................. 4

### JUNIOR YEAR

**1st Quarter**
- Electrical Engineering 100 — Electrical and Electronic Circuits\(^2\) ...................................................... 4
- Materials Science and Engineering 110/110L — Introduction to Materials Characterization A/Laboratory\(^2\) ...................................................................................... 6
- Materials Science and Engineering 130 — Phase Relations in Solids\(^2\) ............................................. 4
- HSSEAS GE Elective\(^3\) ...................................................................................................................... 5

**2nd Quarter**
- Electrical Engineering 101A — Engineering Electromagnetics\(^2\) ...................................................... 4
- Materials Science and Engineering 120 (Physics of Materials) or Electrical Engineering 2 (Physics for Electrical Engineers)\(^2\) .................................................. 4
- Materials Science and Engineering 122 — Principles of Electronic Materials Processing\(^2\) ............. 4
- Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory\(^2\) ...................................................................................... 6

**3rd Quarter**
- Materials Science and Engineering 121/121L — Materials Science of Semiconductors/Laboratory\(^2\) .................. 6
- Materials Science and Engineering 132 — Structures and Properties of Metallic Alloys\(^2\) ............... 4
- Electronic Materials Elective (Materials Science and Engineering 150 — Introduction to Polymers or 160 — Introduction to Ceramics and Glasses)\(^2,4\) ...................................................................................... 4
- Technical Breadth Course\(^1\) ........................................................................................................... 4

### SENIOR YEAR

**1st Quarter**
- Electrical Engineering 121B — Principles of Semiconductor Device Design\(^2\) ................................. 4
- Mechanical and Aerospace Engineering 82 (Mathematics of Engineering) or 181A (Complex Analysis and Integral Transforms)\(^2\) .................................................. 4
- Technical Breadth Course\(^3\) ........................................................................................................... 4

**2nd Quarter**
- Electronic Materials Elective\(^2,4\) ........................................................................................................ 4
- Electronic Materials Laboratory Course\(^2,4\) ....................................................................................... 2
- HSSEAS GE Elective\(^3\) ...................................................................................................................... 5
- Technical Breadth Course\(^3\) ........................................................................................................... 4

**3rd Quarter**
- Materials Science and Engineering 140 — Materials Selection and Engineering Design\(^2\) ............... 4
- Electronic Materials Elective\(^2,4\) ........................................................................................................ 4
- Electronic Materials Laboratory Course\(^2,4\) ....................................................................................... 2

**TOTAL** ................................................................................................................................................ 180

\(^1\) Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.

\(^2\) Counts as Engineering Concepts for ABET, total units Engineering Concepts = 85.

\(^3\) Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 21 for details).

\(^4\) See counselor in 6426 Boelter Hall for details.
# B.S. in Mechanical Engineering Curriculum

## FRESHMAN YEAR

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<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A—Differential and Integral Calculus</td>
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<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B—Integration and Infinite Series</td>
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<td></td>
<td>Physics 1A—Mechanics</td>
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<tr>
<td>3rd Quarter</td>
<td>Mathematics 32A—Calculus of Several Variables</td>
<td>4</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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<tr>
<td></td>
<td>HSSEAS GE Elective</td>
<td>5</td>
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## SOPHOMORE YEAR

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<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Mathematics 32B—Calculus of Several Variables</td>
<td>4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 94—Introduction to Computer-Aided Design and Drafting</td>
<td>4</td>
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<tr>
<td></td>
<td>Physics 1C/4BL—Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
<td>7</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Materials Science and Engineering 104—Science of Engineering Materials</td>
<td>4</td>
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<tr>
<td></td>
<td>Mathematics 33A—Linear Algebra and Applications</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 96—Statics and Strength of Materials</td>
<td>4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 105A—Introduction to Engineering Thermodynamics</td>
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<td>Mechanical and Aerospace Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I)</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 82—Mathematics of Engineering</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 102—Dynamics of Particles and Rigid Bodies</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 103—Elementary Fluid Mechanics</td>
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## JUNIOR YEAR

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<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 100—Electrical and Electronic Circuits</td>
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<td>Mechanical and Aerospace Engineering 105D—Transport Phenomena</td>
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<td>Mechanical and Aerospace Engineering 183A (Introduction to Manufacturing Processes) or M183B (Introduction to Microscale and Nanoscale Manufacturing)</td>
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<td>HSSEAS Ethics Course</td>
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<tr>
<td>2nd Quarter</td>
<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems</td>
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<td>HSSEAS GE Elective</td>
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<td>Technical Breadth Course</td>
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<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering 131A (Intermediate Heat Transfer) or 133A (Engineering Thermodynamics)</td>
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<td>Mechanical and Aerospace Engineering 157—Basic Mechanical and Aerospace Engineering Laboratory</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 162A—Introduction to Mechanisms and Mechanical Systems</td>
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<tr>
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<td>Technical Breadth Course</td>
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## SENIOR YEAR

<table>
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<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 110L—Circuit Measurements Laboratory</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 156A—Advanced Strength of Materials</td>
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<td></td>
<td>Mechanical and Aerospace Engineering 171A—Introduction to Feedback and Control Systems</td>
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<tr>
<td>2nd Quarter</td>
<td>Mechanical and Aerospace Engineering 162D—Mechanical Engineering Design</td>
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<td>HSSEAS GE Electives (2)</td>
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<tr>
<td></td>
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<tr>
<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering 162E—Mechanical Engineering Design II</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td></td>
<td>Mechanical Engineering Elective</td>
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</tr>
</tbody>
</table>

**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 21 for details).
### Index

**A**
- ABET, 27, 38, 48, 60, 78, 94, 102, 103
- academic excellence workshops, 13
- academic residence requirement, 21
- active materials laboratory, 105
- admission to the school, 18
  - as a freshman, 18
  - as a graduate student, 25
  - as a transfer student, 18
- advanced placement examinations, 23
- CEED, 14
- American Indian science and engineering society, 14
- artificial intelligence laboratories, 66
- automated reasoning group, 66
- autonomous vehicle systems instrumentation laboratory, 105

**B**
- bachelor of science degrees, requirements for, 21
- beam control laboratory, 105
- biocybernetics laboratory, 66
- bioengineering department, 26
  - bachelor of science degree, 27
  - course descriptions, 31
  - faculty areas of thesis guidance, 30
  - graduate study, 28
- bioinformatics minor, 61
- biomechatronics laboratory, 105
- biomolecular engineering laboratories, 41
- bionics laboratory, 106
- boiling heat transfer laboratory, 106
- bridge review for enhancing engineering students (BREES), 13
- building earthquake instrumentation network, 52

**C**
- career services, 10
- center for autonomous intelligent networks (CAINS), 67
- center for development of emerging storage systems (CoDESS), 82
- center for domain-specific computing (CDSC), 67, 121
- center for encrypted functionalities, 121
- center for engineering economics, learning, and networks, 82
- center for excellence in engineering and diversity (CEED), 13
- center for function accelerated nanomaterial engineering (FAME), 121
- center for high-frequency electronics, 82
- center for information and computation security (CICS), 67
- center for translational applications of nanoscale multiferroic systems (TANMS), 14, 121
- center for vision, cognition, learning, and art, 66
- center of excellence for green nanotechnologies (CEGN), 122
- ceramic processing laboratory, 97
- chemical and biomolecular engineering department, 38
- bachelor of science degree, 38
- course descriptions, 43
- facilities, 41
- faculty areas of thesis guidance, 42
- graduate study, 39
- chemical kinetics, catalysis, reaction engineering, and combustion laboratory, 41
- circuits laboratories, 83
- civil and environmental engineering department, 47
- bachelor of science degree, 48
- course descriptions, 53
- environmental engineering minor, 48
- facilities, 51
- faculty areas of thesis guidance, 53
- fields of study, 51
- graduate study, 49
- instructional laboratories, 51
- research laboratories, 52
- clean energy research center–Los Angeles (CERC-LA), 83
- cognitive systems laboratory, 66
- collective on vision and image sciences, UCLA, 66
- compilers laboratory, 67
- computational genetics laboratory, 66
- computational systems biology laboratories, 66
- computer graphics and vision laboratory (MAGIX), 66
- computer science centers, 67
- computer science department, 59
- bachelor of science degrees, 61
- bioinformatics course descriptions, 70
- computer science course descriptions, 70
- computing resources, 68
- facilities, 66
- faculty areas of thesis guidance, 68
- fields of study, 63
- graduate study, 62
- computer systems architecture laboratories, 66
- concurrent systems laboratory, 66
- continuing education, UCLA extension, 9
- correspondence directory, 7
- counseling, 7
- CEED, 14
- cybernetic control laboratory, 106

**D**
- Dashew center for international students and scholars, 10
- degrees
  - bachelor of science (B.S.), 21
  - doctor of philosophy (Ph.D.), 24
  - engineer (Engr.), 24
  - master of engineering (M.Engr.), 24
  - master of science (M.S.), 24
  - master of science in engineering (online), 24
- department requirements, 22
- departmental scholar program, 16
- design and manufacturing laboratory, 106
- digital arithmetic and reconfigurable architecture laboratory, 66

**E**
- electrical engineering department, 77
  - bachelor of science degree, 79
- computing resources, 82
- course descriptions, 86
- facilities and programs, 82
- faculty areas of thesis guidance, 85
- graduate study, 79
- research centers and laboratories, 82
- electrochemical engineering and catalysis laboratories, 41
- electromagnetics laboratories, 83
- electron microscopy laboratories, 97
- electronic materials processing laboratory, 41
- embedded and reconfigurable system design laboratory, 66
- endowed chairs, 5
- energy and propulsion research laboratory, 106
- energy innovation laboratory, 106
- environmental engineering laboratories, 51, 52
- environmental engineering minor, 48
- ethics requirement, 21
- experimental fracture mechanics laboratory, 51, 52
- experimental mechanics laboratory, 52
- externally funded research centers and institutes, 121

**F**
- faculty groups and laboratories, 84
- fees and financial support, 10
  - graduate students, 12
  - undergraduate students, 11
- fees, annual, 11
- fellowships, 12
- financial aid, 11, 14
- flexible research group, 106
- freshman orientation course, 13
- fusion science and technology center, 106

**G**
- general education requirements, 21
- glass and ceramics research laboratories, 97
- grade disputes, 16
- grading policy, 16
- grants, 12
- graphics and vision laboratories, 66

**H**
- harassment, 16
- health center, 10
- honorary societies, 15
- honors
  - dean’s honors list, 23
  - Latin honors, 23
- hydrology laboratory, 51
information and data management

laboratory for advanced system research (LASR), 67
laboratory for the chemistry of construction materials (LC2), 52
laboratory for the physics of amorphous and inorganic soils (PARISlab), 52
large-scale structure test facility, 52
laser laboratory, 83
laser spectroscopy and gas dynamics laboratory, 106
library facilities
  science and engineering library (SEL), 9
  university library system, 9
living accommodations, 11
loans, 12
master of science in engineering online programs, 116
  graduate study, 116
materials and plasma chemistry laboratory, 42
materials degradation characterization laboratory, 106
materials in extreme environments (MATRIX) laboratory, 106
materials science and engineering department, 94
  bachelor of science degree, 95
course descriptions, 98
facilities, 97
faculty areas of thesis guidance, 97
fields of study, 96
graduate study, 95
mechanical and aerospace engineering department, 101
  bachelor of science degrees, 102, 124
course descriptions, 109
facilities, 105
faculty areas of thesis guidance, 107
fields of study, 104
graduate study, 103
mechanical testing laboratory, 97
mechanical vibrations laboratory, 52
mechatronics and controls laboratory, 106
MESA schools program, 13
metallographic sample preparation laboratory, 97
micro-manufacturing laboratory, 106
modeling of complex thermal systems laboratory, 106
Morrin-Gier-Martinelli heat transfer memorial laboratory, 106
multidisciplinary research facilities, 84
multiscale thermosciences laboratory (MTSL), 107
named data networking project, 122
nano-electronics research facility, 83
nano-materials laboratory, 97
nanoparticle technology and air quality engineering laboratory, 42
national science foundation (NSF), 4, 14, 67, 121
national society of black engineers, 15
network research laboratory, 67
nondestructive testing laboratory, 97
nondiscrimination, 16
official publications, 16
online master of science in engineering, 116
optical metrology laboratory, 52
organic electronic materials processing laboratory, 97
photonics and optoelectronics laboratories, 83
plasma and beam assisted manufacturing laboratory, 107
plasma and space propulsion laboratory, 107
plasma electronics facilities, 83
polymer and separations research laboratory, 42
precollege outreach programs, 13
prizes and awards, 15
process systems engineering laboratory, 42
reinforced concrete laboratory, 52
research centers, externally funded, 121
research intensive series in engineering for underrepresented populations (RISE-UP), 14
robotics and mechanics laboratory, 107
scalable analytics institute (ScAI), 68
scholarship requirement, 21
scholarships, 11, 14
school requirements, 21
schoolwide programs, courses, and faculty, 118
course descriptions, 118
faculty areas of thesis guidance, 118
graduate study, 118
scifacturing laboratory, 107
semiconductor and optical characterization laboratory, 97
solid-state electronics facilities, 84
special programs, activities, and awards, 13
structural design and testing laboratory, 52
student health center, 10
student organizations, 14
student societies, 15
student study center, 14
study list, 22
summer bridge program, 13
teaching assistantships, 12
technical breadth requirement, 21
thermochemical energy storage laboratory, 107
thin film deposition laboratory, 97
thin films, interfaces, composites, characterization laboratory, 107
unit requirement, 21
university requirements, 21
VAST laboratory, 66
vision laboratory, UCLA, 66
wireless health institute (WHI), 68, 84, 123
wireless networking group (WING), 67
women in engineering, 15
work-study programs, 12
writing requirement, 21
X-ray diffraction laboratory, 97
X-ray photoelectron spectroscopy and atomic force microscopy facility, 97
null