282. Glass: Science and Technology (3)
Lecture—2 hours; extensive writing—1 hour. Prerequisite: graduate standing in Chemistry, Physics or Engineering, or consent of instructor. Modern paradigms in glass science and their applications to technologies. Relation of macroscopic properties of glasses and glass-forming liquids to atomic-level structures, including principles of formation, relaxation, transport phenomena, nucleation, crystallization and phase separation in glasses. Offered in alternate years.—III. Sen

289A-G. Special Topics in Materials Science (1-5)
Lecture and/or laboratory. Prerequisite: consent of instructor. Special topics in: (A) Electronic Materials; (B) Ceramics and Minerals; (C) Physics and Chemistry of Materials; (D) Materials Processing; (E) Materials Science and Forensics; (F) Biomaterials; (G) Surface Chemistry of Metal Oxides. May be repeated for credit when topic differs.—I, II, III. (I, II, III.)

290C. Graduate Research Conference (1)
Discussion—1 hour. Prerequisite: consent of instructor. Individual and/or group conference on problems, progress, and techniques in materials science and engineering research. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

294. Materials Science Seminar (1)
Seminar—1 hour. Current literature and developments in materials science with presentations by individual students. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.) Shackelford, Mukherjee, Munir, Howitt, Gibeling, Groza, Risbud

298. Group Study (1-5)

299. Research (1-12)
Prerequisite: consent of instructor. (S/U grading only.)

Professional Course

390. The Teaching of Materials Science (1)
Discussion—1 hour. Prerequisite: meet qualifications for teaching assistant and/or associate-in in materials science and engineering. Participation as a teaching assistant or associate-in in a designated engineering course. Methods of leading discussion groups or laboratory sections, writing and grading quizzes, use of laboratory equipment, and grading laboratory reports. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

Engineering: Civil and Environmental

(College of Engineering)

Jeannie L. Darby, Ph.D., Chairperson of the Department (530) 752-0586

Department Office. 2001 Engineering III
(530) 752-0586; *http://cee.engr.ucdavis.edu*

Faculty

John Bolander, Ph.D., Professor
Fabian A. Bombardelli, Ph.D., Assistant Professor
Ross W. Boulanger, Ph.D., Professor
Y. H. (Rob) Chai, Ph.D., Professor
Christopher D. Cappa, Ph.D., Assistant Professor
Lijuan Cheng, Ph.D., Assistant Professor
Yannis F. Dafalias, Ph.D., Professor
Jeannie L. Darby, Ph.D., Professor
Academic Senate Distinguished Teaching Award
Jason T. DeJong, Ph.D., Associate Professor
Yueyue Fan, Ph.D., Assistant Professor
Timothy R. Ginn, Ph.D., Professor
John T. Harvey, Ph.D., Professor
Boris Jeremic, Ph.D., Associate Professor
Amit Kanvinde, Ph.D., Assistant Professor
M. Levent Kavvas, Ph.D., Professor
Alissa Kendall, Ph.D., Assistant Professor
Michael J. Kleeman, Ph.D., Professor
Sashi K. Kunnath, Ph.D., Professor
Bruce L. Kutter, Ph.D., Professor
Frank J. Loge, Ph.D., Associate Professor
Jay R. Lund, Ph.D., Professor
Miguel A. Mariño, Ph.D., Professor *(Civil and Environmental Engineering; Land, Air, and Water Resources)*
Patricia L. Mokhtarian, Ph.D., Professor
Parviz Nader-Tehrani, Ph.D., Lecturer
Debbie Niemeier, Ph.D., Professor
Mark M. Rashid, Ph.D., Professor
Academic Senate Distinguished Teaching Award
S. Geoffrey Schladow, Ph.D., Professor
Daniel Sperling, Ph.D., Professor *(Civil and Environmental Engineering; Environmental Science and Policy)*
N. Sukumar, Ph.D., Assistant Professor
Anthony S. Wexler, Ph.D., Professor *(Civil and Environmental Engineering; Mechanical and Aeronautical Engineering; Land, Air, and Water Resources)*
Stefan Wuertz, Ph.D., Professor
Thomas M. Young, Ph.D., Professor
Bassam A. Younis, Ph.D., Professor
H. Michael Zhang, Ph.D., Professor

Emeriti Faculty

Takashi Asano, Ph.D., Professor Emeritus
Don O. Brush, Ph.D., Professor Emeritus
Robert H. Burgy, M.S., Professor Emeritus
Daniel P. Y. Chang, Ph.D., Professor Emeritus
James A. Cheney, Ph.D., Professor Emeritus
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Gerald T. Orlob, Ph.D., Professor Emeritus
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Academic Senate Distinguished Teaching Award
Verne H. Scott, Ph.D., Professor Emeritus
Chih-Kang Shen, Ph.D., Professor Emeritus
Michael A. Taylor, Ph.D., Professor Emeritus
George Tchobanoglous, Ph.D., Professor Emeritus

Affiliated Faculty

Norman A. Abrahamson, Ph.D., Adjunct Professor
Britt A. Holmén, Ph.D., Adjunct Associate Professor
Ryuichi Kitamura, Ph.D., Adjunct Professor
Brian Maroney, D.Engr., Adjunct Assistant Professor
David Schoellhamer, Ph.D., Adjunct Associate Professor

The Civil and Environmental Engineering Programs

Mission. The Department of Civil and Environmental Engineering integrates research, education, and professional service in areas related to civil infrastructure and the environment. We provide the profession and academia with outstanding graduates who advance both engineering practice and fundamental knowledge.

Program Educational Objectives. Fundamentals: To educate students in the fundamental principles needed for civil and environmental engineering: mathematics, basic sciences, and engineering sciences. Application: To educate students in the application of fundamental principles for solving civil and environmental engineering problems; provide proficiency in at least four of the environmental, geotechnical, structural, transportation, and water resource areas; and expose students to current research. Professionalism: To imbue students with attributes that lead to professional growth throughout their careers: a sense of community and ethical responsibility; an awareness of business practices; a recognition of the need for life-long learning, continuing education, and participation in professional societies; a preparedness for graduate education; an appreciation for diversity in the engineering profession; the ability to think independently and perform effectively in multidisciplinary teams; and the ability to communicate effectively. Service to State and Profession: To provide an educational program that serves the needs of the state and profession; recruit and retain a diverse student population that is representative of the state; engage in outreach activities; provide an efficient program that minimizes the time-to-degree and maximizes enrollment opportunities; and prepare students for entry into post-graduate education or practice.

Study Abroad and Civil Engineering. It is possible for students to complete a portion of the civil engineering program at an international institution, such as the University of Edinburgh, by participating in an Education Abroad Program. The department encourages interested students to select a campus through the Education Abroad Program, then consult with the undergraduate staff adviser in Civil Engineering about their individual course plan. Often students are in their junior or senior year of study when they participate in this option.

Civil Engineering Program

The Civil Engineering program is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; (410) 347-7700.

Lower Division Required Courses

	UNITS
Mathematics 21A-21B-21C-21D	16
Mathematics 22A-22B	6
Physics 9A-9B-9C and choice of Physics 9D, Chemistry 2C, Biological Science 2A or Geology 50-50L*	19
Chemistry 2A-2B or 2AH-2BH	10
Civil and Environmental Engineering 3	4
(Civil and Environmental Engineering 3 is designed for freshman students and is not open to upper division students. Students who do not take this course will substitute 4 units of additional engineering coursework. Non-engineering units from the approved Technical Elective list** may be substituted if within the four unit maximum.)	
One course from Civil and Environmental Engineering 19, Engineering 6, or Computer Science Engineering 30	4
Engineering 17, 35, 45	11
Civil and Environmental Engineering 10	4
English 3 or University Writing Program 1, or Comparative Literature 1, 2, 3, or 4, or Native American Studies 5	4
Communication 1 or 3	4
General Education electives	12
Minimum Lower Division Units	**94**

*Units in excess of the requirement from Chemistry, Biological Sciences, Physics, or Geology courses may count toward the technical elective requirement. Please consult with the departmental staff adviser.
**Departmental technical elective listing available from staff advisor. Maximum of four units from this list may count toward degree requirements.

Upper Division Requirements:

Areas of Specialization

Undergraduates may emphasize one or more of the following areas of specialization, or generalize across all areas. You are urged to consult a departmental adviser when developing your individual program. Additional information on areas of specialization and potential faculty advisers can be obtained from the College of Engineering *Bulletin* and the departmental Web page.

Environmental Engineering. The focus of this area is on the management and improvement of air, land, and water quality in the face of increasing population and expanding industrialization. Examples of environmental engineering problems include innovative analysis and design of air, water, wastewater, and solid waste treatment systems; mathematical modeling of natural and engineered systems; sampling, analysis, and transport and transformation of natural and anthropogenic pollutants; and modeling of air pollutant emissions.

Suggested technical electives:

Applied Science Engineering 116; Atmospheric Science 121A, 158, 160; Chemical Engineering 143, 146, 161A, 161B, 170; Chemistry 107A, 107B, 128A, 128B; Civil and Environmental Engineering 140, 142, 143, 144, 145, 146, 148A, 148B, 149, 150, 153, 163; Engineering 180; Environmental Science and Policy 150A, 151; Mathematics 128A, 128B, 128C; Mechanical Engineering 161, 163, Microbiology 102, 105, 120, 140, 150; Soil Science 111, 112; Statistics 130A, 130B

Suggested Advisers: C. Cappa, J. L. Darby, T. R. Ginn, B. A. Holmén, M. J. Kleeman, F.J. Loge, J. R. Lund, D. Niemeier, S. G. Schladow, S. Wuertz, T. M. Young

Geotechnical Engineering. This area deals with civil infrastructure and environmental problems that require quantifying the behavior of geologic materials (e.g., soils and rocks). Examples of geotechnical engineering problems include foundations for buildings and bridges, earthwork (e.g., dams, tunnels, highways), earthquake hazards (e.g., ground motions, liquefaction, soil-structure interaction), and geo-environmental problems (ground water flow, subsurface contaminant transport and remediation).

Suggested technical electives:

Civil and Environmental Engineering 131, 132, 135, 137, 138, 139, 140, 144, 171, 171L, 173, 175, 179; Engineering 180; Geology 17, 50, 50L, 134, 161; Hydrologic Science 146; Mathematics 128A, 128B, 128C

Suggested Advisers: R. W. Boulanger, Y. F. Dafalias, J.T. DeJong, J. T. Harvey, B. Jeremic, B. L. Kutter

Structural Engineering and Structural Mechanics. The focus of this area is the conception, design, analysis, construction, and life-cycle modeling of all types of civil infrastructure, including buildings, bridges, dams, ports, highways, and industrial facilities. Structural materials include metals, reinforced concrete, timber, and advanced composites. Loads range from earthquakes to adverse environmental conditions. Structural mechanics emphasizes theoretical and computational tools that may be used in structural engineering.

Suggested technical electives:

Civil and Environmental Engineering 130, 131, 132, 135, 136, 137, 138, 139, 171, 171L, 173, 175, 179; Engineering 122, 180; Materials Science and Engineering 174; Mathematics 128A, 128B, 128C

Suggested Advisers: J. E. Bolander, Y. K. Chai, L. Cheng, Y. F. Dafalias, J.T. Harvey, A. Kanvinde, S. Kunnath, B. Maroney, M. M. Rashid, N. Sukumar

Transportation Planning and Engineering. This area deals with the movement of people and goods in a manner consistent with society's environmental (e.g. air and water quality) and socio-economic goals (e.g. equity and mobility). Transportation engineering applies engineering, economic, and behavioral science principles to the planning, analysis, design, and operation of transportation systems such as highways and public transit. Transportation planning involves the formulation and analysis of transportation policy, program, and project alternatives in consideration of societal goals, budgetary constraints, economic objectives, and technological feasibilities.

Suggested technical electives: Civil and Environmental Engineering 137, 149, 153, 161, 162, 163, 165; Engineering 160; Environmental Science and Policy 167, 168A, 168B, 171, 173, 178, 179

Suggested Advisers: Y. Fan, J. T. Harvey, A. Kendall, P. L. Mokhtarian, D. Niemeier, D. Sperling, H. M. Zhang

Water Resources Engineering. This area includes hydrology, hydraulics, fluid mechanics, and water resources systems planning and design. Hydrology deals with quantifying and understanding all aspects of the hydrologic cycle, including the relationships between precipitation, runoff, groundwater, and surface water. Water quality and contaminant transport issues are linked to hydrologic conditions. Hydraulics and fluid mechanics deal with flows in pipes, open-channel water-distribution systems, and natural systems, such as lakes and estuaries. Water resources systems planning and design deals with the comprehensive development of water resources to meet the multiple needs of industry, agriculture, municipalities, recreation, and other activities.

Suggested technical electives: Agricultural and Resource Economics 176; Atmospheric Science 121A; Biological and Agricultural Engineering 145; Civil and Environmental Engineering 141, 141L, 142, 144, 145, 148B, 153, 155; Environmental Science and Policy 150A, 151; Hydrologic Science 110.

Suggested Advisers: F. Bombardelli, T. R. Ginn, M. L. Kavvas, J. R. Lund, M. A. Marino, S. G. Schladow, B. A. Younis

Civil Engineering

Upper Division Required Courses

Engineering 102, 103, 104, 104L, 105, 106 20
Applied Science Engineering 115 4
Civil and Environmental Engineering 114 4
One course from Applied Science Engineering 116, Civil and Environmental Engineering 153, Mathematics 118A, or Statistics 108 4
A minimum of four of the following group options (a minimum of two courses in each of the four areas and a minimum of 19 design units from group option selections, technical electives, and programming elective. Courses listed in more than one group may be counted only once. The design unit content of each course is noted on the Civil Engineering degree requirement advising sheet, available from the department, also shown in its entirety on the department's undergraduate Web site.) 28*

Environment: Civil and Environmental Engineering148A or 149 and at least one from courses 140, 143, 148B, 150;
Geotechnical: Civil and Environmental Engineering 171 and 171 Lab and at least one from courses 173, 175, 179;
Structures: Civil and Environmental Engineering 135 and at least one from courses 130, 131, 132, 136, 137, 138, 139, 179;
Transportation: Civil and Environmental Engineering 161 or 163 and at least one from courses 162, 165, 179;
Water Resources: Civil and Environmental Engineering 141 and 141 Lab and at least one from courses 142, 144, 145, 146, 155

Technical electives 18
Fourteen units to be selected from upper division engineering courses not already used to fulfill another requirement; of these, seven units must be selected from letter-graded Civil and Environmental Engineering courses. Non-engineering units from the Technical Elective list** may be included, not to exceed four units total toward the degree.
General Education electives................... 12
Minimum Upper Division Units 90

Minimum Units Required for Major 184

*Units in excess of the 28 unit requirement may count toward the technical elective requirement. Please consult with the departmental staff adviser.
**Departmental technical elective listing available from staff advisor. Maximum of four units from this list may count toward degree requirements.

Civil Engineering/Materials Science and Engineering

Upper Division Required Courses

Engineering 100, 102, 103, 104, 104L, 105, 106 23
Applied Science Engineering 115............ 4
Civil and Environmental Engineering 114 4
One course from Applied Science Engineering 116, Civil and Environmental Engineering 153, Mathematics 118A, 121, or Statistics 108..................................... 4
Civil and Environmental Engineering 130, 135, 141, 141L, 148A, 171, 171L....... 21
Three courses from Civil and Environmental Engineering 132, 136, 143, 145, 148B, 150, 155, 162, 173 (and must include one of Civil and Environmental Engineering 136, 145, 148B, 150, 162, or 173)............. 11
Materials Science and Engineering 160, 162, 162L, 164, 174, and one course from Materials Science and Engineering 172, 180, 181, 182, 188A and 188B (these courses must be taken in consecutive quarters to fulfill one course requirement) 22
General Education electives 12
Minimum Upper Division Units ... 101

Minimum Units Required for Major 194

The Minor in Construction Engineering and Management

To pre-apply to this minor program offered by Civil and Environmental Engineering, find full details regarding admission and completion in the Application Form available from the department Web site or the undergraduate advisor in 2045 Engineering III.

Minor Program Requirements:

Prerequisite courses must be completed prior to enrollment in coursework taken for minor.

UNITS

Construction Engineering and Management 24

Civil and Environmental Engineering 137, 143, 153 12
Twelve units from Civil and Environmental Engineering 179, Agricultural and Resource Economics 112, 155, 157, 171A, 171B, Economics 134, 162, Psychology 156; may include one course from Agricultural and Resource Economics 18, Management 11A, 11B 12

Minor advisors. J. Darby, J.T. Harvey, J. Lund

The Graduate Program

M.S., M.Engr., D.Engr. and Ph.D.
Professional Certificate
Designated Ph.D. emphasis available in Biotechnology
http://cee.engr.ucdavis.edu
(530) 752-1441

With over 30 faculty, over $13 million in annual research expenditures and over 220 graduate students, the department of Civil and Environmental Engineering integrates research, education and professional service in areas related to civil infrastructure and the environment. Graduate students benefit from close working relationships with professors who are the leading international experts in their field. They are supported in their study and research by robust funding, and they have access to state-of-the-art research centers. For example, one of the experimental laboratories that constitutes NEES, the Network for Earthquake Engineering Simulation, *nees@ucdavis.edu*, has the largest centrifuge of its kind in the nation and gives researchers access to their peers

at other unique centers via high-speed networks. Since 1960, researchers at the J. Amorocho Hydraulics Laboratory (JAHL) have served the state of California by solving ecological, biological, environmental and hydraulic engineering problems. Our graduates go on to serve the profession and academia by advancing the leading edge of fundamental knowledge, as well as engineering practice.

Generous financial support is available in the form of research assistantships, teaching assistantships, fellowships and financial aid. About 75% of the graduate students in our program are either fully or partially supported.

Research Highlights:

- Environmental Engineering
- Structural Engineering and Structural Mechanics
- Geotechnical Engineering
- Water Resources Engineering
- Hydraulics and Fluid Mechanics
- Hydrology
- Systems Planning and Design
- Transportation Engineering
- Transportation Planning and Design
- Alternative Fuel Transportation Infrastructure
- Environmental Planning and Management

Research Facilities and Partnerships:

- NSF NEES Geotechnical Centrifuge
- Institute of Transportation Studies
- J. Amorocho Hydraulics Laboratory (JAHL)
- Center for Environmental and Water Resources Engineering
- Tahoe Environmental Research Center

Complete Information on our Web site.

Courses in Engineering: Civil and Environmental (ECI)

Lower Division Courses

3. Introduction to Civil and Environmental Engineering Systems (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: trigonometry; restricted to lower division students. pass 1 restricted to Civil Engineering majors. An introduction to civil engineering systems. A general view of the engineering process as obtained by participation in laboratory experiments illustrative of the solution of representative, but simplified, engineering problems. Not open for credit to upper division students.—I. (I.) Darby

10. Introduction to Surveying (4)
Lecture—2 hours; laboratory—6 hours. Prerequisite: Physics 9A (may be taken concurrently). Restricted to majors in Civil Engineering, Civil Engineering/Materials Science and Engineering, and Biological Systems Engineering. Theory and practice of civil engineering surveying. Modern methods of land surveying and computer-aided design and geographic information systems in civil engineering practice. Only 3 units of credit for students who have previously taken Biological Systems Engineering 1.—III. (III.)

19. C Programming for Civil and Environmental Engineers (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Mathematics 22A (may be taken concurrently). Computational problem solving techniques for civil and environmental engineering applications using structured C programming. Algorithm design applied to realistic problems. Not open for credit to students who have completed course 119A.—II. (II.) Jeremic, Kleeman

90X. Lower Division Seminar (1-4)
Seminar—1-4 hours. Prerequisite: consent of instructor. Examination of a special topic in a small group setting. May be repeated for credit.

92. Internship in Engineering (1-5)
Internship. Prerequisite: lower division standing; approval of project prior to period of internship. Supervised work experience in civil engineering. May be repeated for credit. (P/NP grading only.)

98. Directed Group Study (1-5)
Prerequisite: consent of instructor and lower division standing. (P/NP grading only.)

99. Special Study for Undergraduates (1-5)
Prerequisite: consent of instructor; lower division standing. (P/NP grading only.)

Upper Division Courses

114. Probabilistic Systems Analysis for Civil Engineers (4)
Lecture—4 hours. Prerequisite: Mathematics 21C. Probabilistic concepts and models in engineering. Statistical analysis of engineering experimental and field data. Introduction to stochastic processes and models of engineering systems. Not open for credit to students who have completed Statistics 120.—I, II. (I, II.) Mokhtarian

119. Parallel Processing for Engineering Applications (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: C programming or consent of instructor. Fundamental skills in parallel computing for engineering applications; emphasis on structured parallel programming for distributed memory parallel clusters. Not open for credit to students who have completed course 119B. Offered in alternate years.—III. (III.) Kleeman, Jeremic

123. Urban Systems and Sustainability (4)
Lecture—4 hours. Prerequisite: upper division standing. Systems-level approach of how to evaluate and then modify sustainability of urban systems based on interaction with natural environments. Topics include: definition/metrics of urban sustainability; system analyses of urban systems; enabling technology, policies, legislation; measures and modification of ecological footprints. GE Credit: SciEng, SocSci, Div, Wri.—I. (I.) Loge, Niemeier

130. Structural Analysis (4)
Lecture—4 hours. Prerequisite: Mathematics 22A, Engineering 104. Elastic structural analysis of determinate and indeterminate trusses, beams and frames. Plastic bending and limit analysis.—III. (III.)

131. Matrix Structural Analysis (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 6 and 104; retricted to Engineering majors only. Matrix formulation and computer analysis of statically indeterminate structures. Stiffness and flexibility formulations for elastic structures. Finite element methods for elasticity and bending problems.—I. (I.) Bolander

132. Structural Design: Metallic Elements (4)
Lecture—4 hours. Prerequisite: Engineering 104. Design of metallic beams, columns, and other members for various types of loading and boundary conditions; design of connections between members; member performance within structural systems.—II. (II.) Kanvinde

135. Structural Design: Concrete Elements (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 104; restricted to majors in Civil Engineering, Civil Engineering/Materials Science and Engineering, or Materials Science and Engineering only. Strength design procedures for columns, rectangular beams, T-beams and beams of general cross-section. Building code requirements for bending, shear, axial load, combined stresses and bond. Introduction to prestressed concrete.—I, III. (I, III.) Chai

136. Building Design: Wood, Steel, and Concrete Applications (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: courses 130 or 131, course 135; course 132 recommended. Horizontal and lateral load paths; dead and live loading; earthquake and wind forces. Approximate analyses of building frames; wood engineering for buildings. Steel, concrete and wood building design.—III. (III.)

137. Construction Principles (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: upper division standing in Engineering; Engineering 104 recommended. Project management, with civil engineering construction and design applications, including project scope, schedule, resources, cost, quality, risk, and control. Construction industry overview. Interactions between planning, design, construction, operations. Construction operations analysis. Contract issues. Project management software, field trips, guest lectures.—III. (III.) Harvey

138. Earthquake Loads on Structures (4)
Lecture—4 hours. Prerequisite: Engineering 102, course 130 or 131. Determination of loads on structures due to earthquakes. Methods of estimating equivalent static lateral forces; response spectrum and time history analysis. Concepts of mass, damping and stiffness for typical structures. Design for inelastic behavior. Numerical solutions and Code requirements.—II. (II.)

139. Advanced Structural Mechanics (3)
Lecture—3 hours. Prerequisite: Engineering 104 or the equivalent. Review of stress, strain, equilibrium, compatibility, and elastic material behavior. Plane stress and plane strain problems in elasticity theory; stress function. Theories for straight, tapered, composite, and curved beams. Beams on elastic foundations. Introduction to plates, curved membranes, and cables.—III. (III.) Dafalias

140. Environmental Analysis of Aqueous Systems (3)
Lecture—3 hours. Prerequisite: Chemistry 2B; course 148A recommended. Introduction to chemical principles underlying current practices in sampling and analysis of water and wastewater.—I. (I.) Young

140L. Environmental Analysis of Aqueous Systems Laboratory (1)
Laboratory—3 hours. Prerequisite: Chemistry 2B or the equivalent; course 140 (may be taken concurrently). Restricted to Civil Engineering undergraduate and graduate students. Introduction to "wet chemical" and instrumental techniques commonly used in the examination of water and wastewater and associated data analysis.

141. Engineering Hydraulics (3)
Lecture—3 hours. Prerequisite: Engineering 103. Nature of flow of a real fluid; flow in pipes; open channel flow; turbomachinery; fluid forces on objects: boundary layers, lift and drag.—I, III. (I, III.) Schladow

141L. Engineering Hydraulics Laboratory (1)
Laboratory—3 hours. Prerequisite: course 141 (may be taken concurrently). Open to Engineering students only. Laboratory experiments and demonstrations on flow measurement, sluice gates, hydraulic jump, flow characteristics, and centrifugal pumps.—I, III. (I, III.) Schladow

142. Engineering Hydrology (4)
Lecture—4 hours. Prerequisite: courses 141 (may be taken concurrently); course 114 recommended. The hydrologic cycle. Evapotranspiration, interception, depression storage and infiltration. Streamflow analysis and modeling. Flood routing through channels and reservoirs. Frequency analysis of hydrologic variables. Precipitation analysis for hydrologic design. Hydrologic design.—I. (I.) Kavvas

143. Green Engineering Design and Sustainability (4)
Lecture—4 hours. Prerequisite: upper division standing; restricted to Civil Engineering and Civil Engineering/Materials Science and Engineering majors only. Application of concepts, goals, and metrics of sustainability, green engineering, and industrial ecology to the design of engineered systems. Life-cycle analyses, waste audit and environmental management systems, economics of pollution prevention and sustainability, and substitute materials for products and processes.—I. (I.) Loge

144. Groundwater Systems Design (4)
Lecture—4 hours. Prerequisite: course 141. Groundwater occurrence, distribution, and movement; groundwater flow systems; radial flow to wells and aquifer testing; aquifer management; groundwater contamination; solute transport by groundwater; fate and transport of subsurface contaminants. Groundwater supply and transport modeling.—I. (I.) Ginn

145. Hydraulic Structure Design (4)
Lecture—2 hours; discussion—1 hour; laboratory—3 hours. Prerequisite: course 141 and 141L; course 142 recommended. Fundamental principles and practical aspects of the design of hydraulic structures including water storage, conveyance, and pumping systems. Emphasis on use of industry-standard computer software for hydraulic design.—III. (III.) Younis

146. Water Resources Simulation (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Engineering 103; Applied Science Engineering 115, course 141, 142 recommended. Computer simulation techniques in the analysis, design and operation of surface water systems; modeling concepts and practices with application to surface runoff; water quality in rivers and streams and dispersion of contaminants in water bodies. GE credit: Wrt.—II. (II.) Bombardelli

148A. Water Quality Management (4)
Lecture—4 hours. Prerequisite: Engineering 103. Basic concepts of water quality. Fundamentals of water and wastewater treatment processes. Analysis of treatment process flowsheets. Analysis of water quality management alternatives.—II. (II.) Wuertz

148B. Water Quality Management Systems Design (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 148A. Application of the principles of fluid mechanics to the analysis and design of flow measuring devices, pumps and pump station design, water distribution systems, wastewater collection systems, water and wastewater treatment plant headloss analysis, and bioremediation systems.—III. (III.) Darby

149. Air Pollution (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Mathematics 21D, 22B, Chemistry 2B, Atmospheric Science 121A or Engineering 103. Physical and technical aspects of air pollution. Emphasis on geophysical processes and air pollution meteorology as well as physical and chemical properties of pollutants. (Same course as Atmospheric Science 149.)—I. (I.) Cappa

150. Air Pollution Control System Design (4)
Lecture—2 hours; laboratory—3 hours; discussion—1 hour. Prerequisite: Engineering 103, 105, 106, course 149. Design and evaluation of air pollution control devices and systems.—II. (II.) Cappa

153. Deterministic Optimization and Design (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Mathematics 21C, 22A, computer programming course; Applied Science Engineering 115 recommended. Operations research. Optimization techniques such as linear programming, dynamic programming, and non-linear programming. Applications in water, transportation, environmental, infrastructure systems, and other civil engineering disciplines through computer-based course projects.—I. (I.) Fan

155. Water Resources Engineering Planning (4)
Lecture—4 hours. Prerequisite: Engineering 106 or Economics 1A, course 114, 142; course 153 recommended. Basic engineering planning concepts; role of engineering, economic, environmental and social information and analysis; institutional, political and legal aspects. Case studies and computer models illustrate the planning of water resource systems. GE credit: Wrt.—III. (III.) Lund

161. Transportation System Operations (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Engineering 6 (or the equivalent) and 102. Principles of transportation system operations; traffic characteristics and methods of measurement; models of transportation operations and congestion applied to urban streets and freeways.—I. (I.) Zhang

162. Transportation System Design (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 161 or 163. Driver, vehicle and roadway factors and their relationship to transportation planning and system design. Generalized design paradigm; group problem solving.—III. (III.)

163. Energy and Environmental Aspects of Transportation (4)
Lecture—3 hours; extensive writing. Prerequisite: Economics 1A and course 162. Engineering, economic, and systems planning concepts. Analysis and evaluation of energy, air quality and selected environmental attributes of transportation technologies. Strategies for reducing pollution and petroleum consumption in light of institutional and political constraints. Evaluation of vehicle emission models. (Same course as Environmental Science and Policy 163.) Offered in alternate years. GE credit: Wrt.—I. Sperling

165. Transportation Policy (3)
Lecture—3 hours. Prerequisite: Economics 1A and Engineering 106 recommended. Transportation and associated environmental problems confronting urban areas, and prospective technological and institutional solutions. Draws upon concepts and methods from economics, engineering, political science and environmental studies. Offered in alternate years. GE credit: SocSci, Wrt.—(I.) Sperling

171. Soil Mechanics (4)
Lecture—4 hours. Prerequisite: Engineering 103 and 104 (may be taken concurrently), course 171L must be taken concurrently. Restricted to Civil Engineering and Civil Engineering/Materials Science and Engineering majors only. Soil formations, mass-volume relationships, soil classification, effective stress, soil-water-void relationships, compaction, seepage, capillarity, compressibility, consolidation, strength, states of stress and failure, lateral earth pressures, and slope stability.—I, III. (I, III.) Kutter

171L. Soil Mechanics Laboratory (1)
Laboratory—3 hours. Prerequisite: course 171 must be taken concurrently. Laboratory studies utilizing standard testing methods to determine physical, mechanical and hydraulic properties of soil and demonstration of basic principles of soil behavior.—I, III. (I, III.) Kutter

173. Foundation Design (4)
Lecture—4 hours. Prerequisite: courses 135 (may be taken concurrently) and 171. Soil exploration and determination of soil properties for design; consolidation and elastic settlements of foundations; bearing capacity of soils and footing design; lateral earth pressures and retaining wall design; pile foundations; excavations and dewatering.—II. (II.) Boulanger

175. Geotechnical Earthquake Engineering (4)
Lecture—4 hours. Prerequisite: course 171 and 171L. Earthquake sources and ground motions. Cyclic behavior of soils; triggering, consequences, and mitigation of effects of liquefaction. NEES (Network for Earthquake Engineering Simulation) equipment and techniques for studying earthquake engineering with focus on liquefaction problems.—II. (II.) Kutter

179. Pavement Engineering (4)
Lecture—3 hours; discussion/lecture—3 hours. Prerequisite: Engineering 104. Pavement types (rigid, flexible, unsurfaced, rail), their applications (roads, airfields, ports, rail) and distress mechanisms. Materials, traffic and environment characterization. Empirical and mechanistic-empirical design procedures. Maintenance, rehabilitation and reconstruction; construction quality; asphalt concrete mix design.—I. (I.) Harvey

189A-J. Selected Topics in Civil Engineering (1-5)
Prerequisite: consent of instructor. Directed group study of selected topics with separate sections in (A) Environmental Engineering; (B) Hydraulics and Hydrologic Engineering; (C) Engineering Planning; (D) Geotechnical Engineering; (E) Structural Engineering; (F) Structural Mechanics; (G) Transportation Engineering; (H) Transportation Planning; (I) Water Resources Engineering; (J) Water Resources Planning. May be repeated for credit when the topic is different.—I, II, III. (I, II, III.)

190C. Research Group Conferences in Civil and Environmental Engineering (1)
Discussion—1 hour. Prerequisite: upper division standing in Civil and Environmental Engineering; consent of instructor. Research group conferences. May be repeated for credit. (P/NP grading only.)—I, II, III. (I, II, III.)

192. Internship in Engineering (1-5)
Internship. Prerequisite: upper division standing; approval of project prior to the period of the internship. Supervised work experience in civil engineering. May be repeated for credit. (P/NP grading only.)

198. Directed Group Study (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)

199. Special Study for Advanced Undergraduates (1-5)
Prerequisite: senior standing in engineering and at least a B average. (P/NP grading only.)

Graduate Courses

201. Introduction to Theory of Elasticity (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Engineering 104. Fundamental equations of elasticity in three dimensions; plane stress and plane strain; flexture and torsion of bars of various shapes. Introduction to variational and approximate methods.—I. (I.) Rashid

203. Inelastic Behavior of Solids (3)
Lecture—3 hours. Prerequisite: course 201. Fundamentals of theories of plasticity, viscoelasticity and viscoplasticity for solids. Macroscopic constitutive modelling for engineering materials, e.g., metals, polymers, soils, etc., and microscopic motivation. Offered in alternate years.—II. Dafalias

205. Continuum Mechanics (3)
Lecture—3 hours. Prerequisite: course 201. Tensor formulation of the field equations for continuum mechanics, including large deformation effects. Invariance and symmetry requirements. Introduction to nonlinear thermoelasticity and thermodynamics. Solution of three-dimensional problems. Selected topics. Offered in alternate years.—(II.) Dafalias

206. Fracture Mechanics (4)
Lecture—4 hours. Prerequisite: course 201; Engineering 104. Linear and nonlinear fracture mechanics, stress analysis, energy concepts, brittle fracture criteria, path independent integrals, Dugdale- Barenblatt model, general cohesive zone models, ductile fracture criteria, crack tip fields for stationary and propagating cracks, fatigue. Application of numerical methods for fracture mechanics.Offered in alternate years.—II. (II.) Rashid

211. Advanced Matrix Structural Analysis (4)
Lecture—4 hours. Prerequisite: course 131. Analysis of complex frameworks by the displacement method; treatment of tapered beams, curved beams, and beams on elastic foundations; partially rigid connections; geometric and material nonlinearities; buckling; flexibility-based formulations; FEM-software for nonlinear analysis of structures.—I. (I.) Kunnath

212A. Finite Element Procedures in Applied Mechanics (4)
Lecture—4 hours. Prerequisite: Applied Science Engineering 115, or Mathematics 128A and Mathematics 128B (may be taken concurrently). Weighted-residual and Rayleigh-Ritz methods. Weak/variational formulation and development of discrete equations using finite element approximations. Application to one- and two-dimensional problems (heat conduction).—II. (II.) Sukumar

212B. Finite Elements: Application to Linear and Non-Linear Structural Mechanics Problems (4)
Lecture—4 hours. Prerequisite: course 212A. Application to linear and nonlinear structural mechanics problems. Linear elasticity, weak form, and finite element approximation. Incompressible media problems. Non-linear problems with material nonlinearity.—III. (III.) Sukumar

213. Analysis of Structures Subjected to Dynamic Loads (4)
Lecture—4 hours. Prerequisite: courses 138 and 211. Analysis of structures subjected to earthquake, wind and blast loading; distributed, consistent and lumped mass techniques; computer implementation; nonlinear response spectrum; frequency and time domain analysis; seismic protection of structures; numerical methods in linear and nonlinear structural dynamics.—II. (II.) Kunnath

221. Theory of Plates and Introduction to Shells (3)
Lecture—3 hours. Prerequisite: course 201 (may be taken concurrently). Development of classical and refined plate theories. Application to isotropic, orthotropic and composite plates. Solutions for rectangular and circular plates. Membrane theory for axisymmetric shells and bending of circular shells.

232. Advanced Topics in Concrete Structures (4)
Lecture—4 hours. Prerequisite: course 130, 135, 138 and graduate standing. Ductility of reinforced concrete; strength of two-way slabs; modified compression field theory.—I. (I.) Chai

233. Advanced Design of Steel Structures (4)
Lecture—4 hours. Prerequisite: courses 130 or 131, 132. Review of Load and Resistance Factor Design (LRFD); steel-plate girder design; plastic design of indeterminate systems; moment frames and bracing systems; connection design; seismic design of steel structures; vibration of flooring systems; steel-concrete composite design.—III. (III.) Kanvinde

234. Prestressed Concrete (4)
Lecture—4 hours. Prerequisite: courses 130 or 131, 135. Survey of methods and applications; prestressing materials and systems; prestress losses; flexural design; design for shear and torsion; deflection computation and control; continuous beams and indeterminate structures; floor systems; partial prestressing; design of compression members; strut-and-tie models. Offered in alternate years—II. Bolander

235. Cement Composites (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 104. Applications of cement composites; materials selection and proportioning; component and composite properties; hydration reactions and microstructure development; mechanisms of failure; nondestructive test methods; fiber reinforcement; concrete durability; novel reinforcing materials; ferrocement; repair and retrofit technologies; applications to structural design. Offered in alternate years.—(II.) Bolander

236. Design of Fiber Reinforced Polymer Composite Structures (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 135. Basics of mechanics and design of polymer matrix composites: composite classification, manufacturing process, micromechanical property determination, classical lamination theory, strength theories, first-ply-failure, test methods, design practice, strengthening and retrofitting of existing reinforced concrete structures.—II. (II.) Cheng

237. Bridge Design (4)
Lecture—4 hours. Prerequisite: courses 130, 135; course 234 recommended. Open to graduate students only. Bridge types, behavior and construction characteristics; design philosophy, details according to Caltrans and American Association of State Highway and Transportation Officials codes, principles; seismic design and retrofit of concrete bridges; modern bridges using advanced fiber reinforced polymer composites; fieldtrip required.—II. (II.) Cheng

238. Performance-Based Seismic Engineering (4)
Lecture—4 hours. Prerequisite: Courses 138 and 213. Modern seismic design; performance-based seismic design; seismic hazard; seismic demands: linear and nonlinear procedures; performance assessment: deterministic and probabilistic procedure; review of FEMA-350, FEMA-356, ATC-40 and other performance-based guidelines.—(III.) Kunnath

240. Water Quality (4)
Lecture—4 hours. Prerequisite: courses 141 and 142. Quality requirements for beneficial uses of water. Hydrologic cycle of quality. Hydromechanics in relation to quality of surface and groundwaters; transport and fate of waterborne pollutants. Heat budget for surface waters; predictive methods; introduction to water quality modeling.—II. (II.) Schladow

241. Air Quality Modeling (4)
Lecture—4 hours. Prerequisite: Applied Science Engineering 115, course 119A, 149, 150, one from course 242 or 247, or the equivalent, graduate standing. Modeling of urban and regional air quality problems including gas-phase chemical reactions, aqueous-phase chemical reactions, phase partitioning, and numerical solution schemes. Offered in alternate years.—I. Kleeman

242. Air Quality (4)
Lecture—4 hours. Prerequisite: Engineering 105, course 141, 149 or the equivalent. Factors determining air quality. Effects of air pollutants. Physical and chemical fundamentals of atmospheric transport and reaction. Introduction to dispersion modeling. Offered in alternate years.—(III.) Kleeman

243A. Water and Waste Treatment (4)
Lecture—4 hours. Prerequisite: course 148A or the equivalent. Characteristics of water and airborne wastes; treatment processes and process kinetics; treatment system design.—I. (I.) Young

243B. Water and Waste Treatment (4)
Lecture—4 hours. Prerequisite: course 243A. Continuation of course 243A. Aeration, thickening, biological processes, design of biological treatment systems.—II. (II.) Loge

245A. Applied Environmental Chemistry: Inorganic (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Engineering 105, Chemistry 2B or the equivalent, course 140; Chemistry 2C or 107A recommended. Chemistry of natural and polluted waters. Topics include chemical, kinetic and equilibrium principles, redox reactions, gas solution and solid-solution equilibria, thermodynamics, carbonate systems, coordination chemistry, interfacial phenomena. Offered in alternate years.—(III.) Young

245B. Applied Environmental Chemistry: Organic (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Chemistry 128A, 128B, 128C, or the equivalent; Chemistry 2C or 107A recommended. Transport and transformation of organic chemicals in the environment. Topics include application of thermodynamics to predict solubility and activity coefficients; distribution of organic chemicals between the aqueous phase and air, solvent, or solid phases; chemical, photochemical and biological transformation reactions. Offered in alternate years.—III. Young

246. Pilot Plant Laboratory (4)
Lecture—1 hour; discussion—1 hour; laboratory—6 hours. Prerequisite: course 243A, 243B (may be taken concurrently) or consent of instructor, graduate standing. Laboratory investigation of physical, chemical, and biological processes for water and wastewater treatment.—II. (II.) Darby

247. Aerosols (4)
Lecture—4 hours. Prerequisite: Engineering 103, 105, course 141, 149. Behavior of airborne particles including particle formation, modification, and removal processes. Offered in alternate years.—I. Kleeman

247L. Aerosols Laboratory (4)
Lecture—2 hours; laboratory—6 hours. Prerequisite: course 247. Methods of generation and characterization of aerosols. Detailed topics may include flow rate measurement, aerosol generation, aerosol collection, ions measurement, metals measurement, and carbon measurement. May be repeated once for credit.—(I.) Kleeman

248. Biofilm Processes (4)
Lecture—4 hours. Prerequisite: Soil Science 111 or 211 or course 243B or consent of instructor; calculus and basic cell molecular biology recommended. Natural and engineered biofilms, including biofilm occurrence and development, spatial structure, microbial processes, fundamental and applied research tools, biofilm reactors, beneficial uses, and detrimental effects.—(III.) Wuertz

249. Probabilistic Design and Optimization (4)
Lecture—4 hours. Prerequisite: courses 114 and 153 and Engineering 106, or equivalents. Design by optimization for probabilistic systems, decision theory, the value of information, probabilistic linear programming, probabilistic dynamic programming, nonlinear probabilistic optimization. Applications in civil engineering design, project evaluation, and risk management. Offered in alternate years.—II. Lund

250. Civil Infrastructure System Optimization and Identification (4)
Lecture—4 hours. Prerequisite: Mathematics 21C, 22A, programming course; Applied Science Engineering 115 and mathematical modeling course recommended. Applied mathematics with a focus on modeling, identifying, and controlling dynamic, stochastic, and underdetermined systems. Applications in transportation networks, water resource planning, and other civil infrastructure systems. Offered in alternate years.—(III.) Fan

251. Transportation Demand Analysis (4)
Lecture—4 hours. Prerequisite: course 114 or the equivalent. Procedures used in urban travel demand forecasting. Principles and assumptions of model components (trip generation, trip distribution, model split). New methods of estimating travel demand. Computer exercises using empirical data to calibrate models and forecast travel demand.—I. (I.) Niemeier

252. Sustainable Transportation Technology and Policy (3)
Lecture—2 hours; discussion—1 hour. Prerequisite: course 165. Role of technical fixes and demand management in creating a sustainable transportation system. Emphasis on technology options, including alternative fuels, electric propulsion, and IVHS. Analysis of market demand and travel behavior, environmental impacts, economics and politics. (Same course as Environmental Science and Policy 252.) Offered in alternate years—III. Sperling

253. Dynamic Programming and Multistage Decision Processes (4)
Lecture—4 hours. Prerequisite: Mathematics 21C, 22A, programming course; Applied Science Engineering 115 recommended. Operations research. Optimization techniques with a focus on dynamic programming in treating deterministic, stochastic, and adaptive multistage decision processes. Brief review of linear programming and non-linear programming. Applications in transportation networks and other civil infrastructure systems.—III. (III.) Fan

254. Discrete Choice Analysis of Travel Demand (4)
Lecture—4 hours. Prerequisite: course 114. Behavioral and statistical principles underlying the formulation and estimation of discrete choice models. Practical application of discrete choice models to characterization of choice behavior, hypothesis testing, and forecasting. Emphasis on computer exercises using real-world data sets.—III. (III.) Mokhtarian

256. Urban Traffic Management and Control (4)
Lecture—4 hours. Prerequisite: course 114. Basic concepts, models, and methods related to the branch of traffic science that deals with the move-

ment of vehicles on a road network, including travel speed, travel time, congestion concepts, car-following and hydrodynamic traffic models.—II. (II.) Zhang

257. Flow in Transportation Networks (4)
Lecture—4 hours. Prerequisite: course 153; 161 or 256 recommended. Elements of graph theory, a survey of pertinent optimization techniques, extremal principles in network flow problems, deterministic equilibrium assignment, stochastic equilibrium assignment, extensions of equilibrium assignments and dynamic transportation network assignment.—III. (III.) Zhang

258. Transportation Planning in Developing Countries (3)
Lecture—3 hours. Prerequisite: course 160 or consent of instructor. Investigation of the role that transportation investments and policies play in the development of regions and countries. Emphasis is on identifying appropriate technologies, policies, and planning methods for designing transportation systems in regions of differing socioeconomic, geographic, and institutional settings. Offered in alternate years.—(III.) Sperling

259. Asphalt and Asphalt Mixes (4)
Lecture—4 hours. Prerequisite: course 179 or consent of instructor. Asphalts and asphalt mix types and their use in civil engineering structures, with primary emphasis on pavements. Asphalt, aggregate properties and effects on mix properties. Design, construction, recycling. Recent developments and research. Offered in alternate years.—(II.) Harvey

260. Sediment Transport (4)
Lecture—4 hours. Prerequisite: course 141 or equivalent. Sediment transport in hydrologic systems. Process-oriented course which will emphasize how sediment moves and the physical processes that affect sediment transport. Field trip. Offered in alternate years.—I. Schoellhamer

264A. Transport, Mixing and Water Quality in Rivers and Lakes (4)
Lecture—4 hours. Prerequisite: course 141 and 240. Principal causes of mixing and transport in rivers, lakes and reservoirs, and their impacts on water quality. Case studies of specific lakes and rivers. Offered in alternate years.—III. Schladow

264B. Transport, Mixing and Water Quality in Estuaries and Wetlands (4)
Lecture—4 hours. Prerequisite: courses 141 and 240. Principal causes of mixing and transport in estuaries and wetlands, and their impacts on water quality. Topics include advection/diffusion; tides; transverse mixing; longitudinal dispersion; sediment transport; nutrient cycling; computer modeling of estuaries. Case studies of specific systems. Offered in alternate years.—(III.) Schladow

265. Stochastic Contaminant Transport (4)
Lecture—4 hours. Prerequisite: course 266. Stochastic theory of molecular diffusion covered by means of Taylor-Chandrasekhar theory. Turbulence diffusion covered in the Lagrangian-Eulerian frameworks. Application of theory to contaminant transport in groundwater aquifers, atmosphere, river and oceanic environments. Offered in alternate years.—(I.) Kavvas

266. Applied Stochastic Methods in Engineering (4)
Lecture—4 hours. Prerequisite: course 114 or Mathematics 131 or Statistics 130A or 131A; Mathematics 118A (may be taken concurrently). Stochastic processes classification; Gaussian random fields; stochastic calculus in mean square; Ito and Stratonovich stochastic differential equations; Fokker-Planck equation; stochastic differential equations with random coefficients. Offered in alternate years.—I. Kavvas

267. Water Resources Management (3)
Lecture—3 hours. Prerequisite: courses 114, 141 and 142; course 153 recommended. Engineering, institutional, economic, and social basis for managing local and regional water resources. Examples in the context of California's water development and management. Uses of computer modeling to improve water management.—I. (I.) Lund

268. Infrastructure Economics (3)
Lecture—3 hours. Prerequisite: Economics 1A, Engineering 106 or the equivalent. Economics applied to infrastructure engineering planning, operations, maintenance, and management problems; microeconomic and macroeconomic theories; benefit-cost analysis; effect of uncertainty; optimization economics; non-classical economics; public finance. Offered in alternate years.—(II.) Lund

269. Transportation-Air Quality: Theory and Practice (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 149 or the equivalent. Health and regulatory aspects of airborne pollutants. Principles of modeling vehicle emissions. Conformity issues and the regulatory framework. Regional and micro-scale modeling. Offered in alternate years.—(III.) Niemeier

270. Advanced Water Resources Management (3)
Lecture—3 hours. Prerequisite: courses 153 and 267 or the equivalent. Discussion of technical papers related to planning theory, system maintenance, regionalization, multi-objective methods, risk analysis, institutional issues, pricing model application, economic development, forecasting, operations, and other topics. Offered in alternate years.—III. Lund

272A. Advanced Hydrogeology (4)
Lecture—4 hours. Prerequisite: course 144; Mathematics 118A recommended. Flow in confined, unconfined, and leaky aquifers. Geological aspects of aquifers. Regional groundwater flow and hydraulics of pumping and recharging wells. Identification of aquifer parameters. Isotope hydrogeology and recharge estimation.—II. (II.) Ginn

272B. Advanced Hydrogeology (4)
Lecture—4 hours. Prerequisite: courses 212A and 272A. Processes of subsurface flows and transport. Numerical methods of subsurface fluid flow and transport systems. Flow in the unsaturated zone. Fresh water/salt water interface in coastal aquifers. Macrodispersion. Identification of regional aquifer parameters. Modeling of aquifer systems. Offered in alternate years.—(III.) Ginn

272C. Multiphase Reactive Transport (4)
Lecture—4 hours. Prerequisite: courses 142, 144, 148A. Multicomponent reactive transport including multiple phases. Advective/dispersive transport, chemical equilibria, and mass transformation kinetics. Natural chemical/microbiological processes including sorption, complexation, biodegradation, and diffusive mass transfer. Eulerian and Lagrangean averaging methods. Applications to contaminant remediation problems in river and subsurface hydrology. Offered in alternate years.—III. Ginn

273. Water Resource Systems Engineering (3)
Lecture—3 hours. Prerequisite: courses 114 and 153 or the equivalent. Planning, design, and management of water resource systems. Application of deterministic and stochastic optimization techniques. Water allocation, capacity expansion, and design and operation of reservoir systems. Surface water and groundwater management. Offered in alternate years.—(I.) Marino

275. Hydrologic Time-Series Analysis (4)
Lecture—4 hours. Prerequisite: course 114 and 142. Application of statistical methods for analysis and modeling of hydrologic series. Statistical simulation and prediction of hydrologic sequences using time series methodology. Offered in alternate years.—(III.) Kavvas

276. Watershed Hydrology (4)
Lecture—4 hours. Prerequisite: course 142 or the equivalent. Analysis and mathematical modeling of hydrologic processes taking place in a watershed. Precipitation analysis and modeling. Theory of overland flow and its kinematic wave approximation. Analysis and modeling of saturated and unsaturated subsurface flow processes taking place on a hill slope.—II. (II.) Kavvas

277A. Computational River Mechanics I (4)
Lecture—4 hours. Prerequisite: Applied Science Engineering 115, course 141 (both may be taken concurrently). Unsteady open channel flows, computation of water surface profiles, shallow water equations, St. Venant equations, method of characteristics, finite difference methods, stability and accuracy of explicit and implicit schemes, flood routing in simple and compound channels, advection of plumes. Not open for credit to students who have completed course 277.—I. (I.) Younis

277B. Computational River Mechanics II (4)
Lecture—4 hours. Prerequisite: course 277A. Open channel flows, physical aspects of river mechanics, formulation of depth-averaged equations, boundary conditions, coordinates transformation and grid generation, finite-difference solution techniques, applications to two-dimensional momentum and pollutant transport in rivers. Offered in alternate years.—(III.) Younis

277C. Turbulence and Mixing Processes (4)
Lecture—4 hours. Prerequisite: graduate standing. Nature of turbulent flows, conservation equations, momentum, heat and mass transport in free and wall-bounded flows, body forces and mixing, roughness effects, turbulence modeling and simulation. Offered in alternate years.—(III.) Younis

278. Hydrodynamics (3)
Lecture—3 hours. Prerequisite: course 141. Perturbation methods. Basic water waves. Governing equations for fluid motion on a rotating earth. Rotation effects, vorticity dynamics, Ekman layer. Stratification effects, internal waves and turbulent mixing. Combined effects. Offered in alternate years.—(II.)

279. Advanced Mechanics of Fluids (4)
Lecture—4 hours. Prerequisite: course 141. Rotational flows. Navier-Stokes equations and solutions for laminar flow; boundary layer equations and solution techniques. Nature of turbulence. Reynolds equations. Introduction to turbulence modeling. Offered in alternate years.—I.

280A. Nonlinear Finite Elements for Elastic-Plastic Problems (4)
Lecture—4 hours. Prerequisite: consent of instructor. State of the art finite element methods and tools for elasticplastic problems, including computational techniques based on the finite element method and the theory of elastoplasticity. Offered in alternate years.—(III.) Jeremic

280B. Nonlinear Dynamic Finite Elements (4)
Lecture—4 hours. Prerequisite: consent of instructor. State of the art computational methods and tools for analyzing linear and nonlinear dynamics problems. Offered in alternate years.—III. Jeremic

281A. Advanced Soil Mechanics (4)
Lecture—4 hours. Prerequisite: course 171. Consolidation and secondary compression. Preloading and wick drains. Seepage and seepage pressures. Filtration, drainage, and dewatering. Shear strength: friction, cohesion, dilatancy and critical states.—I. (I.) Jeremic

281B. Advanced Soil Mechanics (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 281A. Site investigation methods: CPT, SPT, pressuremeter, vane, seismic investigation, electrical properties. Slope stability, including seepage pressures and earthquake effects. Slope stabilization and reinforcement methods. Centrifuge modeling.—II. (II.) DeJong

282. Pavement Design and Rehabilitation (4)
Lecture—4 hours. Prerequisite: course 179 or consent of instructor. Advanced pavement design and structural/functional condition evaluation for concrete and asphalt pavements. Highways, airfields, port facilities; new facilities, rehabilitation, reconstruction. Mechanistic-empirical procedures, materials, climate and traffic characterization. Use of current design methods; recent developments and research. Offered in alternate years.—II. Harvey

283. Physico-Chemical Influences and In Situ Evaluation of Soil Behavior (3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: course 171. Analysis of the mechanical behavior of soils from consideration of clay mineralogy, colloidal phenomena, ion-exchange. Soil-water-electrolyte characteristics and soil structure. Laboratory includes methods of characterization of soils, quantification of soil structure, and rotating cylinder tests to evaluate soil erosion.—I. (I.) Kutter

284. Theoretical Geomechanics (4)
Lecture—4 hours. Prerequisite: course 171. Elasticity, plasticity, micromechanics, coupled behavior and large deformations for geomaterials. Prediction of stress-strain-volume change behavior of geomaterials. Monotonic and cyclic loading, anisotropy, bifurcation of deformation.—II. (II.) Kutter

286. Advanced Foundation Design (4)
Lecture—4 hours. Prerequisite: course 173. Design and analysis of pile and pier foundations, including seismic effects; deep excavation systems; tie-back, nailing, and anchor systems; coffer dams; loads on buried conduits; ground modification techniques; and other related topics.—III. (III.) DeJong

287. Geotechnical Earthquake Engineering (4)
Lecture—4 hours. Prerequisite: courses 138 and 281A. Characteristics and estimation of earthquake ground motions; wave propagation and local site response; liquefaction potential and remediation; residual strength and stability considerations; ground deformations; dynamic soil-structure interaction.—(III.)

288. Earth and Rockfill Dams (4)
Lecture—4 hours. Prerequisite: courses 281A and 281B (may be taken concurrently). Site selection; design considerations; layout; seismic effects including considerations of fault movements; construction; environmental considerations, instrumentation; maintenance remediation and retrofit of existing dams. Offered in alternate years.—(II.)

289A-I. Selected Topics in Civil Engineering (1-5)
Lecture, laboratory, or combination. Prerequisite: consent of instructor. Directed group study of special topics with separate sections in (A) Environmental Engineering; (B) Hydraulics and Hydrologic Engineering; (C) Engineering Planning; (D) Geotechnical Engineering; (E) Structural Engineering; (F) Structural Mechanics; (G) Transportation Engineering; (H) Transportation Planning; (I) Water Resources Engineering; (J) Water Resources Planning. May be repeated for credit.—I, II, III. (I, II, III.)

290. Seminar (1)
Seminar—1 hour. Discussion of current graduate research, and guest lectures on recent advances. Oral presentation of individual study. Course required of graduate degree candidates. (S/U grading only.)—I, II, III. (I, II, III.)

290C. Graduate Research Group Conference (1)
Discussion—1 hour. Research problems, progress, and techniques in civil engineering. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

296. Topics in Water and Environmental Engineering (1)
Seminar—2 hours. Seminars presented by visiting lecturers, UC Davis faculty and, graduate students. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

298. Group Study (1-5)
Prerequisite: consent of instructor. (S/U grading only.)

299. Research (1-12)
(S/U grading only.)

Professional Course

390. The Teaching of Civil Engineering (1)
Discussion—1 hour. Prerequisite: meet qualifications for teaching assistant and/or associate-in in Civil Engineering. Participation as teaching assistant or associate-in in a designated engineering course. Methods of leading discussion groups or laboratory sections, writing and grading quizzes, use of laboratory equipment, and grading laboratory reports. May be repeated for total of 9 units. (S/U grading only.)—I, II, III. (I, II, III.)

Engineering: Computer Science

(College of Engineering)

Prasant Mohapatra, Ph.D., Chairperson of the Department

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Faculty

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Nina Amenta, Ph.D., Professor
Zhaojun Bai, Ph.D., Professor
Matthew Bishop, Ph.D., Professor
Hao Chen, Ph.D., Assistant Professor
Ian Davidson, Ph.D. Assistant Professor
Premkumar T. Devanbu, Ph.D., Professor
Matthew K. Farrens, Ph.D., Professor
Vladimir Filkov, Ph.D, Assistant Professor
Matthew Franklin, Ph.D., Professor
Michael Gertz, Ph.D., Associate Professor
Dipak Ghosal, Ph.D., Professor
Daniel Gusfield, Ph.D., Professor
Bernd Hamann, Ph.D., Professor
Kenneth I. Joy, Ph.D., Professor
Academic Senate Distinguished Teaching Award
Patrice Koehl, Ph.D., Associate Professor
Karl Levitt, Ph.D., Professor
Xin Liu, Ph.D., Assistant Professor
Bertram Ludaescher, Ph.D., Associate Professor
Kwan-Liu Ma, Ph.D., Professor
Charles U. Martel, Ph.D., Professor
Norman S. Matloff, Ph.D., Professor
Nelson Max, Ph.D., Professor
Prasant Mohapatra, Ph.D., Professor
Biswanath Mukherjee, Ph.D., Professor
Distinguished Graduate Mentoring Award
Michael Neff, Ph.D., Assistant Professor
Ronald A. Olsson, Ph.D., Professor
Academic Senate Distinguished Teaching Award
Raju Pandey, Ph.D., Associate Professor
Phillip Rogaway, Ph.D., Professor
Zhendong Su, Ph.D., Assistant Professor
S. Felix Wu, Ph.D., Associate Professor

Emeriti Faculty

Lawrence T. Kou, Ph.D., Professor Emeritus
Peter Linz, Ph.D., Professor Emeritus
Manfred G. Ruschitzka, Ph.D., Professor Emeritus
Richard F. Walters, Ph.D., Professor Emeritus,
Academic Senate Distinguished Teaching Award

Affiliated Faculty

Sean Davis, M.S., Lecturer

The Computer Science and Engineering Major Program

The Department of Computer Science administers two curricula: Computer Science and Engineering in the College of Engineering, and Computer Science in the College of Letters and Science. It also administers a minor in the College of Letters and Science. For information on the Computer Science curriculum and minor, see Computer Science, on page 196.

The field of Computer Science and Engineering encompasses the organization, design, analysis, theory, programming, and application of digital computers and computing systems. It develops versatile engineers with backgrounds spanning a broad computer hardware/software spectrum.

The Computer Science and Engineering major provides students with a solid background in mathematics, physics, chemistry, and electronic circuits and systems, all supporting the computer hardware and computer software courses that constitute the focus of the curriculum.

A key theme of this curriculum is the hardware/software interaction in today's computer systems design, a theme reflected in the balance between computer hardware and computer software aspects in the course requirements. The key theme of hardware/software interaction is also reflected in the orientation of the courses themselves. The Computer Science and Engineering major also requires additional general education electives, helping to develop the verbal skills and intellectual breadth demanded by today's employers.

The Computer Science and Engineering program prepares students to do further work in hardware, software, or electronics, either in industry or post-graduate study.

Mission. The University of California, Davis, is first and foremost, an institution of learning and teaching, committed to serving the needs of society. The Department of Computer Science contributes to the mission of the University in three ways. First, its undergraduate and graduate education programs seek to educate students in the fundamental principles of computer science and the skills needed to solve the complex technological problems of modern society; the breadth of course work provides a framework for life-long learning and an appreciation for multidisciplinary activities. Second, through its research programs, the department contributes to the development and progress of computer science, and software and information technology, to provide innovative, creative solutions for societal needs. Finally, the department disseminates its research—to enhance collaborations with the public sector, further interdisciplinary interests that benefit society, and educate the public—through publications, public service, and professional activities.

Department Objectives. *Teaching*—To provide undergraduate students with a thorough understanding of the key principles and practices of computing, which include a strong theoretical background in mathematics, basic sciences, and engineering fundamentals and an ability to apply this knowledge to practical problems. To provide students with sufficient breadth to work creatively and productively in multidisciplinary work teams; this breadth, in its broadest context, will form the basis for an appreciation and interest in life-long learning. To provide students with the ability to design and conduct experiments, and to collect and analyze data in core, as well as more specialized, areas of computer science. To provide students with breadth in the humanities and social sciences so they learn to communicate effectively, understand professional and ethical issues in society, and appreciate the interrelatedness between computing and society. To educate graduate students to be our next generation of teachers or leaders in industry, or to pursue meaningful, creative research in industry, government, or academia. *Research*—To develop and maintain research programs that produce fundamental scientific advances, as well as useful technological innovations, while simultaneously training the next generation of researchers and leaders in the field of computer science.

Objectives. To train graduates to practice computer science and engineering in a broad range of industries; to prepare interested graduates for graduate education or other professional degrees; to give students an understanding of computer software and hardware systems, and both theoretical and experimental approaches to problem solving; to ready graduates for lifelong learning; and to encourage graduates to contribute to their profession and society.

Integrated Degree Program. An integrated B.S./M.S. plan in Computer Science allows Davis students in Computer Science, Computer Science Engineering, or Computer Engineering to complete a master's degree in Computer Science in one year. Formal course work for the master's degree is reduced by 6 units for students. Students can begin graduate studies immediately after completing their