# GRADUATE SCHOOL OF BUSINESS

*Emeriti: (Professors)* Charles P. Bonini,* Alain C. Enthoven,* Gayton E. Germane, Charles A. Holloway,* Charles T. Horngren, James E. Howell, Robert K. Jaedicke, Harold J. Leavitt, James G. March, Gerald M. Meier, Arjay Miller, James R. Miller III, William F. Miller, David B. Montgomery, Jerry I. Porras, James T. S. Porterfield, Michael L. Ray, Henry S. Rowen, Myron S. Scholes, Oscar N. Serbein, William F. Sharpe, George P. Shultz, A. Michael Spence, Robert B. Wilson*; *(Associate Professor)* Andrea Shepard; *(Senior Lecturers)* Steven Brandt, Kirk O. Hanson; *(Lecturer)* Robert Augsburger

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*Associate Professors:* C. Lanier Benkard, Yossi Feinberg, Chip Heath, Peter B. Henry, Ming Huang, Ron Kasznik, Ilan Kremer, Sunil Kumar, Erica L. Plambeck, Kenneth W. Shotts, Andrzej Skrzypacz, Larissa Z. Tiedens, Romain Wacziarg, Stefanos Zenios, Jeffrey H. Zwiebel

*Assistant Professors:* Manuel Amador, Daniel T. Byrd, Antonio Davila, Jerker Denrell, Michaela M. Draganska, Yonca Ertimur, Gráinne M. Fitzsimons, Sonya A. Grier, Ilan Guttman, Wesley Hartmann, Alan D. Jagolinzer, Phillip Leslie, Brian S. Lowery, Ulrike Malmendier, Stefan Nagel, Katja Seim, Mark T. Soliman, Alan T. Sorensen, Ilya A. Strebulaev. Tunay I. Tunca, V. Brian Viard, S. Christian Wheeler, Eric Zitzewitz

*Professor (Teaching):* George G. C. Parker

*Associate Professor (Teaching):* James A. Phills, Jr.

*Courtesy Professors:* Timothy F. Bresnahan, Robert M. Daines, John A. Ferejohn, Alan M. Garber, Warren H. Hausman, Ronald A. Howard, Michael W. Kirst, Susanna Loeb, Debra E. Meyerson, Paul R. Milgrom, Norman H. Nie, Roger G. Noll, Walter W. Powell, Myra H. Strober, Robert I. Sutton

*Senior Lecturers:* David L. Bradford, R. Bruce McKern, Jeffrey H. Moore

*Lecturers:* Dick Allen, Laura K. Arrillaga, Rick Aubry, Wasim Azhar, Scott Bristol, Christopher J. Canellos, Robert B. Chess, Margaret L. Eaton, R. James Ellis, Richard P. Francisco, John W. Glynn Jr., Andrew S. Grove, William Guttentag, Brad Handler, David Hornik, Florence M. Hoylman, Mary Ann Huckabay, Franklin P. Johnson Jr., Mark Leslie, William L. McLennan, William F. Meehan III, John P. Morgridge, Joel C. Peterson, Carole Robin, Dennis M. Rohan, Diane W. Savage, Eric E. Schmidt, F. Victor Stanton, William Walsh, Peter C. Wendell, Samuel C. Wood

*Consulting Professors:* H. Irving Grousbeck, Mark A. Wolfson

*Visiting Professors:* Terry L. Anderson, Guido Imbens

*Visiting Associate Professors:* Paul Fischer, Eva-Marie Meyersson Milgrom, Tyler Shumway

*Visiting Assistant Professor:* Malcolm P. Baker

* Recalled to active duty.

The mission of the Graduate School of Business is to create ideas that deepen and advance the understanding of management and, with these ideas, develop innovative, principled, and insightful leaders.

The two-year Master of Business Administration (M.B.A.) degree program is for students who aspire to contribute to society through leadership in business, government, and the nonprofit sector. The general management curriculum rests on a foundation of social science principles and management functions layered with interdisciplinary themes of leadership, entrepreneurship, global management, and social responsibility. M.B.A. curricular options include: the Leadership Development Platform; certificates in Global Management, Public Management, and Product Creation and Innovative Manufacturing; and joint degrees with the Schools of Education (M.A./M.B.A.) and Law (J.D./M.B.A.). The primary criteria for admission are demonstrated leadership potential, intellectual vitality, and diversity among students. No specific undergraduate major or courses are required for admission, but experience with analytic and quantitative concepts is important. Some students enter directly following undergraduate study, but most obtain one or more years of work experience.

The Stanford Sloan Program is an intensive, one-year course of study for middle management executives leading to the degree of Master of Science in Management. Participants must have demonstrated superior achievement and are normally sponsored by their company.

Those interested in college teaching and research are served by the Doctor of Philosophy program.

For detailed information on programs, curricula, and faculty, see the School's web site at http://www.gsb.stanford.edu.

# SCHOOL OF EARTH SCIENCES

*Dean:* Pamela A. Matson

The School of Earth Sciences includes the departments of Geological and Environmental Sciences, Geophysics, Petroleum Engineering, the interdisciplinary Earth Systems undergraduate program, and the graduate level Interdisciplinary Program in Environment and Resources (IPER). The Earth Systems Program offers study of biophysical and social dimensions of the Earth system focusing on environment and resource issues.

The aims of the school are (1) to prepare students for careers in the fields of biogeochemistry, environment and sustainable resource studies, geology, geochemistry, geomechanics, geophysics, geostatistics, hydrogeology, petroleum engineering, and petroleum geology; (2) to conduct research in the Earth sciences; and (3) to provide opportunities for Stanford undergraduates to learn about the planet's history, to understand the natural energy and resource base that supports humanity, and to appreciate the geological and geophysical hazards that affect human societies, as well as those factors that contribute to the quality of our environment.

To accomplish these objectives, the school offers a variety of programs adaptable to the needs of the individual student: four-year undergraduate programs leading to the degree of Bachelor of Science (B.S.); five-year programs leading to the coterminal Bachelor of Science and Master of Science (M.S.); and graduate programs offering the degrees of Master of Science, Engineer, and Doctor of Philosophy as described below. Details of individual degree programs are found in the section for each department or program. In addition, it is possible for an undergraduate to develop an individually designed major in the Earth Sciences.

## UNDERGRADUATE PROGRAMS

Any undergraduate student admitted to the University may declare a major in one of the Earth Science departments or programs by contacting the appropriate department or program office. Students interested in creating an individually designed major should visit the dean's office.

Specific requirements for the B.S. degree are listed in each department or program section. Departmental academic advisers work with students to define a career or academic goal and assure that the student's curricular choices are appropriate to the pursuit of that goal. Advisers can help devise a sensible (and enjoyable) course of study that meets degree requirements and provides the student with opportunities to experience advanced courses, seminars, and research projects. To maximize such opportunities, students are encouraged to complete basic science and mathematics courses in high school or during their freshman year.

Each department offers an honors program that involves research during the senior year. Each department also offers an academic minor for those undergraduates majoring in compatible fields. For the Earth Systems Program, an honors program in Environmental Science, Technology, and Policy is available through the Institute for International Studies.

## COTERMINAL BACHELOR'S AND MASTER'S DEGREES

The Stanford coterminal degree plan enables an undergraduate to embark on an integrated program of study leading to the master's degree before requirements for the bachelor's degree have been completed. This may result in more expeditious progress towards the advanced degree than would otherwise be possible, making the program especially important to Earth scientists because the master's degree provides an excellent basis for entry into the profession. The coterminal plan permits students to be admitted to a graduate program as early as their eighth quarter at Stanford, or after earning 105 units, and no later than the eleventh quarter.

Under the plan, the student may meet the degree requirements in the more advantageous of the following two ways: by first completing the 180 units required for the B.S. degree and then completing the three quarters required for the M.S. degree; or by completing a total of 15 quarters during which the requirements for the two degrees are completed concurrently. In either case, the student has the option of receiving the B.S. degree upon meeting all the B.S. requirements or of receiving both degrees at the end of the coterminal program. Students earn degrees in the same department or program, in two different departments, or even in different schools; for example, a B.S. in Physics and an M.S. in Geological and Environmental Sciences. Students are encouraged to discuss the coterminal program with their advisers during their junior year. Additional information is available in the individual department offices.

## GRADUATE PROGRAMS

*Admission to the Graduate Program*—A student who wishes to enroll for graduate work in the school must be qualified for graduate standing in the University and also must be accepted by one of the school's three departments or the interdisciplinary Ph.D. program. One requirement for admission is submission of scores on the verbal and quantitative sections of the Graduate Record Exam. Admission to one department of the school does not guarantee admission to other departments.

*Faculty Adviser*—Upon entering a graduate program, the student should report to the head of the department or program who arranges with a member of the faculty to act as the student's adviser, if that has not already been established through prior student-faculty discussions. The student, in consultation with the adviser, then arranges a course of study for the first quarter and ultimately develops a complete plan of study for the degree sought.

*Financial Aid*—Detailed information on scholarships, fellowships, and research grants is available from the school's individual departments and programs. Applications should be filed by the various dates listed in the application packet for awards that become effective in Autumn Quarter of the following academic year.

# EARTH SYSTEMS PROGRAM

*Director:* Robert Dunbar
*Associate Director:* Julie Kennedy
*Advisory Committee:* Kevin Arrigo (Geophysics), Gregory Asner (Department of Global Ecology, Carnegie Institution), Carol Boggs (Biological Sciences), Brendan Bohannan (Biological Sciences), Margaret Caldwell (Law), Page Chamberlain (Geological and Environmental Sciences), Gretchen Daily (Biological Sciences), Mark Denny (Biological Sciences, Hopkins Marine Station), Robert B. Dunbar (Geological and Environmental Sciences), William Durham (Anthropological Sciences), Gary Ernst (Geological and Environmental Sciences), Walter Falcon (Stanford Institute for International Studies), Scott Fendorf (Geological and Environmental Sciences), Margot Gerritsen (Petroleum Engineering), Deborah Gordon (Biological Sciences), Christopher Field (Department of Global Ecology, Carnegie Institution), Lawrence Goulder (Economics), Elizabeth Hadly (Biological Sciences), Sara Hoagland (Interdisciplinary Program in Environment and Resources), Donald Kennedy (Biological Sciences, Stanford Institute for International Studies; emeritus), Julie Kennedy (Earth Systems), Rosemary Knight (Geophysics), Jeffrey Koseff (Civil and Environmental Engineering), Anthony Kovscek (Petroleum Engineering), Gilbert Masters (Civil and Environmental Engineering), Pamela Matson (Dean, School of Earth Sciences, Stanford Institute for International Studies), Michael McWilliams (Geological and Environmental Sciences), Stephen Monismith (Civil and Environmental Engineering), Harold Mooney (Biological Sciences), Rosamond Naylor (Stanford Institue for International Studies), Franklin M. Orr, Jr. (Global Climate and Energy Project, Petroleum Engineering), Adina Paytan (Geological and Environmental Sciences), Joan Roughgarden (Biological Sciences), Stephen H. Schneider (Biological Sciences, Stanford Institute for International Studies), Karen Seto (Geological and Environmental Sciences, Stanford Institute for International Studies), Jonathan Stebbins (Geological and Environmental Sciences), James Sweeney (Management Science and Engineering), Barton Thompson (Law), David Victor (Center for Environmental Science and Policy), Peter Vitousek (Biological Sciences), Virginia Walbot (Biological Sciences), Mark Zoback (Geophysics)
*Senior Lecturer:* Julie Kennedy

*Program Offices:* Mitchell Building, Room 138
*Mail Code:* 94305-2210
*Phone:* (650) 725-7427
*Email:* deana@stanford.edu
*Web Site:* http://pangea.stanford.edu/ESYS/

Courses given in Earth Systems Program have the subject code EARTHSYS. For complete list of subject codes, see Appendix.

The Earth Systems Program is an interdisciplinary environmental studies major. Students learn about and independently investigate complex environmental problems caused by human activities in interaction with natural changes in the Earth System. Earth Systems majors become skilled in those areas of science, economics, and policy needed to tackle the globe's most pressing environmental problems, becoming part of a generation of scientists, professionals, and citizens who approach and solve problems in a new way: a systematic, interdisciplinary way.

For students to be effective contributors to solutions for such problems, their training and understanding must be both broad and deep. To this end, Earth Systems students take courses in the fundamentals of biology, calculus, chemistry, geology, and physics, as well as in computer science, economics and policy, and statistics. After completing breadth training, they concentrate on advanced work in one of seven focus areas: biology, energy, environmental economics and policy, geology, land management, education, or oceanography. Along with formal course requirements, Earth Systems students complete a 9-unit (270-hour) internship. The internship provides a hands-on academic experience working on a supervised field, laboratory, government or private sector project of their choice.

The following is an outline of the sequential topics covered and skills developed in this major.

1. The fundamental components of the Earth System help students understand current environmental problems against the backdrop of natural change. Training in the fundamentals comes through introductory course work in geology, biology, and economics. Depending on the Earth Systems track chosen, training may also include introductions to the study of energy systems, microbiology, oceans, or soils. As students begin to question the role that humans play in affecting these systems, they find that many programs and departments at Stanford offer courses that approach this question from different directions. Students are encouraged to come to the Earth Systems office for course selection advice or to pick up a current list of environmental courses at Stanford.
2. Focus is on the fundamental interactions among the physical, biological, and human components of the Earth System: the dynamics of the interplay between natural variation and human-imposed influences must be understood to achieve effective solutions to environmental problems.

   Several Earth Systems courses introduce students to the dynamic and multiple interactions that characterize global change problems. They include the introductory course, Introduction to Earth Systems, and three core courses, the Geosphere, the Biosphere, and the Anthrosphere.

   Competence in understanding system-level interactions is critical to development as an Earth Systems thinker, so additional classes that meet this objective are excellent choices as electives. More information on such classes is available in the program office.
3. Development of skills to recognize, quantify, and report change in the environment: key analytical and computational tools and measurement systems are used for insight into global and regional environmental change, and in the development of solutions.

   The test of an Earth Systems degree is the student's ability to recognize, describe, quantify, and help solve complex problems that face our society. Through required cognates and specific track classes, students build skills in these areas. For example, training in satellite remote sensing and geographic information systems is either required or highly recommended for all tracks. Quantification of environmental problems requires solid training in calculus, linear algebra, chemistry, physics, programming, and statistics. These courses are required of all majors. Specialized training, such as in laboratory or field methods, may be necessary and is highly recommended.

   Having the ability to effectively communicate ideas and results is critical. Indeed, workable solutions to our environmental problems begin with common understanding of the issues. Writing intensive courses (WIM) help students to communicate complex concepts to expert and non-expert audiences alike. Stanford requires that each student complete one WIM course in his or her major. The WIM requirement is met through completion of the Senior Seminar. Several Earth Systems courses focus on effective written and oral communication.
4. Work to design solutions to environmental problems that take into consideration natural processes as well as human needs: human needs must be met in sustainable ways that focus on ecosystem health, human prosperity, and long-term effectiveness.

Many courses at Stanford focus on solutions. A comprehensive list of environmental courses, and advice on those that focus on problem solving, is available in the program office. Students can also review the quarterly *Time Schedule* for solution-based courses. Among others, the following departments may provide subject areas that are a useful guide: Anthropological Sciences, Biological Sciences, Civil and Environmental Engineering, Earth Systems, Economics, Geological and Environmental Sciences, Geophysics, Human Biology, International Policy Studies, International Relations, Latin America Studies, Law, Petroleum Engineering, Political Science, Public Policy, and Urban Planning. The Earth Systems Program emphasizes the importance of workable solutions in several ways, including a required 9-unit internship, knowledge synthesis in the Senior Seminar, an optional upper division course on environmental problem solving, or an honors through the Goldman Environmental

Honors Program. Potential honors students must complete the Geosphere, Biosphere, Anthrosphere sequence by the end of the junior year.

Students interested in Earth Systems should come to the program office for current information on our curriculum, alumni career paths, environmental jobs and internships, and undergraduate honors options. The Earth Systems Program provides an advising network that includes faculty, staff, and student peer advisers.

## UNDERGRADUATE PROGRAMS

## BACHELOR OF SCIENCE

The B.S. in Earth Systems (ESYS) requires the completion of at least 110 units that can be divided into three levels of courses. The student must complete a series of courses comprising a broad base of specialized study and must complete five required and three elective courses in that track. Finally, the student must carry out a senior-level research or internship project and participate in the senior seminar (WIM). *Note:* students interested in earning a California Teaching Credential for general high school science through the STEP Program should contact the program office for specific guidelines. The Education Track has State of California specific cognate requirements which vary from the other tracks.

### REQUIRED CORE

| *Course No. and Subject* | *Units* |
|---|---|
| EARTHSYS 10. Introduction to Earth Systems | 4 |
| EARTHSYS 110. Geosphere | 3 |
| EARTHSYS 111. Biosphere | 3 |
| EARTHSYS 112. Anthrosphere | 5 |
| EARTHSYS 210. Senior Seminar | 4 |
| EARTHSYS 260. Internship | |
| *or* EARTHSYS 250. Directed Research | 9 |

### REQUIRED COGNATE COURSES

| | |
|---|---|
| **Biology** (any one course below): | |
| BIOSCI 41. Evolution, Genetics, Genomes, and Biochemistry | 5 |
| *or* BIOSCI 43. Physiology, Ecology, and Behavioral Biology | 5 |
| **Chemistry:** | |
| CHEM 31. Chemical Principles | 3 |
| CHEM 33. Organic Chemistry* | 4 |
| **Computer Programming:** | |
| CS 106. Programming Methodology | 5 |
| *or* CS 138. Matlab and Maple for Science and Engineering Applications | 5 |
| **Economics:** | |
| ECON 1. Elementary Economics | 5 |
| ECON 50. Economic Analysis I | 5 |
| **Geological and Environmental Sciences:** | |
| GES 1. Fundamentals of Geology | 5 |
| **Mathematics:** | |
| MATH 19. Calculus and Analytic Geometry | 3 |
| MATH 20. Calculus and Analytic Geometry | 3 |
| MATH 21. Calculus and Analytic Geometry | 4 |
| *or* MATH 41. Calculus and Analytic Geometry | 5 |
| MATH 42. Calculus and Analytic Geometry | 5 |
| *and* MATH 51. Linear Equations and Differential Calculus | 5 |
| **Probability and Statistics** (any one course below): | |
| BIOSCI 141. Biostatistics | 4 |
| ECON 102A. Introduction to Statistical Methods | 5 |
| GES 160. Statistical Methods for Earth and Environmental Sciences | 4 |
| GES 161. Geostatistics | 4 |
| STATS 110. Statistical Methods in Engineering and Physical Sciences | 4 |
| **Physics:** | |
| PHYSICS 53. Mechanics | 4 |
| PHYSICS 51. Light and Heat* | 4 |
| (Additional physics cognate for Energy Track): | |
| PHYSICS 55. Electricity and Magnetism | 3 |

* Students may take either PHYSICS 51 or CHEM 33; Biosphere students must take CHEM 33.

More extensive work in mathematics and physics may be expected for those planning graduate study. Graduate study in ecology and evolutionary biology and in economics requires familiarity with differential equations, linear algebra, and stochastic processes. Graduate study in geology, oceanography, and geophysics may require more physics and chemistry. Check with your adviser about recommendations beyond the requirements specified above.

### TRACKS

#### GEOSPHERE

#### ADDITIONAL COGNATES:

| | |
|---|---|
| GES 80. Earth Materials | 5 |
| GES 90. Introduction to Geochemistry | 3 |
| **Earth's Surface and Fluid Envelopes:** | |
| Choose one from these three: | |
| GES 8. The Oceans: An Introduction to the Marine Environment | 3 |
| GES 159. Marine Chemistry | 4 |
| GEOPHYS 130. Biological Oceanography | |
| **Plus one of the two following groups of courses:** | |
| GEOPHYS 104. The Water Course | 3 |
| *and* GES 175. Science of Soils | 3 |
| *or* GES 130. Environmental Earth Science I: Soil Physics and Hydrology | 5 |
| *and* GES 131. Environmental Earth Science II: Fluvial Systems & Landscape Evolution | 5 |
| **Human Society in the Geosphere:** | |
| CEE 173A. Energy Resources | 4 |
| *or* PETENG 101. Energy and the Environment | 3 |
| *and* one from the following list: | |
| EARTHSYS 113. Earthquakes and Volcanoes | 3 |
| EARTHSYS 169. Science and Politics of Radioactive Waste Management | 3 |
| EARTHSYS 180. Fundamentals of Sustainable Agriculture | 3 |
| **Measuring and Observing the Earth** (choose two): | |
| GEOPHYS 140. Introduction to Remote Sensing | 3 |
| GEOPHYS 141. Remote Sensing of the Ocean | 3 |
| *or* choose one course from the previous list and one from the following: | |
| GES 142. Remote Sensing of Land Use and Land Cover Change | 5 |
| EARTHSYS 189. Field Studies in Earth Systems | 5 |

#### BIOSPHERE

| | |
|---|---|
| BIOSCI 41. Evolution, Genetics, Genomes, and Biochemistry | 5 |
| BIOSCI 42. Cell Biology, Developmental Biology, and Neurobiology | 5 |
| BIOSCI 43. Physiology, Ecology, and Behavioral Biology | 5 |
| **Biogeochemistry** (choose one): | |
| BIOSCI 124. Plant Physiological Ecology | 4 |
| BIOSCI 216. Terrestrial Biogeochemistry | 4 |
| EARTHSYS 189. Field Studies in Earth Systems | 5 |
| GES 159. Marine Chemistry | 2-4 |
| GES 175. Science of Soils | 3 |
| **Conservation Biology** (choose one): | |
| HUMBIO 119. Conservation Biology | 4 |
| *or* BIOSCI 173H. Ecosystems of California | 3 |
| **Ecology** (choose two): | |
| BIOSCI 101. Ecology | 4 |
| BIOSCI 125. Ecosystems of California | 3-4 |
| BIOSCI 136. Evolutionary Paleobiology | 4 |
| BIOSCI 145. Behavioral Ecology | 4 |
| **Ecosystems and Society** (choose one): | |
| ANTHSCI 124. Sustainable Development in Latin America | 5 |
| ANTHSCI 161B. Human Ecology of the Amazon | 5 |
| ANTHSCI 162. Indigenous Peoples and Environmental Problems | 3-5 |
| ANTHSCI 164A. Ethnoecology | |
| ANTHSCI 165 Ecological Anthropology | 5 |

#### ANTHROSPHERE

| | |
|---|---|
| **Economics and Environmental Policy** (choose three): | |
| ECON 51. Economic Analysis II | 5 |
| ECON 102B. Introduction to Econometrics | 5 |
| ECON 106. The World Food Economy | 5 |
| ECON 118. Economics of Development | 5 |
| ECON 150. Economics and Public Policy | 5 |
| **Legal and Political Institutions and the Environment** (choose one): | |
| ECON 154. Economics of Legal Rules and Policy | 5 |
| PUBLPOL 101. Politics and Public Policy | 5 |

#### LAND MANAGEMENT

| | |
|---|---|
| **The Natural Environment** (choose one from each grouping): | |
| GES 101. Environmental and Geological Field Studies in the Rocky Mountains | 3 |
| *or* GES 175. Science of Soils | 4 |
| *or* EARTHSYS 189. Field Studies in Earth Systems | 5 |
| *or* GES 130. Environmental Earth Sciences I: Soil Physics & Hydrology | 4 |
| *or* GES 131. Environmental Earth Sciences II: Fluvial Systems and Landscape Evolution | 5 |

| | |
|---|---|
| HUMBIO 119. Conservation Biology | 3-4 |
| *or* BIOSCI 125. Ecosystems of California | 3-4 |
| GEOPHYS 140. Introduction to Remote Sensing | 3 |
| *or* GES 142. Remote Sensing of Land Cover and Land Use | 4 |
| *or* GES 144. Fundamentals of GIS | 4 |

**The Managed Environment** (choose one):

| | |
|---|---|
| EARTHSYS 180. Sustainable Agriculture | 3 |
| ECON 106. The World Food Economy | 5 |
| GEOPHYS 104. The Water Course | 3 |

**The Built Environment** (choose one from each grouping):

| | |
|---|---|
| URBANST 110. Introduction to Urban Studies | 4 |
| *or* URBANST 170. Introduction to Urban Design | 5 |
| *or* URBANST 183. Land Use Control | 4 |
| CEE 176A. Energy Efficient Building Design | 4 |
| *or* CEE 148. Design and Construction of Affordable Housing | 4 |
| URBANST 181. Environmentally Sustainable Cities | 4 |
| *or* CEE 171. Environmental Planning Methods | 4 |

#### ENERGY SCIENCE AND TECHNOLOGY

| | |
|---|---|
| CEE 173B. The Coming Energy Revolution | 3 |
| CEE 176A. Energy Efficient Buildings | 4 |
| CEE 176B. Electric Power: Generation and Conservation | 4 |
| EARTHSYS 103. Energy Resources | 3 |
| *or* EARTHSYS 101. Energy and the Environment | 3 |
| ENGR 30. Engineering Thermodynamics | 3 |

#### OCEANS

| | |
|---|---|
| GES 8. The Oceans: An Introduction to the Marine Environment | 3 |

**Physics of the Sea**

| | |
|---|---|
| CEE 164. Introduction to Physical Oceanography | 4 |

**Biological Oceanography**

| | |
|---|---|
| GEOPHYS 130. Biological Oceanography | 4 |

**Marine Chemistry**

| | |
|---|---|
| GES 159. Marine Chemistry | 3 |

**Remote Sensing of the Ocean** (choose one):

| | |
|---|---|
| GEOPHYS 141. Remote Sensing of the Ocean | 4 |

### EDUCATION

New track designed in concert with Stanford's STEP Program to meet the State of California's Commission on Teaching Credentialing requirement for general science.

#### COGNATES AND CORE:

| | |
|---|---|
| EARTHSYS 10. Introduction to Earth Systems | 4 |
| EARTHSYS 110. Geosphere | 3 |
| EARTHSYS 111. Biosphere | 3 |
| EARTHSYS 112. Anthrosphere | 5 |
| EARTHSYS 210. Senior Seminar | 4 |
| EARTHSYS 260 Internship | 9 |
| BIOSCI 41. Genetics, Biochemistry, and Molecular Biology | 5 |
| BIOSCI 42. Cell Biology and Animal Physiology | 5 |
| BIOSCI 43. Plant Biology, Evolution, and Ecology | 5 |
| CEE 63. Weather and Storms | 3 |
| CHEM 31. Chemical Principles | 4 |
| CHEM 33. Structure and Reactivity | 4 |
| ECON 1. Elementary Economics | 5 |
| ECON 50. Economics Analysis I | 5 |
| GES 1. Fundamentals of Geology | 5 |
| GES 8. The Oceans: An Introduction to the Marine Environment | 3 |
| GES 160. Statistical Methods for Earth and Environmental Sciences | 5 |
| *or* GES 161. Geostatistics | 4 |
| MATH 19. Calculus and Analytic Geometry | 3 |
| MATH 20. Calculus and Analytic Geometry | 3 |
| MATH 21. Calculus and Analytic Geometry | 4 |
| *or* MATH 41. Calculus and Analytic Geometry | 5 |
| MATH 42. Calculus and Analytic Geometry | 5 |
| MATH 51. Linear Equations and Differential Calculus | 5 |
| PHYSICS 15. The Nature of the Universe | 3 |
| PHYSICS 51. Light and Heat | 4 |
| PHYSICS 53. Mechanics | 4 |
| PHYSICS 55. Electricity and Magnetism | 4 |
| Science Education Track Courses: | |
| EARTHSYS 195. Directed Reading on California Geology | 1 |
| EARTHSYS 189. Field Studies in Earth Systems | 5 |
| EDUC 180. Directed Reading in Education | 1-15 |
| STS 101. Science, Technology, and Contemporary Society | 4-5 |

#### DEVELOPMENT PSYCHOLOGY (CHOOSE ONE):

| | |
|---|---|
| PSYCH 60. Introduction to Development Psychology | 3 |
| PSYCH 146. Observation of Children | 3-5 |
| PSYCH 147. development in Early Childhood | 3-5 |
| HUMBIO 126. Adolescent Development | 4 |
| EDUC 239. Contemporary Social Issues in Child &Adolescent Dev't | 4 |

#### TEACHING PRACTICUM COURSE:

| | |
|---|---|
| EDUC 101X. Undergraduate Teaching Practicum | 3-5 |

All students completing the Education track must:

1. be jointly advised during the undergraduate degree by Julie Kennedy and a faculty adviser from the STEP Program.
2. enroll in the coterminal STEP Program in the School of Education upon completion of the undergraduate degree.

*Note:* Students who begin study in the Education Track and subsequently choose not to enroll in the STEP Program must complete the degree requirements for one of the remaining Earth Systems tracks. Degrees are not awarded for the Education Track without subsequent enrollment in STEP.

### UPPER-DIVISION ELECTIVES

Three intermediate to advanced courses, 100 level or above, minimum of 3 units, consistent with the primary track are required of all majors and must be approved. Eligible upper-division electives are listed below. Additional courses may be selected; see the program office for the most current list.

#### GEOSPHERE TRACK

*Note:* Only two electives are required for the Geosphere track.

| | |
|---|---|
| BIOSCI 121. Biogeography | 3 |
| EARTHSYS 103. Energy Resources | 3 |
| GES 110. Structural Geology | 5-6 |
| GES 111. Structural Geology and Rock Mechanics | 4 |
| GES 164. Stable Isotopes | 3 |
| GES 185. Volcanology | 4 |
| GES 220. Terrestrial Biogeochemistry | 3 |
| GES 221. The Origins of Life in the Solar System | 3 |
| GES 255. Introduction to Micropaleontology | 5 |
| PETENG 260. Groundwater Pollution and Oil Spills: Environmental Problems in the Petroleum Industry | 3 |

#### BIOSPHERE TRACK

| | |
|---|---|
| BIOSCI 125. Ecosystems of California | 3-4 |
| BIOSCI 139. Biology of Birds | 3 |
| BIOSCI 184. Principles of Biosystematics | 4 |
| BIOSCI 161H. Invertebrate Zoology | 5 |
| BIOSCI 163H. Principles of Oceanic Biology | 4 |
| BIOSCI 164H. Marine Botany | 4 |
| BIOSCI 215. Biochemical Evolution | 3 |
| BIOSCI 216. Ecosystem Ecology and Global Biogeochemistry | 3 |
| BIOSCI 283. Theoretical Population Genetics | 3 |
| GES 255. Introduction to Micropaleontology | 5 |

#### ANTHROSPHERE TRACK

| | |
|---|---|
| ANTHSCI 161B. Human Ecology of the Amazon | 5 |
| ANTHSCI 172. Indigenous Forest Management | 5 |
| CEE 171. Environmental Planning Methods | 4 |
| ECON 158. Antitrust and Regulation | 5 |
| ECON 165. International Economics | 5 |
| ECON 243. Economics of the Environment | 5 |
| MS&E 194. The Role of Analysis in Environmental Policy Decisions | 3-5 |
| MS&E 243. Energy and Environmental Policy Analysis | 2-3 |
| POLISCI 216M. Environmental Politics in the Asia/Pacific Region | 5 |
| PUBLPOL 103A. Introduction to Political Philosophy | 3 |
| URBANST 183. Land Use Control | 4 |

#### LAND MANAGEMENT TRACK

| | |
|---|---|
| ANTHSCI 162. Indigenous Peoples and Environmental Problems | 3-5 |
| ANTHSCI 163B. Parks and Peoples | 3-5 |
| HISTORY 152. American Spaces | 5 |
| HISTORY 254. Nature | 5 |

#### ENERGY SCIENCE AND TECHNOLOGY TRACK

| | |
|---|---|
| ECON 158. Antitrust and Regulation | 5 |
| EE 293A. Fundamentals of Energy Processes | 3 |
| EE 293B. Fundamentals of Energy Processes | 3 |
| ME. 150 Internal Combustion Engines | 3 |
| ME 131A. Heat Transfer | 3 |
| PETENG 102 Renewable Energy Sources and Greener Energy Processes | 3 |
| PETENG 120. Fundamentals of Petroleum Engineering | 3 |

| | |
|---|---|
| PETENG 260. Groundwater Pollution and Oil Spills | 3 |
| PETENG 269. Geothermal Reservoir Engineering | 3 |
| POLISCI 114. The Political Economy of Development | 3 |
| EARTHSYS 169. Science and Politics of Radioactive Waste Management | 3 |

#### OCEANS TRACK

| | |
|---|---|
| BIOSCI 161H. Invertebrate Zoology | 5 |
| BIOSCI 163H. Principles of Oceanic Biology | 4 |
| BIOSCI 164H. Marine Botany | 4 |
| GES 205. Advanced Oceanography | 3 |
| GES 225. Isotopes in Geological and Environmental Research | 3 |

#### SUMMARY OF COURSE REQUIREMENTS AND UNITS

| | |
|---|---|
| Earth Systems Introduction and Core | 18 |
| Required allied courses | 47-50 |
| **Tracks:** | |
| Anthrosphere | 20 |
| Biosphere | 20 |
| Geosphere | 26 |
| Energy Science and Technology | 23 |
| Land Management | 23 |
| Oceans | 18 |
| Education | 42 |
| Upper-division electives | 9-15 |
| Senior project or internship | 9 |
| Senior seminar | 4 |
| Total units (depending on track, electives) | 110-140 |

## COTERMINAL B.S. AND M.S. DEGREES

The Stanford coterminal degree enables an undergraduate to embark on an integrated program of study leading to the master's degree before requirements for the bachelor's degree have been completed. An undergraduate majoring in Earth Systems may apply to work simultaneously toward B.S. and M.S. degrees. The M.S. degree in Earth Systems provides the student with enhanced tools to evaluate the primary literature of the discipline most closely associated with the student's track and allows an increased specialization through additional course work that may include 9 units of thesis research. Integration of earth systems concepts is furthered by participation in the master's seminar.

To apply, complete and return to the Earth Systems office an application that includes: a statement of purpose; a Stanford transcript; two letters of recommendation, one of which must be from the master's adviser; and a list of courses that fulfill degree requirements signed by the master's adviser. Applications must be submitted by the quarter preceding the anticipated quarter of graduation. A $50 application fee is assessed by the Registrar's Office for coterminal applications, effective Autumn Quarter 2004-05. Students may either (1) complete 180 units required for the B.S. degree and then complete the three quarters required for the M.S. degree, or (2) complete a total of 15 quarters during which the requirements of the degrees are fulfilled concurrently. The student has the option of receiving the B.S. degree after completing that degree's requirements or receiving two degrees concurrently at the end of the master's program. Note: students interested in enrolling in the STEP Program during their fifth year and gaining a California Teaching Credential for high school general science should come to the program office.

Three levels of requirements must be fulfilled to receive an M.S. degree:

1. All requirements for the B.S. degree.
2. Further course work (and/or thesis research), all of which should be at the 100-level or above, including 22 units at the 200-level or above, leading to further focus within the student's track.
3. Participation in the master's seminar.

The program consists of a minimum of 45 units of course work and/or thesis research, at least 22 of which must be at the 200-level or above.

The student must devise a program of study that shows a level of specialization appropriate to the master's level, as determined in consultation with the adviser. At least 22 units must be at the 200-level or above. The program should demonstrate further specialization and focus within the student's undergraduate track.

With the adviser's approval, 9 units may be in the form of research. This may culminate in the preparation of a master's thesis; however, a thesis is not required for the degree. Master's students must take part in the Winter Quarter master's seminar (EARTHSYS 290) and have additional responsibilities appropriate to the master's level (thesis presentation, modeling problems, and so on), 2 units.

A more detailed description of the coterminal master's degree program may be obtained from the program office. For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/publications/#Coterm.

## COURSES

WIM indicates that the course satisfies Writing in the Major requirements.

## UNDERGRADUATE

**EARTHSYS 10. Introduction to Earth Systems**—For nonmajors and prospective Earth Systems majors. Multidisciplinary approach using the principles of geology, biology, engineering, and economics to describe how the Earth operates as an interconnected, integrated system. Goal is to understand global change on all time scales. Focus is on sciences, technological principles, and sociopolitical approaches applied to solid earth, oceans, water, energy, and food and population. Case studies: environmental degradation, loss of biodiversity, and resource sustainability. GER:2a

*4-5 units, Win (Ernst)*

**EARTHSYS 66. Energy Production and its Impact on the Atmosphere**—(Enroll in CEE 66.)

*3 units, Aut (Tabazadeh)*

**EARTHSYS 101. Energy and the Environment**—(Same as PETENG 101.) Energy use in modern society and the consequences of current and future energy use patterns. Case studies illustrate resource estimation, engineering analysis of energy systems, and options for managing carbon emissions. Focus is on energy definitions, use patterns, resource estimation, pollution. Recommended: MATH 21 or 42, ENGR 30. GER:2a

*3 units, Win (Gerritsen, Durlofsky, Kovscek)*

**EARTHSYS 102. Renewable Energy Sources and Greener Energy Processes**—(Same as PETENG 102.) The energy sources that power society are rooted in fossil energy. Energy from the earth's core and the sun is almost inexhaustible, but the rate at which this energy can be drawn with today's technology is limited. The renewable energy resource base, its conversion to useful forms, and practical methods of energy storage. Geothermal, wind, solar, and tidal energies; resource extraction and its consequences. Recommended: 101, MATH 21 or 42. GER:2a

*3 units, Spr (Kovscek)*

**EARTHSYS 103. Energy Resources**—(Same as CEE 173A/207A.) Overview of oil, natural gas, coal, nuclear, hydro, solar, geothermal, biomass, wind, and ocean energy resources in terms of supply, distribution, recovery and conversion, environmental impacts, economics, policy, and technology. Opportunities for energy efficiency, electric power basics, the changing role of electric utilities, transportation basics, and energy use in developing countries. Field trips. Recommended: CEE 70. GER:2b

*4-5 units, Aut (Woodward)*

**EARTHSYS 104. The Water Course**—(Same as GEOPHYS 104.) The pathway that water takes from rainfall to the tap using student home towns as an example. How the geological environment controls the quantity and quality of water; taste tests of water from around the world. Current U.S. and world water supply issues. GER:2a

*3 units, Win (Knight)*

**EARTHSYS 106. Antarctic Marine Geology**—(Enroll in GES 206.)

*3 units (Dunbar, Cooper) alternate years, not given 2005-06*

**EARTHSYS 110. Geosphere**—(Same as GEOPHYS 102.) Large-scale natural systems of the solid earth, oceans, and atmosphere, their variation through space and time, and the implications of how these systems impact and are being impacted by humankind. Topics include plate tectonics and its relationship to natural hazards and climate, large-scale ocean and atmospheric systems, energy systems, and the linkages among these topics. Prerequisites: EARTHSYS 10, GES 1. GER:2a

*3 units, Aut (Zoback, Arrigo) not given 2005-06*

**EARTHSYS 111. Biology and Global Change**—(Same as BIOSCI 117.) The biological causes and consequences of anthropogenic and natural changes in the atmosphere, oceans, and terrestrial and freshwater ecosystems. Topics: glacial cycles and marine circulation, greenhouse gases and climate change, tropical deforestation and species extinctions, and human population growth and resource use. Prerequisite: Biological Sciences or Human Biology core or graduate standing. GER:2a

*3 units, Win (Mooney, Vitousek)*

**EARTHSYS 112. Environmental Economics and Policy**—(Same as ECON 155.) Economic sources of environmental problems and alternative policies for dealing with them (technology standards, emissions taxes, and marketable pollution permits). Evaluation of policies addressing regional air pollution, global climate change, water allocation in the western U.S., and the use of renewable resources. Connections between population growth, economic output, environmental quality, and human welfare. Prerequisite: ECON 50. GER:2a

*5 units, Spr (Goulder)*

**EARTHSYS 113. Earthquakes and Volcanoes**—(Same as GEOPHYS 113.) Earthquake location, magnitude and intensity scales, seismic waves, styles of eruptions and volcanic hazards, tsunami waves, types and global distribution of volcanoes, volcano forecasting. Plate tectonics as a framework for understanding earthquake and volcanic processes. Forecasting; earthquake resistant design; building codes; and probabilistic hazard assessment. For non-majors and potential earth scientists. GER:2b

*3 units, Aut (Beroza, Segall)*

**EARTHSYS 114. Field Course on Tropical Biogeochemistry: Amazon as Case Study**—(Same as BIOSCI 114.) Post-field seminar for students who went on the two-week field trip to the Amazon in September with Brazilian students under Professor Martinelli of the University of São Paulo and Stanford Latin American Studies. Land use changes over the last 30 years including the conversion of natural forest for cattle ranching and soy beans in the Amazon, the largest continuous area of tropical forests on Earth with the greatest number of plant and animal species. In English. GER:2a

*3 units, Aut (Vitousek)*

**EARTHSYS 130/230. Biological Oceanography**—(Same as GEOPHYS 130/231; graduate students register for 230.) Required for Earth Systems students in the oceans track. Interdisciplinary look at how oceanic environments control the form and function of marine life. Topics: distributions of planktonic production and abundance, nutrient cycling, the role of ocean biology in the climate system, expected effects of climate changes on ocean biology. Possible local field trips on weekends. Prerequisites: BIOSCI 43 and GES 8 or equivalent.

*2-4 units, Spr (Arrigo)*

**EARTHSYS 140. Introduction to Remote Sensing**—(Enroll in GEOPHYS 140.)

*3 units (Zebker) alternate years, not given 2005-06*

**EARTHSYS 141/241. Remote Sensing of the Oceans**—(Same as GEOPHYS 141/241; graduate students register for 241.) How to observe and interpret physical and biological changes in the oceans using satellite technologies. Topics: principles of satellite remote sensing, classes of satellite remote sensors, converting radiometric data into biological and physical quantities, sensor calibration and validation, interpreting large-scale oceanographic features. GER:2a

*4 units (Arrigo) alternate years, given 2005-06*

**EARTHSYS 142/242. Remote Sensing of Land Use and Land Cover**—(Same as GES 142; graduate students register for 242.) Satellite remote sensing to monitor land use and land cover emphasizing terrestrial changes. Topics include pre-processing data, biophysical properties of vegetation observable by satellite, accuracy assessment of maps derived from remote sensing, and methodologies to detect changes such as urbanization, deforestation, vegetation health, and wildfires.

*4 units, Win (Seto) alternate years, not given 2005-06*

**EARTHSYS 144. Fundamentals of Geographic Information Science (GIS)**—(Enroll in GES 144.)

*4 units, Spr (Seto)*

**EARTHSYS 147/247. Controlling Climate Change in the 21st Century**—(Same as BIOSCI 147/247; graduate students register for 247.) The science, economics, and environmental diplomacy of global climate change. Topics: the science of climate change, climate change and global environmental law; global economic approaches to carbon abatement, taxes, and tradable permits; joint implementation, consensus, and division in the EU; gaining the support of China, other developing countries, and U.S. corporations; alternative energy and energy efficiencies for less carbon-intensive electric power and transport. GER:2a

*3 units, Win (Schneider, Rosencranz) alternate years, not given 2005-06*

**EARTHSYS 159. Marine Chemistry**—(Enroll in GES 159/259.)

*2-4 units, Spr (Paytan)*

**EARTHSYS 164. Introduction to Physical Oceanography**—(Same as CEE 164/262D.) Introduction to the dynamic basis of physical oceanography. Topics: a general description of the physical environment of the ocean; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; the thermohaline circulation of the deep oceans; and tides. Prerequisite: PHYSICS 53. GER:2a

*4 units, Win (Fong)*

**EARTHSYS 163B/263B. Parks and Peoples: The Impact of Protected Area Conservation on Local Populations—(**Same as ANTHSCI 163B.) The value of parks as a conservation tool affecting biological and cultural systems. The success of parks in protecting biodiversity, cultural diversity, and social justice. The Western park model, its modifications, and solutions to dilemmas about integrating people within parks.

*3-5 units, Win (Ediger)*

**EARTHSYS 165. Ethnoecology**—(Enroll in ANTHSCI 164A/264A.)

*5 units (Irvine) not given 2004-05*

**EARTHSYS 169/269. Science and Politics of Radioactive Waste Management**—(Graduate students register for 269.) The safe storage and disposal of radioactive waste, an environmental legacy of nuclear weapons production and nuclear power generation, is a scientific, engineering, political, and societal issue. Focus is on scientific, engineering, and economic issues, leading to formulation of answers to political questions, particularly the balance between risk and reward to society. Field trips to waste sites. Recommended: working knowledge of first-year physics, chemistry, and geology/hydrology. GER:2a

*3 units, Spr (McWilliams) alternate years, not given 2005-06*

**EARTHSYS 180/280. Fundamentals of Sustainable Agriculture**—(Same as BIOSCI 180/280; graduate students register for 280.) Ecological, economic, and social dimensions of sustainable agriculture in the context of a growing world population. Focus is on both management and technological approaches and on historical content of agricultural growth and change, organic agriculture, soil and water resource management, nutrient and pest management, biotechnology, ecosystem services, and climate change. GER:2a

*3 units, Spr (Naylor, Daily) not given 2005-06*

**EARTHSYS 189. Field Studies in Earth Systems**—(Same as BIOSCI 206.) For advanced upper-division undergraduates and graduate students. Field-based, focusing on the components and processes by which terrestrial ecosystems function. Topics from biology, chemistry, ecology, geology, and soil science. Lecture, field, and lab studies emphasize standard field techniques, experimental design, analysis of data, and written and oral presentation. Small team projects test the original questions in the functioning of natural ecosystems. Admission by application; see *Time Schedule*. Prerequisites: BIOSCI 141 or GES 160, or equivalent. GER:2a

*5 units, Spr (Chiariello, Fendorf, Matson, Miller)*

**EARTHSYS 195. Directed Reading on California Geology**—For Earth Systems education track. Teacher preparation in California geology with focus on regional variability. Preparation of field trip exercises appropriate for K-12 age groups.
*1 unit, Aut, Win, Spr (J. Kennedy)*

**EARTHSYS 210. Senior Seminar**—Oral and written communication skills. Each student presents results of the Earth Systems internship and leads discussion. Group project analyzing local environmental problems with Earth Systems approach. Peer reviews of internship papers. WIM
*4 units, Aut, Spr (J. Kennedy)*

**EARTHSYS 216. The Political Economy of Energy Policy**—(Enroll in POLISCI 216R.)
*5 units, Win (Victor)*

**EARTHSYS 250. Directed Research**—Independent research related to student's primary track, carried out after the junior year, during the summer, and/or during the senior year. Student develops own project with faculty supervision. 10-15 page thesis.
*1-9 units, by arrangement (Staff)*

**EARTHSYS 259. Marine Chemistry**—(Enroll in GES 159/259.)
*2-4 units, Spr (Paytan)*

**EARTHSYS 260. Internship**—Supervised field, lab, private sector, or advocacy project, normally through an internship sponsored by government agencies or research institutions, or independently developed by the student with the written approval of the Associate Director of Academics. 10-15 page report.
*1-9 units, Aut, Win, Spr, Sum (J. Kennedy)*

**EARTHSYS 290. Master's Seminar**—Open to Earth Systems master's students only. Independent research, oral presentation of results, and preparation of an original proposal for innovative Earth Systems science/policy research.
*2 units, Win (J. Kennedy)*

**EARTHSYS 298. Advanced Topics in Earth Systems**—For Earth Systems master's students only. Continuation of 290.
*2 units (J. Kennedy) not given 2004-05*

**EARTHSYS 299. M.S. Thesis**
*1-9 units, Aut, Win, Spr, Sum (Staff)*

**EARTHSYS 300. Earth Sciences Seminar**—(Same as GES 300, GEOPHYS 300, IPER 300, PETENG 300.) Required for all incoming graduate students except coterms. Research questions, tools, and approaches of faculty members from all departments in the School of Earth Sciences. Goals are: to inform new graduate students about the school's range of scientific interests and expertise; and to introduce them to each other across departments and research groups. Two faculty members present work at each meeting.
*1 unit, Aut (Staff)*

**EARTHSYS 323. Stanford at Sea**—(Same as BIOHOPK 182H/323H.) Five weeks of marine science including oceanography, marine physiology, maritime studies including literature, conservation, and policy, and nautical science at Hopkins Marine Station. Onshore course work followed by five weeks at sea aboard a 135-foot sailing research vessel in the Pacific Ocean. Shore component comprised of three multidisciplinary courses meeting daily and continuing aboard ship. Students develop an independent research project plan while ashore, and carry out the research at sea. Course given in collaboration with the Sea Education Association of Woods Hole, MA. GER:2a
*16 units, Spr (Block, Dunbar, Micheli)*
*alternate years, not given 2005-06*

## OVERSEAS STUDIES

Courses approved for the Earth Systems major and taught overseas can be found in the "Overseas Studies" section of this bulletin, or in the Overseas Studies office, 126 Sweet Hall.

### AUSTRALIA

**EARTHSYS 120X. Coral Reef Ecosystems**—(Same as BIOSCI 109Z, HUMBIO 61X.)
*3 units, Aut (Arrigo, Dove, Hoegh-Guldberg)*

**EARTHSYS 121X. Coastal Resource Management**—(Same as BIOSCI 110Z, HUMBIO 62X.)
*3 units, Aut (Johnstone, Udy)*

**EARTHSYS 122X. Coastal Forest Ecosystems**—(Same as BIOSCI 111Z, HUMBIO 63X.)
*3 units, Aut (Duke, Pole)*

### BEIJING

**EARTHSYS 105X. Environmental Challenges in China's Development**
*4 units, Aut (Zhu, Zhang, Hu, Li)*

# GEOLOGICAL AND ENVIRONMENTAL SCIENCES

*Emeriti: (Professors)* Robert Coleman,* Robert R. Compton, Marco T. Einaudi, W. Gary Ernst,* William R. Evitt, John W. Harbaugh,* Ronald J. P. Lyon,* George A. Parks,* Irwin Remson, Tjeerd H. Van Andel
*Chair:* C. Page Chamberlain
*Associate Chair:* Keith Loague
*Professors:* Dennis K. Bird, Gordon E. Brown, Jr., C. Page Chamberlain, Robert B. Dunbar, Steven M. Gorelick,† Stephan A. Graham, James C. Ingle, Jr., Andre G. Journel,** Juhn G. Liou, Keith Loague, Donald R. Lowe, Gail A. Mahood, Pamela A. Matson,†† Elizabeth L. Miller, David D. Pollard, Jonathan F. Stebbins, Paul Switzer***
*Associate Professors:* Christopher F. Chyba,†† Scott E. Fendorf, Michael O. McWilliams
*Assistant Professors:* Christopher Francis, George Hilley, Adina Paytan, Karen Seto
*Professors (Research):* Atilla Aydin, J. Michael Moldowan
*Courtesy Professors:* Ronaldo I. Borja, James O. Leckie, Stephen Monismith
*Courtesy Associate Professors:* Kevin R. Arrigo, David L. Freyberg, Simon L. Klemperer, Anders Nilsson, Alfred M. Spormann
*Courtesy Assistant Professor:* Gregory P. Asner
*Lecturers:* Anne Egger, Bob Jones
*Consulting Professors:* Alan K. Cooper, Francois Farges, Thomas L. Holzer, David G. Howell, Paul Hsieh, Jack J. Lissauer, Mark S. Marley, Timothy R. McHargue, Kevin Zahnle, Siavosh M. Zand
*Consulting Associate Professors:* Marco Antonellini, Trevor Dumitru, Joseph Wooden, Robyn Wright-Dunbar

* Recalled to active duty
† Joint appointment with Geophysics
** Joint appointment with Petroleum Engineering
†† Joint appointment with the Stanford Institute for International Studies
*** Joint appointment with Statistics

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*Web Site:* http://pangea.stanford.edu/GES/

Courses given in Geological and Environmental Sciences have the subject code GES. For a complete list of subject codes, see Appendix.

## UNDERGRADUATE PROGRAMS

### BACHELOR OF SCIENCE

The program leading to the Bachelor of Science degree in Geological and Environmental Sciences (GES) provides the background for a wide variety of careers. It prepares students for employment or graduate studies in earth and environmental sciences, environmental engineering, land use planning, law, public service, teaching and other professions in which an understanding of the earth and a background in science can be important. The geological sciences are broad and include study of the Earth's history and the evolution of life; the oceans and atmosphere; the processes that shape the Earth's mountains, continents, and landscape; the chemistry and physics of earth materials and their interactions with each other and with water; and sources of water, economic minerals, metals, and fuels. Within GES, study of the environmental sciences emphasizes earth surface processes at present and in the future, particularly the ways in which humankind is affected by natural hazards such as volcanic eruptions and earthquakes and the ways in which we affect the planet and its viability by urban and agricultural development, contamination of natural waters, and depletion of resources.

An important emphasis of the B.S. program in GES is the study of earth processes and history in the natural laboratory of the field. Stanford University's location near the Pacific continental margin, the Sierra Nevada mountain range, and the San Andreas fault system provides a nearly unparalleled setting for field studies. At the same time, geological and environmental sciences deal quantitatively with processes on and in the earth and other planets, and with interactions between chemical, biological, and physical systems. The curriculum thus includes courses in chemistry, physics, and/or biology, and mathematics. The range of these requirements and experiences results in graduates with a broad range of skills.

The GES undergraduate major is designed to recognize the diversity of this field and to provide a great deal of flexibility, with a variety of course choices that should be made in consultation with a faculty adviser and/or the undergraduate program coordinator. The department also offers a specialized curriculum in Engineering Geology and Hydrogeology. Students whose educational objectives are within the scope of the department, but not encompassed in our predefined programs, may also design an independent curriculum with the help of a faculty adviser and approvals from the department chair and the undergraduate program director.

The Writing in the Major (WIM) requirement may be fulfilled by taking one of the following courses designated (WIM): GES 54Q, 55Q, 110, 131, 151, 152, or 185 along with the 1-unit WIM Project course, GES 190. Students choosing to take a course for WIM credit should consult with the instructor early in the quarter; additional writing-intensive work is assigned.

GES majors must complete at least 55 units which includes a core sequence of GES courses, a flexible series of electives, and at least 6 units of field research; or, GES majors may choose to follow the specialized curriculum for Engineering Geology and Hydrogeology. Subject to approval of the GES undergraduate program director, the 6-unit field research requirement may be satisfied by completion of a summer field course in geology at another university or by a faculty-directed field research project that involves learning and application of field techniques and the preparation of a written report. Up to 6 units of GES 198 or 199 may be counted toward the required 55 units if they are part of a research program leading to the preparation of an undergraduate thesis or an honors degree. GES 101 is also a required course, involving three weeks of off-campus field study prior to the start of classes in Autumn. In addition, students are required to choose a sequence of mathematics courses (10 units) and two sequences of courses in cognate sciences (7-10 units each or a total of 15-19 units). Substitutions or changes to these requirements may be requested through a formal petition to the undergraduate program director. Letter grades are required in all courses, if available.

## COURSE SEQUENCE (80-91 UNITS TOTAL)

### REQUIRED GEOLOGICAL AND ENVIRONMENTAL SCIENCES (30-37 UNITS)

All of the following courses (17-18 units):

| *Course No. and Subject* | *Units* |
|---|---|
| GES 1. Fundamentals of Geology | 5 |
| *or* GES 49N. Field Trip to Death Valley and Owens Valley | 4 |
| GES 2. Earth History | 3 |
| GES 80. Earth Materials | 4 |
| GES 101. Environmental and Geological Field Studies | 3 |
| GES 150. Senior Seminar | 2 |
| GES 190. Writing in the Major | 1 |

Four of the following courses (13-19 units):

| | |
|---|---|
| GES 90. Introduction to Geochemistry | 3-4 |
| GES 110. Structural Geology and Tectonics | 5 |
| GES 151. Sedimentary Geology and Petrography | 4 |
| GES 175. Science of Soils | 4 |
| *or* GES 130. Environmental Earth Sciences I | 5 |
| *or* GES 170. Environmental Geochemistry | 4 |
| GES 181. Igneous and Metamorphic Processes | 3-5 |
| *or* GES 185. Volcanology | 3 |

### REQUIRED SUPPORTING MATHEMATICS (10 UNITS)

Choose one of the following groups of mathematics courses. The third group is strongly recommended for students planning graduate study in science and engineering:

| Course No. and Subject | Units |
|---|---|
| MATH 19. Calculus | 3 |
| MATH 20. Calculus | 3 |
| MATH 21. Calculus | 4 |
| *or* MATH 41. Calculus | 5 |
| MATH 42. Calculus | 5 |
| *or* MATH 51. Multivariate Mathematics | 5 |
| MATH 52. Multivariate Mathematics | 5 |
| *or* MATH 53. Multivariate Mathematics | 5 |

### REQUIRED SUPPORTING COGNATE SCIENCES (15-19 UNITS)

Choose sequences listed below from two of the following three fields of cognate sciences:

| | |
|---|---|
| *Chemistry (7-8 units):* | |
| CHEM 31A. Chemical Principles I | 4 |
| *or* CHEM 31X. Chemical Principles | 4 |
| CHEM 135. Physical Chemical Principles | 3 |
| *or* CHEM 171. Physical Chemistry | 3 |
| *or* GES 171. Geochemical Thermodynamics | 3 |
| *Physics (8-9 units)*: | |
| PHYSICS 21. Mechanics and Heat | 3 |
| PHYSICS 22. Mechanics and Heat Lab | 1 |
| PHYSICS 23. Electricity and Optics | 3 |
| PHYSICS 24. Electricity and Optics Lab | 1 |
| *or* PHYSICS 51. Light and Heat | 4 |
| PHYSICS 52. Light and Heat Lab | 1 |
| PHYSICS 53. Mechanics | 4 |
| *or* PHYSICS 53. Mechanics | 4 |
| PHYSICS 55. Electricity and Magnetism | 3 |
| PHYSICS 56. Electricity and Magnetism Lab | 1 |
| *Biology (8-10 units):* | |
| BIOSCI 41. Genetics, Biochemistry, and Molecular Biology | 5 |
| BIOSCI 42. Cell Biology and Animal Physiology | 5 |
| *or* BIOSCI 43. Plant Biology, Evolution, and Ecology | 5 |
| *or* BIOSCI 101. Ecology | 3 |

### ELECTIVES (19 UNITS)

Majors must complete at least 19 additional units of GES courses numbered 90 through 290, not including GES 200 and 201. With approval of the Undergraduate Program Director, courses numbered 100 or above in other science and engineering fields may satisfy this requirement. A maximum of 3 of the required elective units may be taken in directed reading or non-required seminar courses.

### FIELD RESEARCH (6 UNITS)

Majors must complete a 6-unit summer field course in geology at another university, or a faculty-directed field research project that involves learning and application of field techniques and the preparation of a written report.

## ENGINEERING GEOLOGY AND HYDROGEOLOGY SPECIALIZED CURRICULUM

The Engineering Geology and Hydrogeology curriculum is intended for undergraduates interested in the application of geological and engineering data and principles to the study of rock, soil, and water to recognize and interpret geological and environmental factors affecting engineering structures and groundwater resources. Students learn to characterize and assess the risks associated with natural geological hazards, such as landslides and earthquakes, and with groundwater flow and contamination. The curriculum prepares students for graduate programs and professional careers in engineering, and environmental geology, geology, geotechnical engineering, and hydrogeology. Students interested in this curriculum should contact a faculty adviser: Professor Loague, Pollard, or Gorelick.

GES majors who elect the Engineering Geology and Hydrogeology curriculum are expected to complete a core course sequence and a set of courses in supporting sciences and mathematics. The core courses come from Earth Sciences and Engineering. Any substitutions for core courses must be approved by the faculty adviser and through a formal petition to the undergraduate program director. In addition, four elective courses, consistent with the core curriculum and required of all majors, are to be selected with the advice and consent of the adviser. Typically, electives are selected from the list below. Letter grades are required if available.

## COURSE SEQUENCE (88-99 UNITS TOTAL)

### REQUIRED GEOLOGICAL AND ENVIRONMENTAL SCIENCES (34-37 UNITS)

| *Course No. and Subject* | *Units* |
|---|---|
| GES 1. Fundamentals of Geology | 5 |
| GES 80. Earth Materials | 4 |
| GES 101. Environmental and Geological Field Studies | 3 |
| GES 111. Structural Geology and Rock Mechanics | 3 |
| *or* GES 215. Advanced Structural Geology and Rock Mechanics | 3-5 |
| GES 115. Engineering Geology Practice | 3 |
| GES 144. Fundamentals of GIS | 4 |
| GES 160. Statistical Methods for Earth and Environmental Sciences: General Introduction | 4 |
| *or* GES 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics | 3-4 |
| GES 190. Writing in the Major | 1 |
| GES 230. Physical Hydrogeology | 5 |
| GEOPHYS 190. Applied Geophysical Methods | 3 |

### REQUIRED ENGINEERING (20 UNITS)

| | |
|---|---|
| CEE 101A. Mechanics of Materials | 4 |
| CEE 101B. Mechanics of Fluids | 4 |
| CEE 101C. Geotechnical Engineering | 4 |
| CS 106A. Programming Methodology | 5 |
| ENGR 14. Applied Mechanics: Statics | 3 |

### REQUIRED SUPPORTING SCIENCES AND MATHEMATICS (23 UNITS)

| | |
|---|---|
| CHEM 31A. Chemistry Principles I | 4 |
| MATH 51. Multivariate Mathematics | 5 |
| MATH 52. Multivariate Mathematics | 5 |
| MATH 53. Multivariate Mathematics | 5 |
| PHYSICS 53. Mechanics | 4 |

### SUGGESTED ELECTIVES (11-19 UNITS)

Choose *four* courses from the following list or, with faculty approval, four related courses:

| | |
|---|---|
| CEE 180. Structural Analysis | 3 |
| CEE 270. Movement, Fate, and Effects of Contaminants in Surface Waters and Groundwater | 3 |
| CEE 293. Foundation Engineering | 3 |
| CEE 296. Experimental Soil Mechanics | 2 |
| ENGR 30. Engineering Thermodynamics | 3 |
| ENGR 50. Introductory Science of Materials | 4 |
| ENGR 155A,B. Mathematical and Computational Methods | 5 |
| GEOPHYS 150. General Geophysics | 4 |
| GES 130. Environmental Earth Sciences I | 5 |
| GES 131. Environmental Earth Sciences II | 5 |
| GES 217. Characterization and Hydraulics of Rock Fracture | 3 |
| GES 231. Contaminant Hydrogeology | 4 |
| GES 235. Role of Fluids in Geologic Processes | 3 |
| GES 237. Surface and Near-Surface Hydrologic Response | 4 |
| MATH 103. Matrix Theory and its Applications | 3 |
| ME 80. Stress, Strain, and Strength | 3 |

## MINORS

A minor in Geological and Environmental Sciences consists of a small set of required courses, plus 12 elective units.

Required courses:

GES 1. Fundamentals of Geology
*or* GES 49N. Field Trip to Death Valley and Owens Valley
*or* GES 2. Earth History
*or* GES 130. Environmental Earth Sciences I
GES 80. Earth Materials
GES 101. Environmental and Geological Field Studies

A minimum of 12 additional units in GES courses, including three courses from the list below:

GES 8. The Oceans
GES 90. Introduction to Geochemistry
GES 110. Structural Geology
*or* GES 111. Structural Geology and Rock Mechanics
GES 130. Environmental Earth Sciences I
GES 131. Environmental Earth Sciences II
GES 144. Fundamentals of GIS
GES 151. Sedimentary Geology and Petrography
GES 152. Stratigraphy and Applied Paleontology
GES 170. Environmental Geochemistry
GES 175. Science of Soils
GES 181. Igneous and Metamorphic Processes
GES 185. Volcanology

All students pursuing a minor in GES are encouraged to take one of the freshman or sophomore seminars (courses with numbers 38-59) and to participate in the senior seminar (GES 150). Up to 3 units of Stanford Introductory Seminar courses may be used in fulfilling the 12-unit requirement above.

Contact the GES department for further information. The variety of courses that may be used to satisfy the requirements should make it possible for students with a wide range of interests and backgrounds to complete a minor in GES.

## HONORS PROGRAM

The Department of Geological and Environmental Sciences offers a program leading to the Bachelor of Science in Geological and Environmental Sciences with honors. The program provides an opportunity for independent study and research on a topic of special interest culminating in a written report. The honors program is open to all seniors with a grade point average (GPA) of at least 3.5 in Earth and Environmental Science courses and a minimum of 3.0 in all University course work. Modest financial support is available to help defray laboratory and field expenses incurred in conjunction with honors research. Students intending to pursue the honors program must submit an application to the department before the beginning of their senior year.

A student selects a research topic and prepares a research proposal in consultation with a faculty adviser of his or her choosing. Research undertaken for the honors program can be of a theoretical, field, or experimental nature, or a combination of these approaches.

Upon approval of the research proposal and formal entrance to the program, course credit for the honors research project and report preparation is assigned by the student's faculty adviser within the framework of GES 199; 3 units each quarter are assigned to the project for three quarters of the student's senior year for a total of 9 units. Research undertaken for the honors program cannot be used as a substitute for regularly required courses.

Both a written and an oral presentation of research results are required of honors students. A formal written report must be submitted to the student's research adviser no later than the fourth week of the student's final senior quarter. To graduate with honors, the report must be read, approved, and signed by the student's faculty adviser and a second member of the faculty. Before the end of the senior year, each honors candidate gives a public seminar on his or her research results.

## COTERMINAL B.S. AND M.S. DEGREES

The coterminal B.S./M.S. program offers a special opportunity for students to pursue a graduate research experience and an M.S. degree concurrently with or subsequent to their B.S. studies. The master's degree may serve as an entrance professional degree in a number of subdisciplines within the earth sciences (for example, engineering geology and environmental geology). Alternatively, graduate course work and the master's research experience can provide an intermediate step prior to pursuit of the Ph.D. Regardless of their professional goal, coterminal B.S./M.S. students are treated as members of the graduate community and are expected to meet all of the standards set for regular M.S. students. Students should apply to the program after their seventh quarter (or after earning 105 units), but no later than their eleventh quarter. They are required to submit a coterminal program application to the GES department which includes a statement of purpose, a copy of their current Stanford transcript, official Graduate Record Examination scores, letters of recommendation from two members of the Stanford faculty (at least one of whom must be in this department), and a list of courses in which they intend to enroll to fulfill degree requirements. Each student must complete a thesis describing the results of his or her research. Specific research interests should be noted in the statement of purpose and discussed with a member of the GES faculty prior to submission of an application to the coterminal program.

Students must meet all requirements for both the B.S. and M.S. degrees. Students may either (1) complete 180 units required for the B.S. degree and then complete three full-time quarters for the M.S. degree, or (2) complete a total of fifteen quarters during which the requirements of the two degrees are fulfilled concurrently. The student has the option of receiving the B.S. degree upon completion of that degree's requirements, or receiving the B.S. and M.S. degrees concurrently at the completion of the master's program. Unit requirements for the coterminal program are a minimum of 180 units for the B.S. degree and a minimum of 45 units of course work at the 100 level or above for the M.S. degree. At least half of the courses used to satisfy the 45-unit requirement must be designated as being primarily for graduate students, normally at the 200 level or above. No more than 15 units of thesis research may be used to satisfy the 45-unit requirement. Further information about this program may be obtained from the GES office. For University coterminal degree program rules and University application forms, see http://registrar. stanford.edu/ publications/#Coterm.

## GRADUATE PROGRAMS

Graduate studies in the Department of Geological and Environmental Sciences (GES) involve academic course work and independent research. Students are prepared for careers as professional scientists in research, education, or the application of the earth sciences to mineral, energy, and water resources. Programs lead to the M.S., Engineer, and Ph.D. degrees. Course programs in the areas of faculty interest are tailored to the student's needs and interests with the aid of his or her research adviser. Students are encouraged to include in their program courses offered in other departments in the School of Earth Sciences as well as in other departments in the University. Diplomas designate degrees in Geological and Environmental Sciences and may also indicate the following specialized fields of study: Geostatistics and Hydrogeology.

*Admission*—For admission to graduate work in the department, the applicant must have taken the Aptitude Test (verbal, quantitative, and analytical writing assessment) of the Graduate Record Examination. In keeping with University policy, applicants whose first language is not English must submit TOEFL (Test of English as a Foreign Language) scores from a test taken within the last 18 months. Individuals who have completed a B.S. or two-year M.S. program in the U.S. or other English-speaking country are not required to submit TOEFL scores. Previously admitted students who wish to change their degree objective from M.S. to Ph.D. must petition the GES Admissions Committee.

## FIELDS WITH DIPLOMA DESIGNATION

*Hydrogeology*—The Hydrogeology program, which leads to an M.S., Engineer, or Ph.D. degree in GES, balances research in the purely scientific and applied aspects of groundwater resources and near-surface processes.

The program requires students to obtain a broad background in earth sciences and engineering. Students in the program must have a strong general scientific background in basic physics, chemistry, computer science, and mathematics, and a demonstrated aptitude for solving quantitative problems. They must complete a core curriculum involving courses in fluid mechanics, hydrogeology, hydrology, and water quality. A list of required and recommended courses is supplied upon request.

*Geostatistics*—The Geostatistics program leads to an M.S. or Ph.D. degree in GES. Strong interactions have been developed with faculty and students in the departments of Geophysics and Petroleum Engineering.

The program requires a geological background and a fair level of calculus and programming (Fortran and/or C++). Recent graduates have found jobs in the extractive (mining, oil) and environmental (EPA) fields.

## MASTER OF SCIENCE

*Objectives*—The purpose of the master's program in Geological and Environmental Sciences is to continue a student's training in one of a broad range of earth science disciplines and to prepare students for either a professional career or doctoral studies.

*Procedures*—The graduate coordinator of the department appoints an academic adviser during registration with appropriate consideration of the student's background, interests, and professional goals. In consultation with the adviser, the student plans a program of course work for the first year. The student should select a thesis adviser within the first year of residence and submit to the thesis adviser a proposal for thesis research as soon as possible. The academic adviser supervises completion of the department requirements for the M.S. program (as outlined below) until the research proposal has been accepted; responsibility then passes to the thesis adviser. The student may change either thesis or academic advisers by mutual agreement and after approval of the graduate coordinator.

*Requirements*—The University's requirements for M.S. degrees are outlined in the "Graduate Degrees" section of this bulletin. Practical training (GES 385) may be required by some programs, with adviser approval, depending on the background of the student. Additional department requirements include the following:

1. A minimum of 45 units of course work at the 100 level or above.
   a. Half of the courses used to satisfy the 45-unit requirement must be intended as being primarily for graduate students, usually at the 200 level or above.
   b. No more than 15 units of thesis research may be used to satisfy the 45-unit requirement.
   c. Some students may be required to make up background deficiencies in addition to these basic requirements.
2. By the end of Winter Quarter of their first year in residence, students must complete at least three courses taught by a minimum of two different GES faculty members.
3. Each student must have a research adviser who is a faculty member in the department and is within the student's thesis topic area or specialized area of study.
4. Each student must complete a thesis describing his or her research. Thesis research should begin during the first year of study at Stanford and should be completed before the end of the second year of residence.
5. Early during the thesis research period, and after consultation with the student, the thesis adviser appoints a second reader for the thesis, who must be approved by the graduate coordinator; the thesis adviser is the first reader. The two readers jointly determine whether the thesis is acceptable for the M.S. degree in the department.

## ENGINEER DEGREE

The Engineer degree is offered as an option for students in applied disciplines who wish to obtain a graduate education extending beyond that of an M.S., yet do not have the desire to conduct the research needed to obtain a Ph.D. A minimum of two years (six quarters) of graduate study is required. The candidate must complete 90 units of course work, no more than 10 of which may be applied to overcoming deficiencies in undergraduate training. The student must prepare a substantial thesis that meets the approval of the thesis adviser and the graduate coordinator.

## DOCTOR OF PHILOSOPHY

*Objectives*—The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship, high attainment in a particular field of knowledge, and the ability to conduct independent research. To this end, the objectives of the doctoral program are to enable students to develop the skills needed to conduct original investigations in a particular discipline or set of disciplines in the earth sciences, to interpret the results, and to present the data and conclusions in a publishable manner.

*Requirements*—The University's requirements for the Ph.D. degree are outlined in the "Graduate Degrees" section of this bulletin. Practical training (GES 385) may be required by some programs, with adviser approval, depending on the background of the student. A summary of additional department requirements is presented below:

1. Ph.D. students must complete the required courses in their individual program or in their specialized area of study with a grade point average (GPA) of 3.0 (B) or higher, or demonstrate that they have completed the equivalents elsewhere. Ph.D. students must complete a minimum of four letter-grade courses of at least 3 units each from four different faculty members on the Academic Council in the University. By the end of Winter Quarter of their first year in residence, students must complete at least three courses taught by a minimum of two different GES faculty members.
2. Each student must qualify for candidacy for the Ph.D. by the end of the sixth quarter in residence, excluding summers. Department procedures require selection of a faculty thesis adviser, preparation of a written research proposal, approval of this proposal by the thesis adviser, selection of a committee for the Ph.D. qualifying examination, and approval of the membership by the graduate coordinator and chair of the department. The research examination consists of three parts: oral presentation of a research proposal, examination on the research proposal, and examination on subject matter relevant to the proposed research. The exam should be scheduled for prior to May 1, so that the outcome of the exam is known at the time of the annual spring evaluation of graduate students.
3. Upon qualifying for Ph.D. candidacy, the student and thesis adviser, who must be a department faculty member, choose a research committee that includes a minimum of two faculty members in the University in addition to the adviser. Annually, in the month of March or April, the candidate must organize a meeting of the research committee to present a brief progress report covering the past year.
4. Under the supervision of the research advisory committee, the candidate must prepare a doctoral dissertation that is a contribution to knowledge and is the result of independent research. The format of the dissertation must meet University guidelines. The student is strongly urged to prepare dissertation chapters that, in scientific content and format, are readily publishable.
5. The doctoral dissertation is defended in the University oral examination. The research adviser and two other members of the research committee are determined to be readers of the draft dissertation. The readers are charged to read the draft and to certify in writing to the department that it is adequate to serve as a basis for the University oral examination. Upon obtaining this written certification, the student is permitted to schedule the University oral examination.

### PH.D. MINOR

Candidates for the Ph.D. degree in other departments who wish to obtain a minor in Geological and Environmental Sciences must complete, with a GPA of 3.0 (B) or better, 20 units in the geosciences in lecture courses intended for graduate students. The selection of courses must be approved by the student's GES adviser and the department chair.

## COURSES

WIM indicates that the course satisfies the Writing in the Major requirements. (AU) indicates that the course is subject to the University Activity Unit limitations (8 units maximum).

### UNDERGRADUATE

**GES 1. Fundamentals of Geology**—For non-majors or prospective majors in Geological and Environmental Sciences or Earth Systems. Topics include: processes that shape the earth's landforms, produce minerals and rocks, create soils, deform its crust, and move continents; surficial processes involving water, wind, and ice, and their role in erosion and sediment production; processes within the earth's interior with emphasis on global tectonics; determining the ages of rocks and geologic events; hazards including earthquakes, volcanoes, flooding, landslides, and their mitigation; and nonrenewable resources, energy, and environmental problems. Field trip; lab. Recommended: high school chemistry and physics. GER:2a

*5 units, Aut (Egger), Win (Ernst), Spr (McWilliams)*

**GES 2. Earth History**—For non-majors and prospective Earth Systems or Geology majors. Overview of how the universe evolved from the creation of the elements to the origin of humans. The origin of the universe, our solar system, and Earth's atmosphere, oceans, and continents. The origin of life, the evolution of life from its earliest beginnings to the rise of metazoans and development of humans, and the relationship between geological and biological evolution. Future scenarios for earth, including human impact on earth systems and how human beings are modifying the atmosphere, oceans, and land. GER:2a

*3 units (Chamberlain) not given 2004-05*

**GES 7A,B. An Introduction to Wilderness Skills**—Living, traveling, and working in the wilderness for those planning fieldwork in the backcountry. Geological processes, land management, environmental ethics, first aid, animal tracking, and plant ecology. Four weekend outings focus on minimum impact backcountry skills including ski techniques, backpacking, caving, food preparation, orienteering, rock climbing, snow shelter building, and telemarking. 7A emphasizes navigation on foot and rock climbing; 7B emphasizes winter camping skills and backcountry skiing. Food, group, and major personal gear provided. Fee. Preregistration required at www.stanford.edu/class/ges7. (AU)

*1 unit, Aut, Win (Bird)*

**GES 7C. Advanced Wilderness Skills**—Introduction to mountaineering techniques and issues of interest to students experienced with outdoor travel. Fee for food and transportation. Preregistration required through OEP at http://www.stanford.edu/class/ges7/. (AU)

*1 unit, Spr (Bird)*

**GES 8. The Oceans: An Introduction to the Marine Environment**—For nonmajors and prospective earth science and environmental majors. Topics: topography and geology of the sea floor, evolution of ocean basins, the circulation of the ocean and atmosphere, the nature of sea water, waves, tides, and the history of the major ocean basins. The interface between continents and ocean basins, emphasizing estuaries, beaches, and continental shelves with California margin examples. Relationships between distribution of inorganic constituents, ocean circulation, biologic productivity, and marine environments from deep sea to the coast. Required one-day field trip to measure and analyze waves and currents. GER:2a

*3 units, Spr, Sum (Ingle)*

**GES 38N. The Worst Journey in the World: The Science, Literature, and History of Polar Exploration**—Stanford Introductory Seminar. Preference to freshmen. The isolation of polar explorers under the harshest conditions on Earth, and the chronicles of their explorations and hardships dating to the 1500s for the Arctic and the 1700s for the Antarctic. Focus is on scientific and geographic achievements. Sources include *The Worst Journey in the World* by Apsley Cherry-Garrard who in 1911 participated in a midwinter Antarctic sledging trip to recover emperor penguin eggs. Class jointly authors essay on themes from such literature. Optional field trip into the high Sierra in December. GER:2a

*3 units, Aut (Dunbar)*

**GES 43N. Environmental Problems**—Stanford Introductory Seminar. Preference to freshmen. Components of multidisciplinary environmental problems and ethical questions associated with decision making in the regulatory arena. Students lead discussions on environmental issues such as groundwater contamination from point and nonpoint sources, cumulative watershed effects related to timber and mining practices, acid rain, subsurface disposal of nuclear waste, the Alaska pipeline, slope stability, and oil tanker spills. GER:2a

*3 units, Win (Loague)*

**GES 47N. Secrets in the Mud: A Look Into the Field of Paleoceanography**—Stanford Introductory Seminar. Preference to freshmen. How oceans responded to natural perturbations helps predict and plan for the potential consequences of human-induced environmental changes. The types of information deduced from marine sediments about Earth's past environments. Lab projects: sediment sample preparation and analysis, description and interpretation of data, and oral and written presentation. One-day field trip. GER:2a

*3 units, Spr (Paytan)*

**GES 49N. Field Trip to Death Valley and Owens Valley**—Stanford Introductory Seminar. Preference to freshmen. California's Death Valley and Owens Valley asnatural laboratories for exploring earth history: ancient ocean sediments, mountain building, earthquake faulting, glacial landscapes, and volcanic eruptions. Desert environments reveal prehistoric climate changes and human impacts. Six-day field trip during Spring Break. Basics of plate tectonics and geology. Rock identification, reading topographic and geologic maps, and interpreting remote sensing imagery. Term paper is a chapter for a field trip guidebook. Oral presentation on the outcrop at the field trip stop described in the guidebook chapter. Camping and moderate hiking required. GER:2a
*3 units, Win (Mahood)*

**GES 50Q. The Coastal Zone Environment**—Stanford Introductory Seminar. Preference to sophomores. The oceanographic, geological, and biological character of coastal zone environments, including continental shelves, estuaries, and coastal wetlands, with emphasis on San Francisco Bay. Five required field trips examine the estuarine and coastal environments of the Bay region, and agencies and facilities concerned with monitoring and management of these resources. Original research on an aspect of the coastal zone results in written and oral reports. Prerequisite: beginning Biology (such as BIOSCI 51), Chemistry (CHEM 30, 31), Earth Sciences (GES 1, 2), or Earth Systems (EARTHSYS 10). GER:2a
*3 units, Aut (Ingle)*

**GES 52Q. Geologic Development of California**—Stanford Introductory Seminar. Preference to sophomores, and to students who have completed introductory geology. Field-based study of the crustal evolution of California in post-Paleozoic time, and covering the geotectonic development of most of the state. Weekend field trips to the Eastern Coast Ranges (two days); Mount Shasta and the central Klamath Mountains (four days); Point Lobos and the Big Sur coast (two days). Camping and hiking. Term paper. GER:2a
*5 units, Spr (Ernst)*

**GES 53Q. In the Beginning: Theories of the Origin of the Earth, Solar System, and Universe**—Stanford Introductory Seminar. Preference to sophomores. What happened in the first few seconds following the Big Bang? Where did all the elements in the periodic table come from? When and how did the Earth, Moon, and solar system form? When and where did life begin on Earth? The history and evolution of theories of the origin of the Earth, Moon, solar system, and the Universe. GER:2a
*3 units, Win (McWilliams)*

**GES 54Q. California Landforms and Plate Tectonics**—Stanford Introductory Seminar. Preference to sophomores. The forces of plate tectonics at work on the landscape of California. The principles of rock deformation are introduced with laboratory experiments. Landforms resulting from deformation of the earth are analyzed with digital and photographic images. Field trips relate these large-scale structures to the human perspective on the ground. Final paper involves literature research on active deformation and earthquakes in a region of the student's choice. Corequisite for WIM: 190. GER:2a,WIM
*3 units, Aut (Miller)*

**GES 55Q. The California Gold Rush: Geologic Background and Environmental Impact**—Stanford Introductory Seminar. Preference to sophomores, and to students who have completed introductory geology. Topics include: geologic processes that led to the concentration of gold in the river gravels and rocks of the Mother Lode region of California; and environmental impact of the Gold Rush due to population increase, mining operations, and high concentrations of arsenic and mercury in sediments from hard rock mining and milling operations. Field trip to the Mother Lode region. Corequisite for WIM: 190. GER:2a,WIM
*3 units, Spr (Bird)*

**GES 57Q. How to Critically Read and Discuss Scientific Literature**—Stanford Introductory Seminar. Preference to sophomores. How to approach the reading of scientific articles; how to understand and evaluate the information in them; and a review of such papers. GER:2a
*3 units, Win (Paytan)*

**GES 80. Earth Materials**—Identification, classification, and interpretation of rock-forming minerals and the igneous, sedimentary, and metamorphic rocks they comprise. Rock cycles are related to earth systems. Lab work emphasizes use of the hand lens in making observations; overnight field trip demonstrates mineral and rock identification in the field, a variety of different pressure and temperature environments where minerals and rocks have formed, and genetic associations. Prerequisite: 1. Recommended: introductory chemistry. GER:2a
*4 units, Aut (Brown, Liou)*

**GES 81. Petrography Tutorial**—Practice and instruction in identifying minerals and rocks using a petrographic microscope. One three-hour lab per week. Prerequisite: 80 or equivalent.
*2 units, Spr (Miller)*

**GES 90. Introduction to Geochemistry**—The chemistry of the solid earth and its atmosphere and oceans, emphasizing the processes that control the distribution of the elements in the earth over geological time and at present, and on the conceptual and analytical tools needed to explore these questions. The basics of geochemical thermodynamics and isotope geochemistry. The formation of the elements, crust, atmosphere and oceans, global geochemical cycles, and the interaction of geochemistry, biological evolution, and climate. Recommended: introductory chemistry. GER:2a
*3-4 units, Win (Stebbins)*

**GES 101. Environmental and Geological Field Studies in the Rocky Mountains**—Introduction to research possibilities in the geological sciences. Field-based program from September 1-22. Weekly meetings on campus during Autumn Quarter. Field portion is based in the Greater Yellowstone/Teton and Bighorn Mountain region of Wyoming and Montana. Topics include the basics of structural geology and petrology, economic geology, glacial geology, regional western cordillera geology, paleoclimatology, chemical weathering and the carbon cycle, aqueous geochemistry, and environmental issues. Earth/environmental science questions in the Precambrian granitic and glacial terranes of the Wind Rivers of Wyoming, the Laramide fold/thrust belt of the Bighorn basin, and the mid-tertiary volcanic center of N.E. Yellowstone National Park. Research papers based on the results of fieldwork. GER:2a
*3 units, Aut (Chamberlain)*

**GES 107. Astrobiology and Space**—(Enroll in HUMBIO 107.)
*3 units, Win (Rothschild)*

**GES 110. Structural Geology and Tectonics**—The basic theory, principles, and techniques used to interpret and measure structures in naturally deformed rocks. Topics: the properties, rheology, and mechanisms of deformation of rocks and minerals; techniques of data collection in the field; lab and computer analysis of structural data; geometry and development of faults and folds; interpretation of geologic maps and construction of geologic cross-sections; strain measurement and structural analysis of metamorphic tectonites; the evolution of mountain belts, formation of rift-related sedimentary basins, and development of strike-slip fault systems. Prerequisites: 1, calculus. Recommended: 80, 102. Corequisite for WIM: GES 190. GER:2a,WIM
*5 units, Spr (Miller)*

**GES 111. Structural Geology and Rock Mechanics**—(Same as CEE 195.) Methodology for understanding tectonic processes and their structural products by combining quantitative field data with conceptual and mechanical models of rock deformation and flow. Topics include: mapping techniques using GPS; characterization of structures using differential geometry; dimensional analysis; kinematics of deformation; stress analysis; elasticity, brittle fracture and faulting; viscosity and flow of rock; modeling geological structures using continuum mechanics. Applications include the role of geological structures in the evolution of the earth's crust and the mitigation of geologic hazards. Prerequisites: GES 1, MATH 51, 52. GER:2a
*3 units, Win (Pollard)*

**GES 115. Engineering Geology Practice**—(Same as CEE 196.) The application of geologic fundamentals to the planning and design of civil engineering projects. Field exercises and case studies emphasize the impact of site geology on the planning, design, and construction of civil works such as buildings, foundations, transportation facilities, excavations, tunnels and underground storage space, and water supply facilities. Topics: Quaternary history and tectonics, formation and physical properties of surficial deposits, site investigation techniques, geologic hazards, and professional ethics. Prerequisite: GES 1 or consent of instructor. GER:2a

*3 units, Spr (Holzer) alternate years, not given 2005-06*

**GES 121. What Makes a Habitable Planet?**—Physical processes affecting habitability such as large impacts and atmospheric greenhouse effect, comets, geochemistry, the rise of oxygen, climate controls, and impact cratering. Detecting and interpreting the spectra of extrasolar terrestrial planets. Student-led discussions of scientific literature. Team taught by planetary scientists from NASA Ames Research Center.

*3 units, Aut (Lissauer, Marley, Zahnle)*

**GES 130. Environmental Earth Sciences I: Soil Physics and Hydrology**—First of a two-part sequence on surface and near-surface processes. The waters of the Earth, their occurrence, distribution, circulation, and reaction with the environment. Topics: precipitation, evapotranspiration, infiltration and vadose zone, groundwater, surface water and streamflow generation, lakes, water supply and use, and water balance and flood frequency estimates. Current and classic theory in soil physics and hydrology. Urban, rangeland, and forested environments. Project throughout sequence involves preparation of a case study report. Students present a reconnaissance report. Field trips to project area and San Mateo County coast. GER:2a

*5 units, Aut (Loague)*

**GES 131. Environmental Earth Sciences II: Fluvial Systems and Landscape Evolution**—Second part of sequence on surface and near-surface processes. Materials of the Earth and hydrologically driven landscape processes. Topics: hillslope hydrology, weathering of rocks and soils, erosion, flow failures, mass wasting, and conceptual models of landscape evolution. Current and classic theory in geomorphology. Groups present a final case study report. Field trips to project area and San Mateo County coast. Corequisite for WIM: 190. GER:2a,WIM

*5 units, Win (Loague)*

**GES 140. Introduction to Remote Sensing**—(Enroll in GEOPHYS 140.)

*3 units (Zebker) alternate years, not given 2005-06*

**GES 141. Remote Sensing of the Oceans**—(Enroll in EARTHSYS 141/241, GEOPHYS 141/241.)

*4 units (Arrigo) alternate years, given 2005-06*

**GES 142. Remote Sensing of Land Use and Land Cover**—(Same as EARTHSYS 142/242.) The use of satellite remote sensing to monitor land use and land cover, with emphasis on terrestrial changes. Topics include pre-processing data, biophysical properties of vegetation observable by satellite, accuracy assessment of maps derived from remote sensing, and methodologies to detect changes such as urbanization, deforestation, vegetation health, and wildfires.

*4 units, Win (Seto) alternate years, not given 2005-06*

**GES 144. Fundamentals of Geographic Information Science (GIS)**—(Graduate students register for 244.) Survey of geographic information including maps, satellite imagery, and census data, approaches to spatial data, and tools for integrating and examining spatially-explicit data. Emphasis is on fundamental concepts of geographic information science and associated technologies. Topics include geographic data structure, cartography, remotely sensed data, statistical analysis of geographic data, spatial analysis, map design, and geographic information system software. Computer lab assignments. GER:2a

*4 units, Spr (Seto)*

**GES 147. Controlling Climate Change in the 21st Century**—(Enroll in EARTHSYS 147/247, BIOSCI 147/247.)

*3 units, Win (Schneider, Rosencranz) alternate years, not given 2005-06*

**GES 150. Senior Seminar**— For juniors and seniors majoring in GES. Current research in earth sciences. Topic and format (lectures, field trips, writing assignments, or discussion sections) vary according to interests of instructor and students.

*2 units, Aut (Staff)*

**GES 151. Sedimentary Geology and Petrography: Depositional Systems**—Topics: weathering, erosion and transportation, deposition, origins of sedimentary structures and textures, sediment composition, diagenesis, sedimentary facies, tectonics and sedimentation, and the characteristics of the major siliciclastic and carbonate depositional environments. Lab: methods of analysis of sediments in hand specimen and thin section. Field trips required. Prerequisite: 1. GER:2a,WIM

*4 units, Win (Graham, Lowe)*

**GES 152. Stratigraphy and Applied Paleontology**—The rudiments of interpreting sedimentary sequences. Emphasis is on the integration of paleontologic and sedimentologic evidence to reconstruct depositional environments, basin history, and paleo-oceanographic settings. The nature of the fossil record, the use of marine fossils for dating, correlation, and paleo-environmental and paleo-oceanographic reconstructions. Characteristic variations of modern and ancient biofacies and lithofacies. Biostratigraphy, magnetostratigraphy, and radiometric dating and correlation. Required research paper. Lectures supplemented by classic and current scientific literature. Weekly lab; two required field trips. Corequisite for WIM: 190. Prerequisites: 1, 2. GER:2a,WIM

*4 units, Spr (Ingle)*

**GES 159. Marine Chemistry**—(Graduate students register for 259.) The oceans are in interactive contact with the atmosphere, biosphere, and lithosphere, and virtually all elements pass through the ocean. First-order processes that take place within the sea and affect its chemistry. What controls the distribution of chemical species in water and sediments? How long do elements spend in the ocean? How do marine chemical processes interact with ocean biological, geological, and physical processes? Prerequisite: GES 8 or consent of instructor.

*2-4 units, Spr (Paytan)*

**GES 160. Statistical Methods for Earth and Environmental Sciences: General Introduction**—Extracting information from data using statistical summaries and graphical visualization, statistical measures of association and correlation, distribution models, sampling, error estimation and confidence intervals, linear models and regression analysis, introduction to time-series and spatial data with geostatistics, applications including environmental monitoring, natural hazards, and experimental design. Either or both of 160 and 161 may be taken. GER:2a

*3-4 units (Switzer) not given 2004-05*

**GES 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics**—(Same as PETENG 161.) Statistical analysis and graphical display of data, common distribution models, sampling, and regression. The variogram as a tool for modeling spatial correlation; variogram estimation and modeling; introduction to spatial mapping and prediction with kriging; integration of remote sensing and other ancillary information using co-kriging models; spatial uncertainty; introduction to geostatistical software applied to large environmental, climatological, and reservoir engineering databases; emphasis is on practical use of geostatistical tools. GER:2a

*3-4 units, Win (Caers)*

**GES 164. Stable Isotopes**—Light stable isotopes and their application to geological and geophysical problems. Isotopic systematics of hydrogen, carbon, nitrogen, oxygen, and sulfur; chemical and biogenic fractionation of light isotopes in the atmosphere, hydrosphere, and in minerals. Isotopic composition of water in the oceans. Paleothermometry and paleoclimatology. Isotope fractionation in igneous, sedimentary, and metamorphic rocks, and in ore-forming fluids. Prerequisite: 163 or consent of instructor. GER:2a

*3 units (Dunbar) not given 2004-05*

**GES 164L. Stable Isotopes Laboratory**—Practical laboratory for GES 164.

*2-3 units (Dunbar) not given 2004-05*

**GES 165. Radiogenic Isotopes and Geochronology**—Principle applications to geological and geophysical problems. Topics: nuclear structure, isotope systematics, decay schemes for the principal nuclides used in earth sciences, equilibrium and disequilibrium, diffusion and transport phenomena, blocking (closure) of isotopic and magnetic systems, creation and annealing of fission tracks, neutron activation, geologic timescales, chronostratigraphy, magnetostratigraphy, and cosmogenic exposure ages. Alpha counting, mass spectrometry by gas source, solid source, ion probe and accelerator methods. Fundamentals of K-Ar, Ar-Ar, Rb-Sr, U-Pb fission track (U+Th)/He, and cosmogenic isotope methods. Recommended: undergraduate calculus, chemistry, geology, and physics. GER:2a

*3 units (McWilliams) alternate years, given 2005-06*

**GES 165L. Geochronology and Thermochronology Laboratory**—Practical laboratory for 165.

*1-2 units (McWilliams) alternate years, not given 2005-06*

**GES 166. Soil Chemistry**—(Graduate students register for 266.) Practical and quantitative treatment of soil processes affecting chemical reactivity, transformation, retention, and bioavailability. Principles of primary areas of soil chemistry: inorganic and organic soil components, complex equilibria in soil solutions, and adsorption phenomena at the solid-water interface. Processes and remediation of acid, saline, and wetland soils. GER:2a

*4 units (Fendorf) alternate years, given 2005-06*

**GES 168. Geomicrobiology**—(Graduate students register for 268.) How microorganisms shape the geochemistry of the earth's crust including oceans, lakes, estuaries, subsurface environments, sediments, soils, mineral deposits, and rocks. Topics include mineral formation/dissolution; biogeochemical cycling of elements (carbon, nitrogen, sulfur, and metals); geochemical and mineralogical controls on microbial activity, diversity, and evolution; life in extreme environments; and the application of new techniques to geomicrobial systems. Recommended: introductory chemistry and microbiology.

*3-4 units, Spr (Francis)*

**GES 170. Environmental Geochemistry**—Solid, aqueous, and gaseous phases comprising the environment, their natural compositional variations, and their chemical interactions. Contrast between natural sources of hazardous elements and compounds and the types and sources of anthropogenic contaminants and pollutants. Chemical and physical processes of weathering and soil formation. Chemical factors that affect the stability of solids and aqueous species under earth surface conditions. Processes that control the release, mobility, and fate of contaminants in natural waters and the roles that water and dissolved substances play in the physical behavior of rocks and soils. The scientific basis for evaluation of the impact of contaminants and the design of remediation strategies. Case studies. Prerequisite: 90 or consent of instructor. GER:2a

*4 units, Win (Brown)*

**GES 171. Geochemical Thermodynamics**—Introduction to the application of chemical principles and concepts to geologic systems. The chemical behavior of fluids, minerals, and gases using simple equilibrium approaches to modeling the geochemical consequences of diagenetic, hydrothermal, metamorphic, and igneous processes. Topics: reversible thermodynamics, solution chemistry, mineral-solution equilibria, reaction kinetics, and the distribution and transport of elements by geologic processes. Prerequisite: 80. GER:2a

*3 units, Aut (Bird)*

**GES 175. Science of Soils**—Physical, chemical, and biological processes within soil systems. Emphasis is on factors governing nutrient availability, plant growth and production, land-resource management, and pollution within soils. How to classify soils and assess nutrient cycling and contaminant fate. Recommended: introductory chemistry and biology. GER:2a

*4 units, Aut (Fendorf)*

**GES 181. Igneous and Metamorphic Processes**—The origin of igneous and metamorphic rocks, emphasizing magmatic differentiation and subsolidus recrystallization processes and their imposed physiochemical and tectonic conditions. The physical properties of magmas, role of volatile components, applications of trace elements and isotopes to igneous processes, geodynamics, and evolution of the crust-mantle system modeling of crystal fractionation and partial melting, experimental data and phase diagrams, and relations of magma types to tectonic settings. Mineral paragenesis, phase relations, metamorphic reactions, fluid/rock interactions, P-T-time paths and their imposed tectonic settings. Lab hand-specimen and petrographic examinations of suites of igneous and metamorphic rocks. Graduate students may take without lab for 3 units. Prerequisites: 80, 90, or equivalents. GER:2a

*3-5 units (Liou) alternate years, not given 2005-06*

**GES 182. Field Seminar on Continental-Margin Volcanism**—For juniors, seniors, and graduate students in the earth sciences and archeology. One weekend-long, and two one-day field trips to study Cenozoic volcanism associated with subduction and with passage of the Mendocino Triple Junction off the west coast of California: Mt. Lassen/Mt. Shasta/Modoc Plateau; Clear Lake/Sonoma Volcanics; Pinnacles National Monument. Features visited and studied: andesite and basalt lavas, cinder cones, mixed magmas, blast deposit, debris avalanches, volcanic mudflows, hydrologic controls of springs in volcanic terrains, hydrothermal alteration and modern geothermal systems, Hg mineralization, obsidian source. Lectures, readings, and videos. Prerequisite: 1, 80 or equivalent.

*2 units (Mahood) alternate years, given 2005-06*

**GES 185. Volcanology**—For juniors, seniors, and beginning graduate students in the earth sciences and in archaeology. Two lecture-lab sessions per week. Lectures emphasize how volcanic landforms and deposits relate to the composition and physical properties of magmas and the modes of emplacement. Labs emphasize recognizing types of lavas and products of explosive eruptions. Volcanic hazards and the effects of eruptions on climate and the atmosphere; volcanic-hosted geothermal systems and mineral resources. Required four-day field trip over Memorial Day weekend to study silicic and mafic volcanism associated with the western margin of the Basin and Range province. Prerequisite: 1, 80 or equivalent. Corequisite for WIM: 190. GER:2a,WIM

*4 units (Mahood) alternate years, given 2005-06*

**GES 186. Geoarchaeology**—For juniors, seniors, and beginning graduate students with interests in archaeology and/or geosciences. Introduction to the use of geological concepts, techniques, and data in the study of artifacts and the interpretation of the archaeological record. Topics include: sediments and soils; sedimentary settings of site formation; postdepositional processes that disturb sites; paleoenvironmental reconstruction of past climates and landscapes using plant and animal remains and isotopic studies; raw materials (minerals, metals, stone, shells, clay, building materials) and methods used in sourcing; estimating age based on stratigraphic and radiometric techniques. Weekly lab; weekend field trips to local archaeological/geological localities. GER:2a

*5 units, Spr (Mahood) alternate years, not given 2005-06*

**GES 189. Field Studies in Earth Systems**—(Enroll in EARTHSYS 189, BIOSCI 206.)

*5 units, Spr (Chiariello, Fendorf, Matson, Miller)*

**GES 190. WIM project**—Students in a GES WIM course (54Q, 55Q, 110, 131, 151, or 185) register for 190 using the section number of the appropriate faculty member.

*1 unit, Aut, Win, Spr, Sum (Staff)*

**GES 192. Undergraduate Research in Geological and Environmental Sciences**—Field-, lab-, or literature-based. Faculty supervision. Written reports.

*1-10 units, Aut, Win, Spr, Sum (Staff)*

**GES 198. Special Problems in Geological and Environmental Sciences**—Reading and instruction under faculty supervision. Written reports.

*1-10 units, Aut, Win, Spr, Sum (Staff)*

**GES 199. Honors Program**—Research on a topic of special interest. See Undergraduate Honors Program above.

*3 units, Aut, Win, Spr, Sum (Staff)*

## GRADUATE

**GES 200. Professional Development in Geoscience Education**
*1 unit, Aut, Spr (McWilliams)*

**GES 201. Science Course Design**—(Same as CTL 201.) For students interested in an academic career and who anticipate designing science courses at the undergraduate or graduate level. Goal is to apply research on science learning to the design of effective course materials. Topics include syllabus design, course content and format decisions, assessment planning and grading, and strategies for teaching improvement.
*2-3 units, Aut (Wright-Dunbar)*

**GES 202. Reservoir Geomechanics**—(Enroll in GEOPHYS 202.)
*3 units, Win (Zoback)*

**GES 205. Advanced Oceanography**—For upper-division undergraduates and graduate students in the earth, biologic, and environmental sciences. Topical issues in marine science/oceanography. Topics vary each year following or anticipating research trends in oceanographic research. Focus is on links between the circulation and physics of the ocean with climate in the N. Pacific region, and marine ecologic responses. Participation by marine scientists from marine research groups and organizations including the Monterey Bay Aquarium Research Institute.
*3 units, Aut (Dunbar)*

**GES 206. Antarctic Marine Geology**—For upper-division undergraduates and graduate students. Intermediate and advanced topics in marine geology and geophysics, focusing on examples from the Antarctic continental margin and adjacent Southern Ocean. Topics: glaciers, icebergs, and sea ice as geologic agents (glacial and glacial marine sedimentology, Southern Ocean current systems and deep ocean sedimentation), Antarctic biostratigraphy and chronostratigraphy (continental margin evolution). Students interpret seismic lines and sediment core/well log data. Examples from a recent scientific drilling expedition to Prydz Bay, Antarctica. Up to two students may have an opportunity to study at sea in Antarctica during Winter Quarter. GER:2a
*3 units (Dunbar, Cooper) alternate years, not given 2005-06*

**GES 210. Geologic Evolution of the Western U.S. Cordillera**—For undergraduates and graduates. Overview of the geology of the western states. The evolution of the mountain belt from its inception in the Precambrian to its contemporary history of extension and strike-slip faulting, based on the description, analysis, subduction, and interpretation of the rock record through time. The characteristic structural styles developed during crustal shortening, extension, and strike-slip tectonic regimes; tectonic controls on sedimentary basin formation; plate-margin magmatism and metamorphism; and the relation of plate motions to the land geologic record all provide insight into the crustal-scale processes and driving mechanisms common to mountain chains.
*2-3 units (Miller) alternate years, given 2005-06*

**GES 211. Topics in Regional Geology and Tectonics**
*3 units (Miller) not given 2004-05*

**GES 215. Advanced Structural Geology and Rock Mechanics**—(Same as CEE 297G.) Solutions to initial and boundary-value problems of continuum mechanics are integrated with quantitative field and laboratory data to develop conceptual and computational models for tectonic processes and the development of geological structures. Topics include: techniques for structural mapping and data analysis; differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; traction and stress analysis; conservation laws; mechanical properties of rock (elasticity, viscosity, strength, friction, fracture toughness). Models formulated and solutions visualized using MATLAB. Prerequisites: GES 1, calculus, MATLAB or equivalent.
*3-5 units, Aut (Pollard)*

**GES 216. Rock Fracture Mechanics**—Principles and tools of elasticity theory and fracture mechanics are applied to the origins and physical behaviors of faults, dikes, joints, veins, solution surfaces, and other natural structures in rock. Field observations, engineering rock fracture mechanics, and the elastic theory of cracks. The role of natural fractures in brittle rock deformation, and fluid flow in the earth's crust with applications to crustal deformation, structural geology, petroleum geology, engineering, and hydrogeology. Prerequisite: 215 or equivalent.
*3-5 units (Pollard) alternate years, given 2005-06*

**GES 216R. The Political Economy of Energy Policy**—(Enroll in POLISCI 216R.)
*5 units, Win (Victor)*

**GES 217. Faults, Fractures, and Fluid Flow**—Process-based approach to rock failure; the microstructures and overall architectures of the failure products including faults, joints, solution seams, and types of deformation bands. Fluid flow properties of these structures are characterized with emphasis on sealing and transmitting of faults and their role in hydrocarbon flow, migration, and entrapment. Case studies of fracture characterization experiments in aquifers, oil and gas reservoirs, and waste repository sites. Guest speakers; weekend field trip. Prerequisite: first-year graduate student in Geological and Environmental Sciences, Geophysics, Petroleum Engineering, or equivalent.
*3 units, Win (Aydin) alternate years, not given 2005-06*

**GES 219. Paleoceanography**—For upper-division undergraduates and graduate students. How can we learn about the chemistry, circulation, biology, and geology of past oceans and why is this of interest? Evidence for substantial changes in earth's climate and surficial environment is contained in the sedimentary record. The fundamentals of gathering and interpreting this information in the context of understanding how earth processes functioned in the past and their relevance for the habitability of our planet in the future.
*1-3 units (Paytan) alternate years, not given 2005-06*

**GES 220. Terrestrial Biogeochemistry**—(Enroll in BIOSCI 216.)
*3 units, Spr (Vitousek) alternate years, not given 2005-06*

**GES 221. The Origins of Life in the Solar System**—Interdisciplinary seminar for upper-division undergraduates and graduate students in the physical and biological sciences. Current topics in exobiology and the origins of life from a planetary sciences perspective. Definitions of life and the origin of information; water, carbon, and energy; phylogenetic and fossil inferences about early life on Earth; the early terrestrial environment, including asteroid and comet impacts; prebiotic organic syntheses and the RNA world; panspermia; the search for life on Mars; Europa, including prospects for an ocean and speculative ecologies; upcoming spacecraft missions and mission planning; planetary protection, back contamination, and legal and ethical issues; and student suggested topics. Student presentations.
*3 units, Spr (Chyba) alternate years, not given 2005-06*

**GES 222. Planetary Systems: Dynamics and Origins**—For students with a background in astronomy, earth sciences, geophysics, or physics. Motions of planets, moons, and small bodies; energy transport in planetary systems; meteorites and the constraints they provide on the formation of the solar system; asteroids and Kuiper belt objects; comets; planetary rings; planet formation; and extrasolar planets. In-class presentation of student papers. GER:2a
*3 units (Lissauer) alternate years, given 2005-06*

**GES 223. Planetary Systems: Atmospheres, Surfaces, and Interiors**—Focus is on physical processes, such as radiation transport, atmospheric dynamics, thermal convection, and volcanism, shaping the interiors, surfaces, and atmospheres of the major planets in the solar system. How these processes manifest themselves under various conditions in the solar system. Case study of the surface and atmosphere of Mars. Application of comparative planetary science to extrasolar planets and brown dwarfs. In-class presentation of student papers.
*3 units (Marley) alternate years, given 2005-06*

**GES 225. Isotopes in Geological and Environmental Research**—For upper-division undergraduates and graduate students. The applications of isotopic systems in geological, oceanographic, and environmental studies at low temperature. The use of isotopes as tracers for weathering rate, biogeochemical cycling, food-web structures, ecology, paleochemistry, provenance, circulation, and anthropogenic and extraterrestrial inputs. Emphasis is on developing skills in reading and evaluation of scientific papers, manuscript reviews, and proposal preparation. Prerequisite: 163, 164, or consent of instructor.

*1-3 units, Win (Paytan) alternate years, not given 2005-06*

**GES 230. Physical Hydrogeology**—(Same as CEE 260A.) Theory of underground water, analysis of field data and pumping tests, geologic groundwater environments, solution of field problems, groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.

*4 units, Aut (Gorelick)*

**GES 231. Contaminant Hydrogeology**—(Same as CEE 260C.) For earth scientists and engineers. Environmental and water resource problems involving contaminated groundwater. Processes affecting contaminant migration through porous media including interactions between dissolved substances and solid media. Conceptual and quantitative treatment of advective-dispersive transport with reacting solutes. Predictive models of contaminant behavior controlled by local equilibrium and kinetics. Modern methods of contaminant transport simulation and optimal aquifer remediation. Prerequisite: 230 or CEE 260A or equivalent.

*4 units, Spr (Staff)*

**GES 235. Role of Fluids in Geologic Processes**—The principles governing groundwater flow and its interaction with crustal stress, heat flow, and chemical mass transport. Topography-driven flow of groundwater on a regional scale; compaction-driven flow in the sedimentary basin; development of anomalous fluid pressure; the role of fluid in tectonism; migration and entrapment of petroleum; density driven flow and thermal anomaly; formation of mineral deposits. Prerequisite: 230.

*2-3 units (Hsieh) alternate years, given 2005-06*

**GES 236. Hydraulic and Tracer Tests for Groundwater Resource Evaluations**—Theory and application of hydraulic and tracer tests to determine flow and the transport properties of aquifers. Analysis of well tests in single-layer aquifers and multiple aquifer-aquitard systems; water table conditions; anisotropy; double-porosity; effects due to wellbore storage, wellbore skin, aquifer boundaries, and heterogeneities such as faults and fracture zones; natural and forced gradient tracer tests.

*2-3 units, Spr (Hsieh) alternate years, not given 2005-06*

**GES 237. Surface and Near-Surface Hydrologic Response**—(Same as CEE 260B.) Quantitative review of process-based hydrology and geomorphology. Introduction to finite-difference and finite-element methods of numerical analysis. Topics: biometeorology, unsaturated and saturated subsurface fluid flow, overland and open channel flow, erosion and mass wasting, and physically-based simulation of coupled surface and near-surface hydrologic response and landscape evolution. Links hydrogeology, soil physics, and surface water hydrology.

*4 units, Aut (Loague) alternate years, not given 2005-06*

**GES 238. Soil Physics**—Advanced level, focusing on the physical and chemical properties of the soil solid phase, with emphasis on the transport, retention, and transformation of water, heat, gases, and solutes in the unsaturated subsurface. Agricultural systems. Field techniques and classic experiments demonstrated and reproduced in the lab. Prerequisite: elementary calculus.

*4 units (Loague) alternate years, given 2005-06*

**GES 239. Advanced Geomorphology**—Advanced level, focusing on the surface/near-surface hydrologic processes governing landscape evolution. Topics: channel networks and landscape dissection. Current and classic theory. Case histories and experimental studies. Prerequisites: elementary calculus, 131.

*4 units, Win (Loague) alternate years, not given 2005-06*

**GES 240. Geostatistics for Spatial Phenomena**—(Same as PETENG 240.) Probabilistic modeling of spatial and/or time dependent phenomena. Kriging and cokriging for gridding and spatial interpolation. Integration of heterogeneous sources of information. Stochastic imaging of reservoir/field heterogeneities. Introduction to GSLIB software. Case studies from the oil and mining industry and environmental sciences. Prerequisites: introductory calculus and linear algebra, STATS 116, GES 161 or equivalent.

*3-4 units, Win (Journel)*

**GES 241. Practice of Geostatistics and Seismic Data Integration**—(Enroll in GEOPHYS 241, PETENG 241.)

*3-4 units, Spr (Caers, Mukerji)*

**GES 242. Topics in Advanced Geostatistics**—(Same as PETENG 242.) Conditional expectation theory and projections in Hilbert spaces; parametric versus non-parametric geostatistics; Boolean, Gaussian, fractal, indicator, and annealing approaches to stochastic imaging; multiple point statistics inference and reproduction; neural net geostatistics; Bayesian methods for data integration; techniques for upscaling hydrodynamic properties. May be repeated for credit. Prerequisites: 240, advanced calculus, C++/Fortran.

*3-4 units, Aut (Journel) alternate years, not given 2005-06*

**GES 244. Fundamentals of Geographic Information Science (GIS)**—(For graduate students; see 144.)

*4 units, Spr (Seto)*

**GES 246. Reservoir Characterization and Flow Modeling with Outcrop Data**—(Same as PETENG 246.) Project provides earth science students with an understanding of how to use outcrop observations in quantitative geological modeling and flow simulation, and addresses a specific reservoir management problem by studying a suitable outcrop analog (weekend field trip), constructing geostatistical reservoir models, and performing flow simulation. An introduction, through an applied example, to the relationship between the different disciplines.

*3 units, Aut (Aziz, Graham, Journel)*

**GES 249. Petroleum Geochemistry in Environmental and Earth Science**—How molecular fossils in crude oils, oil spills, refinery products, and human artifacts identify their age, origin, and environment of formation. The origin and habitat of petroleum, technology for its analysis, and parameters for interpretation, including: origins of molecular fossils; function, biosynthesis, and precursors; tectonic history related to the evolution of life, mass extinctions, and molecular fossils; petroleum refinery processes and the kinds of molecular fossils that survive; environmental pollution from natural and anthropogenic sources including how to identify genetic relationships among crude oil or oil spill samples; applications of molecular fossils to archaeology; worldwide petroleum systems through geologic time.

*3 units, Win (Moldowan, Peters)*

**GES 250. Sedimentation Mechanics**—The mechanics of sediment transport and deposition and the origins of sedimentary structures and textures as applied to interpreting ancient rock sequences. Dimensional analysis, fluid flow, drag, boundary layers, open channel flow, particle settling, erosion, sediment transport, sediment gravity flows, soft sediment deformation, and fluid escape. Field trip required.

*4 units (Lowe) alternate years, given 2005-06*

**GES 251. Sedimentary Basins**—Analysis of the depositional framework and tectonic evolution of sedimentary basins. Topics: tectonic and environmental controls on facies relations, synthesis of basin development through time in terms of depositional systems and tectonic settings. Weekend field trip required. Prerequisites: 110, 151.

*3 units (Graham) not given 2004-05*

**GES 252. Sedimentary Petrography**—Siliciclastic sediments and sedimentary rocks. Research in modern sedimentary mineralogy and petrography and the relationship between the composition and texture of sediments and their provenance, tectonic settings, and diagenetic histories. Topics vary yearly. Prerequisite: 151 or equivalent.

*4 units (Lowe) not given 2004-05*

**GES 253. Petroleum Geology and Exploration**—The origin and occurrence of hydrocarbons. Topics: thermal maturation history in hydrocarbon generation, significance of sedimentary and tectonic struc-

tural setting, principles of accumulation, and exploration techniques. Prerequisites: 110, 151. Recommended: GEOPHYS 184.
*3 units (Graham) alternate years, given 2005-06*

**GES 258. Introduction to Depositional Systems**—The characteristics of the major sedimentary environments and their deposits in the geologic record, including alluvial fans, braided and meandering rivers, aeolian systems, deltas, open coasts, barred coasts, marine shelves, and deep-water systems. Emphasis is on subdivisions; morphology; the dynamics of modern systems; and the architectural organization and sedimentary structures, textures, and biological components of ancient deposits.
*3 units (Lowe) alternate years, given 2005-06*

**GES 259. Marine Chemistry**—(For graduate students; see 159.)
*2-4 units, Spr (Paytan)*

**GES 260. Laboratory Methods in Organic Geochemistry**—Knowledge of components in geochemical mixtures to understand geological and environmental samples. The presence and relative abundance of these compounds provides information on the biological source, depositional environment, burial history, biodegradation, and toxicity of organic materials. Laboratory methods detect and quantify components of these mixtures. Hands-on experience of methods for separation and analysis of organic compounds in geologic samples: extraction, liquid chromatography, absorption by zeolites, gas chromatography and gas chromatography-mass spectrometry. Student samples considered as material for analysis. Recommended: 249.
*2-3 units, Spr (Moldowan)*

**GES 261. Physics and Chemistry of Minerals and Mineral Surfaces**—The concepts of symmetry and periodicity in crystals; the physical properties of crystals and their relationship to atomic-level structure; basic structure types; crystal chemistry and bonding in solids and their relative stability; the interaction of x-rays with solids and liquids (scattering and spectroscopy); structural variations in silicate glasses and liquids; UV-visible spectroscopy and the color of minerals; review of the mineralogy, crystal chemistry, and structures of selected rock-forming silicates and oxides; mineral surface and interface geochemistry.
*4 units (Brown) alternate years, given 2005-06*

**GES 264. Aquatic Chemistry**—(Enroll in CEE 273.)
*3 units, Aut (Leckie)*

**GES 265. Micobially Mediated Redox Processes**—Chemical and biologically mediated oxidation and reduction processes within soils, sediments, and surface/subsurface waters. Emphasis is on reactions and processes at the solid-water interface. Topics include electron transfer processes, dissimilatory metal reduction, redox reaction rates, alterations in mineralogy, and modifications in chemical behavior with changes in redox state.
*3 units, Win (Fendorf, Francis) alternate years, not given 2005-06*

**GES 266. Soil Chemistry**—(For graduate students; see 166.)
*4 units (Fendorf) alternate years, given 2005-06*

**GES 267. Solution-Mineral Equilibria: Theory**—Procedures for calculating and evaluating the thermodynamic properties of reversible and irreversible reactions among rock-forming minerals and aqueous solutions in geologic systems. Emphasis is on the generation and utility of phase diagrams depicting solution-mineral interaction relevant to phase relations associated with weathering diagenetic, hydrothermal, and metamorphic processes, and the prediction of temperature, pressure, and the chemical potential of thermodynamic components compatible with observed mineralogic phase relations in geologic outcrops. Individual research topics. Prerequisite: 171.
*3 units, Win (Bird) alternate years, not given 2005-06*

**GES 268. Geomicrobiology**—(For graduate students; see 168.)
*3-4 units, Spr (Francis)*

**GES 275. Electron Probe Microanalytical Techniques**—Practical and theoretical aspects of x-ray generation and detection, and the behavior of electron beams and x-rays in solids. Principles to quantitatively analyze chemically complex geological materials. Operation of the JEOL 733 electron microprobe and associated computer software for quantitatively analyzing materials. X-ray chemical mapping. Enrollment limited to 8.
*2-3 units, Win (Jones)*

**GES 283. Biomineralization**—(Enroll in ME 283.)
*2 units (Constantz) alternate years, given 2005-06*

**GES 283B. Tissue Engineering**—(Enroll in BIOE 360A, ME 385A.)
*2 units, Win (Smith, Carter)*

**GES 284. Field Seminar on Eastern Sierran Volcanism**—For graduate students in the earth sciences and archaeology. Four-day trip over Memorial Day weekend to study silicic and mafic volcanism associated with the western margin of the Basin and Range province: basaltic lavas and cinder cones erupted along normal faults bounding Owens Valley, Long Valley caldera, postcaldera rhyolite lavas, hydrothermal alteration and hot springs, Holocene rhyolite lavas of the Inyo and Mono Craters, volcanism of the Mono Basin with subaqueous basaltic eruptions, floating pumice blocks, and cryptodomes punching up lake sediments. If snow-level permits, silicic volcanism associated with the Bodie gold district. Prerequisite: 1, 80 or equivalent.
*2 units (Mahood) alternate years, given 2005-06*

**GES 285. Petrogenesis of Crustal Magmatism**—Radiogenic isotopes, stable isotopes, and trace elements applied to igneous processes; interaction of magmas with mantle and crust; convergent-margin magmatism; magmatism in extensional terrains; origins of rhyolites; residence times of magmas and magma chamber processes; granites as imperfect mirrors of their source regions; trace element modeling of igneous processes; trace element discriminant diagrams in tectonic analysis; sources of ore forming metals. Topics emphasize the interest of students. Prerequisite:181, or equivalent.
*3 units, Aut (Mahood) alternate years, not given 2005-06*

**GES 286. Geoarchaeology**—For juniors, seniors, and beginning graduate students with interests in archaeology or geosciences. The use of geological concepts, techniques, and data in the study of artifacts and interpretation of the archaeological record. Topics include: sediments and soils; sedimentary settings of site formation; postdepositional processes that disturb sites; paleoenvironmental reconstruction of past climates and landscapes using plant and animal remains and isotopic studies; raw materials (minerals, metals, stone, shells, clay, building materials) and methods used in sourcing; estimating age based on stratigraphic and radiometric techniques. Weekly lab; weekend field trips to local archaeological/geological localities. GER:2a
*5 units, Spr (Mahood) alternate years, not given 2005-06*

**GES 287. Tectonics, Topography, and Climate Change**—For upper-division undergraduates and graduate students. The links between tectonics and climate change with emphasis on the Cenozoic era. Focus is on terrestrial climate records and how they relate to large-scale tectonics of mountain belts. Topics include stable isotope geochemistry, geochronology, chemical weathering, stratigraphy of terrestrial rocks, paleofauna and flora, climate proxies and records, and Cenozoic tectonics. Guest speakers, student presentations, required field trip.
*3 units (Chamberlain) alternate years, given 2005-06*

**GES 300. Earth Sciences Seminar**—(Same as EARTHSYS 300, GEOPHYS 300, IPER 300, PETENG 300.) Required for all incoming graduate students. Research questions, tools, and approaches of faculty members from all departments in the School of Earth Sciences. Goals are: to inform new graduate students about the school's range of scientific interests and expertise; and to introduce them to each other across departments and research groups. Two faculty members present work at each meeting.
*1 unit, Aut (Staff)*

**GES 314. Structural Geology and Geomechanics**—Research seminar. May be repeated for credit.
*1 unit, Aut, Win, Spr (Staff)*

**GES 320. Gas Hydrates in the Environment**—The location, formation, chemistry, and implications of gas hydrates (methane and carbon dioxide) in marine environments. Topics include seismic surveys to identify where clathrates are located, conditions for stability of clathrates and implications of destabilization leading to catastrophic release of methane, and formation of carbon dioxide clathrates as a means for sequestration.
*1 unit, Spr (Patayan)*

**GES 322A,B,C. Seminar in Biogeochemistry**—Current topics. May be repeated for credit.
*1-2 units, Aut, Win, Spr (Matson)*

**GES 323. Stanford at Sea**—(Enroll in BIOHOPK 182H/323H, EARTHSYS 323.)
*16 units, Spr (Block, Dunbar, Micheli) alternate years, not given 2005-06*

**GES 324. Seminar in Oceanography**—Current topics. May be repeated for credit.
*1-2 units, Aut, Win, Spr (Arrigo, Dunbar, Paytan)*

**GES 326. Isotopes and Biogeochemical Tracers in the Hydrological Cycle**—Practical applications of environmental isotopes. The systematics of isotope fractionations and the distributions of isotopes in natural systems. Focus is on applications of isotopes for tracing waters, solutes, and biogeochemical reactions in hydrologic systems. Hydrological topics include tracing sources of ground and surface water, isotope hydrograph separations, groundwater influence on coastal systems, rock-water interactions, recharge rate, and groundwater dating. Biogeochemical topics include sources of contaminants, biogeochemical reaction mechanisms, nutrient sources and pathways, and food web studies.
*3 units, Aut (Paytan, Kendall, Bullen)*

**GES 327. The Glacial World**—(Same as GEOPHYS 327.) The environmental changes that took place on Earth between the last glacial maximum (LGM) and the present. Focus is on the cause of the low atmospheric $CO^2$ concentrations characteristic of the LGM and what conditions explain these reduced $CO^2$ levels. How changes in sea level, marine primary production, ocean circulation, and elemental cycling may have contributed to past global changes.
*2-3 units, Aut (Arrigo, Paytan) alternate years, not given 2005-06*

**GES 329. Advanced Topics in Near-Surface Hydrologic Processes**—Classic studies and current research in hydrology, geomorphology, and soil physics. Topics: nonpoint source groundwater contamination (agriculture), evapotranspiration, unsaturated fluid flow and solute transport, rainfall-runoff mechanisms, slope stability, restoration geomorphology.
*1-2 units, Aut, Win, Spr (Loague)*

**GES 330. Advanced Topics in Hydrogeology**—Topics: questioning classic explanations of physical processes; coupled physical, chemical, and biological processes affecting heat and solute transport.
*1-2 units, Aut, Win (Gorelick)*

**GES 332A,B. Seminar in Hydrogeology**—Current topics. May be repeated for credit. Autumn Quarter has open enrollment; Winter Quarter requires consent of instructor.
*1 unit, Aut, Win (Gorelick)*

**GES 333. Water Policy Seminar**—(Enroll in CEE 333, IPER 333.)
*1 unit, Spr (Freyberg)*

**GES 342A,B,C. Geostatistics**—Classic results and current research. Topics based on interest and timeliness. May be repeated for credit.
*1-2 units, Aut, Win, Spr (Journel)*

**GES 343. Geographic Science Seminar: Why Space Matters**—Current environmental research incorporating geographic and spatial analysis using technological and analytical methods such as spatial econometrics, geostatistics, remote sensing, and GIS. May be repeated for credit.
*1 unit, Spr (Seto)*

**GES 362. Silicate Glasses and Liquids**—Current topics. May be repeated for credit.
*2-3 units (Stebbins) alternate years, given 2005-06*

**GES 365. Current Topics in Isotope Geology**—Current topics. May be repeated for credit.
*1 unit, Aut, Win, Spr (McWilliams)*

**GES 385. Practical Experience in the Geosciences**—On-the-job training in the geosciences. May include summer internship; emphasizes training in applied aspects of the geosciences, and technical, organizational, and communication dimensions. Meets INS requirements for F-1 curricular practical training.
*1 unit, Aut, Win, Spr, Sum (Staff)*

**GES 399. Advanced Projects**—Graduate research projects that lead to reports, papers, or other products during the quarter taken. On registration, students designate faculty member and agreed-upon units.
*1-10 units, Aut, Win, Spr, Sum (Staff)*

**GES 400. Graduate Research**—Faculty supervision. On registration, students designate faculty member and agreed-upon units.
*1-15 units, Aut, Win, Spr, Sum (Staff)*

# GEOPHYSICS

*Emeriti:* Antony Fraser-Smith,†† George A. Thompson
*Chair:* Jerry M. Harris
*Associate Chair:* Rosemary J. Knight
*Professors:* Gregory Beroza, Jon F. Claerbout, Steven Gorelick,† Jerry M. Harris, Rosemary J. Knight, Robert L. Kovach, Marcia McNutt,** Amos M. Nur, Joan Roughgarden,* Paul Segall, Norman H. Sleep, Mark D. Zoback
*Associate Professors:* Kevin Arrigo, Simon L. Klemperer, Howard Zebker††
*Professor (Research):* Gerald M. Mavko
*Associate Professor (Research):* Biondo Biondi
*Courtesy Professors:* Stephan A. Graham, David D. Pollard
*Consulting Professors:* James Berryman, William Ellsworth, Walter Mooney, Steven R. Pride, David Scholl, William Symes
*Consulting Associate Professor:* Andrew Calvert, Stewart A. Levin
*Visiting Professors:* Pratap Narayan Sahay
*Senior Research Scientist:* Jack Dvorkin
*Research Associates:* Robert Clapp, Francis Muir, Tapan Mukerji, Manika Prasad, Youli Quan

* Joint appointment with Biological Sciences
† Joint appointment with Geological and Environmental Sciences
** Joint appointment with Monterey Bay Aquarium Research Institute
†† Joint appointment with Electrical Engineering

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Courses given in Geophysics have the subject code GEOPHYS. For a complete list of subject codes, see Appendix.

Geophysics is the branch of earth science concerned with exploring and analyzing active processes of the earth through physical measurement. The undergraduate and graduate programs are designed to provide a background of fundamentals in science, and courses to coordinate these fundamentals with the principles of geophysics. The program leading to the Bachelor of Science (B.S.) in Geophysics permits many electives and a high degree of flexibility for each individual student. Graduate programs provide specialized training for professional work in resource exploration, research, and education and lead to the degrees of Master of Science and Doctor of Philosophy.

The Department of Geophysics is housed in the Ruth Wattis Mitchell Earth Sciences Building. It has numerous research facilities, among which are a state-of-the-art broadband seismic recording station, high pressure and temperature rock properties and rock deformation laboratories, computers, various instruments for field measurements including seismic recorders, nine dual frequency GPS receivers, and field equipment for measuring in-situ stress at great depth. Current research activities include biogeochemical cycling; crustal deformation; earthquake archaeology; earthquake seismology and earthquake mechanics; reflection, refraction, and tomographic seismology; rock mechanics, rock physics; seismic studies of the continental remote sensing. lithosphere, and environmental geophysics; and synthetic aperture radar studies.

# UNDERGRADUATE PROGRAMS

## BACHELOR OF SCIENCE

*Objectives*—To provide a solid background in the essentials of math, physics, and geology, while at the same time providing knowledge about the entire spectrum of geophysics ranging from exploration geophysics to earthquake seismology and plate tectonics. Students are prepared for either an immediate professional career in the resources and environmental sciences industries or future graduate study.

The following courses are required for the B.S. degree in Geophysics. A written report on original research or an honor's thesis is also required through participation in three quarters of Research Seminar (the GEOPHYS 185 series) during the senior year. Seniors in Geophysics who expect to do graduate work are urged to take the Graduate Record Examination as early as is convenient in their final undergraduate year.

### CURRICULUM

*Course No. and Subject*
CHEM 31. Chemical Principles
EE 141. *or* PHYSICS 120. Electromagnetic Fundamentals
GES 1. Fundamentals of Geology
GEOPHYS 185. Research Seminars
MATH 19, 20, 21 *or* 41, 42, *or* 51, 52
MATH 130. Ordinary Differential Equations
PHYSICS 53. Mechanics
PHYSICS 110. Intermediate Mechanics
9 units of Geophysics electives selected from GEOPHYS 40, 104, 106, 111, 130, 135,150, 160, 182, 183, 190, 196, 262
9 units of other Earth Science electives selected from GES 80, 90, 102, 110, 111, 112; *or* PETENG 120, 160

Recommended elective: CS 106A, Programming Methodology

### MINORS

The Geophysics minor provides students with a general knowledge of geophysics in addition to a background in the related fields of physics, mathematics, and geology.

*Curriculum*—
EARTHSYS 110. Geosphere *or* GES 1. Fundamentals of Geology
GEOPHYS 150. General Geophysics *or* 190. Environmental Geophysics
MATH 41. Single Variable Calculus
PHYSICS 53. Mechanics
Two approved Geophysics courses of 3 units each

## HONORS PROGRAM

The department offers a program leading to the B.S. degree in Geophysics with Honors. The guidelines are:

1. Select a research project, either theoretical, field, or experimental, that has the approval of an adviser.
2. Submit a proposal to the department, which will decide on its suitability as an honors project. Necessary forms are in the department office.
3. Course credit for the project is assigned by the adviser within the framework of GEOPHYS 205.
4. The decision whether a given independent study project does or does not merit an award of honors shall be made jointly by the department and the student's adviser. This decision shall be based on the quality of both the honors work and the student's other work in earth sciences.
5. The work done on the honors program should not be used as a substitute for regularly required courses.

## COTERMINAL B.S./M.S. PROGRAM

The department offers a coterminal program. Interested individuals should check with a member of the department faculty for details. For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/publications/#Coterm.

# GRADUATE PROGRAMS

University requirements for the M.S. and Ph.D. are described in the "Graduate Degrees" section of this bulletin.

## MASTER OF SCIENCE

*Objectives*—To enhance the student's training for professional work in geophysics through the completion of fundamental courses, both in the major fields and in related sciences, and to begin independent work and specialization.

*Requirements for the Degree*—The candidate must complete 45 units from the following groups of courses:

1. Complete 15 units of Geophysics lecture courses with at least nine units numbered 200 level or higher.
2. Complete six units numbered 100 level or higher and three units of 200 level, non-Geophysics lecture courses in earth sciences.
3. Complete one to four electives selected from courses numbered 100 or higher from mathematics, chemistry, engineering, physics, biology, computer science or earth science. At least one course must be numbered 200 level or higher.
4. At least 9, but not more than 18, of the 45 units must be independent work on a research problem resulting in a written report accepted and archived by the candidate's faculty adviser. Normally, this research is undertaken as part of the candidate's participation in multiple quarters of research seminar (the GEOPHYS 385 series). A summer internship is encouraged as a venue for research, but no academic credit is given.
5. Submit a program proposal for approval by a faculty adviser in the first quarter of enrollment.
6. Each candidate must present and defend the results of his or her research at a public oral presentation attended by at least two faculty members.

## DOCTOR OF PHILOSOPHY

*Objectives*—The Ph.D. degree is conferred upon evidence of high attainment in Geophysics, and ability to conduct an independent investigation and present the results of such research.

*Requirements for the Degree*—A minimum of 135 units of graduate study at Stanford must be satisfactorily completed. An acceptable program will normally consist of at least 45 lecture units of which 18 units may be satisfied by post-baccalaureate courses taken elsewhere. The following course and groups of courses must be completed:

1. ENGR 102W
2. 12 units of Geophysics lecture courses numbered 100 level or higher.
3. 12 units of Geophysics lecture courses numbered 200 level or higher, taken from at least four faculty members with a different research specialization.
4. One 3-unit course numbered 100 level or higher in math, science or engineering covering mathematical methods, continuum or fluid mechanics, Fourier/spectral analysis, or other quantitative courses.
5. 9 units of 200 level or higher courses in math, science or engineering.
6. 6 units of non-Geophysics lecture courses numbered 100 level or higher in earth or planetary sciences, ecology, hydrology, chemistry or relevant biology.
7. One 3-unit non-Geophysics lecture course numbered 200 level or higher.
8. Additional units of course work or independent work on a research problem to meet the University requirement of 135 total units. 12 units of this requirement must be met by participation in the GEOPHYS 385 series. Students are encouraged to participate in the GEOPHYS 385 series from more than one faculty member or group.

Waiving of any course requirements or substitution of other electives requires the written consent of the student's faculty adviser and the Geophysics graduate coordinator.

The student's record must indicate outstanding scholarship, and deficiencies in previous training must be removed. Experience as a teaching assistant (quarter-time for at least two academic quarters) is required for the Ph.D. degree. The student must pass the departmental oral examination by presenting and defending a written research paper or proposal by the end of the second year; prepare under faculty supervision a dissertation that is a contribution to knowledge and the result of independent work expressed in satisfactory form; and pass the University oral examination. The Ph.D. dissertation must be submitted in its final form within five calendar years from the date of admission to candidacy. The Geophysics faculty monitor student progress by carrying out an annual performance appraisal (at a closed faculty meeting) of all students who have not yet passed their department oral examination. Following successful completion of the department oral examination, students are required to organize an annual meeting of their research committee to review their progress towards the Ph.D. degree.

## COURSES

**GEOPHYS 20Q. Predicting Volcanic Eruptions**—Stanford Introductory Seminar. Preference to sophomores. Volcanoes represent spectacular manifestations of the Earth's internal energy, and a hazard to society. In the past few decades, earth scientists have learned to better forecast eruptive activity by monitoring seismic activity, bulging of the ground surface, and the discharge of volcanic gases, as well as by studying the deposits from past eruptions. Focus is on the interface between scientists and policy makers and the challenges of decision making with incomplete information. The physics and chemistry of volcanic processes and modern methods of volcano monitoring. Field trip to Mt. St. Helens, site of the devastating 1980 eruption.

*3 units, Spr (Segall)*

**GEOPHYS 25. Planetary Habitability**—Hands on introduction to astrobiology. Are human beings alone; are microbes common in the universe? Historical development and modern status of topics such as: the vastness of space and time; star evolution; planetary climate; effects of geological processes and asteroid impacts on life; other habitable places in the solar system with updates on Mars; the Earth as a biological organism; maintenance of society for a geologically long time; and the search for intelligent extraterrestrials. Outdoor lab exercises designed to work in K-12 science classes. Non-science majors welcome.

*3 units, Aut (Sleep)*

**GEOPHYS 30Q. The 1906 San Francisco Earthquake**—Stanford Introductory Seminar. Preference to sophomores. The impact of this event on the history of N. California and on the scientific study of earthquakes. What happened during the earthquake and the days that followed, and what experts think might happen the next time a large earthquake strikes the San Francisco Bay Area. Field trips to the San Andreas Fault and to San Francisco to view the source and effects of the earthquake first hand.

*2 units, Spr (Beroza)*

**GEOPHYS 50Q. Earthquakes and Archaeology: Lectures and Field Trip to Mexico**—Stanford Introductory Seminar. Preference to sophomores. The geography and science of earthquakes, their historical perception, and how to recognize earthquake damage in archaeological excavations and resulting mythological lore. Their role in the demise of ancient civilizations such as the Maya, the eastern Mediterranean Bronze Age, and Indus Valley civilization. Examples include Mycenea, Delphi, Knossos, Pergamum, Troy, Luxor, Thebes, Jericho, Jerusalem, Teotihuacan, Monte Alban, and Antigua. Spring break field trip the to archaeological sites in Mexico; students contribute a portion of their expenses.

*3 units, Win (Kovach, Nur)*

**GEOPHYS 60Q. Man versus Nature: Coping with Disaster Using Space Technology**—(Same as EE 60Q.) Stanford Introductory Seminar. Preference to sophomores. Natural hazards (earthquakes, volcanoes, floods, hurricanes, and fires) affect thousands of people everyday. Disasters such as asteroid impacts periodically obliterate many species of life. Spaceborne imaging technology makes it possible to respond quickly to such threats to mitigate consequences. How these new tools are applied to natural disasters, and how remotely sensed data are manipulated and analyzed. Basic scientific issues, political and social consequences, costs of disaster mitigation, and how scientific knowledge affects policy. GER:2b

*3 units, Aut (Zebker)*

**GEOPHYS 100. Directed Reading**

*1-2 units, Aut, Win, Spr, Sum (Staff)*

**GEOPHYS 102. Geosphere**—(Same as EARTHSYS 110.) Large-scale natural systems of the solid earth, oceans, and atmosphere, their variation through space and time, and the implications of how these systems impact and are being impacted by humankind. Topics include plate tectonics and its relationship to natural hazards and climate, large-scale ocean and atmospheric systems, energy systems, and the linkages among these topics. Prerequisites: EARTHSYS 10, GES 1. GER:2a

*3 units, Aut (Zoback, Arrigo) not given 2005-06*

**GEOPHYS 104. The Water Course**—(Same as EARTHSYS 104.) The pathway that water takes from rainfall to the tap using student home towns as an example. How the geological environment controls the quantity and quality of water; taste tests of water from around the world. Current U.S. and world water supply issues. GER:2a

*3 units, Win (Knight)*

**GEOPHYS 106. Planetary Exploration**—(Enroll in EE 106.)

*3 units, Spr (Fraser-Smith)*

**GEOPHYS 112. Exploring Geosciences with MATLAB**—Introduction to efficient use of Matlab as a tool for research in Engineering and Earth Sciences. Hands-on, computer-based exercises explore the 2-D and 3-D visualization features, numerical capabilities, and various Matlab toolboxes, addressing simple problems in widely applicable areas such as data analysis, statistics, regressions, least-squares, Fourier transforms and filtering in 1- and 2-D, simple spectral analysis, differential equations, and simulations.

*1-3 units, Aut (Mukerji)*

**GEOPHYS 113. Earthquakes and Volcanoes**—(Same as EARTHSYS 113.) Earthquake location, magnitude and intensity scales, seismic waves, styles of eruptions and volcanic hazards, tsunami waves, types and global distribution of volcanoes, volcano forecasting. Plate tectonics as a framework for understanding earthquake and volcanic processes. Forecasting; earthquake resistant design; building codes; and probabilistic hazard assessment. For non-majors and potential earth scientists. GER:2b

*3 units, Aut (Beroza, Segall)*

**GEOPHYS 120. Frontiers of Geophysical Research at Stanford: Faculty Lectures**—Required for new students entering the department. Second-year and other graduate students may attend either for credit or as auditors. Department and senior research staff lectures introduce the frontiers of research problems and the methods being employed or developed in the department and unique to department faculty and students: what the current research is, why the research is important, what methodologies and technologies are being used, and what the potential impact of the results might be.

*1 unit, Aut (Harris)*

**GEOPHYS 130/231. Biological Oceanography**—(Graduate students register for 231; same as EARTHSYS 130/230.) Required for Earth Systems students in the oceans track. Interdisciplinary look at how oceanic environments control the form and function of marine life. Topics: distributions of planktonic production and abundance, nutrient cycling, the role of ocean biology in the climate system, expected effects of climate changes on ocean biology. Possible local field trips on weekends. Prerequisites: BIOSCI 43 and GES 8 or equivalent.

*2-4 units, Spr (Arrigo)*

**GEOPHYS 140. Introduction to Remote Sensing**—Global change science as viewed using space remote sensing technology. Global warming, ozone depletion, the hydrologic and carbon cycles, topographic mapping, and surface deformation. Physical concepts in remote sensing. EM waves and geophysical information. Sensors studied: optical, near and thermal IR, active and passive microwave. GER:2b

*3 units (Zebker) not given 2005-06*

**GEOPHYS 141/241. Remote Sensing of the Oceans**—(Graduate students register for 241; same as EARTHSYS 141/241.) How to observe and interpret physical and biological changes in the oceans using satellite technologies. Topics: principles of satellite remote sensing, classes of satellite remote sensors, converting radiometric data into biological and physical quantities, sensor calibration and validation, interpreting large-scale oceanographic features. GER:2a

*4 units (Arrigo) alternate years, given 2005-06*

**GEOPHYS 142. Remote Sensing of Land Use and Land Cover**—(Enroll in GES 142, EARTHSYS 142/242.)

*4 units, Win (Seto) alternate years, not given 2005-06*

**GEOPHYS 144. Fundamentals of Geographic Information Science (GIS)**—(Enroll in GES 144.)

*4 units, Spr (Seto)*

**GEOPHYS 150. General Geophysics and Physics of the Earth**—Elementary study of gravitational, magnetic, seismic, and thermal properties of the earth. Earth's crust, mantle, core. Plate tectonics and mantle convection. Probing earth structure with seismic waves. Measurements, interpretation, and applications to earth structure and exploration. Prerequisites: calculus, first-year college physics. GER:2a

*3 units, Win (Sleep, Klemperer)*

**GEOPHYS 160. Waves**—Topics: derivations of wave equations and their solutions in 1-D, 2-D, and 3-D; amplitude, polarization, phase and group velocities, attenuation, and dispersion; reflection and transmission at single and multiple interfaces; ray theory. Applications from acoustics, elastodynamics, and electromagnetics. Prerequisites: differential/integral calculus and complex functions. GER:2a

*3 units, Win (Harris, Claerbout, Beroza)*

**GEOPHYS 162. Laboratory Methods in Geophysics**—Lectures, laboratory experiments, and demonstrations explore principles and measurements of geophysical properties such as velocity, attenuation, porosity, permeability, electrical resistivity, and magnetic susceptibility. Foundation for conducting experiments and assessing accuracy and variability in reported experimental data. No laboratory experience required.

*1-3 units, Spr (Prasad)*

**GEOPHYS 180. Geophysical Inverse Problems**—Fundamental concepts of inverse theory, with application to geophysics. Inverses with discrete and continuous models, generalized matrix inverses, resolving kernels, regularization, use of prior information, singular value decomposition, nonlinear inverse problems, back-projection techniques, and linear programming. Application to seismic tomography, earthquake location, migration, and fault-slip estimation. Prerequisite: MATH 103. GER:2c

*3 units (Beroza, Segall) alternate years, not given 2005-06*

**GEOPHYS 182. Reflection Seismology**—The principles of seismic reflection profiling, focusing on methods of seismic data acquisition and seismic data processing for hydrocarbon exploration. GER:2a

*3 units, Aut (Klemperer)*

**GEOPHYS 183. Reflection Seismology Interpretation**—The structural and stratigraphic interpretation of seismic reflection data, emphasizing hydrocarbon traps in two and three dimensions on industry data, including workstation-based interpretation. Lectures only, 1 unit. Prerequisite: 182, or consent of instructor.

*1-4 units (Klemperer, Graham) not given 2004-05*

**GEOPHYS 184. Seismic Reflection Processing**—Workshop experience in computer processing of seismic reflection data. Students individually process a commercial seismic reflection profile from field tapes to migrated stack, using interactive software on a workstation. Prerequisite: consent of instructor. GER:2a

*3 units (Klemperer) not given 2004-05*

**GEOPHYS 185. Research Seminar Series**—(Graduate students register for 385 series.) Limited to Geophysics undergraduates and coterminal master's candidates. Undergraduates participate directly in an ongoing research project: experimental and computational work, joining in reading and study groups, giving seminar papers, and doing original research for the undergraduate thesis. Prerequisite: consent of instructor. WIM

*1-2 units, Aut, Win, Spr*

**GEOPHYS 185A. Reflection Seismology**—(Graduate students register for 385A.) Research in reflection seismology and petroleum prospecting.

*(Biondi, Claerbout)*

**GEOPHYS 185B. Environmental Geophysics**—(Graduate students register for 385B.) Research on the use of geophysical methods for near-surface environmental problems.

*(Knight)*

**GEOPHYS 185C. Topics in Biological Oceanography**—(Graduate students register for 385C.) Research on biological processes of the world's oceans.

*(Arrigo)*

**GEOPHYS 185D. Tectonophysics**—(Graduate students register for 385D.) Research in interdisciplinary problems involving the state and movement of fluids in the earth's crust. Content varies each quarter.

*(Nur)*

**GEOPHYS 185E. Tectonics**—(Graduate students register for 385E.) Research on the origin, major structures, and tectonic processes of the earth's crust. Emphasis is on use of deep seismic reflection and refraction data.

*(Klemperer, Sleep, Thompson)*

**GEOPHYS 185K. Crustal Mechanics**—(Graduate students register for 385K.) Research in areas of petrophysics, seismology, in situ stress, and subjects related to characterization of the physical properties of rock in situ.

*(Zoback)*

**GEOPHYS 185L. Earthquake Seismology, Deformation, and Stress**—(Graduate students register for 385L.) Research on seismic source processes, crustal stress, and deformation associated with faulting and volcanism.

*(Segall, Zoback, Beroza)*

**GEOPHYS 185S. Seismic Tomography**—(Graduate students register for 385S.) Research in transmission and reflection tomography, including topics on forward modeling, inversion, and data acquisition.

*(Harris)*

**GEOPHYS 185V. Poroelasticity**—(Graduate students register for 385V.) Research on the mechanical properties of porous rocks: dynamic problems of seismic velocity, dispersion, and attentuation; and quasi-static problems of faulting, fluid transport, crustal deformation, and loss of porosity. Participants define, investigate, and present an original problem of their own.

*(Mavko)*

**GEOPHYS 185Y. Theoretical Ecology**—(Same as BIOSCI 384; graduate students register for 385Y.) Recent and classical research papers in ecology, and presentation of work in progress by participants. Prerequisite: consent of instructor.

*(Roughgarden)*

**GEOPHYS 185Z. Radio Remote Sensing**—(Graduate students register for 385Z.) Research applications, especially crustal deformation measurements. Recent instrumentation and system advancements.

*(Zebker)*

**GEOPHYS 190. Near-Surface Geophysics**—Applications of geophysical methods for imaging and characterizing the top 100 meters of the Earth. Focus is on the use of electrical and seismic methods for environmental and engineering applications. Introduction to the link between electrical and elastic properties of rocks, soils, and sediments, and their physical, chemical, and biological properties. Surface and borehole methods used for data acquisition. GER:2b

*3 units (Knight) alternate years, given 2005-06*

**GEOPHYS 200. Fluids and Tectonics**—Interdisciplinary problems involving the state and movement of fluids in the earth's crust: basics of the coupling in porous and cracked rocks between chemical transport, fluid flow, deformation and stress, and waves; applications to gas hydrates under the oceans; pore pressure in faulting and aftershocks and in the earth's crust; dilatancy; permeability from seismic; aseismic plate deformation; viscoelastic earthquake rebound; pore fluids and subduction; sediment transport and seismic reflection; deformation by pressure solution and stylolites; the opening of backarc basins, and time/space patterns of large earthquakes. Prerequisite: consent of instructor.
*3 units (Nur) alternate years, given 2005-06*

**GEOPHYS 202. Reservoir Geomechanics**—Basic principles of rock mechanics and the state of stress and pore pressure in sedimentary basins related to exploitation of hydrocarbon and geothermal reservoirs. Mechanisms of hydrocarbon migration, exploitation of fractured reservoirs, reservoir compaction and subsidence, hydraulic fracturing, utilization of directional and horizontal drilling to optimize well stability.
*3 units, Win (Zoback)*

**GEOPHYS 205. Honors Program**—Experimental, observational, or theoretical honors project and thesis in geophysics under supervision of a faculty member. Students who elect to do an honors thesis should begin planning it no later than Winter Quarter of the junior year. Prerequisites: superior work in the earth sciences and approval of the department.
*1-3 units, Aut, Win, Spr, Sum (Staff)*

**GEOPHYS 210. Basic Earth Imaging**—Echo seismogram recording geometry, head waves, moveout, velocity estimation, making images of complex shaped reflectors, migration by Fourier and integral methods. Anti-aliasing. Dip moveout. Computer labs. See http://sep.stanford.edu/sep/prof.
*3-4 units, Aut (Claerbout)*

**GEOPHYS 211. Environmental Soundings Image Estimation**—Imaging principles exemplified by means of imaging geophysical data of various uncomplicated types (bathymetry, altimetry, velocity, reflectivity). Adjoints, back projection, conjugate-gradient inversion, preconditioning, multidimensional autoregression and spectral factorization, the helical coordinate, and object-based programming. Common recurring issues such as limited aperture, missing data, signal/noise segregation, and nonstationary spectra. See http://sep.stanford.edu/sep/prof/.
*3 units, Win (Claerbout)*

**GEOPHYS 215. Advanced Structural Geology and Rock Mechanics**—(Enroll in CEE 297G, GES 215.)
*3-5 units, Aut (Pollard)*

**GEOPHYS 216. Rock Fracture Mechanics**—(Enroll in GES 216.)
*3-5 units (Pollard) alternate years, given 2005-06*

**GEOPHYS 222. Planetary Systems: Dynamics and Origins**—(Enroll in GES 222.)
*3 units, Aut (Lissauer)*

**GEOPHYS 223. Planetary Systems: Atmospheres, Surfaces, and Interiors**—(Enroll in GES 223.)
*3 units, Win (Marley)*

**GEOPHYS 230. Advanced Topics in Well Logging**—(Same as PETENG 230.) Designed to follow a course in basic well logging, and assumes knowledge of standard practice and application of electric well logs. State of the art tools and analyses; the technology, rock physical basis, and applications of each measurement. Hands-on computer-based analyses illustrate instructional material. Guest speakers on specific formation evaluation topics. Prerequisite: 130 or equivalent.
*3 units, Spr (Lindblom)*

**GEOPHYS 233. Advanced Biological Oceanography**—For upper-division undergraduates and graduate students. Themes vary annually but include topics such as marine bio-optics, marine ecological modeling, and phytoplankton primary production. Hands-on laboratory and computer activities, and field trips into local waters. Prerequisite: familiarity with concepts presented in GEOPHYS 130/231 or equivalent. May be repeated for credit.
*3-4 units, Spr (Arrigo)*

**GEOPHYS 240. Borehole Seismology**—The study and application of seismic-acoustic waves in and around boreholes for application to sonic well logging, crosswell seismic profiling, and vertical seismic profiling. Topics: forward modeling, seismogram interpretation, data processing, imaging, and inversion. Applications from reservoir and site characterization studies and reservoir monitoring. Prerequisite: consent of instructor.
*3 units (Harris) alternate years, given 2005-06*

**GEOPHYS 241. Practice of Geostatistics and Seismic Data Integration**—(Same as PETENG 241.) Students build a synthetic 3D fluvial channel reservoir model with layer depths, channel geometry, and facies-specific petrophysic and seismic properties, stressing the physical significance of geophysical data. Reference data set is sparsely sampled, providing the sample data typically available for an actual reservoir assessment. Geostatistical reservoir modeling uses well and seismic data, with results checked against the reference database. All software provided (GSLIB and SRBtools). Recommended: basic prior experience with Unix, Matlab/C++/Fortran programming. Prerequisite: PETENG 240.
*3-4 units, Spr (Caers, Mukerji)*

**GEOPHYS 245. Probability Theory**—(Same as PETENG 245.) Probabilistic formulations and solutions to inverse problems. Monte Carlo methods for solving inverse problems. Metropolis algorithm. Deterministic solutions using maximum likelihood, gradient methods. Dealing with prior probability and data uncertainty. Gaussian and non-Gaussian model formulations. Application to Earth Science problems. Prerequisite: introduction to probability theory course.
*3 units (Tarantola) not given 2004-05*

**GEOPHYS 255. Report on Energy Industry Training**—On-the-job-training for master's and doctoral degree students under the guidance of experienced, on-site supervisors. Students submit a concise report detailing work activities, problems, assignment, and key results. Prerequisite: written consent of adviser.
*1-3 units, Aut, Win, Spr, Sum (Staff)*

**GEOPHYS 260. Rock Physics for Reservoir Characterization**—How to integrate well log and laboratory data to determine and theoretically generalize rock physics transforms between sediment wave properties (acoustic and elastic impendence), bulk properties (porosity, lithology, texture, permeability), and pore fluid conditions (pore fluid and pore pressure). These transforms are used in seismic interpretation for reservoir properties, and seismic forward modeling in what-if scenarios.
*3 units (Dvorkin) alternate years, given 2005-06*

**GEOPHYS 262. Rock Physics**—Properties of and processes in rocks as related to geophysical exploration, crustal studies, and tectonic processes. Emphasis is on wave velocities and attenuation, hydraulic permeability, and electrical resistivity in rocks. Application to in situ problems, using lab data and theoretical results.
*3 units, Spr (Mavko)*

**GEOPHYS 265. Radar Remote Sensing: Fundamentals and Geophysical Application of Imaging Radar Systems**—Topics include radar system elements, the radar equation and signal to noise ratio, signal and image processing, range/Doppler algorithms, interferometric measurements. Applications to crustal deformation, topographic mapping, velocities of ice sheets and glaciers, polarimetry and terrain analysis. Computational labs give hands-on-experience with real data.
*3 units (Zebker) alternate years, given 2005-06*

**GEOPHYS 280. 3-D Seismic Imaging**—The principles of imaging complex structures in the Earth subsurface using 3-D reflection seismology. Emphasis is on processing methodologies and algorithms, with examples of applications to field data. Topics: acquisition geometrics of land and marine 3-D seismic surveys, time vs. depth imaging, migration by Kirchhoff methods and by wave-equation methods, migration velocity analysis, velocity model building, imaging irregularly sampled and aliased data. Computational labs involve some programming. Lab for 3 units.

*2-3 units, Spr (Biondi)*

**GEOPHYS 287. Earthquake Seismology**—Basic theorems in elastodynamics, Green's functions, attenuation, wave propagation in layered media, ray theory, seismic moment tensors, finite-source effects, kinematics and dynamics of earthquakes, engineering aspects of seismology.

*3 units (Beroza) alternate years, not given 2005-06*

**GEOPHYS 288. Crustal Deformation**—Earthquake and volcano deformation. Modern data collection methods, including GPS, InSAR, and borehole strain meters, have revolutionized the study of earthquakes and active volcanoes. The analytical methods used to interpret these data. Topics include elastic dislocation theory; crack models of earthquakes and volcanic dikes; dislocations in layered and elastically heterogeneous earth models; viscoelasticity and postseismic rebound; plate boundary deformation; dikes, sills and inflating magma chambers; gravity changes induced by deformation and elastogravitational coupling; effects of topography on deformation; poroelasticity, subsidence due to fluid withdrawal, coupled fluid flow and deformation; earthquake nucleation and rate-state friction.

*3-5 units (Segall) alternate years, given 2005-06*

**GEOPHYS 289. Global Positioning System in Earth Sciences**—Basics of GPS, emphasizing monitoring crustal deformation with a precision of millimeters over baselines tens to thousands of kilometers long. Applications: mapping with GIS systems, airborne gravity and magnetic surveys, marine seismic and geophysical studies, mapping atmospheric temperature and water content, measuring contemporary plate motions, and deformation associated with active faulting and volcanism.

*3-5 units (Segall) alternate years, not given 2005-06*

**GEOPHYS 290. Tectonophysics**—The physics of faulting and plate tectonics. Topics: plate driving forces, lithospheric rheology, crustal faulting, and the state of stress in the lithosphere.

*3 units (Zoback) alternate years, given 2005-06*

**GES 300. Earth Sciences Seminar**—(Same as EARTHSYS 300, GEOPHYS 300, IPER 300, PETENG 300) Required for all incoming graduate students. Research questions, tools, and approaches of faculty members from all departments in the School of Earth Sciences. Goals are: to inform new graduate students about the school's range of scientific interests and expertise; and to introduce them to each other across departments and research groups. Two faculty members present work at each meeting.

*1 unit, Aut (Staff)*

**GEOPHYS 385. Research Seminar Series**—See 185 series for offerings and descriptions. Opportunity for advanced graduate students to frame and pursue research or thesis research within the context of one of the ongoing research projects in the department, and present thesis research progress reports before a critical audience on a regular basis. Prerequisite: consent of the instructor.

*1-3 units, Aut, Win, Spr*

**GEOPHYS 399. Teaching Experience in Geophysics**—On-the-job training in the teaching of geophysics. An opportunity to develop problem sets and lab exercises, grade papers, and give occasional lectures under the supervision of the regular instructor of a geophysics course. Regular conferences with instructor and with students in the class provide the student teacher with feedback about effectiveness in teaching.

*2-4 units, Aut, Win, Spr, Sum (Staff)*

**GEOPHYS 400. Research in Geophysics**

*1-15 units, Aut, Win, Spr, Sum (Staff)*

# INTERDISCIPLINARY GRADUATE PROGRAM IN ENVIRONMENT AND RESOURCES (IPER)

*Co-Directors:* Robert B. Dunbar, Stephen H. Schneider

*Associate Director:* Sara Hoagland

*Faculty:* Kevin Arrigo (Geophysics), Kenneth J. Arrow (Economics, Emeritus), Gregory Asner (Carnegie Institute, Department of Global Ecology), Barbara Block (Biological Sciences), Carol Boggs (Biological Sciences), Margaret Caldwell (Law), Gretchen Daily (Biological Sciences), Robert B. Dunbar (Geological and Environmental Sciences), William H. Durham (Anthropological Sciences), Joshua Eagle (Law), Anne Ehrlich (Biological Sciences), Paul Ehrlich (Biological Sciences), Gary Ernst (Geological and Environmental Sciences), Walter Falcon (Stanford Institute for International Studies, Economics), Christopher B. Field (Biological Sciences), David Freyberg (Civil and Environmental Engineering), Steven Gorelick (Geological and Environmental Sciences, Geophysics), Lawrence Goulder (Economics, Stanford Institute for International Studies), Akhil Gupta (Cultural and Social Anthropology), Elizabeth Hadly (Biological Sciences), Dominique Irvine (Anthropological Sciences), Mark Jacobson (Civil and Environmental Engineering), Donald Kennedy (Biological Sciences, Stanford Institute for International Studies, Emeritus), Julie Kennedy (Earth Systems), Jeffrey Koseff (Civil and Environmental Engineering), Anthony Kovscek (Petroleum Engineering), Richard Luthy (Civil and Environmental Engineering), Pamela Matson (Dean, School of Earth Sciences, Stanford Institute for International Studies), Stephen Monismith (Civil and Environmental Engineering), Harold Mooney (Biological Sciences), Rosamond Naylor (Stanford Institute for International Studies), Franklin M. Orr, Jr. (Global Climate and Energy Project, Petroleum Engineering), Leonard Ortolano (Civil and Environmental Engineering), Adina Paytan (Geological and Environmental Sciences), Terry L. Root (Stanford Institute for International Studies, Biological Sciences), Armin Rosencranz (Human Biology), Stephen H. Schneider (Biological Sciences, Stanford Institute for International Studies), Karen Seto (Geological and Environmental Sciences, Stanford Institute for International Studies), James Sweeney (Management Science and Engineering), Barton Thompson (Law), Shripad Tuljapurkar (Biological Sciences), David Victor (Stanford Institute for International Studies), Peter Vitousek (Biological Sciences), John Weyant (Management Science and Engineering, Stanford Institute for International Studies), Mark Zoback (Geophysics)

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Courses given in the Interdisciplinary Program in Environment and Resources have the subject code IPER. For a complete list of subject codes, see Appendix.

Over the last 30 years, environmental and resource investigations have focused on problems with acute local impacts, such as urban air pollution, pesticide use, or groundwater depletion. These problems have been addressed principally at the national and local level through research and policies that address specific media such as air or water; threats such as toxic chemicals; or resources such as forests or wetlands. More global challenges such as climate change and biodiversity loss pose fundamental threats to the health of the planet. Solutions to these problems must be multifaceted, addressing the interactions among threats and resources, and engaging diverse actors, including academia, national governments, international institutions, business, and civil society. The research and understanding necessary to devise such solutions thus must be both multidisciplinary and interdisciplinary, integrating the analytical tools of diverse fields to yield new insights and promising responses.

The Interdisciplinary Graduate Program in Environment and Resources (IPER) responds to these challenges by leveraging Stanford's faculty strengths in disciplines ranging from ecology and engineering to law and economics, all of which are increasingly directed toward interdisciplinary research and problem solving, and teaching that encompasses collaborative and synthetic courses that cross departmental boundaries.

Interdisciplinary work requires that individuals and groups become familiar with the concepts, methods, data, and analyses of several disciplines in order to focus research questions more sharply. It requires the integration of multidisciplinary knowledge in the formulation of research questions and hypotheses, and in the execution and analyses of results. Students in the IPER program learn through interactions with a cohort of students and a dedicated faculty who influence each other's ways of thinking and asking questions.

## FOUNDATION AND FLEXIBILITY

IPER students construct an integrative graduate curriculum through shared foundational study and flexibility in a research course. Students in the program are expected to make significant progress in each of three intellectual areas:

1. The linkages between physical and biological systems, and understanding the potential environmental consequences associated with the dynamics or evolution of these joint systems.
2. The interplay between human activities and the Earth system, and how human influence on the environment, such as through methods of production or patterns of consumption, is affected by social and economic institutions, legal rules, and cultural values, and how resources and environment in turn affect human actions and decision making.
3. Skills for gauging the potential impacts of alternative public policy options for dealing with environmental problems, for evaluating such policy alternatives according to various normative criteria, and for integrating scientific research into policy formulation.

The program is flexible enough to enable students to focus on areas of greatest interest. For example, a student with a strong interest in the relationship between the nitrogen cycle and climate might concentrate on biology, biogeochemistry, and climatology; a student aiming to understand the environmental impacts from agricultural production decisions might focus on the interplay between economics and ecology; and a student interested in the design and evaluation of policies to curb emissions of greenhouse gases might learn about scientific, technological, and economic issues, as well as gain skills in policy analysis, evaluation, and implementation.

## RESEARCH HIGHLIGHTS

Research is the cornerstone of the Interdisciplinary Graduate Program in Environment and Resources. Faculty and graduate students at Stanford are engaged in interdisciplinary research projects such as studying the effects and constraints of agricultural intensification and urbanization in the Yaqui Valley of Sonora, Mexico, and spatial analysis of land use changes in Vietnam. Students in IPER have the opportunity to work on existing projects and are expected to develop their own research directions and topics.

Research projects by students in the program address issues such as the science and policy of global climate change, environmental quality, regional security, the valuation of ecosystem services, energy development, agricultural intensification and variability, characterization and effects of land use change, and natural resource management. Examples of research projects include:

1. Investigating the causes and consequences of coastal land use change in Sonora, Mexico, focusing on how the interaction of macro policies and local institutional and biophysical factors are shaping the patterns and scale of shrimp aquaculture development.
2. Evaluating electric power sector development in China and India, and the potential for international policy mechanisms to steer these countries toward less $CO^2$-intensive growth paths.

For more information about integrative environmental research at Stanford, see the Stanford Environmental Science, Engineering, and Policy web site at http://environment.stanford.edu.

## GRADUATE PROGRAMS

The University's basic requirements for the M.S. and Ph.D. degrees are discussed in the "Graduate Degrees" section of this bulletin.

## DUAL DEGREE MASTER OF SCIENCE

The Interdisciplinary Program in Environment and Resources offers a dual program of study leading to the Master of Science degree. It provides training in interdisciplinary environmental problem solving. Only students enrolled in a professional school (Law, Business, Medicine) at the University are eligible for the dual M.S. program. IPER gives these graduate students the benefit of a rigorous interdisciplinary course of study, which complements their main degree program. Students interested in the M.S. program apply no later than the first year of their primary graduate program. To be admitted, a student needs the approval of both the interdisciplinary graduate program and his or her principal school and/or department. Applicants to the M.S. program are required to submit a statement of purpose as part of the admissions process, clearly explaining the importance of interdisciplinary studies to the student's research or career. Admission to the M.S. program depends both on the applicant's ability to successfully complete a demanding program in interdisciplinary studies and the applicant's justification for pursuing the M.S. program.

Students in the dual Master of Science program participate in a 45-unit program, to be completed over a period of three or more quarters. All students in the M.S. program take the three core courses: IPER 310, Environmental Forum Seminar, IPER 320, Case Studies in Environmental Problem Solving, and IPER 330, Interdisciplinary Research Approaches and Analysis; students also complete at least eight other graded courses at the 100 level or higher, of which at least two must be at the 200 level. M.S. students need at least 45 units for graduation. Directed research may count for a maximum of eight of these units. Students design their elective courses around one or more of the program's concentration areas (economics and policy analysis; culture, law, institutions, and politics; natural sciences; and technology and engineering) chosen to complement but not duplicate their primary research or professional degree program at Stanford. The faculty advisory team reviews and approves the adequacy of each student's course of study.

## DOCTOR OF PHILOSOPHY

1. The student works with faculty advisers to design a course of study that allows the student to develop and exhibit 1) depth in at least two concentration areas, 2) adequate preparation in analytical methods and skills, and 3) interdisciplinary breadth in all four concentration areas (economics and policy analysis; culture, law, institutions, and politics; natural sciences; and technology and engineering). Depth requirements are determined by the student and the student's advising team. Breadth requirements vary by concentration area and are normally satisfied through a sequences of prescribed courses, independent study, and demonstration of proficiency through prior course work and/or field experience. Additional information about breadth requirements can be found on the IPER website or obtained from the IPER office. The three core courses to be taken by all Ph.D. students are IPER 310, Environmental Forum Seminar, IPER 320, Case Studies in Environmental Problem Solving, and IPER 330, Interdisciplinary Research Approaches and Analysis. The IPER faculty advising team has primary responsibility for ensuring the adequacy of the course of study. The student meets with these advisers quarterly during the first year and annually thereafter.

2. To be admitted to candidacy for the Ph.D. degree, a student must have successfully completed at least 25 graded units (not including research credits) of graduate courses (200 level and above) maintaining a 'B' average. In addition, the student must pass an oral qualifying exam that demonstrates command of two areas of specialization as well as interdisciplinary breadth. The qualifying exam should be successfully completed by the end of the eighth quarter in the program.
3. By the end of the sixth quarter of study, students present a Ph.D. candidacy plan to their primary advisers, with a copy to the Associate Director. This plan should include the following items: (a) the names of 4-5 proposed oral qualifying exam committee members; (b) a list of courses or experiences used to fulfill the IPER breadth and depth requirements and certify completion of the IPER core curriculum; and (c) a proposed date for the oral qualifying exam. The oral qualifying exam consists of two parts: a presentation of a dissertation proposal, and a question and answer period during which the student should be prepared to address questions and issues about the proposal, and broader questions arising from IPER breadth and depth course work. The oral qualifying exam committee should include at least two members of the IPER affiliated faculty, and each of the student-designated depth areas should be represented by at least one faculty member with expertise in that particular area. A member-at-large is selected by the student. The oral qualifying exam should be successfully completed by the end of the eighth quarter. To complete the Ph.D., the student must pass a University oral examination in defense of the dissertation.
4. Teaching experience is an essential element of training in the Ph.D. Program. Each student is required to complete two quarters of teaching which can be fulfilled by serving as a teaching assistant for one quarter of the IPER 310, Forum Seminar and working as a TA for a course with a discussion section.

The interdisciplinary Ph.D. program is complementary to the disciplinary environmental science, engineering, and policy analysis taught in Stanford departments and schools. Students in IPER develop depth in multiple disciplinary fields and integrate the knowledge across those fields. The goal of the interdisciplinary Ph.D. program is for students to achieve an integrated understanding of environmental processes or problems, and the tools they need to address these challenge in the real world.

Additional information may be found in the *Graduate Student Handbook* at http://www.stanford.edu/dept/DoR/GSH/.

The following courses may be of interest to IPER students.

### ECONOMICS AND POLICY ANALYSIS

ECON 106. World Food Economy
ECON 155. Environmental Economics and Policy
ECON 165. International Economicss
ECON 243. Economics of the Environment
IPER 243. Energy and Environmental Policy Analysis
MS&E 248. Economics of Natural Resources
POLISCI 140. Political Economy of Development
PUBLPOL 103B. Ethics and Public Policy
PUBLPOL 104. Economic Policy Analysis

### CULTURE, LAW, INSTITUTIONS, AND POLITICS

ANTHSCI 164. Ecological Anthropology
ANTHSCI 162. Indigenous Peoples and Environ. Problems
ANTHSCI 168C. Environmental Politics in Latin America
ANTHSCI 263. Human Behavioral Ecology
BIOSCI 247. Controlling Climate Change in the 21st Century
LAW 280. Toxic Harms
LAW 281. Natural Resources Law and Policy
LAW 282. Environmental Ethics
LAW 437. Water Law
LAW 592. International Conflict
LAW 594. International Law: The National-International Interface
LAW 603. Environmental Law: Pollution
LAW 604. Environmental Law and Policy Workshop
POLISCI 441. Politics of Development

### NATURAL SCIENCES

BIOHOPK 263H. Oceanic Biology
BIOHOPK 264H. Marine Botany
BIOHOPK 273H. Marine Conservation Biology
BIOSCI 101. Ecology
BIOSCI 117. Biology and Global Change
BIOSCI 121. Biogeography
BIOSCI 136. Evolutionary Paleobiology
BIOSCI 144. Conservation Biology
BIOSCI 146. Population Studies
BIOSCI 216. Terrestrial Biogeochemistry
BIOSCI 245. Behavioral Ecology
CEE 274A,B. Environmental Microbiology I and II
CEE 164. Introduction to Physical Oceanography
EARTHSYS 189. Field Studies in Earth Systems
EARTHSYS 280. Fundamentals of Sustainable Agriculture
GES 166. Soil Chemistry
GES 170. Environmental Geochemistry
GES 205. Advanced Oceanography
GES 225. Isotopes in Geological and Environmental Research
GES 230/CEE 260A. Physical Hydrogeology
GES 231/CEE 260C. Contaminant Hydrogeology
GES 239. Advanced Geomorphology
GES 259. Marine Chemistry
GES 240. Geostatistics for Spatial Phenomena
GEOPHYS 130. Biological Oceanography
GEOPHYS 141/241. Remote Sensing of the Oceans
IPER 250. Ecological Principles for Environmental Problem Solving
PETENG 260. Groundwater Pollution and Oil Slicks: Environmental Problems in Petroleum Engineering

### TECHNOLOGY AND ENGINEERING

CEE 171. Environmental Planning Methods
CEE 172. Air Quality Management
CEE 176A. Energy Efficient Buildings
CEE 176B. Electric Power: Renewables and Efficiency
CEE 262A. Hydrodynamics
CEE 263A. Air Pollution Modeling
CEE 265. Sustainable Water Resources Development
CEE 270. Movement and Fate of Organic Contaminants in Surface Waters and Groundwater
CEE 278A. Air Pollution Physics and Chemistry
EE 293A,B. Fundamentals of Energy Processes
MS&E 446. Policy and Economics Research Roundtable (PERR)
PETENG 101. Energy and the Environment

## COURSES

Additional courses may be listed in the quarterly *Time Schedule*.

**IPER 210. Communication and Leadership Skills**—(Same as BIOSCI 388.) Focus is on delivering information to policy makers and the lay public. How to speak to the media, congress, and the general public; how to write op-eds and articles; how to package ideas including titles, abstracts, and CVs; how to survive peer review, the promotion process, and give a job talk; and how to be a responsible science advocate.

*2 units (Root) alternate years, given 2005-06*

**IPER 220. Special Topics Seminar**—IPER graduate students pursue areas of specialization in an institutional setting such as a laboratory, clinic, research institute, governmental agency, non-governmental organization, or multilateral organization.

*1-5 units, Aut, Win, Spr, Sum (Staff)*

**IPER 225. Intellectual Foundations of Interdisciplinary Research**—Competing philosophical perspectives on the epistemological and ontological underpinnings of knowledge from positivism to postmodernism. Contrasting notions of theory from deductive explanations to inductive interpretations. Methodological options and types of data. Goal is to demystify the process of scholarly research.

*3-5 units, Win (Khagram)*

**IPER 230. Environment and Resources Field Research**—Contemporary environment and resource challenges at sites around the world. Courses are offered on a variable schedule depending on the interests of IPER students and faculty. See the *Time Schedule* for current offerings.
*1-9 units, Aut, Win, Spr, Sum (Staff)*

**IPER 243. Energy and Environmental Policy Analysis**—(Same as MS&E 243.) Concepts, methods, and applications. Energy/environmental policy issues such as automobile fuel economy regulation, global climate change, research and development policy, and environmental benefit assessment. Group project. Prerequisite: MS&E 241 or ECON 50, 51.
*3 units, Spr (Goulder, Sweeney)*

**IPER 244. Fundamentals of Geographic Information Science (GIS)**—(Enroll in GES 244.)
*4 units, Spr (Seto)*

**IPER 250. Ecological Principles for Environmental Problem Solving**—For students in Law, Business, or Medicine, or IPER students with limited biology background. Topics include field methods, climate, biogeography, biogeochemical cycles, physiology, population genetics, and environmental ethics.
*3 units, Aut (Root) alternate years, not given 2005-06*

**IPER 260. The Social Sciences and Environmental Problem Solving**—For students with little background in the social sciences interested in incorporating them into their research. Focus is on the contribution that the social sciences of international relations, political science, anthropology, and sociology make to environmental problem solving. Case studies from international regime building, inter-agency politics, organizational behavior, and cultural dynamics.
*2-3 units (Staff) not given 2004-05*

**IPER 265. Central America: Environment, Sustainable Development, and Security**—(Same as ANTHSCI 165B/265B.) Interrelationships among environmental stress, poverty, and security in Central America, with focus on Costa Rica. The legacy of the Cold War in Central America as manifested in the Contra War and U.S. policy. Current development schemes and their impact on environment and security in the region. Dilemmas between population growth in the developing world and consumption patterns in the industrial world. Some years, the course includes an optional field trip to Costa Rica over Spring Break at extra expense; limited capacity. GER:3b
*3-5 units (Hoagland) not given 2004-05*

**IPER 270. Graduate Practicum in Environment and Resources**—IPER graduate students pursue areas of specialization in an institutional setting such as a laboratory, clinic, research institute, governmental agency, non-governmental organization, multilateral organization.
*1-9 units, Aut, Win, Spr, Sum (Staff)*

**IPER 310. Environmental Forum Seminar**—Required IPER core course; three-part sequence during an IPER graduate student's first year in the program. The seminar takes advantage of the multiple forum series presented throughout the year that address environmental issues. Students and faculty attend a forum and meet the following Monday morning to address issues such as the conceptual framework of the topic, the analytical approaches used, the validity of conclusions from an interdisciplinary perspective, and alternative approaches that would have enhanced the analysis presented.
*1-2 units, Aut, Win, Spr (Staff)*

**IPER 320. Case Studies in Environmental Problem Solving**—Interacting proximal and distal causes of environmental problems and integrative approaches to solutions. Cases may include the Cal Fed Bay Delta project or the Everglades project with respect to water allocation and quality issues; the agro-metro-plex approach to evaluating and solving atmospheric problems; environmental issues in the Searsville Dam/San Francisquito Creek watershed; the Kyoto Protocol and alternatives; integrated conservation and development projects such as Madagascar's Masoala National Park project. Data and modeling needs, and analytical frameworks to understand causes, consequences, and solutions.
*3 units (Thompson) alternate years, given 2005-06*

**IPER 330. Interdisciplinary Research Approaches and Analysis**—Required IPER core course. The analytical tools, models, and approaches central to interdisciplinary research on the world's leading environmental issues. Topics include: observing systems and data sources; computation and modeling approaches to complex problems; translation and integration of alternative disciplinary approaches to research, analysis, and uncertainty; policy analysis; cost benefit analysis, risk benefit analysis, qualitative methods, and other decision analytic frameworks and valuation approaches; team building and leadership roles; review and proposal writing.
*3 units (Schneider) alternate years, given 2005-06*

**IPER 333. Water Policy Seminar**—(Same as CEE 333.) Student-organized interdisciplinary seminar. Focus is on creation, implementation, and analysis of policy affecting the use and management of water resources. Weekly speakers from academia and local, state, national, and international agencies and organizations. Previous topics include water policy in California and developing countries.
*1 unit, Spr (Freyberg)*

**IPER 366. Implementing Environmental and Water Management Programs**—(Same as CEE 366.) Alternative environmental management programs created by governments and advocated by international aid agencies. Role of legislatures, courts, agencies, firms, nongovernmental organizations, media, and citizens in implementation. Alternative measures of program performance. Design of research to investigate performance of program implementation. Theories of decision making to interpret findings. Theory development and hypothesis testing based on empirical studies of policy and program implementation. Limited enrollment. Preference to doctoral students involved in environmental or water policy research.
*3 units, Spr (Ortolano)*

**IPER 398. Directed Individual Study in Environment and Resources**—Under supervision of an IPER faculty member on a subject of mutual interest.
*1-9 units, Aut, Win, Spr, Sum (Staff)*

**IPER 399. Directed Research in Environment and Resources**—For advanced graduate students.
*1-9 units, Aut, Win, Spr, Sum (Staff)*

**IPER 410. Ph.D. Qualifying Tutorial**—For Ph.D. students only.
*1 unit, Aut, Win, Spr, Sum (Staff)*

**IPER 460. Proposal Writing Seminar**—Practical training in grant writing methods. Students draft research proposals relevant to their individual interests with supervision from IPER faculty.
*1-2 units, Aut, Win, Spr (Staff)*

**IPER 480. Dissertation Writing Seminar in Environment and Resources**—Required of all IPER Ph.D. candidates.
*1-15 units, Aut, Win, Spr, Sum (Staff)*

# PETROLEUM ENGINEERING

*Emeriti: (Professors)* John W. Harbaugh,† Sullivan S. Marsden, Jr.
*Chair:* Roland N. Horne
*Associate Chair:* Louis J. Durlofsky
*Professors:* Khalid Aziz, Louis J. Durlofsky, Roland N. Horne,† André Journel, Franklin M. Orr, Jr.
*Associate Professor:* Anthony R. Kovscek, Hamdi Tchelepi
*Assistant Professors:* Jef Caers, Margot Gerritsen
*Courtesy Professor:* Stephan A. Graham
*Lecturer:* Louis M. Castanier
*Acting Assistant Professors:* Kristian Jessen, Ruben Juanes
*Consulting Professors:* Warren K. Kourt, Robert G. Lindblom, Kiran Pande

* Recalled to active duty
† Joint appointment with Geological and Environmental Sciences

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Courses given in Petroleum Engineering have the subject code PETENG. For a complete list of subject codes, see Appendix.

Petroleum engineers are concerned with the design of processes for energy recovery from oil and gas reservoirs. Included in the design process are characterizing the spatial distribution of reservoir properties, drilling wells, designing and operating production facilities, selecting and implementing methods for enhancing fluid recovery, examining the environmental aspects of petroleum exploration and production, monitoring reservoirs, and predicting recovery process performance. The Department of Petroleum Engineering curriculum provides a sound background in basic sciences and their application to practical problems to address the complex and changing nature of the field. Course work includes the fundamentals of chemistry, computer science, engineering, geology, geophysics, mathematics, and physics. Applied courses cover most aspects of petroleum engineering and some related fields like geothermal engineering and geostatistics. The curriculum emphasizes the fundamental aspects of fluid flow in the subsurface. These principles apply equally well to optimizing oil recovery from petroleum reservoirs and remediating contaminated groundwater systems.

Faculty and graduate students in the department conduct research in a variety of areas including: enhanced oil recovery by thermal means, gas injection, and the use of chemicals; flow of fluids in pipes; geostatistical reservoir characterization and mathematical modeling; geothermal engineering; natural gas engineering; optimization; properties of petroleum fluids; reservoir simulation using computer models; and well test analysis. Undergraduates are encouraged to participate in research projects. Graduate programs lead to the degrees of Master of Science (M.S.), Engineer, and Doctor of Philosophy (Ph.D.) in Petroleum Engineering.

M.S., Engineer, and Ph.D. degrees may be awarded with field designations for students who follow programs of study in the fields of geostatistics, geothermal, crustal fluids, or environmental specialties.

The department is housed in the Green Earth Sciences Building and it operates laboratories for research in various enhanced oil recovery processes and geothermal engineering. Students have access to a variety of computers for research and course work. Computers available for instruction and research include three UNIX workstations (Compaq Digital Unix and SGI Irix) and ten multiprocessor NT servers within the department, as well as extensive campus-wide computer clusters. Each graduate student office has one Pentium 4 computer per student.

## UNDERGRADUATE PROGRAMS

## BACHELOR OF SCIENCE

The four-year program leading to the B.S. degree provides a foundation for careers in many facets of the energy industry. The curriculum includes basic science and engineering courses that provide sufficient depth for a wide spectrum of careers in the energy and environmental industries.

One of the goals of the program is to provide experience integrating the skills developed in individual courses to address a significant design problem. In PETENG 180, taken in the senior year, student teams design facilities for a real petroleum reservoir to meet specific management objectives.

### PROGRAM

The requirements for the B.S. degree in Petroleum Engineering are similar to those described in the "School of Engineering" section of this bulletin. Students must satisfy the University general education, writing, and language requirements. The normal Petroleum Engineering undergraduate program automatically satisfies the University General Education Requirements (GERs) in area 2a (Natural Sciences), area 2b (Technology and Applied Sciences), and area 2c (Mathematics). Engineering fundamentals courses and Petroleum Engineering depth and elective courses must be taken for a letter grade.

In brief, the credit and subject requirements are:

| *Subject* | *Minimum Units* |
|---|---|
| Engineering fundamentals | 25 |
| General Education, writing, language, and electives | 68-69 |
| Mathematics | 23 |
| Petroleum Engineering depth | 39-40 |
| Science | 26 |
| Total | 181 |

The following courses constitute the normal program leading to a B.S. in Petroleum Engineering. The program may be modified to meet a particular student's needs and interests with the adviser's prior approval.

### MATHEMATICS

| *Course No. and Subject* | *Units* |
|---|---|
| MATH 41. Single Variable Calculus | 5 |
| *and* MATH 42. Single Variable Calculus | 5 |
| *or* MATH 19. Calculus | 3 |
| *and* MATH 20. Calculus | 3 |
| *and* MATH 21. Calculus | 4 |
| MATH 51. Linear Algebra &Differential Calculus of Several Variables | 5 |
| MATH 52. Integral Calculus of Several Variables | 5 |
| Total | 23 |

### SCIENCE

| | |
|---|---|
| CHEM 31. Chemical Principles | 4 |
| CHEM 33. Structure and Reactivity | 4 |
| CHEM 171. Physical Chemistry | 3 |
| GES 1. Fundamentals of Geology | 5 |
| PHYSICS 53. Mechanics | 4 |
| PHYSICS 55. Electricity and Magnetism | 4 |
| PHYSICS 56. Electricity and Magnetism Laboratory | 1 |
| Total | 26 |

### ENGINEERING FUNDAMENTALS

| | |
|---|---|
| CS 106A. Programming Methodology | 5 |
| *or* CS 106X. Programming Methodology and Abstractions | 5 |
| ENGR 14. Applied Mechanics: Statics and Deformables | 5 |
| *and* ENGR 15. Dynamics | 5 |
| ENGR 30. Engineering Thermodynamics | 3 |
| ME 70. Introductory Fluids Engineering | 4 |
| ENGR 60. Engineering Economy | 3 |
| Total | 25 |

### ENGINEERING DEPTH

The following courses constitute the core program in Petroleum Engineering:

| | |
|---|---|
| CHEMENG 120A. Fluid Mechanics | 3 |
| *or* CHEMENG 180. Chemical Engineering Plant Design | 3 |
| CHEMENG 185A. Chemical Engineering Laboratory | 3 |
| CHEMENG 185B. Chemical Engineering Laboratory | 3 |
| GES 151. Sedimentary Geology and Petrography: Depositional Systems | 4 |
| PETENG 120. Reservoir Engineering | 3 |

| | |
|---|---|
| PETENG 121. Fundamentals of Multiphase Flow | 3 |
| PETENG 130. Well Log Analysis I | 3 |
| PETENG 140. Drilling and Completion Technology | 3 |
| PETENG 175. Well Test Analysis | 3 |
| PETENG 180. Oil and Gas Production Engineering | 3 |
| PETENG 260. Groundwater Pollution and Oil Spills | 3 |
| Total | 40 |

A list of suggested electives and sample course programs are available in the Department of Petroleum Engineering, room 65, Green Earth Sciences Building. It is important to start mathematics courses in the first year and engineering and geology early in the second year. Computers are used extensively in most petroleum engineering courses. Students must develop programming skills through course work and self-study and are expected to achieve fluency in the use of FORTRAN, C, or C++ by their junior year.

### MINORS

To be recommended for a B.S. degree with Petroleum Engineering as a minor subject, a student must take the following courses in addition to those required by the major department or program: PETENG 120, 121, 130, 175, 180; GES 111 and 151. In some programs, GES 111 or 151 may also satisfy major requirements.

## HONORS PROGRAM

A limited number of undergraduates may be admitted to the honors program at the beginning of their senior year.

To be admitted, the student must have a grade point average (GPA) of at least 3.0 in all course work in the University. In addition to the minimum requirements for the B.S. degree, the student must complete 6 units of advanced petroleum engineering courses and at least 3 units of research (PETENG 193).

Students who wish to be admitted to the honors program should consult with their adviser before the start of their senior year. Those who do not meet all of the formal requirements may petition the department for admission. Those completing the program receive the B.S. degree in Petroleum Engineering with Honors. An overall 3.5 GPA is required in all petroleum engineering courses for graduation with honors.

## COTERMINAL B.S. AND M.S. PROGRAM

The coterminal B.S./M.S. program offers a unique opportunity for Stanford University students to pursue a graduate experience while completing the B.S. degree in any relevant major. Petroleum Engineering graduate students generally come from backgrounds such as chemical, civil, or mechanical engineering; geology or other earth sciences; or physics or chemistry. Students should have a background at least through MATH 53 and CS 106 before beginning graduate work in this program.

The two types of M.S. degrees, the course work only degree and the research degree, as well as the courses required to meet degree requirements, are described below in the M.S. section. Both degrees require 45 units and may take from one to two years to complete depending on circumstances unique to each student.

Requirements to enter the program are two letters of recommendation from faculty members or job supervisors, a statement of purpose, scores from the GRE general test, and a copy of Stanford University transcripts. While the department does not require any specific GPA or GRE score, potential applicants are expected to compete favorably with graduate student applicants.

A Petroleum Engineering master's degree can be used in many ways. It is considered a terminal professional degree which prepares the student to obtain a professional job in the petroleum or geothermal industry, or in any related industry where analyzing flow in porous media or computer simulation skills are required. It can also be a stepping stone to a Ph.D. degree, which usually leads to a professional research job or an academic position.

Students should apply to the program any time after they have completed 105 undergraduate units, and in time to take PETENG 120, the basic introductory course in Autumn Quarter of the year they wish to begin the program. Contact the Department of Petroleum Engineering to obtain additional information. For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/publications/#Coterm.

## GRADUATE PROGRAMS

The University's basic requirements for M.S., Engineer, and Ph.D. degrees are discussed in the "Graduate Degrees" section of this bulletin.

The energy industry provides a variety of employment opportunities for petroleum engineers with advanced training. A balanced master's degree program including both engineering course work and research requires a minimum of one maximum tuition academic year beyond the baccalaureate to meet the University residence requirements. Most full-time students spend at least one additional summer to complete the research requirement. An alternative master's degree program based only on course work is available, also requiring at least one full tuition academic year to meet University residence requirements.

M.S. students who anticipate continuing in the Ph.D. program should follow the research option. M.S. students receiving financial aid normally require two academic years to complete the degree. Such students must take the research option and are limited to an 8-10 unit course load per quarter.

The degree of Engineer requires a comprehensive maximum tuition two-year program of graduate study. This degree permits more extensive course work than the master's degree, with an emphasis on professional practice. All Engineer's degree students receiving financial aid are also limited to an 8-10 unit course load per quarter and need at least ten quarters of work to complete the degree.

The Ph.D. degree is awarded primarily on the basis of completion of significant, original research. Extensive course work and a minimum of 90 units of graduate work beyond the master's degree is required. Doctoral candidates planning theoretical work are encouraged to gain experimental research experience in the M.S. program. Ph.D. students receiving financial assistance are limited to 8-10 units per quarter and often require more than three years to complete the Ph.D.

In special cases, the M.S., Engineer, and Ph.D. degrees may be awarded with field designations for students who follow programs of study in the particular fields of (1) geostatistics, (2) geothermal, (3) crustalfluids, or (4) environmental. For example, students may be awarded the degree Master of Science in Petroleum Engineering (Geothermal).

## MASTER OF SCIENCE

The objective is to prepare the student for professional work in the energy industry through completion of fundamental courses in the major field and in related sciences as well as independent research.

Students entering the graduate program are expected to have an undergraduate-level petroleum engineering background. Competence in computer programming in a high-level language (CS 106X or the equivalent) and knowledge of petroleum engineering and geological fundamentals (PETENG 120, 130, and GES 151) are prerequisites for taking most graduate courses.

The candidate must fulfill the following requirements:

1. Register as a graduate student for at least 45 units.
2. Submit a program proposal for the Master's degree approved by the adviser during the first quarter of enrollment.
3. Complete 45 units with at least a grade point average (GPA) of 3.0. This requirement is satisfied by taking the core sequence, selecting one of the seven elective sequences, an appropriate number of additional courses from the list of technical electives, and completing 6 units of master's level research. Students electing the "course work only" M.S. degree are strongly encouraged to select an additional elective sequence in place of the research requirement. Students interested in continuing for a Ph.D. are expected to choose the research option and enroll in 6 units of PETENG 361. All courses must be taken for a letter grade.
4. Students entering without an undergraduate degree in Petroleum Engineering must make up deficiencies in previous training. Not more than 10 units of such work may be counted as part of the minimum total of 45 units toward the M.S. degree.

Research subjects include certain groundwater hydrology and environmental problems, energy industry management, flow of non-Newtonian fluids, geothermal energy, natural gas engineering, oil and gas recovery, pipeline transportation, production optimization, reservoir characterization and modeling, carbon sequestration, reservoir engineering, reservoir simulation, and transient well test analysis.

## RECOMMENDED COURSES AND SEQUENCES

The following list is recommended for most students. With the prior special consent of the student's adviser, courses listed under technical electives may be substituted based on interest or background.

### CORE SEQUENCE

| *Course No. and Subject* | *Units* |
|---|---|
| CME 200. Linear Algebra with Application to Engineering Computations (formerly ME 300A) | 3 |
| CME 204. Partial Differential Equations in Engineering (formerly ME 300B) | 3 |
| PETENG 175. Well Test Analysis | 3 |
| *or* PETENG 130. Well Log Analysis | 3 |
| PETENG 221. Fundamentals of Multiphase Flow | 3 |
| PETENG 222. Reservoir Engineering* | 3 |
| PETENG 246. Reservoir Characterization and Flow Modeling with Outcrop Data | 3 |
| PETENG 251. Thermodynamics of Equilibria† | 3 |
| Total | 21 |

* Students taking the Environmental sequence may substitute PETENG 227.

† Optional for students taking the Geostatistics and Reservoir Modeling sequence.

### ELECTIVE SEQUENCE

Choose one of the following:

| | |
|---|---|
| **Crustal Fluids:** | |
| GES 230. Physical Hydrogeology | 5 |
| GES 231. Contaminant Hydrogeology | 4 |
| GEOPHYS 200. Fluids and Tectonics | 3 |
| Total | 12 |
| **Environmental:** | |
| GES 231. Contaminant Hydrogeology | 4 |
| PETENG 227. Enhanced Oil Recovery | 3 |
| Plus two out of the following courses: | |
| CEE 270. Movement, Fate, and Effect of Contaminants in Surface Water and Groundwater | 3 |
| CEE 274A. Environmental Microbiology | 3 |
| GES 230. Physical Hydrogeology | 3 |
| GES 264. Low Temperature Aqueous Geochemistry | 3 |
| PETENG 240. Geostatistics | 3-4 |
| PETENG 260. Environmental Problems in Petroleum Engineering | 3 |
| Total | 13-14 |
| **Enhanced Recovery:** | |
| PETENG 225. Theory of Gas Injection Processes | 3 |
| PETENG 226. Thermal Recovery Methods | 3 |
| PETENG 227. Enhanced Oil Recovery | 3 |
| Total | 9 |
| **Geostatistics and Reservoir Modeling:** | |
| GEOPHYS 182. Reflection Seismology | 3 |
| *or* GEOPHYS 262. Rock Physics | 3 |
| PETENG 240. Geostatistics for Spatial Phenomena | 3-4 |
| PETENG 241. Practice of Geostatistics | 3-4 |
| Total | 9-11 |
| **Geothermal:** | |
| CHEMENG 120B. Energy and Mass Transport | 4 |
| ME 131A. Heat Transfer | 3 |
| PETENG 269. Geothermal Reservoir Engineering | 3 |
| *or* PETENG 102 Renewable Energy Sourses | 3 |
| Total | 10 |
| **Reservoir Performance:** | |
| GEOPHYS 202. Reservoir Geomechanics | 3 |
| PETENG 223. Reservoir Simulation | 3-4 |
| PETENG 280. Oil and Gas Production Engineering | 3 |
| Total | 9-11 |
| **Simulation and Optimization:** | |
| PETENG 223. Reservoir Simulation | 3-4 |
| PETENG 224. Advanced Reservoir Simulation | 3 |
| PETENG 284. Optimization | 3 |
| Total | 9-10 |

### RESEARCH SEQUENCE

| | |
|---|---|
| PETENG 361. Master's Degree Research in Petroleum Engineering* | 6 |
| Total units required for M.S. degree | 45 |

* Students selecting the company sponsored "course work only" for the M.S. degree may substitute an additional elective sequence in place of the research.

### TECHNICAL ELECTIVES

Technical electives from the following list of advanced-level courses usually complete the M.S. program. In unique cases, when justified and approved by the adviser prior to taking the course, courses listed here may be substituted for courses listed above in the elective sequences.

| | |
|---|---|
| GEOPHYS 182. Reflection Seismology | 3 |
| GEOPHYS 190. Near Surface Geophysics | 3 |
| GEOPHYS 202. Reservoir Geomechanics | 3 |
| CME 204. Partial Differential Equations to Engineering (formerly 300B) | 3 |
| PETENG 130. Well Log Analysis | 3 |
| PETENG 211. Computer Applications for Petroleum Engineers | 1 |
| PETENG 224. Advanced Reservoir Simulation | 3 |
| PETENG 230. Advanced Topics in Well Logging | 3 |
| PETENG 260. Environmental Aspects of Petroleum Engineering | 3 |
| PETENG 267. Engineering Valuation and Appraisal of Oil and Gas Wells, Facilities and Properties | 3 |
| PETENG 269. Geothermal Reservoir Engineering | 3 |
| PETENG 273. Special Production Engineering Topics in Petroleum Engineering | 1-3 |
| PETENG 280. Oil and Gas Production | 3 |
| PETENG 281. Applied Mathematics in Reservoir Engineering | 3 |
| PETENG 284. Optimization | 3 |

## M.S. IN INTEGRATED RESERVOIR MODELING

Starting with academic year 2002-03, a Master of Sciences option in Integrated Reservoir Modeling is offered in the Department of Petroleum Engineering for full-time students. This M.S. degree requires a minimum of 45 units of which 39 should be course units. The following courses are suggested for this program.

### MATH SEQUENCE:

| *Course No. and Subject* | *Units* |
|---|---|
| CME 200 Linear Algebra with Application to Engineering Computations (formerly ME 300A) | 3 |
| CME 204 Partial Differential Equations in Engineering (formerly ME 300B) | 3 |

### PETROLEUM ENGINEERING SEQUENCE:

| | |
|---|---|
| PETENG 246. Reservoir Characterization and Flow Modeling | 3 |
| PETENG 130. Well Logging; *or* | 3 |
| PETENG 175. Well Test Analysis | 3 |
| PETENG 221. Fundamentals of Multiphase Flow, *or* | 3 |
| PETENG 222. Advanced Reservoir Engineering | 3 |
| PETENG 223. Reservoir Simulation | 3-4 |

### GEOSTATISTICS SEQUENCE:

| | |
|---|---|
| PETENG 240. Geostatistics for Spatial Phenomena | 3-4 |
| PETENG 241. Practice of Geostatistics and Seismic Data Integration | 3-4 |

### GEOLOGY SEQUENCE:

| | |
|---|---|
| GES 151. Sedimentary Geology | 4 |
| GES 253. Petroleum Geology | 3 |

### GEOPHYSICS SEQUENCE:

| | |
|---|---|
| GEOPHYS 182 Reflection Seismology, or | 3 |
| GEOPHYS 183. Reflection Seismology Interpretation | 1-4 |
| GEOPHYS 262. Rock Physics | 3 |

## ENGINEER

The objective is to broaden training through additional work in engineering and the related sciences and by additional specialization.

Basic requirements include completion of 90 units of course work including 15 units of research (PETENG 362), and including all course requirements of the department's master's degree (39 units, excluding research). If the candidate has received credit for research in the M.S. degree, this credit ordinarily would be transferable to the Engineer degree, in which case a total of 9 additional research units would be required. No more than 10 of the 90 required units can be applied to overcoming deficiencies in undergraduate training.

At least 30 units in Engineering and closely allied fields must be taken in advanced work, that is, work beyond the master's degree requirements and in addition to research (PETENG 362). These may include courses from the Ph.D. degree list below or advanced-level courses from other departments with prior consent of the adviser. All courses must be taken for a letter grade. The student must have a grade point average (GPA) of at least 3.0 in courses taken for the degree of Engineer. A thesis based on 15 units of research must be submitted and approved by the adviser, another faculty member, and the University Committee on Graduate Studies.

## DOCTOR OF PHILOSOPHY

The Ph.D. degree is conferred upon demonstration of high achievement in independent research and by presentation of the research results in a written dissertation and oral defense.

Basic requirements include a minimum of 135 units of satisfactorily completed graduate study. Students must take at least 90 units beyond the 45 units required for the master's degree. The 90 units are composed of 54 units of research and 36 units of course work. The student's record must indicate outstanding scholarship. The student must pass the department's qualifying examination, submit an approved research proposal, fulfill the requirements of the minor department if a minor is elected, and pass the University oral examination, which is a defense of the dissertation. The student must prepare a dissertation based on independent research and that makes a significant contribution to the field.

The specification of 36 units of course work is a minimum; in some cases the research adviser may specify additional requirements to strengthen the student's expertise in particular areas. The 36 units of course work does not include teaching experience (PETENG 359), which is a requirement for the Ph.D. degree, nor any units in research seminars, which students are required to attend. All courses must be taken for a letter grade, with an average grade point average (GPA) of at least 3.25 in the 36 units of course work. Incoming Ph.D. students who earned their master's degree at another institution are required to take at least 36 units of course work. No more than four of the nine courses that make up the strategic requirements for the Ph.D. qualifying exams are included in these 36 units (PETENG 175, 221, 222, 223, 227, 240, 251, 281). The 36 units of course work may include graduate courses in Petroleum Engineering (numbered 200 and above) and courses selected from the following list. Other courses may be substituted with prior approval by the adviser. In general, non-technical courses are not approved.

### MATH AND APPLIED MATH

| *Course No. and Subject* | *Units* |
|---|---|
| AA 210A. Fundamentals of Compressible Flow | 3 |
| AA 214A. Numerical Methods in Fluid Mechanics | 3 |
| AA 214B. Numerical Computation of Compressible Flow | 3 |
| CHEMENG 300. Applied Mathematics in Chemical Engineering | 3 |
| CEE 268. Groundwater Flow | 3-4 |
| CS 106X. Programming Methodology and Abstractions | 5 |
| CS 137. Introduction to Scientific Computing | 3-4 |
| CS 193D. C++ and Object Oriented Programming | 4 |
| CS 237A,B,C. Advanced Numerical Analysis | 3 ea. |
| MATH 106. Introduction to Theory of Functions of a Complex Variable | 3 |
| MATH 113. Linear Algebra and Matrix Theory | 3 |
| MATH 114. Linear Algebra and Matrix Theory | 3 |
| MATH 115. Functions of a Real Variable | 3 |
| MATH 131. Partial Differential Equations I | 3 |
| MATH 132. Partial Differential Equations II | 3 |
| MATH 220A,B,C. Partial Differential Equations of Applied Mathematics | 3 ea. |
| CME 200. Linear Algebra with Application to Engineering Computations (formerly ME 300A) | 3 |
| CME 204. Partial Differential Equations in Engineering (formerly ME 300B) | 3 |
| CME 206. Introduction to Numerical Methods for Engineering (formerly ME 300C) | 3 |
| ME 331A,B. Classical Dynamics | 3 ea. |
| ME335A,B,C. Finite Element Analysis | 3 ea. |
| STATS 110. Statistical Methods in Engineering and Physical Sciences | 4 |
| STATS 116. Theory of Probability | 4 |
| STATS 200. Introduction to Statistical Inference | 3 |
| STATS 202. Data Analysis | 3 |

### SCIENCE

| | |
|---|---|
| GES 231. Contaminant Hydrogeology | 4 |
| GES 253. Petroleum Geology and Exploration | 3 |
| GEOPHYS 182. Reflection Seismology | 3 |
| GEOPHYS 190. Near Surface Geophysics | 3 |
| GEOPHYS 262. Rock Physics | 3 |

### ENGINEERING

| | |
|---|---|
| CHEMENG 110. Equilibrium Thermodynamics | 3 |
| CHEMENG 120A. Fluid Mechanics | 3 |
| CHEMENG 120B. Energy and Mass Transport | 3 |
| CHEMENG 310A. Microscale Transport in Chemical Engineering | 3 |
| ENGR 298. Seminar in Fluid Mechanics | 1 |

Ph.D. students are required to take the doctoral qualifying examination at the beginning of the second year of study. Students receiving a master's degree from the Department of Petroleum Engineering and continuing on for a Ph.D. are required to take the qualifying examination at the first opportunity after the completion of the requirements for the master's degree.

The qualifying examination consists of both a written and an oral section. The written part consists of three or four three-hour examinations on different subjects. The oral part is a three-hour examination in which members of the department faculty question the student. Students are required to apply for candidacy for the Ph.D. degree after passing the department's qualifying examination.

Within a year of passing the qualifying examination, the student must prepare a short written report that contains a literature review and a research proposal. This proposal must be approved after oral examination by a committee made up of the student's adviser and two other faculty, at least one of whom must be from the department.

The dissertation must be submitted in its final form within five calendar years from the date of admission to candidacy. Candidates who fail to meet this deadline must submit an Application for Extension of Candidacy for approval by the department chair if they wish to continue in the program.

### PH.D. MINOR

To be recommended for a Ph.D. degree with Petroleum Engineering as a minor subject, a student must take 20 units of selected graduate-level lecture courses in the department. These courses must include PETENG 221 and 222. The remaining courses should be selected from PETENG 175, 223, 224, 225, 227, 240, 241, 251, 280, 281, and 284.

## COURSES

WIM indicates that the course satisfies the Writing in the Major requirements. (AU) indicates that the course is subject to the University Activity Unit limitations (8 units maximum).

**PETENG 101. Energy and the Environment**—(Same as EARTHSYS 101.) Energy use in modern society and the consequences of current and future energy use patterns. Case studies illustrate resource estimation, engineering analysis of energy systems, and options for managing carbon emissions. Focus is on energy definitions, use patterns, resource estimation, pollution. Recommended: MATH 21 or 42, ENGR 30. GER:2a
*3 units, Win (Gerritsen, Durlofsky, Kovscek)*

**PETENG 102. Renewable Energy Sources and Greener Energy Processes**—(Same as EARTHSYS 102.) The energy sources that power society are rooted in fossil energy. Energy from the earth's core and the sun is almost inexhaustible, but the rate at which this energy can be drawn with today's technology is limited. The renewable energy resource base, its conversion to useful forms, and practical methods of energy storage. Geothermal, wind, solar, and tidal energies; resource extraction and its consequences. Recommended: 101, MATH 21 or 42. GER:2a
*3 units, Spr (Kovscek)*

**PETENG 110Q. Technology in the Greenhouse: Options for Reducing Greenhouse Emissions from Energy Use**—Stanford Introductory Seminar. Preference to sophomores. Technologies that might be used to reduce emissions of greenhouse materials such as carbon dioxide, methane, and black soot. Sources of greenhouse materials in the current energy mix. Advantages and limitations of technologies that could be applied to reduce emissions. Examples include renewable sources such as wind and solar energy, more efficient use of energy, hydrogen, capture and storage of carbon dioxide, and nuclear power. Students choose energy areas for presentation and paper. GER:2b
*3 units, Spr (Orr)*

**PETENG 120. Fundamentals of Petroleum Engineering**—(Same as ENGR 120.) Lectures, problems, field trip. Engineering topics in petroleum recovery; origin, discovery, and development of oil and gas. Chemical, physical, and thermodynamic properties of oil and natural gas. Material balance equations and reserve estimates using volumetric calculations. Gas laws. Single phase and multiphase flow through porous media. GER:2b
*3 units, Aut (Juanes)*

**PETENG 121. Fundamentals of Multiphase Flow**—(Same as 221.) Multiphase flow in porous media. Wettability, capillary pressure, imbibition and drainage, Leverett J-function, transition zone, vertical equilibrium. Relative permeabilities, Darcy's law for multiphase flow, fractional flow equation, effects of gravity, Buckley-Leverett theory, recovery predictions, volumetric linear scaling, JBN and Jones-Rozelle determination of relative permeability. Frontal advance equation, Buckley-Leverett equation as frontal advance solution, tracers in multiphase flow, adsorption, three-phase relative permeabilities. GER:2b
*3 units, Win (Tchelepi)*

**PETENG 130. Well Log Analysis I**—For earth scientists and engineers. Interdisciplinary, providing a practical understanding of the interpretation of well logs. Lectures, problem sets using real field examples: methods for evaluating the presence of hydrocarbons in rock formations penetrated by exploratory and development drilling. The fundamentals of all types of logs, including electric and non-electric logs.
*3 units, Aut (Lindblom)*

**PETENG 155. Undergraduate Report on Energy Industry Training**—Provides on-the-job practical training under the guidance of experienced, on-site supervisors geared to undergraduate level students. A concise report detailing work activities, problems, assignments and key results is required. Prerequisite: written consent of instructor.
*1-3 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics**—(Same as GES 161.) Statistical analysis and graphical display of data, common distribution models, sampling, and regression. The variogram as a tool for modeling spatial correlation; variogram estimation and modeling; introduction to spatial mapping and prediction with kriging; integration of remote sensing and other ancillary information using co-kriging models; spatial uncertainty; introduction to geostatistical software applied to large environmental, climatological, and reservoir engineering databases; emphasis is on practical use of geostatistical tools. GER:2a
*3-4 units, Win (Caers)*

**PETENG 167. Engineering Valuation and Appraisal of Oil and Gas Wells, Facilities, and Properties**—(Same as 267.) Appraisal of development and remedial work on oil and gas wells; appraisal of producing properties; estimation of productive capacity, reserves; operating costs, depletion, and depreciation; value of future profits, taxation, fair market value; original or guided research problems on economic topics with report. Prerequisite: consent of instructor. GER:2b
*3 units, Win (Kourt, Pande)*

**PETENG 175. Well Test Analysis**—Lectures, problems. Application of solutions of unsteady flow in porous media to transient pressure analysis of oil, gas, water, and geothermal wells. Pressure buildup analysis and drawdown. Design of well tests. Computer-aided interpretation.
*3 units, Spr (Gerritsen, Tchelepi)*

**PETENG 180. Oil and Gas Production Engineering**—(Same as 280.) Design and analysis of production systems for oil and gas reservoirs. Topics: well completion, single-phase and multi-phase flow in wells and gathering systems, artificial lift and field processing, well stimulation, inflow performance. Prerequisite: 120. Recommended: 130. GER:2b,WIM
*3 units (Tchelepi) not given 2004-05*

**PETENG 192. Undergraduate Teaching Experience**—Leading field trips, preparing lecture notes, quizzes under supervision of the instructor.
*1-3 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 193. Undergraduate Research Problems**—Original and guided research problems with comprehensive report.
*1-3 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 194. Special Topics in Energy and Mineral Fluids**—Lectures, problems.
*1-3 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 202. Reservoir Geomechanics**—(Enroll in GEOPHYS 202.)
*3 units, Win (Zoback)*

**PETENG 221. Fundamentals of Multiphase Flow**—(For graduate students; see 121.)
*3 units, Win (Tchelepi)*

**PETENG 222. Advanced Reservoir Engineering**—Lectures, problems. General flow equations, tensor permeabilities, steady state radial flow, skin, and succession of steady states. Injectivity during fill-up of a depleted reservoir, injectivity for liquid-filled reservoirs. Flow potential and gravity forces, coning. Displacements in layered reservoirs. Transient radial flow equation, primary drainage of a cylindrical reservoir, line source solution, pseudo-steady state. Prerequisite: 221.
*3 units, Spr (Durlofsky)*

**PETENG 223. Reservoir Simulation**—Lectures, problems, and class project provide a thorough understanding of the fundamentals of petroleum reservoir simulation. Development of equations for multicomponent, multiphase flow between gridblocks comprising a petroleum reservoir. Relationships between black-oil and compositional models. Various techniques for developing black-oil, compositional, thermal, and dual-porosity models. Practical considerations in the use of simulators for predicting reservoir performance. Prerequisite: 221 and 246, or consent of instructor. Recommended: CME 206 (formerly ME 300C).
*3-4 units, Win (Durlofsky, Gerritsen, Tchelepi)*

**PETENG 224. Advanced Reservoir Simulation**—Topics include modeling of complex wells, coupling of surface facilities, compositional modeling, dual porosity models, treatment of full tensor permeability and grid nonorthogonality, local grid refinement, higher order methods, streamline simulation, upscaling, algebraic multigrid solvers, unstructured grid solvers, history matching, other selected topics. Prerequisite: 223 or consent of instructor.
*3 units, Aut (Aziz, Durlofsky, Juanes, Tchelepi)*

**PETENG 225. Theory of Gas Injection Processes**—Lectures, problems. Theory of multicomponent, multiphase flow in porous media. Miscible displacement: diffusion and dispersion, convection-dispersion equations and its solutions. Method of characteristic calculations of chromatographic transport of multicomponent mixtures. Development of miscibility and interaction of phase behavior with heterogeneity. Prerequisite: CME 200 (formerly ME 300A).
*3 units, Win (Orr, Jessen)*

**PETENG 226. Thermal Recovery Methods**—Theory and practice of thermal recovery methods: steam drive, cyclic steam injections, and in-situ combustion. Models of combined mass and energy transport. Estimates of heated reservoir volume and oil recovery performance. Wellbore heat losses, recovery production, and field examples.
*3 units (Castanier) alternate years, not given 2005-06*

**PETENG 227. Enhanced Oil Recovery**—Lectures, problems. Introduction to the physics, theories, and methods of evaluating chemical, miscible, and thermal enhanced oil recovery projects. Existing methods and screening techniques, and analytical and simulation based means of evaluating project effectiveness. Dispersion-convection-adsorption equations, coupled heat, and mass balances and phase behavior provide requisite building blocks for evaluation.
*3 units (Kovscek) not given 2004-05*

**PETENG 230. Advanced Topics in Well Logging**—(Same as GEOPHYS 230.) Designed to follow a course in basic well logging, and assumes knowledge of standard practice and application of electric well logs. State of the art tools and analyses; the technology, rock physical basis, and applications of each measurement. Hands-on computer-based analyses illustrate instructional material. Guest speakers on specific formation evaluation topics. Prerequisite: 130 or equivalent.

*3 units, Spr (Lindblom)*

**PETENG 240. Geostatistics for Spatial Phenomena**—(Same as GES 240.) Probabilistic modeling of spatial and/or time dependent phenomena. Kriging and cokriging for gridding and spatial interpolation. Integration of heterogeneous sources of information. Stochastic imaging of reservoir/field heterogeneities. Introduction to GSLIB software. Case studies from the oil and mining industry and environmental sciences. Prerequisites: introductory calculus and linear algebra, STATS 116, GES 161 or equivalent.

*3-4 units, Win (Journel)*

**PETENG 241. Practice of Geostatistics and Seismic Data Integration**—(Same as GEOPHYS 241.) Students build a synthetic 3D fluvial channel reservoir model with layer depths, channel geometry, and facies-specific petrophysic and seismic properties, stressing the physical significance of geophysical data. Reference data set is sparsely sampled, providing the sample data typically available for an actual reservoir assessment. Geostatistical reservoir modeling uses well and seismic data, with results checked against the reference database. All software provided (GSLIB and SRBtools). Recommended: basic prior experience with Unix, Matlab/C++/Fortran programming. Prerequisite: 240.

*3-4 units, Spr (Caers, Mukerji)*

**PETENG 242. Topics in Advanced Geostatistics**—(Same as GES 242.) Conditional expectation theory and projections in Hilbert spaces; parametric versus non-parametric geostatistics; Boolean, Gaussian, fractal, indicator, and annealing approaches to stochastic imaging; multiple point statistics inference and reproduction; neural net geostatistics; Bayesian methods for data integration; techniques for upscaling hydrodynamic properties. May be repeated for credit. Prerequisites: 240, advanced calculus, C++/Fortran.

*3-4 units, Aut (Journel) alternate years, not given 2005-06*

**PETENG 244. Modeling of 3D Geological Objects with Gocad**—Accurate 3D modeling of subsurface structures as prerequisite for decision making. Concepts and methods for modeling the complex geometries and spatial distribution of geological objects. Building 3D models using the Gocad software. The definition and placement of discrete curves and surfaces. Integration of diverse types of data. Flexible volume modeling algorithms used to conform the volume objects to both the structural model and the data.

*3 units (Journel, Caumon) not given 2004-05*

**PETENG 245. Probability Theory**—(Same as GEOPHYS 245.) Probabilistic formulations and solutions to inverse problems. Monte Carlo methods for solving inverse problems. Metropolis algorithm. Deterministic solutions using maximum likelihood, gradient methods. Dealing with prior probability and data uncertainty. Gaussian and non-Gaussian model formulations. Application to Earth Science problems. Prerequisite: introduction to probability theory course.

*3 units (Tarantola) not given 2004-05*

**PETENG 246. Reservoir Characterization and Flow Modeling with Outcrop Data**—(Same as GES 246.) Project provides earth science students with an understanding of how to use outcrop observations in quantitative geological modeling and flow simulation, and addresses a specific reservoir management problem by studying a suitable outcrop analog (weekend field trip), constructing geostatistical reservoir models, and performing flow simulation. An introduction, through an applied example, to the relationship between the different disciplines.

*3 units, Aut (Aziz, Graham, Journel)*

**PETENG 251. Thermodynamics of Equilibria**—Lectures, problems. The volumetric behavior of fluids at high pressure. Equation of state representation of volumetric behavior. Thermodynamic functions and conditions of equilibrium, Gibbs and Helmholtz energy, chemical potential, fugacity. Phase diagrams for binary and multicomponent systems. Calculation of phase compositions from volumetric behavior for multicomponent mixtures. Experimental techniques for phase-equilibrium measurements.

*3 units, Aut (Jessen)*

**PETENG 255. Master's Report on Energy Industry Training**—Provides on-the-job training for master's degree students under the guidance of experienced, on-site supervisors. Students must submit a concise report detailing work activities, problems, assignments, and key results. Prerequisite: consent of adviser.

*1-3 units, Sum (Staff)*

**PETENG 259. Basic T.A. Training**—For teaching assistants in Petroleum Engineering. Five two-hour sessions in the first half of the quarter. Awareness of different learning styles, grading philosophies, fair and efficient grading, text design; presentation and teaching skills, Powerpoint slide design; presentation practice in small groups. Taught in collaboration with the Center for Teaching and Learning.

*1 unit, Spr (Gerritsen)*

**PETENG 260. Groundwater Pollution and Oil Slicks: Environmental Problems in Petroleum Engineering**—Sources and types of wastes in petroleum operations. Partitioning of hydrocarbons in soil. Review of single phase flow. Multiphase flow of oil, water, and air. Movement of hydrocarbons in the vadose zone and in the groundwater. Remediation and cleanup techniques: air stripping and sparging, bioremediation, steam flooding, and solvent and surfactant injection. Drilling wastes. The physical processes affecting the spread of oil slicks at sea. Methods for containing and removing the spill and cleaning polluted beaches.

*3 units (Juanes) not given 2004-05*

**PETENG 267. Engineering Valuation and Appraisal of Oil and Gas Wells, Facilities, and Properties**—(Same as PETENG 167.) Appraisal of development and remedial work on oil and gas wells; appraisal of producing properties; estimation of productive capacity, reserves; operating costs, depletion, and depreciation; value of future profits, taxation, fair market value; original or guided research problems on economic topics with report. Prerequisite: consent of instructor. GER:2b

*3 units, Win (Kourt, Pande)*

**PETENG 268. Arctic Energy Resources and their Utilization**—Pressure to develop these resources. Techniques for accessing Arctic energy resources, environmental impact, the transportation of oil and gas over long distances, and how environmental impact is minimized. The magnitude and uncertainty associated with estimates of energy resources within the Arctic. Field trip to the Alaskan North Slope during Spring Break. Enrollment limited to 12. Prerequisite: consent of instructor. Recommended: Petroleum Engineering or Earth Systems background.

*1 unit, Win (Kovscek)*

**PETENG 269. Geothermal Reservoir Engineering**—Conceptual models of heat and mass flows within geothermal reservoirs. The fundamentals of fluid/heat flow in porous media; convective/conductive regimes, dispersion of solutes, reactions in porous media, stability of fluid interfaces, liquid and vapor flows. Interpretation of geochemical, geological, and well data to determine reservoir properties/characteristics. Geothermal plants and the integrated geothermal system.

*3 units (Horne) alternate years, not given 2005-06*

**PETENG 273. Special Topics in Petroleum Engineering**

*1-3 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 280. Oil and Gas Production Engineering**—(For graduate students; see 180.)

*3 units (Tchelepi) not given 2004-05*

**PETENG 281. Applied Mathematics in Reservoir Engineering**—Lectures, problems. The philosophy of the solution of engineering problems. Methods of solution of partial differential equations: Laplace transforms, Fourier transforms, wavelet transforms, Green's functions, and boundary element methods. Prerequisites: ME 300B or MATH 131, and consent of instructor.

*3 units (Juanes) alternate years, not given 2005-06*

**PETENG 284. Optimization: Deterministic and Stochastic Approaches**—Deterministic and stochastic methods for optimization in earth sciences and engineering. Linear and nonlinear regression, classification and pattern recognition using neural networks, simulated annealing and genetic algorithms. Deterministic optimization using non-gradient-based methods (simplex) and gradient-based methods (conjugated gradient, steepest descent, Levenberg-Marquardt, Gauss-Newton), eigenvalue and singular value decomposition. Applications in petroleum engineering, geostatistics, and geophysics. Prerequisite: ME 200A. Notions of Probability Theory, or consent of instructor.

*3 units, Aut (Caers)*

**PETENG 285A. SUPRI-A Research Seminar: Enhanced Oil Recovery**—Focused study in research areas within the department. Graduate students may participate in advanced work in areas of interest prior to making a final decision on a thesis subject. Prerequisite: consent of instructor. (AU)

*1 unit, Aut, Win, Spr (Kovscek, Castanier)*

**PETENG 285B. SUPRI-B Research Seminar: Reservoir Simulation**—Focused study in research areas within the department. Graduate students may participate in advanced work in areas of interest prior to making a final decision on a thesis subject. Prerequisite: consent of instructor. (AU)

*1 unit Aut, Win, Spr (Aziz, Durlofsky, Tchelepi, Juanes)*

**PETENG 285C. SUPRI-C Research Seminar: Gas Injection Processes**—Focused study in research areas within the department. Graduate students may participate in advanced work in areas of interest prior to making a final decision on a thesis subject. Prerequisite: consent of instructor. (AU)

*1 unit, Aut, Win, Spr (Orr, Gerritsen, Jessen, Juanes)*

**PETENG 285D. SUPRI-D Research Seminar: Well Test Analysis**—Study in research areas within the department. Graduate students may participate in advanced work in areas of interest prior to making a final decision on a thesis subject. Prerequisite: consent of instructor. (AU)

*1 unit, Aut, Win, Spr (Horne)*

**PETENG 285F. SCRF Research Seminar: Geostatistics and Reservoir Forecasting**—Study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Stanford Center for Reservoir Forecasting program. Prerequisite: consent of instructor. (AU)

*1 unit, Aut, Win, Spr (Journel, Caers)*

**PETENG 285G. Geothermal Reservoir Engineering Research Seminar**—Study in research areas within the department. Graduate students may participate in advanced work in areas of interest prior to making a final decision on a thesis subject. Presentation required for credit. Prerequisite: consent of instructor. (AU)

*1 unit, Aut, Win, Spr (Horne)*

**PETENG 285H. SUPRI-HW Research Seminar: Horizontal Well Technology**—Study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Current research in productivity and injectivity of horizontal wells. Prerequisite: consent of instructor. (AU)

*1 unit, Aut, Win, Spr (Aziz, Durlofsky)*

**PETENG 290. Numerical Modeling of Fluid Flow in Heterogeneous Porous Media**—How to mathematically model and solve elliptic partial differential equations with variable and discontinuous coefficients describing flow in highly heterogeneous porous media. Topics include finite difference and finite volume approaches on structured grids, efficient solvers for the resulting system of equations, Krylov space methods, preconditioning, multi-grid solvers, grid adaptivity and adaptivity criteria, multiscale approaches, and effects of anistropy on solver efficiency and accuracy. MATLAB programming and application of commercial or public domain simulation packages. Prerequisites: CME 200, 204, 206 (formerly ME 300A,B,C), or equivalents with consent of instructor.

*3 units (Gerritsen, Tchelepi) not given 2004-05*

**PETENG 300. Earth Sciences Seminar**—(Same as EARTHSYS 300, GEOPHYS 300, GES 300, IPER 300.) Required for all incoming graduate students. Research questions, tools, and approaches of faculty members from all departments in the School of Earth Sciences. Goals are: to inform new graduate students about the school's range of scientific interests and expertise; and to introduce them to each other across departments and research groups. Two faculty members present work at each meeting.

*1 unit, Aut (Staff)*

**PETENG 355. Doctoral Report on Energy Industry Training**—On-the-job training for doctoral students under the guidance of on-site supervisors. Students submit a report on work activities, problems, assignments, and results. Prerequisite: consent of adviser.

*1-3 units, Sum (Staff)*

**PETENG 359. Teaching Experience in Petroleum Engineering**—Advanced training course for TAs in Petroleum Engineering. Three two-hour sessions in the first half of the quarter: course design; lecture design and preparation; and lecturing practice in small groups. Classroom teaching practice in a Petroleum Engineering course for which the participant is the TA (may be in a later quarter). Taught in collaboration with the Center for Teaching and Learning.

*1 unit, Aut (Gerritsen, Dunbar)*

**PETENG 360. Advanced Research Work in Petroleum Engineering**—Graduate-level work in experimental, computational, or theoretical research. Special research not included in graduate degree program.

*1-10 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 361. Master's Degree Research in Petroleum Engineering**—Experimental, computational, or theoretical research. Advanced technical report writing. Limited to 6 units total.

*1-6 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 362. Engineer's Degree Research in Petroleum Engineering**—Graduate-level work in experimental, computational, or theoretical research for Engineer students. Advanced technical report writing. Limited to 15 units total, or 9 units total if 6 units of 361 previously credited.

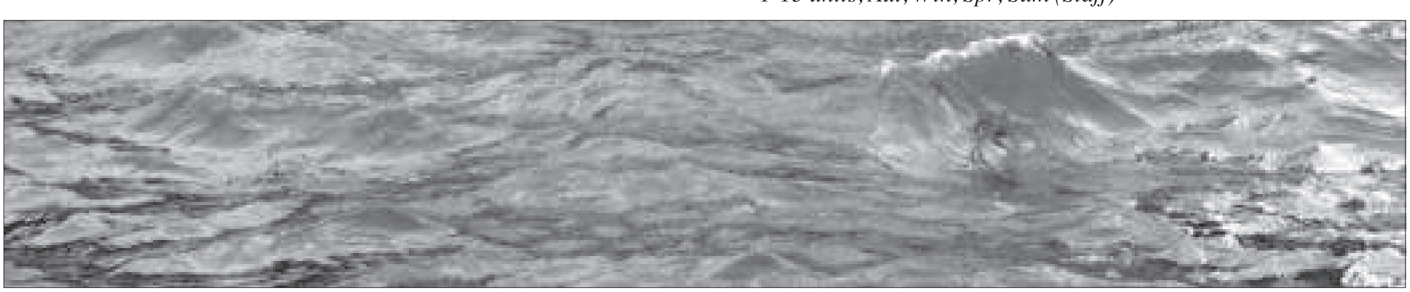
*1-10 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 363. Doctoral Degree Research in Petroleum Engineering**—Graduate-level work in experimental, computational, or theoretical research for Ph.D. students. Advanced technical report writing.

*1-10 units, Aut, Win, Spr, Sum (Staff)*

**PETENG 365. Special Research Topics in Petroleum Engineering**—Graduate-level research work not related to report, thesis, or dissertation.

*1-15 units, Aut, Win, Spr, Sum (Staff)*



# SCHOOL OF EDUCATION

*Emeriti: (Professors)* J. Myron Atkin, Edwin M. Bridges, Robert C. Calfee, Elizabeth Cohen, Larry Cuban, Nathaniel L. Gage, James Greeno, Henry M. Levin, Richard Lyman (President emeritus), James G. March, William F. Massy, Nel Noddings, Thomas Rohlen, Lee S. Shulman, George D. Spindler, Carl E. Thoresen, David B. Tyack, Hans Weiler

*Dean:* Deborah J. Stipek

*Associate Dean for Academic Affairs:* Eamonn Callan

*Associate Dean for Administration:* Victoria Oldberg

*Associate Dean for External Relations:* Patricia Nicholson

*Professors:* John Baugh, Anthony Bryk, Eamonn Callan, Martin Carnoy, William Damon, Linda Darling-Hammond, Elliot W. Eisner, Pamela Grossman, Patricia J. Gumport, Edward Haertel, Connie Juel, Michael W. Kirst, John D. Krumboltz, David Labaree, Raymond P. McDermott, Milbrey McLaughlin, Debra Meyerson, Ingram Olkin, Amado M. Padilla, Roy Pea, Denis C. Phillips, Walter Powell, Francisco O. Ramirez, Richard J. Shavelson, Deborah J. Stipek, Myra H. Strober, Guadalupe Valdés, Decker F. Walker, Sam Wineburg

*Associate Professors:* Arnetha Ball, Joanne T. Boaler, Teresa C. LaFromboise, Susanna Loeb, David Rogosa, Daniel Schwartz

*Assistant Professors:* Anthony L. Antonio, Brigid J. Barron, Bryan Brown, Daniel McFarland, Deanne R. Perez-Granados, Na'ilah Suad Nasir, Joy Williamson

*Associate Professors (Teaching):* Stephen Davis, Shelley Goldman, Rachel Lotan, Debra Meyerson

*Lecturers:* Denise Pope, Ann Porteus

*Courtesy Professors:* Eric Hanushek, John Rickford

*Courtesy Assistant Professor:* Robert Reich

*Consulting Assistant Professors:* B.J. Fogg, Nancy Baker

*Visiting Professor:* Nadeen Ruiz

*School Offices:* Cubberley 101

*Mail Code:* 94305-3096

*Phone:* (650) 723-2109

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*Web Site:* http://ed.stanford.edu/suse

Courses given in the School of Education have the subject code EDUC. For a complete list of subject codes, see Appendix.

The School of Education prepares scholars, teachers, teacher educators, policy analysts, evaluators, researchers, administrators, and other educational specialists. Four graduate degrees with specialization in education are granted by the University: Master of Arts, Master of Arts in Teaching (Subject), Doctor of Education, and Doctor of Philosophy. While no undergraduate majors are offered, the school does offer a number of courses for undergraduates, an undergraduate honors program, and a variety of tutoring programs.

The School of Education is organized into three Program Area Committees: Curriculum Studies and Teacher Education (C&TE); Psychological Studies in Education (PSE); and Social Sciences, Policy, and Educational Practice (SSPEP).

In addition, several cross-area programs are sponsored by faculty from more than one area. These programs include the doctoral Learning Sciences and Technology Design Program (LSTD); three master's level programs: the Stanford Teacher Education Program (STEP); the Prospective Principals Program (PPP); and the Learning, Design, and Technology Program (LDT); and the undergraduate honors program.

These Program Area Committees function as administrative units that act on admissions, plan course offerings, assign advisers, and determine program requirements. Various subspecialties or concentrations exist within most of these areas. Faculty members are affiliated primarily with one area but may participate in several programs. While there is a great deal of overlap and interdisciplinary emphasis across areas and programs, students are affiliated with one area committee or program and must meet its degree requirements.

Detailed information about admission and degree requirements, faculty members, and specializations related to these area committees and programs can be found in the publication *School of Education Guide to Graduate Studies* and at http://ed.stanford.edu/suse.

The School of Education offers an eight-week summer session for admitted students only. The school offers no correspondence or extension courses, and in accordance with University policy, no part-time enrollment is allowed. Work in an approved internship or as a research assistant is accommodated within the full-time program of study. Exceptions are the Prospective Principals and Honors Coop Programs.

## UNDERGRADUATE PROGRAMS

The School of Education focuses on graduate education and research training and does not offer an undergraduate major. However, undergraduate education is of concern to the School, and courses and programs are available to those interested in the field of education. The following courses are appropriate for undergraduates:

99X. The Undergraduate Community Internship Practicum
102. Culture, Class and Educational Opportunity
103A. Exploring Elementary Teaching Junior Seminar
106. Interactive Media in Education
107. The Politics of International Cooperation in Education
110. Sociology of Education: The Social Organization of Schools
111X. The Young Adult Novel: A Literature for and about Adolescents
124X. Collaborative Design and Research of Technology: Integrated Curriculum
130. Introduction to Counseling
131X. Mediation for Dispute Resolution
134. Career and Personal Counseling
135X. Race, Ethnicity, and Linguistic Diversity in Teacher Preparation
138Q. Educational Testing in American Society
149. Theory and Issues in the Study of Bilingualism
155. Development of Measuring Instruments
156A. Understanding Racial and Ethnic Identity
165X. History of Higher Education in the United States
178X. Latino Families, Languages, and Schools
179. Urban Youth and their Institutions: Research and Practice
193A. Peer Counseling: Bridge Community
196. Feminist Theories of Work and Family
197. Education and the Status of Women: Comparative Perspective
199. Undergraduate Honors Seminar
201. History of Education in the United States
201A. History of African American Education
201B. Education for Liberation
202. Introduction to Comparative and International Education
204. Introduction to Philosophy of Education
208B. Curriculum Construction
212X. Urban Education
214. Popper, Kuhn, and Lakatos
218X. Topics in Cognition and Learning: Spatial Cognition
220B. Introduction to the Politics of Education
220D. History of School Reform: Origins, Policies, Outcomes, and Explanations
221A. Policy Analysis in Education
224. Information Technology in the Classroom
232C. Introduction to Learning
243. Writing Across Languages and Cultures: Research on Writing and Writing Instruction
247. Moral Education
250B. Statistical Analysis in Educational Research: Analysis of Variance
255. Human Abilities
270A. Learning to Lead in Public Service Organizations
290. Leadership: Research, Policy, and Practice
294. Theories of Human Development
298. Online Learning Communities
304. The Philosophical and Educational Thought of John Dewey
306D. World, Societal, and Educational Change: Comparative Perspectives

312. Microsociology: Interaction Processes in Education
323A. Introduction to Education Policy Analysis
326X. Legal Dilemmas and Administrative Decision Making in Schools
342. Child Development and New Technologies
354X. School-Based Decision Making
356X. Memory, History, and Education
359A. Research in Science and Math Education: Assessment and Evaluation
370X. Theories of Cognitive Development
371X. Cognitive Development in Childhood and Adolescence
374A. Research Workshop: Knowledge Networks
377. Organization and Style in Research Reports Comparing Institutional Forms
382. Student Development and the Study of College Impact
384. Advanced Topics in Higher Education

## HONORS PROGRAM

An honors program is available to undergraduates to supplement their regular majors outside the school. This program permits interested and able undergraduates at Stanford to build on the training received in their major field of study by pursuing additional courses and a research or practicum project in a related area of education.

Students apply for entry during the junior year. Applications are available on the web at http://www.stanford.edu/dept/SUSE/honors. The current director of the program is Professor John Krumboltz. At least one course must be taken from each of the following areas:

1. Educational policy and history in the U.S.: courses include American Education and Public Policy; History of Education in the United States; Children, Civil Rights, and Public Policy in the U.S.; Introduction to the Study of International Comparative Education; History of Higher Education in the U.S.
2. Contemporary problem areas: courses include Urban Youth and their Institutions: Research and Practice; Theory and Issues in the Study of Bilingualism; Education and the Status of Women: Comparative Perspectives; Contemporary Social Issues in Child and Adolescent Development.
3. Foundational disciplines: courses include Social Sciences and Educational Analysis; Problems in Sociology of Education; Problems of Intelligence, Information, and Learning; Introduction to Philosophy of Education.

A directed reading course as well as directed research courses with a faculty member in Education are also required. Students in the program should enroll in 199A,B,C, Undergraduate Honors Seminar, during their senior year.

Near the end of Spring Quarter, successful candidates for honors orally present brief reports of their work and findings at a mini-conference. All honors students in Education are expected to attend this conference.

## COTERMINAL BACHELOR'S AND MASTER'S PROGRAM

The School of Education admits a small number of students from undergraduate departments within the University into a coterminal bachelor's and M.A. program. Two of the three program area committees offer the coterminal degree, as does the Stanford Teacher Education Program (STEP). For information about the STEP coterminal option, see the details under STEP below. Students in this program receive the bachelor's degree in their undergraduate major and the master's degree in Education. Approval of the student's undergraduate department and the School of Education is required. Undergraduates may apply when they have completed 120 units, and must submit their application no later than the quarter prior to the expected completion of their undergraduate degree. Students study for both the bachelor's and master's degrees simultaneously. The number of units required for the M.A. degree depends on the program requirements within the School of Education; the minimum is 45 units.

Applicants may obtain coterminal degree application materials from the School of Education's Academic Services Office.

## GRADUATE PROGRAMS

Several advanced degree programs are offered by the School of Education and are described below. Requirements vary somewhat across programs. Both University and School of Education requirements must be met for each degree. The University requirements are detailed in the "Graduate Degrees" section of this bulletin. Students are urged to read this section carefully, noting residency, tuition, and registration requirements. A student who wishes to enroll for graduate work in the School of Education must be qualified and admitted to graduate standing by one of the school's area committees.

Complete information about admissions procedures and requirements is available at http://gradadmissions.stanford.edu, or by writing Stanford University Graduate Admissions, Old Union, 520 Lasuen Mall, Stanford, CA 94305-3005, or at http://ed.stanford.edu/suse. The admissions packet includes the publication *School of Education Guide to Graduate Studies*, which outlines degrees, programs, admission and graduation requirements, and research interests of the faculty. All applicants must submit scores from the Graduate Record Examination General Test (verbal, quantitative, and analytical or analytical writing areas); TOEFL scores are also required from those whose first language is not English.

## MASTER OF ARTS

The M.A. degree is conferred by the University upon recommendation of the faculty of the School of Education and the University Committee on Graduate Studies. The minimum unit requirement is 45 quarter units earned at Stanford as a graduate student. Students must maintain a grade point average (GPA) of 3.0 or better in courses applicable to the degree, and a minimum of 27 units must be taken in the School of Education. Students typically enroll in 15 to 18 units per quarter. They must enroll in at least 11 units of work each quarter unless their program makes special provision for a lower quarterly minimum. Master's students should obtain detailed program requirements from the Master's Coordinator, located in Academic Services in the School of Education. All programs require a final project, scholarly paper, or monograph. Additional detailed information regarding program content, entrance, and degree requirements is available at http://ed.stanford.edu/suse and in the *School of Education Guide to Graduate Studies*. Upon admission, each student is assigned a faculty adviser from the appropriate area committee to begin early planning of a coherent program.

Master of Arts degrees are offered for the following specializations (the sponsoring area committee and concentration is listed in parentheses):

Art Education (C&TE)
Curriculum and Teacher Education (C&TE).* Students may specialize in English, Literacy, Mathematics, Science, or History/Social Science Education.
International Comparative Education (SSPEP-ICE)
International Educational Administration and Policy Analysis (SSPEP-ICE)
Dual Degree Program with Graduate School of Business (SSPEP)
Joint Degree in Policy, Organization, and Leadership Studies (SSPEP-APA)
Learning, Design and Technology (Cross-Area)
Prospective Principals Program (SSPEP-APA) (not offered 2004-05)
Social Sciences in Education (SSPEP-SSE). Students may specialize in Anthropology, Economics, Educational Linguistics, History, Philosophy or Sociology of Education.

* This program in CTE is not a credentialing program; for the latter, see STEP below.

In addition, an M.A. degree with a teaching credential is offered in the Stanford Teacher Education Program (Cross-Area—STEP).

### STANFORD TEACHER EDUCATION PROGRAM (STEP)

STEP offers a Master of Arts program to prepare humanities and sciences college graduates for careers as teachers of English, languages (French, German, Japanese, Spanish), mathematics, science (biology, chemistry, earth science, physics), and social science. To be successful in classrooms with diverse students, STEP helps participants become more aware of their values, more flexible in their teaching and learning styles, and more knowledgeable in their subject matter.

The 12-month STEP year begins in June with a Summer Quarter of intensive academic preparation and experience in a local summer school. During the academic year, students take courses in professional education and academic subjects; they also teach part-time in middle or high schools for the entire public school year. The master's degree and Single Subject Teaching Credential require 45 quarter units, taken during four quarters of continuous residency.

A coterminal teaching program is also available to Stanford undergraduates. Students are strongly encouraged to apply in their eighth quarter, or Autumn Quarter of their junior year. Students complete their disciplinary degree while beginning education study that concludes in a master's degree following the STEP student teaching year. This program also includes the preparation of elementary (K-8) school teachers.

Applicants are required to pass the California Basic Educational Skills Test (CBEST) and must demonstrate subject matter competence in one of two ways: (1) by passing the CSET subject assessment test in their field, or (2) by completing a California state-approved subject matter preparation program.

Further information regarding admission requirements, course work, and credential requirements is available at http://ed.stanford.edu/suse and in the *School of Education Guide to Graduate Studies*.

### PROSPECTIVE PRINCIPALS PROGRAM (PPP) (NOT OFFERED 2004-05)

The Prospective Principals Program at Stanford offers the M.A. degree with the Preliminary Administrative Services Credential (Tier 1). It enables prospective principals to become leaders, to manage ideas and resources, and to achieve worthwhile educational results for a diverse student population. This is accomplished through three consecutive summers of full-time study and is therefore available to persons working in a school system during the academic year. Teaching experience is a prerequisite for admission to this program. The master's degree requires 45 quarter units. In order to qualify for the credential, three additional quarter units for a total of 48 quarter units, including internship units, are necessary. Additional information regarding admission requirements, course work, and credential requirements is available in the *School of Education Guide to Graduate Studies* or at http://ed.stanford.edu/suse.

### MASTER OF ARTS IN TEACHING (SUBJECT)

The degree of Master of Arts in Teaching (M.A.T.) is reserved for experienced teachers or individuals who have completed a program of teacher preparation; it is offered in conjunction with a variety of academic departments in the School of Humanities and Sciences.

## DOCTORAL DEGREES

The School of Education offers two types of doctoral degrees. The Doctor of Philosophy (Ph.D.) degree is offered by all program area committees. The Doctor of Education (Ed.D.) degree (not offered 2004-05) is offered only in the higher education concentration within the area of SSPEP. Both degrees are conferred by the University upon recommendation by the faculty of the School of Education and the University Committee on Graduate Studies. The timetable for the stages of progress is the same for both degrees. The unit requirement for both degrees is a minimum of 135 units of course work and research completed at Stanford beyond the baccalaureate degree. Students may transfer up to 45 units of graduate course work taken within the past seven years. Students must maintain a grade point average (GPA) of 3.0 (B) or better in courses applicable to the degree.

Students should note carefully that admission to graduate standing by the University to work toward a doctoral degree does not in itself constitute admission to candidacy for the degree. Students must qualify and apply for candidacy by the end of their second year of study and should obtain information about procedures and requirements during their first year.

The two doctoral degrees offered in the School of Education differ in emphasis, purpose, and the intended careers of those who pursue them. They are equivalent with respect to the amount of time required and the rigor and quality of work demanded. In the Ph.D. degree program, there is greater emphasis on theory and research; the emphasis in the Ed.D. program is on informed and critical applications of existing knowledge to educational practice.

The Ph.D. degree is designed for students who are preparing for (1) research work in public school systems, branches of government, or specialized institutions; (2) teaching roles in education in colleges or universities, and research connected with such teaching; or (3) other careers in educational scholarship and research.

The Ed.D. degree is a professional educational degree intended to meet the needs of (1) those who wish a thorough and comprehensive professional understanding of and competence in dealing with educational problems met by administrators, supervisors, and curriculum specialists; and (2) those who wish a scholarly preparation for teaching education in colleges or universities.

Ph.D. students must complete a minor in another discipline taught outside the school, or hold an acceptable master's degree outside the field of education, or complete an approved distributed minor that combines relevant advanced work taken in several disciplines outside the school. A minor is not required for the Ed.D.

Upon admission, an initial adviser assigned from the admitting area committee works with the student to establish an appropriate and individualized course of study, a relevant minor, and project research plans. Other faculty members may also be consulted in this process. Details about the various administrative and academic requirements for each area committee and the School of Education, along with general time frame expectations, are given at http://ed.stanford.edu/suse and in the *School of Education Guide to Graduate Studies*. Complete guidelines may be obtained from the specific area committees.

The following doctoral specializations (with their sponsoring area and concentration) are offered:

Administration and Policy Analysis (SSPEP-APA)
Anthropology of Education (SSPEP-SSE)
Art Education (C&TE)
Child and Adolescent Development (PSE)
Economics of Education (SSPEP-SSE)
Educational Linguistics (SSPEP-SSE)
Educational Psychology (PSE)
English Education/Literacy Education (C&TE)
General Curriculum Studies (C&TE)
Higher Education (SSPEP-APA) (Ed.D. degree not offered 2004-05)
History of Education (SSPEP-SSE)
International Comparative Education (SSPEP-ICE)
Learning Sciences and Technology Design (CTE, PSE, SSPEP)
Mathematics Education (C&TE)
Philosophy of Education (SSPEP-SSE)
Science Education (C&TE)
Interdisciplinary Studies (SSPEP-SSE)
History/Social Science Education (C&TE)
Sociology of Education (SSPEP-SSE)
Teacher Education (C&TE)

### PH.D. MINOR FOR STUDENTS OUTSIDE EDUCATION

Candidates for the Ph.D. degree in other departments or schools of the University may elect to minor in Education. Requirements include a minimum of 20 quarter units of graduate course work in Education and a clear field of concentration. Students choosing to minor in education should meet with the Associate Dean for Academic Affairs to determine a suitable course of study early in their program.

# COURSES

## OTHER DIVISIONS OF THE UNIVERSITY

Teachers, administrators, researchers, and specialists are expected to have substantial knowledge of a variety of academic fields outside the areas encompassed by professional education. Graduate students in the School of Education are, therefore, urged to consider the courses offered in other divisions of the University in planning their programs.

The numbering of courses in the School of Education identifies approximately the course level and the audience to which a given course is offered:

*Below 100 level*—For undergraduates
*100-level*—Primarily for undergraduates (graduate students may enroll)
*200- and 300-level*—For M.A. and first- and second-year doctoral students, and qualified undergraduates
*400-level*—Research seminars or similar courses primarily for third-year doctoral students and beyond

Course descriptions are in numerical order and indexed by program areas.

An 'X' suffix denotes a new experimental course. With faculty approval, after being taught twice, it can be offered as a regular course in the School of Education.

An 'S' suffix denotes a special course, given only once and usually taught by visiting faculty.

## EDUCATION COURSES

**EDUC 95Q. Exploring School Reform**—Stanford Introductory Seminar. Preference to sophomores considering careers in education and who want to combine this course with fieldwork or school visits. Case studies of school reform and issues of continuity and change in education. Topics: origins, outcomes, and explanations of social movements that have worked for social justice in education; the balance of social diversity and shared political values; the assessment of success in education reform; the meanings of progressive and traditional in teaching and learning, and their relationship to the No Child Left Behind law.
*2 units, Win (Tyack)*

**EDUC 99X. The Undergraduate Community Internship Practicum**—Goal is to provide undergraduates with understanding of the environments and contexts of school-age youth and their families. Students, primarily juniors in the STEP Coterminal Teaching Program engaged in approved community-based internships, discuss the nature of community and how community dynamics affect youth and their families, students' relationships to school, and academic achievement.
*1-2 units, Aut, Win, Spr (Stout)*

**EDUC 101X. Undergraduate Teaching Practicum**—Students engage in real world teaching by observing and assisting teachers in the classroom, and being involved in structured interactions such as tutoring. Weekly meetings concerning field experiences, readings, and developing skills and knowledge. This course provides the opportunity to consider whether a teaching career is a good match.
*3-5 units, Aut (Staff)*

**EDUC 102. Culture, Class, and Educational Opportunity**—Upward Bound and EPASSA counselors work with students from educationally disadvantaged backgrounds. Topics: language education, culture and family, class management, school finance, and community-school relations. Mandatory school visits and classroom observations. Enrollment limited to 15. (SSPEP)
*4 units, Spr (Staff)*

**EDUC 103A. Exploring Elementary Teaching: Seeing a Child through Literacy**—Undergraduates engage in the real world of teaching by visiting classrooms and other venues for children; observing teachers in the practice of their craft; observing children in the processes of learning and social interaction; assisting teachers and child-support professionals by engaging children in structured interactions such as tutoring and after-school programs; reflecting on the roles and purposes of teaching and schooling.
*3 units, Aut (Juel)*

**EDUC 103B. Exploring Elementary Teaching: The Complexities of the Teaching Profession**—Schools as a reflection of society. What is the purpose of school? How are schools organized? How do students from different backgrounds experience school? What structures support or diminish student success in school? Who decides these fundamental issues? Issues of classroom culture and community and the relationship between content and structure.
*3 units, Win (Lit)*

**EDUC 103C. Exploring Elementary Teaching Junior Seminar: Issues in the Teaching of English** —Undergraduates engage in the real world of teaching. Historical and legal foundations, and materials, methods, and strategies for English and primary language development. Students tutor an English learner.
*3 units, Spr (Ruiz)*

**EDUC 106. Interactive Media in Education**—Workshop. (CTE)
*3-5 units (Walker) not given 2004-05*

**EDUC 107. The Politics of International Cooperation in Education**—(Ph.D. students register for 306B; see 306B.) For undergraduates and master's students. (SSPEP/ICE, APA)
*4 units, Win (Inoue)*

**EDUC 108X. Case Studies from the History of Science**—Case studies, primarily from the histories of chemistry, geology, and biology, inform the practice of secondary science teaching, primarily for coterminal students.
*2 units (Lythcott) not given 2004-05*

**EDUC 110. Sociology of Education**—(Graduate students register for 310; same as SOC 132/232.) Sociological approaches to school organization and its effects. Introduction to topics and case studies that elaborate on the embeddedness of classrooms and schools in social environments, spanning school processes such as stratification, authority, moral and technical specialization, curricular differentiation, classroom instruction, voluntary associations, social crowds, and peer influence. (SSPEP) GER:3b
*4 units, Spr (McFarland)*

**EDUC 111X. The Young Adult Novel: A Literature For and About Adolescents**—For undergraduates considering teaching or working with adolescents, and for those planning to apply to the coterminal program in the Stanford Teacher Education program (STEP). Students work together to define the genre of young adult novels. What they reveal about adolescence in America. How to read and teach young adult literature.
*5 units, Aut (Grossman)*

**EDUC 117X. Research and Policy on Postsecondary Access**—The transition from high school to college. Focus is on high school preparation, college choice, remediation, pathways to college, and first-year adjustment. The role of educational policy in affecting postsecondary access.
*3 units, Spr (Antonio)*

**EDUC 124X. Collaborative Design and Research of Technology: Integrated Curriculum**—For education students interested in curriculum development in math and science education. Studio-based, hands-on approach to the research and development of technology tools and curriculum materials. Focus is on the role that technologies can play in teaching and learning in the content areas.
*3-4 units, Win (Goldman)*

**EDUC 130. Introduction to Counseling**—The theories and techniques of counseling, emphasizing the clients' individual and cultural differences, and construction of one's own theory of the counseling process and outcome. Two psychotherapeutic theories, cognitive-behavioral and existential-humanistic, are supplemented with a third theory of each student's choice. Experiential, problem-based focus on how to develop self-awareness and conceptual understandings of the counseling process in culturally diverse contexts. (PSE)
*3 units, Win (Krumboltz)*

**EDUC 131X. Mediation for Dispute Resolution**—(Same as PSYCH 152.) Mediation is more effective and less expensive than other forms of settling disputes such as violence, lawsuits, or arbitration. How mediation can be structured to maximize the chances for success. Simulated mediation sessions.
*3 units, Aut (Krumboltz)*

**EDUC 134. Career and Personal Counseling**—(Graduate students register for 234; same as PSYCH 192.) Methods of integrating career and personal counseling with clients and counselors from differing backgrounds. Practice with assessment instruments. Case studies of bicultural role conflict. Informal experience in counseling. (PSE)
*3 units, Spr (Krumboltz)*

**EDUC 135X. Race, Ethnicity, and Linguistic Diversity in Teacher Preparation**—(Graduate students register for 337X; see 337X)
*3-4 units, Spr (Ball)*

**EDUC 138Q. Educational Testing in American Society**—Stanford Introductory Seminar. Preference to sophomores. Explanations for group and individual differences in test performance have been controversial this century, right up to current debates over affirmative action. The purposes and the logic of various testing programs, including classroom testing, admissions testing, and state and national testing programs. The meanings of reliability, validity, bias, and fairness in testing, developing the notion of validity argument as a conceptual tool for analyzing testing applications. Paper on some educational testing application.
*3 units, Aut (Haertel)*

**EDUC 144X. STEP Elementary Child Development**—How schools form a context for children's social and cognitive development. Focus is on early and middle childhood. Transactional processes between children and learning opportunities in classroom contexts. Topics include: alternative theoretical perspectives on the nature of child development; early experience and fit with traditional school contexts; assessment practices and implications for developing identities as learners; psychological conceptions of motivational processes and alternative perspectives; the role of peer relationships in schools; and new designs for learning environments. Readings address social science and methodological issues.
*3-4 units, Aut (Barron, Perez-Granados), Spr (Barron)*

**EDUC 147X. Human-Computer Interaction in Education**—Required for students in the Learning Design and Technology Master's Program. Introduction to the concepts underlying the design of human-computer interaction, including usability and affordances, direct manipulation, systematic design methods, user conceptual models and interface metaphors, design languages and genres, human cognitive and physical ergonomics, information and interactivity structures, design tools, and environments. Studio/discussion component applies these principles to the design of interactive technology for teaching and learning.
*3 units, Aut (Walker)*

**EDUC 148X. Critical Perspectives on Tutoring English Language Learners**—Theoretical foundation for volunteer tutors of English language learners in urban environments working with children in school-based programs or adults in community-based settings.
*3-5 units (Valdés) not given 2004-05*

**EDUC 149. Theory and Issues in the Study of Bilingualism**—(Graduate students register for 249; see 249; same as SPANLIT 207.)
*3-5 units, Aut (Valdés)*

**EDUC 150X. Introduction to Data Analysis and Interpretation**—Primarily for master's students with little or no experience. Focus is on reading literature and interpreting descriptive and inferential statistics, especially those commonly found in education. Topics: basic research design, instrument reliability and validity, description statistics, correlation, t-tests, simple analysis of variance, simple and multiple regression, and contingency analysis.
*4 units, Aut, Win (Porteus)*

**EDUC 151B. Qualitative Research Methods: Part 2**—Primarily for master's students. Prerequisite: 151X.
*4 units, Win (Staff)*

**EDUC 151X. Introduction to Qualitative Research Methods**—Primarily for master's students. Issues, ideas, and methods.
*3-4 units, Aut (Pope)*

**EDUC 155. Development of Measuring Instruments**—For students planning to develop written or performance tests or questionnaires for research and evaluation, and for teachers wishing to improve classroom examinations. Planning tests, writing items, item tryout and criticism, qualities desired in tests, and interview techniques. Lectures, case studies, and practical exercises. (PSE)
*3 units (Haertel) not given 2004-05*

**EDUC 156A. Understanding Racial and Ethnic Identity**—African American, Native American, Mexican American, and Asian American racial and ethnic identity development is explored to better understand the influence of social/political and psychological forces in shaping the experience of people of color in the U.S. Issues: the relative salience of race in relationship to other social identity variables, including gender, class, occupational, generational, and regional identifications. Bi- and multiracial identity status, and types of white racial consciousness.
*3-5 units (LaFromboise) alternate years, given 2005-06*

**EDUC 160. Introduction to Statistical Methods in Education**—(Master's students register for 150X.) Introduction to quantitative methods in educational research for doctoral students with little or no prior statistics. Organization of data, descriptive statistics, elementary methods of inference, hypothesis testing, and confidence intervals. Computer package used. Students cannot also receive credit for PSYCH 60 or for STATS 60/160. (all areas)
*4 units, Aut (Shavelson)*

**EDUC 165X. History of Higher Education in the U.S.**—(Graduate students register for 265X.) Major periods of evolution, particularly since the mid-19th century. The premise is that insights into contemporary higher education can be obtained through examining its antecedents, particularly regarding issues of governance, mission, access, curriculum, and the changing organization of colleges and universities. (SSPEP-APA)
*3-4 units, Aut (Labaree)*

**EDUC 166. The Centrality of Literacies in Teaching and Learning**—Focus is on principles in understanding, assessing, and supporting the reading and writing processes, and the acquisition of content area literacies in secondary schools. Literacy demands within particular disciplines and how to use oral language, reading, and writing to teach content area materials more effectively to all students. (STEP)
*3 units, Sum (Ball)*

**EDUC 167. Educating for Equity and Democracy**—Introduction to the theories and practices of equity and democracy in education. How to think about teaching and schooling in new ways; the individual moral and political reasons for becoming a teacher. (STEP)
*3 units, Sum (McDermott)*

**EDUC 175. African American English in Educational Context**—(Graduate students register for 275; see 275.)
*3 units (Staff) alternate years, given 2005-06*

**EDUC 177. Education of Immigrant Students: Psychological Perspectives**—(Graduate students register for 277.) Historical and contemporary approaches to educating immigrant students. Case study approach focuses on urban centers to demonstrate how stressed urban educational agencies serve immigrants and native-born U.S. students when confronted with overcrowded classrooms, controversy over curriculum, current school reform movements, and government policies regarding equal educational opportunity. (SSPEP)
*4 units (Padilla) not given 2004-05*

**EDUC 178X. Latino Families, Languages, and Schools**—The challenges facing schools to establish school-family partnerships with newly arrived Latino immigrant parents. How language acts as a barrier to home-school communication and parent participation. Current models of parent-school collaboration and the ideology of parental involvement in schooling. (SSPEP)
*3-5 units, Spr (Valdés)*

**EDUC 179. Urban Youth and Their Institutions: Research and Practice**—(Graduate students register for 279.) The determinants and consequences of urban life for youth, emphasizing disciplinary and methodological approaches to the study of policies and practices, and the growing gap between the perspectives of state and local organizations and those of youth and their communities. The diversity of urban youth experiences with respect to ethnicity, gender, and immigration histories. Case studies illustrate civic-level and grassroots institutions, their structures, networks, and philosophies; historical and contemporary examination of diverse realities of urban youth for policy makers, educators, and researchers. Limited enrollment. Prerequisite: consent of instructor. (SSPEP/APA)
*4-5 units, Aut (McLaughlin)*

**EDUC 179B. Best Practice and Policy in Youth Development**—(Graduate students register for 279B.) Focus is on youth development policies and practices: what makes them effective, and how they operate in broader institutional contexts. Research-based information; conceptual underpinnings; best learning from experience; and the perspective of expert youth workers, policy makers, and youth about what works.
*2-4 units, Spr (McLaughlin)*

**EDUC 180. Directed Reading in Education**—For undergraduates and master's degree students. (all areas)
*1-15 units, Aut, Win, Spr, Sum (Staff)*

**EDUC 185. Master's Thesis**—(all areas)
*1-15 units, Aut, Win, Spr, Sum (Staff)*

**EDUC 189. Introduction to Linguistics for Educational Researchers**—(Graduate students register for 289; see 289.)
*4 units (Baugh) not given 2004-05*

**EDUC 190. Directed Research in Education**—For undergraduates and master's degree students. (all areas)
*1-15 units, Aut, Win, Spr, Sum (Staff)*

**EDUC 193A. Peer Counseling: Bridge Community**—Topics: verbal and non-verbal skills, open and closed questions, paraphrasing, working with feelings, summarization, and integration. Individual training, group exercises, role play practice with optional video feedback. Sections on relevance to crisis counseling and student life. Guest speakers from University and community agencies. Students develop and apply skills in University settings.
*2 units, Aut, Win, Spr (Mendoza-Newman)*

**EDUC 193B. Peer Counseling: Chicano Community**—Topics: verbal and non-verbal attending and communication skills, open and closed questions, working with feelings, summarization, and integration. Salient counseling issues including Spanish-English code switching in communication, the role of ethnic identity in self-understanding, the relationship of culture to personal development, and Chicano student experience in University settings. Individual training, group exercises, role play, and videotape practice.
*2 units, Aut (Martinez)*

**EDUC 193C. Peer Counseling: The African American Community**—Topics: the concept of culture, Black cultural attributes and their effect on reactions to counseling, verbal and non-verbal attending, open and closed questions, working with feelings, summarization, and integration. Reading assignments, guest speakers, role play, and videotaped practice. Students develop and apply skills in the Black community on campus or in other settings that the student chooses.
*2 units, Aut (Edwards)*

**EDUC 193F. Peer Counseling: Asian American Community**—Topics: the Asian family structure, and concepts of identity, ethnicity, culture, and racism in terms of their impact on individual development and the counseling process. Emphasis is on empathic understanding of Asians in America. Group exercises.
*2 units, Spr (Brown)*

**EDUC 193N. Peer Counseling: Native American Community**—Topics: verbal and non-verbal communication, strategic use of questions, methods of dealing with strong feelings, and conflict resolution. How elements of counseling apply to Native Americans including client, counselor, and situational variables in counseling, non-verbal communication, the role of ethnic identity in self-understanding, the relationship of culture to personal development, the impact of family on personal development, gender roles, and the experience of Native American students in university settings. Individual skill development, group exercises, and role practice.
*2 units (Simms, Martinez) not given 2004-05*

**EDUC 196. Feminist Theories of Work and Families**—(Same as FEMST 102L.) Economic, sociological, and legal perspectives; mainstream and feminist theories are contrasted. Emphasis is on the present day U.S. with issues in other countries and/or other historical periods. Topics: labor force participation, occupational segregation, labor market discrimination, emotional labor, unpaid work, caring labor, child care, combining work and family, single-parent families, poverty, marriage, and divorce.
*4-5 units (Strober) not given 2004-05*

**EDUC 197. Education and the Status of Women: Comparative Perspective**—Theories and perspectives from the social sciences relevant to understanding the role of education in changing, modifying, or reproducing structures of gender differentiation and hierarchy. Cross-national research on the status of women and its uses to evaluate knowledge claims from varying perspectives. (SSPEP) GER:4c
*4-5 units, Spr (Staff)*

**EDUC 199A,B,C. Undergraduate Honors Seminar**—Required for all juniors and seniors in the honors program in the School of Education. Supports students' involvement and apprenticeships in educational research. Participants are expected to share ongoing work on their honors thesis. Prerequisite: consent of instructor.
*1 unit, Aut, Win, Spr (Krumboltz)*

**EDUC 200. The Work of Art and the Creation of Mind**—Collaboration among the Art, Dance, Drama, and Music programs, and the School of Education. The relationship between the work of art and the creation of mind: the work of art as a task of making something and as a form that has been made. How a conception of art develops and refines the mind. Observation of artists at work. The relationship between forms of art and forms of thought. What does either the perception or creation of art in any of its forms do to how one thinks and knows? GER:3a
*4 units, Win (Staff)*

**EDUC 201. History of Education in the United States**—How education came to its current forms and functions. From the colonial experience to the present. Focus is on the 19th-century invention of the common school system, 20th-century emergence of progressive education reform, and the developments since WW II. The role of gender and race, the development of the high school and the university, and school organization, curriculum, and teaching. (SSPEP) GER:3a
*4 units, Win (Labaree)*

**EDUC 201A. History of African American Education**—Survey of the pivotal points in African American educational history, including literacy attempts during slavery, the establishment of historically Black colleges and universities, the debate between liberal and vocational education, Black student rebellions on campuses during the 20s, and the establishment of Black studies and cultural centers. (SSPEP)
*3-4 units, Win (Williamson)*

**EDUC 201B. Education for Liberation**—How ethnic, gender, and religious groups have employed education to advance group self-determination and autonomy throughout history. How reformers attempted to impose educational prescriptions on these groups

*3-4 units, Spr (Williamson)*

**EDUC 202. Introduction to Comparative and International Education**—Introduction to the field of comparative and international education. Contemporary theoretical debates about educational change and development, and the international dimension of several contemporary issues in education. Emphasis is on the development of students' abilities to make cross-national and historical comparisons of educational phenomena. (SSPEP/ICE)

*4-5 units, Aut (Inoue)*

**EDUC 202I. Education Policy Workshop in International and Comparative Education**—For students in International and Comparative Education. Practical introduction to issues in educational policy making, educational planning, implementation, and the role of foreign expertise/ consultants in developing country contexts. (SSPEP/ICE)

*3-4 units, Spr (Staff)*

**EDUC 203B. The Problem of Arrogant Knowledge**—How the naming and maiming of learners is supported by a vocabulary of ability and disability and institutional slots and budget lines. How alienation can be a first step in reorganization. Marx on estranged labor, Lave and Mcdermott on estranged learning, and Merleau-Ponty and Volosinov on the dramatics of language activities in human affairs.

*2-3 units (McDermott) not given 2004-05*

**EDUC 204. Introduction to Philosophy of Education**—How to think philosophically about educational problems. Recent influential scholarship in philosophy of education. No previous study in philosophy required. (SSPEP)

*3 units, Aut (Callan)*

**EDUC 206A. Applied Research Methods in International and Comparative Education I: Introduction**—Required for all M.A. students in ICE and IEAPA; others by consent of instructor. Orientation to the M.A. program and research project, exploration of resources for study and research. (SSPEP/ICE)

*1 unit, Aut (Inoue)*

**EDUC 206B. Applied Research Methods in International and Comparative Education II: Master's Monograph Proposal**—Required for all M.A. students in ICE and IEAPA; others by consent of instructor. Development of research skills through discussion of theoretical and methodological issues in comparative and international education. Preparation of a research proposal for the M.A. monograph. (SSPEP/ICE)

*3 units, Win (Inoue)*

**EDUC 206C. Applied Research Methods in International and Comparative Education III: Masters Monograph Workshop**—The conclusion of the four quarter M.A. program in ICE and IEAPA; required of all M.A. students. Reviews of students' research in preparation for completion of their master's monograph. (SSPEP/ICE)

*3 units, Sum (Inoue)*

**EDUC 207A,B,C. Master's Seminar in Curriculum and Teacher Education**—Limited to master's students in C&TE. Designed to support students as they develop and conduct a master's project. Students discuss ideas for their project, learn about possibilities for master's projects, develop a plan for a project, carry it out, and write up the results with the assistance of the instructors and peers.

*1-2 units,* **A:** *Aut (Post)*
*1-5 units,* **B:** *Win,* **C:** *Spr (Post)*

**EDUC 208B. Curriculum Construction**—The theories and methods of curriculum development and improvement. Topics: curriculum ideologies, perspectives on design, strategies for diverse learners, and the politics of curriculum construction and implementation. Students develop curriculum plans for use in real settings. (CTE)

*3-4 units, Win (Pope)*

**EDUC 211. Master's Seminar in Social Sciences in Education**—Limited to master's students in SSE. Hands-on forum. The process of developing and shaping a research program, integrating it with academic and field experiences, and building relationships beyond the program. Students conceptualize their projects and focus on researchable topics: effective revising and editing, job searches, working with your adviser, what next? or a celebration of achievements so far. (SSPEP)

*1-3 units, Aut, Win, Spr (Staff)*

**EDUC 212X. Urban Education**—Open to graduate students and undergraduates. Combination of historical and anthropological perspectives trace the major developments, contexts, tensions, challenges, and policy issues of urban education. GER:3a

*3-4 units, Spr (McDermott)*

**EDUC 213. Aesthetic Foundations of Education**—What role might the arts play in education? Do the arts contribute to the development of cognitive skills? Do they help humans understand the world in which they live? Are aesthetic considerations central in the way we think about the aims of education? Do they enhance teaching and school organization? (CTE)

*4 units, Win (Eisner)*

**EDUC 214. Popper, Kuhn, and Lakatos**—(Same as PHIL 156.) These 20th-century philosophers of science raise fundamental issues dealing with the nature of scientific progress: the rationality of change of scientific belief, science versus non-science, role of induction in science, truth or verisimilitude as regulative ideals. Their impact in the social sciences and applied areas such as educational research. (SSPEP) GER:3a

*3 units, Spr (Phillips)*

**EDUC 218X. Topics in Cognition and Learning: Spatial Cognition**—How people recruit perceptual mechanisms (such as for navigating, learning about spatial relations such as driving a car, or inferring the behavior of novel device) to understand symbolic and conceptual domains. Do hands-on activities with physical objects promote the development of mathematical thinking?

*3 units, Aut (Schwartz)*

**EDUC 219. Artistic Development of the Child**—How can children's and adolescents' development in the arts be described? What role does the symbolic transformation of experience play in the creation of those images we regard as art? What can teachers do to promote the development of artistic thinking? These and other questions are examined through the study of theory and research conducted within the social sciences. (CTE)

*4 units (Eisner) not given 2004-05*

**EDUC 220A,B,C,D,Y. The Social Sciences and Educational Analysis**—Required of students in APA and open to all. Economics, political science, sociology, and history, and their applications to education in the U.S.

**EDUC 220A. Introduction to the Economics of Education**—Overview of the relationship between education and economic analysis. Topics: labor markets for teachers, the economics of child care, the effects of education on earnings and employment, the effects of education on economic growth and distribution of income, and the financing of education. Students who lack training in microeconomics, register for 220Y for 1 additional unit of credit. (SSPEP/APA)

*4 units, Aut (Carnoy)*

**EDUC 220B. Introduction to the Politics of Education**—(Same as GSBGEN 349.) The relationships between political analysis and policy formulation in education; focus is on alternative models of the political process, the nature of interest groups, political strategies, community power, the external environment of organizations, and the implementations of policy. Applications to policy analysis, implementation, and politics of reform. (APA) GER:3b

*4 units, Spr (Kirst)*

**EDUC 220C. Education and Society**—(Same as SOC 130/230.) The effects of schools and schooling on individuals, the stratification system, and society. Education as socializing individuals and as legitimizing social institutions. The social and individual factors affecting the expansion of schooling, individual educational attainment, and the organizational structure of schooling. GER:3b

*4-5 units, Aut (Ramirez)*

**EDUC 220D. History of School Reform: Origins, Policies, Outcomes, and Explanations**—Required for students in the POLS M.A. program; others welcome. Focus is on 20th-century U.S. Intended and unintended patterns in school change; the paradox of reform that schools are often reforming but never seem to change much; rhetorics of reform and factors that inhibit change. Case studies emphasize the American high school. (SSPEP/APA)

*4 units, Aut (Labaree)*

**EDUC 220Y. Introduction to the Economics of Education: Economics Section**—For those taking 220A who have not had microeconomics before or who need a refresher. Corequisite: 220A. (SSPEP/APA)

*1-2 units, Aut (Carnoy)*

**EDUC 221A. Policy Analysis in Education**—Major concepts associated with the development, enactment, and execution of educational policy. Issues of policy implementation, agenda setting and problem formulation, politics, and intergovernmental relations are examined through case materials and supplementary readings. Objective: identify and understand the factors that affect the ways in which analysts and policymakers learn about education in the policy system and the ways in which they can influence it. Limited enrollment. Prerequisite: consent of instructor. (SSPEP/APA)

*3-5 units, Win (McLaughlin)*

**EDUC 221B. Micro and Macro Issues in Policy Analysis**—Doctoral students use their own research interests to explore the analytical, empirical, and methodological aspects of micro and macro perspectives on policy and action.

*3 units (McLaughlin) not given 2004-05*

**EDUC 222. Resource Allocation in Education**—Problems of optimization and design, and evaluation of decision experience. Marginal analysis, educational production functions, cost effectiveness and cost-benefit analysis, constrained maximization, program evaluation. Introduction to linear models for large-scale data analysis. Implications to model assumptions. (SSPEP)

*4-5 units, Spr (Loeb)*

**EDUC 223. Good Schools: Research, Policy, and Practice**—Recent studies of schools that exceed expectations in producing desired results. Research methodologies, findings of studies, and efforts to implement results. Components of good schools analyzed: effective teaching, principal leadership, organizational processes, parent involvement, cultures in schools, the role of the superintendent. Required project studies a school and determines goodness. Enrollment limited to 20. (SSPEP/APA, CTE)

*3-4 units, Win (Cuban)*

**EDUC 224. Information Technology in the Classroom**—The use of information technology (computers, interactive video, telecommunications) in classroom teaching. Basic computer operations and terminology; challenges of planning and teaching with technology; judging the merits of products for educational uses; survey of the types of uses made of technology in schools; and economic, social, and ethical issues, emphasizing equity. (CTE)

*3 units, Win (Walker)*

**EDUC 227X. Interaction Design for Learning Environments**—Principles and methods of interaction design prototyping emphasizing interactive learning environments. Students individually or in small groups work on an interaction design project, developing detailed prototypes of key interaction ideas.

*3-4 units, Win (Walker)*

**EDUC 229A,D. Learning Design and Technology**—Four quarter core of the LDT master's program. Topics: learning, cognition, and development; design principles for technological learning environments; technological literacy and skills; research methods and evaluation; curriculum and content; and organization structure and operation. Students navigate design sequences in learning environments rooted in a practical problem. Topics in learning, design, and technology from a theoretical and a practical application perspective. Readings and hands-on development are a team-collaborative effort. (all areas)

*3 units,* **A:** *Sum (Walker),* **D:** *Spr (Schwartz)*

**EDUC 232A. The Study of Teaching**—Second of three core courses in CTE. Theory and practice of teaching, past and present, K-12 and higher education. (CTE)

*4 units, Win (Juel)*

**EDUC 232B. Introduction to Curriculum**—First of three core courses in CTE. What should American schools teach? How should school programs be organized? How can schools determine whether the goals they have formulated have been achieved? What kind of school organization helps teachers improve their teaching practices? Students secure a historical and contemporary perspective on the curriculum of American schools. The interactions among curriculum, the organizational structure of schools, the conception of the teacher's role, and how teaching and student learning are assessed. Text, video analysis of teaching, and small group discussions examine competing ideas regarding the content and aims of school programs. (CTE)

*4 units, Aut (Eisner)*

**EDUC 232C. Introduction to Learning**—Core course in CTE and PSE. The theoretical perspectives and research on learning, emphasizing principles that inform the design and study of learning environments. Historical background to current controversies in the field. Issues: the ways of assessing learning, learning by individuals and groups who differ in gender or in cultural and social backgrounds, the generality of learning outcomes, relations between the growth of conceptual understanding and cognitive skill, learning considered as becoming a more effective participant in social practices, and a brief history of the development of currently influential conceptualizations of learning. (CTE, PSE)

*4 units, Spr (Brown)*

**EDUC 234. Career and Personal Counseling**—(For graduate students; see 134.) (PSE)

*3 units, Spr (Krumboltz)*

**EDUC 239. Emerging Issues in Child and Adolescent Development**—Focus is on critical social and developmental issues that affect children and adolescents. Topics: divorce and single parenting, child care, poverty, sexuality, and mass media, emphasizing the impact of these conditions on normal development, education, and school-related social and cognitive performance. (PSE)

*4 units (Padilla) not given 2004-05*

**EDUC 240. Adolescent Development and Learning**—How do adolescents develop their identities, manage their inner and outer worlds, and learn? Presuppositions: that fruitful instruction takes into account the developmental characteristics of learners and the task demands of specific curricula; and that teachers can promote learning and motivation by mediating among the characteristics of students, the curriculum, and the wider social context of the classroom. Prerequisite: STEP student or consent of instructor. (STEP)

*3 units, Aut (LaFromboise, Padilla)*

**EDUC 243. Writing Across Languages and Cultures: Research in Writing and Writing Instruction**—The theoretical perspectives that have dominated the literature on writing research over the years. Examination of reports, articles, and chapters on writing research, writing theory, and writing instruction; current and historical perspectives in writing research and research findings relating to teaching and learning in this area.

*3-4 units, Win (Ball)*

**EDUC 244. Classroom Management**—Student and teacher's roles in developing a classroom community. Strategies for classroom management discussed, practiced, and placed within a theoretical framework.
*1 unit, Aut (Haysman)*

**EDUC 246A,B,C,D. Secondary Teaching Seminar**—Preparation and practice in issues and strategies for teaching in classrooms with diverse students. Topics: instruction, curricular planning, classroom interaction processes, portfolio development, teacher professionalism, patterns of school organization, teaching contexts, and government educational policy. Classroom observation and student teaching with accompanying seminars during each quarter of STEP year. 16 units required for completion of the program. Prerequisite: STEP student.
*2 units,* **A:** *Sum (Lotan),* **B:** *3 units, Aut (Lotan)*
*5 units,* **C:** *Win (Lotan),* **D:** *2-4 units, Spr (Lotan, Haysman)*

**EDUC 247. Moral Education**—Contemporary scholarship and educational practice related to the development of moral beliefs and conduct in young people. The psychology of moral development; major philosophical, sociological, and anthropological approaches. Topics include: natural capacities for moral awareness in the infant; peer and adult influences on moral growth during childhood and adolescence; extraordinary commitment during adulthood; cultural variation in moral judgment; feminist perspectives on morality; the education movement in today's schools; and contending theories concerning the goals of moral education. (PSE)
*3 units, Win (Damon)*

**EDUC 249. Theory and Issues in the Study of Bilingualism**—(Undergraduates register for 149.) Sociolinguistic perspective. Emphasis is on typologies of bilingualism, the acquisition of bilingual ability, description and measurement, and the nature of societal bilingualism. Prepares students to work with bilingual students and their families and to carry out research in bilingual settings. (SSPEP) GER:3a
*3-5 units, Aut (Valdés)*

**EDUC 250A. Statistical Analysis in Educational Research**—Primarily for doctoral students. Regression and categorical models are widely used data-analytic procedures. Topics: basic regression including multiple and curvilinear regression, regression diagnostics, analysis of residuals and model selection, logistic regression, analysis of categorical data. Proficiency with statistical computer packages. Prerequisite: 160 or equivalent. (all areas)
*4 units, Win (Haertel)*

**EDUC 250B. Statistical Analysis in Educational Research: Analysis of Variance**—Primarily for doctoral students. Analysis of variance models are among the most widely used data analytic procedures, especially in experimental, quasi-experimental, and criterion-group designs. Topics: single-factor ANOVA, the factorial between and within subjects and mixed design ANOVA (fixed, random, and mixed models), analysis of covariance, multiple comparison procedures. Prerequisite: 160X or equivalent. (all areas)
*4 units, Spr (Shavelson)*

**EDUC 250C. Statistical Analysis in Educational Research: Multivariate Analysis**—Primarily for doctoral students in education, social and behavioral sciences. Multivariate analysis of variance, discriminant analysis, factor analysis, correlation analysis. Advanced regression methods. Data compression: principle components analysis, clustering. Computer packages for data analysis. Prerequisites: 250B, 257, STATS 200, or equivalent. (all areas)
*2-4 units, Win (Olkin)*

**EDUC 252. Introduction to Test Theory**—Concepts of reliability and validity; derivation and use of test scales and norms; mathematical models and procedures for test validation, scoring, and interpretation. Prerequisite: STATS 190 or equivalent. (PSE)
*3-4 units (Haertel) not given 2004-05*

**EDUC 255. Human Abilities**—(Same as PSYCH 133.) Psychological theory and research on human cognitive abilities; their nature, development, and measurement; and their importance in society. Persistent controversies and new areas of research, recent perspectives on the nature-nurture debate and the roles of genetics, health and education in shaping HCAs. Prerequisite: PSYCH 1 or equivalent. (PSE) GER:3b
*3 units, Win (Shavelson)*

**EDUC 256X. Psychological and Educational Resilience Among Children and Youth**—Psychological and educational theories of resilience as they relate to children and youth. Emphasis is on family, school, and community assets as they relate to protective factors that create conditions of resilience. How protective factors can be used to create healthy communities that enhance the life qualities of at-risk children and youth.
*3-4 units (LaFromboise, Padilla) alternate years, given 2005-06*

**EDUC 257A,B. Statistical Methods for Behavioral and Social Sciences**—For students with experience and training in empirical research. Analysis of data from experimental studies through factorial designs, randomized blocks, repeated measures; regression methods through multiple regression, model building, analysis of covariance; categorical data analysis through log-linear models, logistic regression. Integrated with the use of statistical computing packages. Prerequisite: analysis of variance and regression at the level of STATS 161.
*3 units,* **A:** *Win,* **B:** *Spr (Rogosa)*

**EDUC 258X. Literacy Development and Instruction**—Literacy acquisition as a developmental and educational process. Problems that may be encountered as children learn to read. How to disentangle home, community, and school instruction from development. Models that inform both literacy development. How classroom instruction affects literacy development.
*3 units, Spr (Juel)*

**EDUC 260X. Popular Advanced Statistical Methods**—Overview and implementation of methods for accommodating the nested structure of much educational data (e.g., students within classrooms within schools) which arise as units of analysis problems, ecological regression, or hierarchical linear models. Methods for complex measurement models in regression settings known as structural equation models, causal models, covariance structures. See http://www.stanford.edu/class/ed260.
*3 units (Rogosa) not given 2004-05*

**EDUC 262A,B,C. Curriculum and Instruction in English**—Approaches to teaching English in the secondary school, including goals for instruction, teaching techniques, and methods of evaluation. (STEP)
*2 units,* **A:** *Sum (Grossman)*
*3 units,* **B:** *Aut (Grossman),* **C:** *Win (Staff)*

**EDUC 263A,B,C. Curriculum and Instruction in Mathematics**—The purposes and programs of mathematics in the secondary curriculum; teaching materials, methods. Prerequisite: STEP student or consent of instructor. (STEP)
*2 units,* **A:** *Sum (Boaler)*
*3 units,* **B:** *Aut (Boaler),* **C:** *Win (Staff)*

**EDUC 264A,B,C. Curriculum and Instruction in Foreign Language**—Approaches to teaching foreign languages in the secondary school, including goals for instruction, teaching techniques, and methods of evaluation. Prerequisite: STEP student. (STEP)
*2 units,* **A:** *Sum (Staff)*
*3 units,* **B:** *Aut (Staff),* **C:** *Win (Staff)*

**EDUC 265X. History of Higher Education in the U.S.**—(For graduate students; see 165X.)
*3-4 units, Aut (Labaree)*

**EDUC 267A,B,C. Curriculum and Instruction in Science**—Examination of the possible objectives of secondary science teaching and related methods: selection and organization of content and instructional materials; lab and demonstration techniques; evaluation, tests; curricular changes; ties with other subject areas. Prerequisite: STEP student or consent of instructor. (STEP)
*2 units,* **A:** *Sum (Brown, Lythcott)*
*3 units,* **B:** *Aut (Staff),* **C:** *Win (Brown)*

**EDUC 268A,B,C. Curriculum and Instruction in History and Social Science**—Emphasis is on the methodology of social studies instruction: review of curriculum trends, survey of teaching materials, opportunities to develop teaching and resource units. Prerequisite: STEP student.
*2 units,* **A:** *Sum (Wineburg)*
*3 units,* **B:** *Aut (Wineburg),* **C:** *Win (Staff)*

**EDUC 269. Principles of Learning for Teaching**—Student learning and the epistemology of school subjects as they relate to the planning and implementation of teaching, the analysis of curriculum, and the evaluation of performance and understanding. Readings and activities are coordinated with the student teaching activities of participants. Prerequisite: STEP student or consent of instructor.
*3 units, Spr (Nasir, Pea, Brown, Perez-Granados)*

**EDUC 270A. Learning to Lead in Public Service Organizations**—For Haas Center student service organization leaders.
*3-5 units, Spr (Davis)*

**EDUC 271S. School-Based Strategies for Reform**—Seminar. Major redesign and reform strategies that schools are using to improve their performance. Reflections, and the preparation of a report for local school leaders analyzing school improvement resources and strategies.
*3 units (Staff) not given 2004-05*

**EDUC 273X. Gender and Higher Education**—Focus is on the U.S. The effects of interactions between gender and the structures of higher education; policies seeking changes in those structures. Topics: undergraduate and graduate education, faculty field of specialization, rewards and career patterns, sexual harassment, and the development of feminist scholarship and pedagogy.
*5 units (Strober) not given 2004-05*

**EDUC 275. African American English in Educational Context**—(For graduate students, see 175.)
*3 units (Staff) alternate years, given 2005-06*

**EDUC 276X. Educational Assessment**—Reliability, validity, bias, fairness, and properties of test scores. Uses of tests to monitor, manage, and reform instruction. Testing and competition, meritocracy, achievement gaps, and explanations for group differences.
*3 units, Aut (Haertel)*

**EDUC 277. Education of Immigrant Students: Psychological Perspectives**—(For graduate students, see 177.) (SSPEP)
*4 units (Padilla) not given 2004-05*

**EDUC 278. Introduction to Issues in Evaluation**—Open to master's and doctoral students with priority to students from education. Focus is on the basic literature and major theoretical and practical issues in evaluation. Introduction to basic concepts and intellectual debates in the field: knowledge construction, purpose of evaluation, values in evaluation, knowledge utilization, professional standards of evaluation practice. Enrollment limited to 18. (SSPEP)
*3 units, Win (Phillips)*

**EDUC 279. Urban Youth and Their Institutions: Research and Practice**—(For graduate students, see 179.) (SSPEP/APA)
*4-5 units, Aut (McLaughlin)*

**EDUC 279B. Best Practice and Policy in Youth Development**—(For graduate students, see 179B.)
*2-4 units, Spr (McLaughlin)*

**EDUC 280. Ethnographic Approaches to Cultural Diversity in Schooling**—Techniques of ethnographic research applicable to the study of schooling applied in field research projects. How to learn about culture and analyze situations such as the culturally diverse classroom. Techniques of observation, interview, and interpretation of behavior; how to solicit and record native explanations of behavior; internally consistent conceptual structures that orient observation and elicitation productively; and sensitization to one's own culture and how it influences perception and interpretation of behavior. Research report or proposal for research.
*4 units, Spr (Spindler)*

**EDUC 281X. Using Literacies to Support Struggling Students**—Issues related to meeting the needs of struggling readers and writers and special needs students in their classrooms. Emphasis is on students who appear to be struggling learners in middle and high school classrooms who have not been previously or officially identified to receive special educational resources.
*3 units (Ball) not given 2004-05*

**EDUC 284. Teaching in Heterogeneous Classrooms**—Teaching in academically and linguistically heterogeneous classrooms requires a repertoire of pedagogical strategies. Focus is on how to provide access to intellectually challenging curriculum and equal-status interaction for students in diverse classrooms. Emphasis is on group work and its cognitive, social, and linguistic benefits for students. How to prepare for group work, equalize participation, and design learning tasks that support conceptual understanding, mastery of content and language growth. How to assess group products and individual contributions. (STEP)
*3 units, Win (Lotan)*

**EDUC 287. Culture and Learning**—(Same as CASA 158X.) Learning in institutional settings in the U.S. and around the globe. Learning in families, in schools, on the job, and on the streets. Emphasis is on the cultural organization of success and failure in American schools. Tentative consideration of opportunities for making less inequality. (SSPEP, STEP)
*3-4 units (McDermott) not given 2004-05*

**EDUC 288X. Organizational Behavior and Analysis**—Theories of group and individual behavior; organizational culture; and applications to school organization and design. Case studies.
*4 units, Spr (Meyerson)*

**EDUC 289. Introduction to Linguistics for Educational Researchers**—(Undergraduates register for 189.) For graduate students with interests in educational research, especially those who plan to concentrate on language or linguistics. Basic linguistic concepts, complementary surveys of educationally oriented studies that explore quantitative linguistic analyses, qualitative ethnolinguistic anaylyses, discourse analyses, conversation analyses, and studies of bilingualism. Emphasis is on the linguistic analyses of language minority populations and related educational policies.
*4 units (Baugh) not given 2004-05*

**EDUC 290. Leadership: Research, Policy, and Practice**—Conceptions of leadership that include the classroom, school, district office, and state capitol. The role of complexity; organizational leaders outside of schools past and present, and how that complexity permitted leadership to arise. Case studies. (SSPEP/APA)
*4 units, Win (Davis)*

**EDUC 291. Learning Sciences and Technology Design Research Seminar and Colloquium**—Students and faculty present and critique new and original research relevant to the Learning Sciences and Technology Design doctoral program. Goal is to develop a community of scholars who become familiar with each other's work. Practice of the arts of presentation and scholarly dialogue while introducing seminal issues and fundamental works in the field.
*1-3 units, Aut (Pea), Win (Schwartz), Spr (Barron)*

**EDUC 292X. Cultural Psychology**—The relationship between culture and psychological processes; how culture becomes an integral part of cognitive, social, and moral development. Both historical and contemporary treatments of cultural psychology, including deficit models, cross-cultural psychology, ecological niches, culturally specific versus universal development, sociocultural frameworks, and minority child development. The role of race and power in research on cultural psychology.
*2-3 units, Win (Nasir)*

**EDUC 294. Theories of Human Development**—Concepts and theoretical viewpoints of developmental science. Goal is to evaluate multidisciplinary applications of empirical developmental research including its impact on educational reform, interventions, and social policy issues.
*3 units, Aut (Perez-Granados)*

**EDUC 296. Substance Dependence: Assessment, Treatment, and Prevention**—Open to social sciences graduate students. The prevalence, etiology, and treatment of alcohol and drug-related disorders. Developmental perspective; how substance abuse disorders manifest themselves in men and women at different ages from childhood through late adulthood. Beneficial treatment approaches such as AA, individual and group work, family treatment, and inpatient versus outpatient care. Required visit to treatment programs during the quarter. (PSE)
*3 units, Win (Moffett)*

**EDUC 298. Online Communities of Learning**—Historical foundations, theoretical perspectives, underlying learning theories, case studies, and key enabling technologies of online learning communities across and within K-12 schools, among teachers, in professional collaborations in the sciences, and across informal communities of interest in society.
*3 units, Win (Pea)*

**EDUC 301B. Theoretical Debates in the History of Education**—How should we educate students? To what purpose should students be educated? What is the purpose of education in America? What is an appropriate curriculum? Do all students deserve or need the same curriculum.
*3-4 units, Spr (Williams)*

**EDUC 304. The Philosophical and Educational Thought of John Dewey**—Dewey's pragmatic philosophy and educational thought; his debt to Darwin, Hegel, Peirce, and James; his educational writings including *Democracy and Education;* and his call for a revolution in philosophy in *Reconstruction in Philosophy* (SSPEP)
*4 units, Aut (Phillips)*

**EDUC 305X. Progressive Education, the Free Child, and the Critics**—Radically different models of child rearing and their implications for educational practice. Topics include: Rousseau's Emile, Puritan education, Summerhill School and the philosophy of open education, contemporary orthodox and evangelical schools, and democratic schools. Mock debates. How these models inform educational alternatives locally; classroom observation.
*4 units, Win (Phillips)*

**EDUC 306A. Education and Economic Development**—Case material considers development problems in the U.S. and abroad. Discussion sections on economic aspects of educational development. (SSPEP/ICE)
*5 units, Aut (Carnoy)*

**EDUC 306B. The Politics of International Cooperation in Education**—(Undergraduates and master's students register for 107.) Analysis of policies and practices in international cooperation, assistance, and exchange. Emphasis is on the role of international organizations (World Bank, UNESCO, OECD) and the politics of multilateral and bilateral assistance programs. (SSPEP/ICE, APA)
*4 units, Win (Inoue)*

**EDUC 306C. Political Economy of the Mind**—Theories of political economy related to the learning mind, particularly as in fiction. Readings from Defoe, Smith, Balzac, Dickens, Marx, Veblen, Wharton, Joyce, Galbraith, and Morrison. (SSPEP/ICE)
*3-4 units (Staff) not given 2004-05*

**EDUC 306D. World, Societal, and Educational Change: Comparative Perspectives**—(Undergraduates register for 136; same as SOC 131/231.) Theoretical perspectives and empirical studies on the structural and cultural sources of educational expansion and differentiation, and on the cultural and structural consequences of educational institutionalization. Research topics: education and nation building; education, mobility, and equality; education, international organizations, and world culture. GER:3b
*4-5 units, Win (Ramirez)*

**EDUC 307X. Organizing for Diversity: Opportunities and Obstacles in Groups and Organizations**—Obstacles in organizations and groups that prevent people from participating, working effectively, and developing relationships in the context of diversity. How to create conditions in which diversity enhances learning and effectiveness? Experiential exercises; students experiment with conceptual and analytic skills inside and outside of the classroom.
*4 units, Spr (Meyerson)*

**EDUC 310. Sociology of Education**—(For graduate students, see 110; same as SOC 132/232.) (SSPEP)
*4 units, Spr (McFarland)*

**EDUC 311X. First-Year Doctoral Seminar: Introduction to Research**—Methods in current educational research, focusing on logical and epistemological, design, and ethical issues. (all areas)
*1-2 units, Aut, Win, Spr (Stipek, Callan)*

**EDUC 312. Microsociology**—(Same as SOC 224.) The educational applications of sociological and social psychological theory and research to interaction processes in schools. Readings include: foundational works by Mead, Schutz, and Simmel; contemporary work in sociology by Goffman, Homans, Merton, Blau, and Harold. Readings span empirical settings such as work settings, classrooms, gangs, primate societies, and children's games. Topics: processes of influence, role differentiation, identity formation, social mechanisms, and intra/inter group dynamics of peer relations. Methods for observation and analysis of small groups. (SSPEP)
*4 units, Win (McFarland)*

**EDUC 314. Workshop in Economics of Education**—Research by students and faculty engaged in problems in the economics of education. Students must have advanced graduate training in economics theory and methodology and be engaged in research on the topic. (SSPEP)
*1-2 units, Aut, Win, Spr (Carnoy)*

**EDUC 316. Network Analysis of Formal and Informal Organizations**—The educational applications of social network analysis. Introduction to social network theory, methods, and research applications in sociology. Network concepts of interactionist (balance, cohesion, centrality) and structuralist (structural equivalence, roles, duality) traditions are defined and applied to topics in small groups, social movements, organizations, communities. Students apply these techniques to data on schools and classrooms. (SSPEP)
*4-5 units, Spr (McFarland)*

**EDUC 317X. Workshop on Community and Youth Development**—(Same as SOC 317C.) The Youth Development Seminar presents an opportunity to discuss, read, and collaborate on youth development research issues by providing participants with access to the National Longitudinal Study of Adolescent Health Data (requires permission), tutorials on statistical methods to facilitate analysis of the dataset, and articles that help researchers develop tools of inquiry. Participants present their work for feedback.
*1-2 units (Staff) not given 2004-05*

**EDUC 321A. Emerging Conceptions of Qualitative and Ethnographic Research**—Issues of knowing via forms through which human beings have historically represented the world and how they care about it, including narrative, visual images, and poetry. How to see and represent the educational worlds. Sources include videotaped classrooms in action, film excerpts that reveal human relations, and literary forms that describe classroom situations. Materials and procedures used by researchers, film makers, and fiction writers.
*4-5 units, Spr (Eisner, McDermott)*

**EDUC 322X. Discourse of Liberation and Equity in Schools and Society**—Issues and strategies for studying oral and written discourse as a means for understanding classrooms, students, and teachers, and teaching and learning in educational contexts. The forms and functions of oral and written language in the classroom, emphasizing teacher-student and peer interaction, and student-produced texts. Individual projects utilize discourse analytic techniques. Prerequisite: graduate status or consent of instructor. (SSPEP)
*3-5 units, Spr (Ball)*

**EDUC 323A. Introduction to Education Policy Analysis**—The formulation and improvement of federal and state education and children policies. Key current policy issues and trends in politics. Topics: the federal role in education and child care. (SSPEP)
*3 units, Aut (Kirst)*

**EDUC 324. Emerging Business Opportunities in Education and Training**—(Same as GSBGEN 545.) For students in the joint degree program in Business and Education, and others. A combination of changing market mechanisms and emerging technologies is fueling new opportunities in for-profit education and training organizations. The interaction of firms with the public sector presents challenges for these organizations. The roles of public administrators, educators, investors, and technology providers in defining opportunities, challenges, and constraints for education and training firms. Approaches to strategy formation, product development, and operations. Visiting managers and other experts. (SSPEP/APA)
*2 units, Win (Kirst, Wood)*

**EDUC 326X. Legal Dilemmas and Administrative Decision Making in Schools**—Concepts and issues in school law and their influence on administrative decision making in public schools, skills in the application of legally defensible resolutions to complex educational problems, and theories, principles, and the evolution of education law.
*4 units, Aut (Davis)*

**EDUC 327A,B. The Conduct of Qualitative Inquiry**—Integrated two quarter sequence for doctoral students to engage in research that anticipates, is a pilot study for, or feeds into their dissertations. Prior approval for dissertation study not required. The experience is about the actual conduct of research. All students engage in common research processes from January to June including developing interview questions; interviewing; coding, analyzing, and interpreting data; theorizing; and writing up results. Participant observation as needed. Preference to students who intend to enroll for both quarters.
*3-4 units,* **A:** *Aut,* **B:** *Win (Goldman)*

**EDUC 328X. Topics in Learning and Technology: Interactivity**—Content changes each year. Interactivity including manipulation of an object, talking to another person, or clicking on a mouse. Proposals for the active learning ingredient of interactivity, and how different technologies capitalize on these ingredients.
*3 units, Spr (Schwartz)*

**EDUC 329X. Seminar on Teacher Professional Development**—Theory and practice. Models of professional development. Issues include: conceptions of teachers, practice, and development; the content of professional development; pedagogies; structures that support teacher learning; evaluating professional development; and policy issues. Field observation.
*1-4 units, Spr (Post, Sato)*

**EDUC 330X. Economic Approaches to Education Policy Analysis**—(Same as GSBGEN 347.) Policy issues in education using the tools of microeconomics. How are schools funded and with what implications for the efficiency, equity, and adequacy of resources? What is the impact of school resources on educational and economic well-being? How do teacher labor markets operate and how do teachers impact student achievement? How do systems of school choice affect schools and students? How has accountability changed schooling? What are the effects of changes in affirmative action and financial aid in higher education? Prerequisites: intermediate microeconomics and regression analysis.
*4 units (Loeb) alternate years, given 2005-06*

**EDUC 331A,B. Administration and Policy Analysis Research Seminar**—Limited to first-year APA doctoral students. The rudiments of problem statements, conceptual frameworks, research design, and critical reviews of literature. (SSPEP/APA)
*3 units,* **A:** *Spr (Gumport),* **B:** *Win (Staff)*

**EDUC 333A. Learning, Design and Technology: Analyzing Functions and Needs in Learning Environments**—Advanced seminar. Introduction to the theoretical approaches to learning used to analyze learning environments and develop goals for designing resources and activities to support more effective learning practices.
*3 units (Perez-Granados) not given 2004-05*

**EDUC 335X. Language Policy and Planning: National and International Perspectives**—For graduate students, and undergraduates with consent of instructor. International study of the social, political, and educational tensions that shape language policy. Emphasis is on language education that affects immigrants, guest workers, and indigenous linguistic minority populations; policies that determine foreign language instruction, and U.S. language policies in a comparative approach. (SSPEP) GER:3b
*3 units (Staff) not given 2004-05*

**EDUC 336X. Language, Identity, and Classroom Learning**—As contemporary research focuses on how people act and recognize each other, analyzing interaction while acknowledging identity allows for a dynamic examination of cultural interaction. Broad cultural categorization can be overly expansive in identifying the characteristics of large groups of individuals.
*1-3 units (Brown) not given 2004-05*

**EDUC 337X. Race, Ethnicity, and Linguistic Diversity in Teacher Preparation**—(Undergraduates register for 135X.) Issues related to developing teachers who have attitudes, dispositions, and skills necessary to teach diverse student populations effectively.
*3-4 units, Spr (Ball)*

**EDUC 340X. American Indian Mental Health and Education**—Western medicine tends to define health by first defining sickness, disease, or pathology, and then defining health as the absence of these diseases. Native American cultures understood health to mean the balance or beauty of all things physical, spiritual, emotional, and social. Sickness was something out of balance, the absence of harmony. Representative topics in American Indian psychology and health acquaint students with issues that characterize the field, its methods, goals, and findings. Prerequisite: experience working with American Indian communities. (PSE)
*3-5 units, Spr (LaFromboise)*

**EDUC 342. Child Development and New Technologies**—Focus is on the experiences computing technologies afford children and how these experiences might influence development. Sociocultural theories of development as a conceptual framework for understanding how computing technologies interact with the social ecology of the child and how children actively use technology to meet their own goals. Emphasis is on influences of interactive technology on cognitive development, identity, and social development equity.
*1-3 units, Win (Barron, Perez-Granados)*

**EDUC 344. Child Development and Schooling**—How the practices and activities of schooling influence the social, emotional, and cognitive development of children. Metatheoretical approaches (mechanistic, organismic, developmental contextualist metamodels) and methods of conducting research on schooling and development (experimental, survey, ethnographic, intervention). Topics: how teaching practices influence cognitive growth in academic domains; how the organizational structures of schools (grade related transitions, class organizations) fit or fail to fit developmental needs; how friendship groups create contexts for learning and lead to different trajectories of development; and how grading and evaluative practices influence motivational orientations. Focus is on elementary school years. (PSE)
*3-4 units, Aut (Barron)*

**EDUC 345X. Adolescent Development and Schooling**—How the context of school and its relationship to other major context developments (family, peer group, and neighborhood) influence the social, emotional, and cognitive development of secondary school-aged youths.

Metatheoretical approaches (mechanistic, organismic, developmental contextualist metamodels) and methods of conducting research on schooling and development (laboratory, survey, ethnographic, intervention). Topics: school transitions during adolescence; the role of school functioning in broader patterns of competence or distress; and how the organization of academic tasks, classrooms, and school environments as a whole can influence adolescent development. Focus is on middle and high school years. (PSE)

*3 units, Win (LaFromboise)*

**EDUC 346. Research Seminar in Higher Education**—Required for higher education students. Major issues, current structural features of the system, the historical context that shaped it, and theoretical frameworks. The purposes of higher education in light of interest groups including students, faculty, administrators, and external constituents. Issues such as diversity, stratification, decentralization, and changes that cut across each of these groups. (APA)

*4 units, Win (Antonio)*

**EDUC 347. Economics of Higher Education**—(Same as GSBGEN 348.) Topics: the worth of college and graduate degrees, and the utilization of highly educated graduates; faculty labor markets, careers, and workload; costs and pricing; discounting, merit aid, and access to higher education; sponsored research; academic medical centers; and technology and productivity. Emphasis is on theoretical frameworks, policy matters, and the concept of higher education as a public good. Stratification by gender, race, and social class.

*4 units (Strober) alternate years, given 2005-06*

**EDUC 349X. Accountability and Assessment in Higher Education**

*3 units (Staff) not given 2004-05*

**EDUC 350A,B,C. Research Practicum in Psychological Studies in Education**—Required of first-year doctoral students in Psychological Studies; others by consent of instructor. Introduction to the doctoral program in Psychological Studies in Education and to faculty and student research. (PSE)

*2-3 units,* **A:** *Aut (Nasir),* **B:** *Win (Schwartz),*
*1-2 units,* **C:** *Spr (Haertel)*

**EDUC 351. Workshop in Technical Quality of Educational Assessments**—The analysis of longitudinal data is central to empirical research on learning and development. Topics: growth models, measurement of change, repeated measures design, quasi-experiments, structural regression models, reciprocal effects, analysis of durations including survival analysis. See http://www.stanford.edu/class/ed351/. Prerequisite: statistical training at the level of 257. (PSE)

*3 units, Aut (Rogosa)*

**EDUC 352X. Education Schools: Historical and Sociological Perspectives**—The lowly status of the education school, defined as college, school, or department within a university. Why does the education school get no respect? Its historical development, how it evolved into its current position in the academic hierarchy, and contemporary factors that help to reinforce that position. (SSPEP)

*3 units, Spr (Labaree)*

**EDUC 353A. Problems in Measurement: Item Response Theory**—Alternative mathematical models used in test construction, analysis, and equating. Emphasis is on applications of item response theory (latent trait theory) to measurement problems, including estimation of item parameters and person abilities, test construction and scoring, tailored testing, mastery testing, vertical and horizontal test equating, and detection of item bias. Prerequisites: 252 and 257, or PSYCH 248 and 252, or equivalent. (PSE)

*3 units (Haertel) not given 2004-05*

**EDUC 353C. Problems in Measurement: Generalizability Theory**—Application to analysis of educational achievement data, including performance assessments. Fundamental concepts, computer programs, and actual applications. (PSE)

*3 units (Haertel, Shavelson) not given 2004-05*

**EDUC 354X. School-Based Decision Making**—Leadership and organizational issues. Emphasis is on building capacity for individual schools to make decisions, establishment of an inquiry process at the school level, use and availability of information, implementation and evaluation of decisions, parental involvement, and support of school-based decisions by districts. (SSPEP/APA)

*3-4 units, Win (Davis)*

**EDUC 355X. Higher Education and Society**—For undergraduates and graduate students interested in what colleges and universities do, and what society expects of them. The relationship between higher education and society in the U.S. from a sociological perspective. The nature of reform and conflict in colleges and universities, and tensions in the design of higher education systems and organizations.

*3 units (Gumport) not given 2004-05*

**EDUC 356X. Memory, History, and Education**—Interdisciplinary. Since Herodotus, history and memory have competed to shape minds: history cultivates doubt and demands interpretation; memory seeks certainty and detests that which thwarts its aims. History and memory collide in modern society, often violently. How do young people become historical amidst these forces; how do school, family, nation, and mass media contribute to the process?

*3-5 units, Aut (Wineburg)*

**EDUC 357X. Interdisciplinarity in Higher Education**—The historical prominence of disciplines in higher education, departmental structures, and disciplinary reproduction and professional socialization in graduate education. Definitions of interdisciplinarity and motivations for fostering it in research and teaching. Case studies including feminist, area, environmental, American, and interdisciplinary science studies. The development of interdisciplinary fields and organizational constraints including tenure and promotion, faculty reward systems, and undergraduate curricular structures. Recent initiatives to foster interdisciplinary activity among senior faculty.

*3 units, Spr (Gumport, Strober)*

**EDUC 359A. Research in Science and Mathematics Education: Assessment and Evaluation**—Historical and international perspectives. Emphasis is on trends and issues in contemporary American research and policy. Opportunity to develop and discuss dissertation plans, but are not limited to those students. (CTE)

*2-3 units, Win (Shavelson)*

**EDUC 360. Action Research in Education**—Introduction to the theory and practice of action research. Basic concepts and methods. The historical and ideological influences on this form of inquiry by teachers. Participants analyze action research reports and engage in a small-scale action-research project. (CTE)

*3 units, Win (Atkin)*

**EDUC 370X. Theories of Cognitive Development**—The contributions of Jean Piaget and Lev Vygotsky to the study of the developing mind of the child. The theories, concepts, perspectives, empirical work, and lives of both men. Topics: Piaget's genetic epistemology, constructivism, sensorimotor through formal operational thought; Vygotsky's cultural-historical approach, egocentric speech, and the relation between learning and development. Provides students with a familiarity with some of the major theorists of cognitive development of the 20th century.

*3 units, Aut (Nasir)*

**EDUC 371X. Cognitive Development in Childhood and Adolescence**—Traditional and current research in cognitive development that examine changes that occur within the individual from infancy through adolescence. Theoretical and empirical perspectives that describe the mechanisms and processes researchers use to explain the developmental changes that occur within the individual which affect how human beings think about and experience their world.

*3 units, Spr (Perez-Granados)*

**EDUC 372X. Social Processes in Learning and Development**—Doctoral seminar on how children's learning and development are influenced by social interactions with parents, peers, teachers, and the larger cultural context. Emphasis is on research that illuminates the social/cognitive processes thought to influence the development of individual thinking: observation and imitation of models, co-construction of meaning and achievement of intersubjectivity, providing and receiving explanations, and socio-cognitive conflict. How the larger social culture influences the behavior of individuals in interaction and how forms of school culture influence children's individual thinking and thinking in collaboration with others. (PSE)
*3 units, Aut (Barron)*

**EDUC 374A. Research Workshop: Knowledge Networks**—(Same as SOC 274A.) Factors shaping processes of transferring basic knowledge into commercial development. Topics: the sociology and economics of science, intellectual property and patenting, university-industry relations, cross-national differences in knowledge transfer and science/technology policy, and entrepreneurial activity in universities. Students are expected to have or develop related research projects. Undergraduate prerequisite: consent of instructor.
*1-3 units, Aut (Powell)*

**EDUC 375A. Seminar on Organizational Theory**—(Same as SOC 363A.) For Ph.D. students. The social science literature on organizations. Readings introduce major theoretical traditions and debates. The intellectual development of the field reflects shifts in emphasis in studies from workers to managers, from organizational processes to outputs, and from single organizations to populations of organizations.
*5 units, Aut (Powell)*

**EDUC 375B. Seminar on Organizations: Institutional Analysis**—(Same as SOC 363B.) The fruitfulness of research programs from institutional, network, and evolutionary perspectives in explaining large-scale change in organizational populations and institutions.
*3-5 units, Win (Powell)*

**EDUC 377. Organization and Style in Research Reports Comparing Insitutional Forms**
*4 units, Win (Powell)*

**EDUC 377B. Strategic Management of Nonprofits**—(Enroll in STRAMGT 368.)
*4 units, Spr (Staff)*

**EDUC 379B. Public Policy Towards Disconnected Youth**—(Same as LAW 356.) The situation of youth, 16-24, who are out of school and work for extended periods of time, including those incarcerated as a result of criminal behavior. Focus is on changes in laws, policies, and social service systems, including the education system, needed to help these youth.
*4 units, Aut, Win, Spr (Wald)*

**EDUC 380. Internship in Educational Administration**
*1-15 units, Aut, Win, Spr, Sum (Staff)*

**EDUC 381. Multicultural Issues in Higher Education**—The primary social, educational, and political issues that have surfaced in American higher education due to the rapid demographic changes occurring since the early 80s. Research efforts and the policy debates include multicultural communities, the campus racial climate, and student development; affirmative action in college admissions; multiculturalism and the curriculum; and multiculturalism and scholarship.
*4-5 units (Antonio) not given 2004-05*

**EDUC 382. Student Development and the Study of College Impact**—The philosophies, theories, and methods that undergird most research in higher education. How college affects students. Student development theories, models of college impact, and issues surrounding data collection, national databases, and secondary data analysis.
*4 units, Spr (Antonio)*

**EDUC 384. Advanced Topics in Higher Education**—Topics vary each year and may include faculty development, legal issues, curricular change, knowledge production, professional socialization, management of organizational decline, leadership and innnovation, authority and power, diversity and equity, and interactions with government and industry. Prerequisites: 346, consent of instructor. (APA)
*3-5 units, Win (Gumport)*

**EDUC 387A,B,C. Comparative Systems**—(Same as SOC 311A,B,C.) Analysis of quantitative and longitudinal data on national educational systems and political structures. May be repeated for credit. Prerequisite: consent of instructor. (SSPEP/ICE)
*2-5 units,* **A:** *Aut,* **B:** *Win,* **C:** *Spr (Ramirez)*

**EDUC 388A. Language Policies and Practices**—For credential candidates and for STEP candidates seeking to meet requirements for the English Learner Authorization on their preliminary credential. Historical, political and legal foundations of education programs for English learners. Theories of second language learning, and research on the effectiveness of bilingual education. Theory-based methods to facilitate and measure English learners' growth in language and literacy acquisition, and create environments which promote English language development (ELD) and content area learning through specially designed academic instruction in English (SDAIE). (STEP)
*3 units, Win (Ruiz)*

**EDUC 391. Web-Based Technologies in Teaching and Learning**—Project-based. Overview of instructional design theories and educational technologies to evaluate and develop a web-based educational application or system. Web-based applications and technologies designed for online interactions and collaborations. Instructional systems strategies to develop online environments that support and facilitate interactive learning. Students create a small-scale, web-based learning system.
*3-5 units (Staff) not given 2004-05*

**EDUC 392X. Enterprising Higher Education in the Digital Age**—Trends and impacts of the for-profit higher education industry in the digital age. Business, financial, and technical infrastructure of educational enterprises; accreditation and regulatory implications; technologies employed by major education corporations; practical issues in school establishment and operation; and business measurements. Student teams complete final project which may involve: analyzing existing for-profit educational enterprise, developing a business plan with a pro-forma for a small scale institute for non-traditional students, reporting on accreditation and regulatory issues around for-profit education, or developing a prototype of an online training curriculum.
*3 units, Aut (Kim)*

**EDUC 393X. Proseminar on Research in Education**—Overview of the field of education for joint degree students (M.B.A./M.A.). 2 units for readings and participation. 4 units require four short papers in consultation with instructor. (SSPEP)
*2-4 units, Spr (Strober)*

**EDUC 395X. Scholarly Writing in Education and the Social Sciences**—Workshop. How to write for professional journals.
*3-5 units, Aut (Wineburg)*

**EDUC 401A. Mini Courses in Methodology: Statistical Packages for the Social Sciences**—For doctoral students. Limited enrollment. Prerequisite: consent of instructor.
*1 unit, Aut, Win (Gelbach)*

**EDUC 402. Research Workshop on Gender Issues**—Presentations of research on gender issues by doctoral students, faculty, and visitors. Prerequisite: consent of instructor; doctoral student.
*1 unit, Aut, Win, Spr (Strober)*

**EDUC 408. Research Workshop in International and Comparative Education**—Limited to advanced doctoral students in ICE and SSPEP. Research workshop for the review of key issues in the methodology and epistemology of social research in education, research proposals, and findings by students and faculty. Prerequisites: 306A,B,C,D or equivalents. (SSPEP/ICE)
*2-5 units, Win (Carnoy)*

**EDUC 418. Foundations of Field Research in Higher Education**—For higher education/APA graduate students, and those working on qualifiying papers or dissertations. Rationales for interpretive social science research in higher education settings. Methodological training in fieldwork. Students collect, analyze, and critique case study data obtained from interviews, observation, and document analysis. Prerequisites: 346, consent of instructor.
*3-5 units (Gumport) not given 2004-05*

**EDUC 423A. Introduction to Research Design: Educational Administration and Policy Analysis**—Preference to APA doctoral students working on their sixth-quarter qualifying paper. Focus is on issues in conceptualizing and designing research in the social sciences. (APA)
*3-5 units, Win (Carnoy)*

**EDUC 424. Introduction to Research in Curriculum and Teacher Education**—Limited to second-year doctoral students in CTE. How to conceptualize, design, and interpret research. How to read, interpret, and critique research; formulate meaningful research questions; evaluate and conduct a literature review; and conceptualize a study. Readings include studies from different research paradigms. Required literature review in an area students expect to explore for their qualifying paper.
*3-5 units, Aut (Grossman)*

**EDUC 430A. Advanced Seminar in Childhood and Adolescent Development**—For students interested in research and training opportunities at the Center on Adolescence, and those interested in how to interpret and conduct research in child and adolescent development. Topics include: empathy and prosocial behavior, personality development, self-concept, motivation, peer relations, family influences, and anti-social behavior. Emphasis is on major theoretical and research traditions.
*3 units, Aut (Damon)*

**EDUC 435X. Research Seminar in Applied Linguistics**—For graduate students in the schools of Education and Humanities and Sciences who are engaged in research pertaining to applied linguistic topics in original research. Topics: language policies and planning, language and gender, writing and critical thinking, foreign language education, and social applications of linguistic science. (SSPEP)
*1-4 units (Baugh) not given 2004-05*

**EDUC 453. Doctoral Dissertation**—For doctoral students only. (all areas)
*1-15 units, Aut, Win, Spr, Sum (Staff)*

**EDUC 465X. Seminar in Teacher Education: Issues of Pedagogy**—For doctoral students interested in preparing to work in the area of teacher education. Issues of pedagogy in the professional preparation of preservice teachers. Different pedagogical approaches, including the use of modeling and simulations and the use of hypermedia materials. Theoretical considerations of how teachers learn to teach.
*2-3 units (Grossman) not given 2004-05*

**EDUC 466. Doctoral Seminar in Curriculum**—Required of all doctoral students in CTE, normally during their second year in the program. Students present their ideas regarding a dissertation or other research project, and prepare a short research proposal that often satisfies their second-year review. (CTE)
*2-4 units, Win (Eisner)*

**EDUC 470. Practicum**—For advanced graduate students. (all areas)
*1-15 units, Aut, Win, Spr, Sum (Staff)*

**EDUC 480. Directed Reading**—For advanced graduate students. (all areas)
*1-15 units, Aut, Win, Spr, Sum (Staff)*

**EDUC 490. Directed Research**—For advanced graduate students. (all areas)
*1-15 units, Aut, Win, Spr, Sum (Staff)*

**EDUC 493B. Statistical Methods in Meta-Analysis**—(Same as STATS 211.) Meta-analysis is a quantitative method for combining results of independent studies, and enables researchers to synthesize the results of related studies. Examples from the medical, behavioral, and social sciences. Topics: literature search, publication and selection bias, statistical methods (contingency tables, cumulative methods, sensitivity analyses, non-parametric methods). Project. Prerequisite: basic sequence in Statistics.
*1-3 units, Win (Olkin)*