GEOPHYSICS

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

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 (1) a background of fundamentals in science, and (2) 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 the details.

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 fifteen 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. Twelve (12) units of Geophysics lecture courses numbered 100 level or higher.
3. Twelve (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 or Fourier/spectral analysis.
5. Nine (9) units of 200 level or higher courses in math, science or engineering covering the above topics.
6. Six (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 in the above area.
8. Eighty-seven (87) units or more of independent work on a research problem. Twelve (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 3. Earthquakes and Volcanoes—(Same as EARTHSYS 113.) Introduction to the study of earthquakes and volcanoes: 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. GE:2b

3 units, Aut (Beroza, Segall)

GEOPHYS 4. Natural Hazards and Human Survival—For non-majors and potential earth scientists. Introduction to understanding natural and other hazards, earthquakes, volcanic eruptions, tsunamis, toxic waste disposal, nuclear power plant siting, their risk assessment, possible mitigation, and protective measures. GER:2a

3 units, Win (Kovach)

GEOPHYS 5Q. Earthquakes of the Americas—Stanford Introductory Dialogue. Preference to sophomores. Earthquakes have had an impact on the development of cultures and societies. The early empires of the Maya and the Aztecs undoubtedly experienced earthquakes and volcanic eruptions and we rely on archaeological remains and glyphs from codices to ascertain past occurrences. Evidence from Mexican and Central American archaeological sites uncovers the societial consequences and possible role of these natural events in the abandonment, migration, and settlement of cultural centers.

2 units (Kovachs) alternate years, given 2003-04

GEOPHYS 20Q. Predicting Volcanic Eruptions—Stanford Introductory Dialogue. 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 30Q. The 1906 San Francisco Earthquake—Stanford Introductory Dialogue. 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 40. The Earth from Space: Introduction to Remote Sensing—Global change and remote sensing. Global warming, ozone depletion, the hydrologic and carbon cycles, topographic mapping, surface deformation. Physical concepts in remote sensing. EM waves and geophysical information. Sensors: optical, thermal IR, active and passive microwave. GER:2b

3 units, Spr (Zebker) alternate years, not given 2003-04

GEOPHYS 50Q. Earthquakes and Archaeology in the Eastern Mediterranean—Stanford Introductory Seminar. Preference to sophomores. Why are there so many archaeological ruins in the eastern Mediterranean? Assumed by many to be the result of time and wars, many of these ruins are due to historic and prehistoric earthquakes. Modern science reveals that some of these earthquakes must have been so destructive, or happened at times of such political and military stress, that they changed history (the fall of Jericho before Joshua, the catastrophic collapse at the end of the Bronze Age). Lectures in Winter

Quarter, followed during Spring break by a 6 to 9 day field trip to the eastern Mediterranean or Central America. Students complete a term report on a site or event covered in the field trip.

5 units (Nur) alternate years, given 2003-04

GEOPHYS 60Q. Man versus Nature: Coping with Disasters Using Space Technology—(Same as EE 60Q.) Stanford Introductory Dialogue. Preference to sophomores. Natural hazards (earthquakes, volcanoes, floods, hurricanes, and fires) affect thousands of people every day. 20 years of developments in spaceborne imaging technology help monitor and respond to such disasters more rapidly than in the past, saving lives and money. Understanding the physical processes involved allows us to anticipate and plan for mitigation of the consequences of the disasters. How these new tools are applied to natural disasters, and how remotely-sensed data are manipulated and analyzed.

3 units, Aut (Zebker)

GEOPHYS 70Q. Earth in the News—Stanford Introductory Seminar. How issues such as climate change, management of nuclear waste, and damming of rivers challenge people to make decisions that balance human needs with preserving the integrity of natural earth systems. Decisions are based on values, and science provides the context for placing constraints on choices. How understanding earth science contributes to achieving consensus about earth-in-the-news issues. Focus is on two topics, one each from local and national news. Role play, negotiation games, and simulations to represent various opinions and to identify the relevant aspects of earth science. Repeated role play to find out how attitudes and ability to reach consensus change with more knowledge about the earth sciences.

3 units, Spr (Knight)

GEOPHYS 100. Directed Reading

1-2 units, any quarter (Staff)

GEOPHYS 102. Geosphere—(Same as EARTHSYS 110.) The changing planet presents society with myriad problems. How do global climate systems work and how do natural and anthropogenic sources of climate change affect people? Is society running out of energy? What are the consequences of energy use? How do plate tectonics affect daily life, and what is the nature of earthquake hazard in California and the Bay Area? A large-scale system approach to the earth, oceans, and atmosphere. GER:2a

3 units, Aut (Zoback, Arrigo)

GEOPHYS 104. The Water Course—(Same as EARTHSYS 104.) Current issues associated with the use and abuse of surface and ground water supplies. The ways the geological environment controls the quantity and quality of water; illustrated with a taste test of water from around the world. An understanding of current concerns regarding water supplies is used as a basis for considering the past and future impact of the availability of water on natural ecosystems and human settlement. Lab. GER:2a

3 units, Win (Knight)

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

3 units (Fraser-Smith) not given 2002-03

GEOPHYS 111. Introduction to Unix for Earth Scientists—Computing tools for research in earth sciences at Stanford. Focuses on: UNIX operating system, including file system, editors, process control, and X windows; computer networking services, and management of programming projects.

1 unit, Aut (Farrell)

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, e.g., data analysis, statistics, regressions, least-squares, Fourier transforms and filtering in 1- and 2-D, simple spectral analysis, differential equations, and simulations. Emphasis is from a scientific and engineering application perspective.

1-3 units, Aut (Mukerji)

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.

2 units, Aut (Harris)

GEOPHYS 130. 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.

4 units, Spr (Arrigo)

GEOPHYS 135. Remote Sensing of the Oceans—(Graduate students register for 235; same as EARTHSYS 135/235.) 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.

3 units (Arrigo) alternate years, given 2003-04

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.

3 units, Aut (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.

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. A foundation for conducting experiments and for assessing accuracy and variability in reported experimental data. No previous 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.

3 units, Spr (Beroza, Segall) alternate years, not given 2003-04

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

3 units, Aut (Klemperer) alternate years, not given 2003-04

GEOPHYS 183. Reflection Seismology Interpretation—Lectures and workshops on 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, Spr (Klemperer, Graham) alternate years, not given 2003-04

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.

3 units (Klemperer) alternate years, given 2003-04

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.

1-2 units, Aut, Win, Spr

GEOPHYS 185A. Reflection Seismology—(Graduate students register for 385A.) Department 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.) Current 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.) Current research in transmission and reflection tomography, including forward modeling, inversion, and data acquisition.

(Harris)

GEOPHYS 185V. Poroelasticity—(Graduate students register for 385V.) Current research topics on the mechanical properties of porous rocks: dynamic problems of seismic velocity, dispersion, and attenuation; 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—(Graduate students register for 385Y; same as BIOSCI 384.) 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.) Emphasis is on current research applications, especially crustal deformation measurements. Recent instrumentation and system advancements.

(Zebker)

GEOPHYS 190. Environmental and Applied Geophysics—Principles and applications of geophysical methods, seismic reflection and refraction, gravity, magnetics, electromagnetics, resistivity and ground penetrating radar. Hands-on field exercises and demos, run at the Stanford geophysical test site and other locations on campus, familiarize students with the instrumentation and the application of each method.

3 units, Spr (Harris, Fraser-Smith) alternate years, not given 2003-04

GEOPHYS 196. Introduction to Geographic Information Systems (GIS): Using ARC-View—(Graduate students register for 296; same as GES 196/296.) Hands-on experience with ESRI's Arc-View GIS packages. Topics: setting up geographic databases and manipulating spatial data, including database query and analysis. Hands-on computer-based exercises using sample datasets on workstations. Guest lectures on GIS applications in the environmental, geological, and biological sciences, and in town planning.

2 units, Spr (Klemperer)

GEOPHYS 197. Independent Study in Geographic Information Systems (GIS)—(Graduate students register for 297.) Supervised research and/or reading with written reports.

1-5 units, Aut, Win, Spr (Klemperer)

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 2003-04

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://sepwww.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, precon-

ditioning, multidimensional autoregression and spectral factorization, the helical coordinate, and object-based programming. Common recurring issues such as limited aperature, 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—(Same as CEE 297G, GES 215. Observational techniques, laboratory methods, and the theoretical concepts of structural geology and rock mechanics. Solutions to initial and boundary-value problems of continuum mechanics are integrated with field and laboratory data to develop computational models for geological structures and to understand the mechanics of geological hazards (earthquakes and volcanoes). Topics include: differential geometry to characterize structures; dimensional analysis; use of stress, strain, displacement, and velocity fields in structural analysis; and mechanical properties of rock (elasticity, viscosity, strength, friction, fracture toughness). Prerequisites: 1, Calculus, MATLAB or equivalent.
3-5 units, Aut (Pollard)

GEOPHYS 216. Rock Fracture Mechanics—(Same as GES 216.) 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.
5 units (Pollard) alternate years, given 2003-04

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 231. Biological Oceanography—(Same as EARTHSYS 130/230.) For graduate students; see 130.
4 units, Spr (Arrigo)

GEOPHYS 233. Advanced Biological Oceanography—For upper-division undergraduates and graduate students interested in biological processes in the world's oceans. Themes vary from year to year 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.
3-4 units, Spr (Arrigo)

GEOPHYS 235. Remote Sensing of the Oceans—(For graduate students; see 135; same as EARTHSYS 135/235.)
3 units (Arrigo) alternate years, given 2003-04

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 2003-04

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/Fortran programming. Prerequisite: PETENG 240.
3-4 units, Spr (Caers, Mukerji)

GEOPHYS 255. Report on Energy Industry Training—Provides on-the-job-training for master's and doctoral degree students under the guidance of experienced, on-site supervisors. Students must submit a concise report detailing work activities, problems, assignment, and key results. Prerequisite: written consent of advisor.
1-3 units, any quarter (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, Win (Dvorkin) alternate years, not given 2003-04

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 2003-04

GEOPHYS 280. 3-D Reflection Seismology—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, Win (Beroza) alternate years, not given 2003-04

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 units (Segall) alternate years, given 2003-04

GEOPHYS 289. Global Positioning System in Earth Sciences—The 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 units, Win (Segall) alternate years, not given 2003-04

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, Spr (Zoback) alternate years, not given 2003-04

GEOPHYS 296. Introduction to Geographic Information Systems (GIS): Using ARC-View—(For graduate students; see 196; same as GES 196/296.)
2 units, Spr (Klemperer)

GEOPHYS 297. Independent Study in Geographic Information Systems (GIS)—(For graduate students; see 197.)
1-5 units, Aut, Win, Spr (Klemperer)

GEOPHYS 327. The Glacial World—(Same as GES 327.) The environmental changes that took place on Earth between the last glacial maximum (LGM) and the present day. Focus is on the cause of the low atmospheric CO_2 concentrations characteristic of the LGM and what conditions might explain these reduced CO_2 levels. Literature from various disciplines that illustrate, for example, 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 2003-04

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, any quarter (Staff)

GEOPHYS 400. Research in Geophysics
1-10 units, any quarter (Staff)

This file has been excerpted from the *Stanford Bulletin, 2002-03*, pages 70-75. Every effort has been made to insure accuracy; late changes (after print publication of the bulletin) may have been made here. Contact the editor of the *Stanford Bulletin* via email at arod@stanford.edu with changes, corrections, updates, etc.