

Geophysics

Courses offered by the Department of Geophysics are listed under the subject code GEOPHYS on the (<http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=GEOPHYS&filter-catalognumber-GEOPHYS=on>) Stanford Bulletin's (<http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=GEOPHYS&filter-catalognumber-GEOPHYS=on>) ExploreCourses web site (<http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=GEOPHYS&filter-catalognumber-GEOPHYS=on>).

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 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, 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 crustal deformation; earthquake seismology and earthquake mechanics; reflection, refraction, and tomographic seismology; rock mechanics, rock physics; seismic studies of the continental lithosphere; remote sensing; environmental geophysics; and synthetic aperture radar studies.

Mission of the Undergraduate Program in Geophysics

The mission of the undergraduate program in Geophysics is to expose students to a broad spectrum of geophysics, including resource exploration, environmental geophysics, seismology, and tectonics. Students in the major obtain a solid foundation in the essentials of mathematics, physics, and geology, and build upon that foundation with advanced course work in Geophysics to develop the in-depth knowledge they need to pursue advanced graduate study and professional careers in government or the private sector.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to:

1. understand the physics and geology that form the basis for geophysical observation and measurement.
2. understand Earth structure and evolution.
3. identify the physical processes governing the behavior of common geophysical systems.
4. be able to explain the principles of applying geophysical methods to societally relevant problems, including natural hazards, resource exploration and management, and environmental issues.

5. be able to quantitatively describe the behavior of natural systems and the principles of geophysical measurement with physics-based mathematical models.
6. investigate these models by solving the governing equations with a combination of analytical and computational methods.
7. make their own observations with a variety of geophysical instruments, and reduce, model, and interpret their data and uncertainties.
8. effectively communicate their scientific knowledge through written and oral presentations.
9. be able to interpret and evaluate the published literature and oral and poster presentations at national meetings.

Graduate Programs in Geophysics

University requirements for the M.S. and Ph.D. are described in the "Graduate Degrees (<http://www.stanford.edu/dept/registrar/bulletin/4901.htm>)" section of this bulletin. Lecture course units applied to graduate degree program requirements must be taken for a letter grade if the course is offered for a letter grade.

Learning Outcomes (Graduate)

The objective of the graduate program in Geophysics is to prepare students to be leaders in the geophysics industry, academia, and research organizations through completion of fundamental courses in the major field and in related sciences, as well as through independent research. Students are expected to:

1. apply skills developed in fundamental courses to geophysical problems.
2. research, analyze, and synthesize solutions to an original and contemporary geophysics problem.
3. work independently and as part of a team to develop and improve geophysics solutions.
4. apply written, visual, and oral presentation skills to communicate scientific knowledge.
5. master's students are expected to develop in-depth technical understanding of geophysics problems at an advanced level.
6. doctoral students are expected to complete a scientific investigation that is significant, challenging and original.

Bachelor of Science in Geophysics

The following courses are required for the B.S. degree in Geophysics. A written report on original research or an honors thesis is also required through participation in and GEOPHYS 199 Senior Seminar: Issues in Earth Sciences in Autumn Quarter of the senior year. Seniors in Geophysics who expect to do graduate work should take the Graduate Record Examination (GRE) early in their final undergraduate year.

Optional Pre-Major Class

		Units
GEOPHYS 90	Earthquakes and Volcanoes	3

Geophysics Core Courses (29-32 units)

Students must take all of the following:

		Units
GEOPHYS 110	Earth on the Edge: Introduction to Geophysics	3
GEOPHYS 120	Ice, Water, Fire	3-5

GEOPHYS 130	Introductory Seismology	3
GEOPHYS 150	Geodynamics: Our Dynamic Earth	3
GEOPHYS 162	Laboratory Methods in Geophysics	2-3
or PHYSICS 67	Introduction to Laboratory Physics	
GEOPHYS 190	Near-Surface Geophysics	3
GEOPHYS 196	Undergraduate Research in Geophysics (or approved research internship)	5
GEOPHYS 197	Senior Thesis in Geophysics	3
or GEOPHYS 198	Honors Program	
GEOPHYS 199	Senior Seminar: Issues in Earth Sciences	3
GEOPHYS 201	Frontiers of Geophysical Research at Stanford: Faculty Lectures	1
Total Units		29-32

Geophysics Breadth Courses (18-29 units)

Choose six upper-level courses, one from each of the following six areas (but an additional Geophysics class may substitute for either the Physics of the Geology breadth areas):

1. Resources, hazards, and the environment

Select one of the following:		Units
GEOPHYS 182	Reflection Seismology	3
GEOPHYS 183	Reflection Seismology Interpretation	
GEOPHYS 185	Rock Physics for Reservoir Characterization	
ENERGY 120	Fundamentals of Petroleum Engineering	
GES 130		
GES 131		
Total Units		3

2. Whole-Earth Geophysics

Select one of the following:		Units
GES 122	(Also GEOPHYS 132)	3-4
GEOPHYS 141	Remote Sensing of the Oceans	3-4
GEOPHYS 184	Journey to the Center of the Earth	
GEOPHYS 186	Tectonophysics (Tectonophysics & Global Tectonics)	3
Total Units		12-14

3. Numerical and computational methods

Select one of the following:		Units
GEOPHYS 211	Environmental Soundings Image Estimation	3
GEOPHYS 281	Geophysical Inverse Problems	
EARTHSCI 211		
Select one of the following:		3-4

ENERGY 160	Modeling Uncertainty in the Earth Sciences
EE 102A	Signal Processing and Linear Systems I
CME 108	Introduction to Scientific Computing
CS 106A & CS 106B	Programming Methodology and Programming Abstractions
PHYSICS 113	Computational Physics

4. Geophysical fluid dynamics

Select one of the following:		Units
GEOPHYS 146A	Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation	3-4
GEOPHYS 146B	Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation	
GEOPHYS 181	Fluids and Flow in the Earth: Computational Methods	
ENERGY 121	Fundamentals of Multiphase Flow	
CEE 164	Introduction to Physical Oceanography	
EESS 220		

5. Physics

Select one of the following:		Units
EE 142	Engineering Electromagnetics (formerly EE 141)	3
ME 80	Mechanics of Materials	
PHYSICS 110	Advanced Mechanics	
PHYSICS 120	Intermediate Electricity and Magnetism I	

6. Geology

Select one of the following:		Units
GES 102		3-5
GES 110		
GES 111		
GES 151		

Supporting Mathematics Courses

Students must take one of the following series (15 or 19 units):

		Units
CME 100	Vector Calculus for Engineers	5
CME 102	Ordinary Differential Equations for Engineers	5
CME 104	Linear Algebra and Partial Differential Equations for Engineers	5

(MATH 51 (MATH 51M recommended), MATH 52, and MATH 53 plus either GEOPHYS 112 or CME 192 may substitute for CME series

Supporting Science Courses

Students must take all of the following (8-27 units):

		Units
GES 1A or GES 1B or GES 1C		
CHEM 31A & CHEM 31B or CHEM 31X	Chemical Principles I and Chemical Principles II Chemical Principles Accelerated or a score of 5 on the Chemistry AP exam	5-10
PHYSICS 41 or PHYSICS 61	Mechanics Mechanics and Special Relativity or a score of 4-5 on the Physics C Mechanics AP exam	4
PHYSICS 43 or PHYSICS 63	Electricity and Magnetism Electricity, Magnetism, and Waves or a score of 4-5 on the Physics C E & M AP exam	4
PHYSICS 45 or PHYSICS 65	Light and Heat Quantum and Thermal Physics	4

Optional Field Class

GES 105		3
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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 decides 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 198 Honors Program.
4. The decision whether a given independent study project does or does not merit an award of honors is made jointly by the department and the student's adviser. This decision is 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 cannot be used as a substitute for regularly required courses.

Minor in Geophysics

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. The minor consists of one required class (3 units), three electives (min. 9 units), and supporting classes in geology, mathematics, and physics.

Curriculum

1. Required course:

GEOPHYS 110 Earth on the Edge: Introduction to Geophysics

Units
3

2. Plus three additional approved electives, typically chosen from:
Select three of the following:

GEOPHYS 120 Ice, Water, Fire

GEOPHYS 130 Introductory Seismology

GEOPHYS 141 Remote Sensing of the Oceans

GEOPHYS 150 Geodynamics: Our Dynamic Earth

GEOPHYS 162	Laboratory Methods in Geophysics
GEOPHYS 184	Journey to the Center of the Earth
GEOPHYS 186	Tectonophysics
GEOPHYS 190	Near-Surface Geophysics

3. Supporting Math & Science:

		Units
GES 1A or GES 1B or GES 1C		4-5
CME 100 or MATH 51	Vector Calculus for Engineers Linear Algebra and Differential Calculus of Several Variables	5
PHYSICS 21 or PHYSICS 22 or PHYSICS 23 or PHYSICS 24 or PHYSICS 41 & PHYSICS 43 or PHYSICS 41 & PHYSICS 45	Mechanics Fluids and Heat Mechanics, Fluids, and Heat Laboratory Electricity, Magnetism, and Optics Electricity, Magnetism and Optics Laboratory Mechanics and Electricity and Magnetism Mechanics and Light and Heat	3
	or equivalent AP scores	

Coterminal Master of Science Program in Geophysics

The department offers a coterminal M.S. degree for students wishing to obtain more specialized training in Geophysics than is normally possible during study for the B.S. degree alone. An M.S. degree should be considered as the professional degree in Geophysics, and is aimed at students wishing to work in a related industry, or students desiring more focused academic study in the field than the B.S. program allows.

The coterminal M.S. degree in Geophysics is offered in conjunction with any relevant undergraduate program at Stanford. Geophysics students often enter the department with degrees in Earth Sciences, Mathematics, Physics, Chemistry, or other natural science or engineering fields. Any of these are suitable for the coterminal Geophysics program, and interested students are encouraged to discuss their own background with a Geophysics faculty member.

Admission

The requirements for entry into the coterminal M.S. program are submission of a transcript, a statement of purpose, and at least two letters of recommendation. Applications with a letter of recommendation from a Geophysics faculty are generally considered the strongest. Additional letters from other academic or work-related persons also strengthen the application. There are no specific GPA requirements for entry, but the Department looks for proven performance in a rigorous undergraduate curriculum as a prerequisite for admission.

Undergraduates with at least junior-level standing may apply, and applications should be submitted by the Autumn Quarter of the senior year.

The graduation requirements to obtain the degree are identical to those for the regular Geophysics master's degree.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (<http://exploreddegrees.stanford.edu/cotermddegrees>)" section. University requirements for the master's degree are described in the "Graduate Degrees (<http://exploreddegrees.stanford.edu/graduatedegrees/#masterstext>)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Master of Science in Geophysics 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.

Degree Requirements

The candidate must complete 45 units from the following groups of courses:

1. Complete 15 units of Geophysics lecture courses with at least 9 units numbered 200 or higher.
2. Complete six units numbered 100 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, relevant biology, computer science, ecology, hydrology, or earth science. At least one course must be numbered 200 or higher.
4. Enroll for at least three quarters of research seminar (GEOPHYS 385 series).
5. At least 6, but not more than 15, of the 45 units must be earned by enrollment in GEOPHYS 400 Research in Geophysics for independent work on a research problem resulting in a written report accepted and archived by the candidate's faculty. A summer internship is encouraged as venue for research, but no academic credit is given.
6. Submit a program proposal for approval by a faculty adviser in the first quarter of enrollment.
7. 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; and turn in a thesis/report to adviser.
8. Students are required to attend department seminars.

Doctor of Philosophy in Geophysics 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.

Transfer Credit

An incoming student with a relevant master of science degree may apply for a departmental waiver of up to 12 units of the 30 lecture units required for the Ph.D. degree, for certain courses as approved by the departmental graduate faculty adviser. Credit for courses generally requires that students identify an equivalent Stanford course and obtain the signature of the Stanford faculty responsible for that course, stating its equivalence.

Requirements for the Degree

A minimum of 135 units of graduate study at Stanford must be satisfactorily completed. Required courses must be taken for a letter grade, if offered. Students are required to attend the department seminars, and to complete sufficient units of independent work on a research problem to meet the 135-unit University requirement. 12 units must be met by participation in the GEOPHYS 385 series, or equivalent series in other departments with approval of the adviser and graduate coordinator. Students are encouraged to participate in the GEOPHYS 385 series from more than one faculty member or group and relevant equivalent series in other departments. Students with a Master's degree may waive up to 12 units for approved courses.

ENGR 202W Technical Writing, is recommended but not required.

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. For more information, see the Geophysics Administrative Guide, section 1.4.1.

The student must pass the departmental oral examination by the end of the sixth academic quarter (third academic quarter for students with an M.S. degree); 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. Upon formal acceptance into a research group, the student and faculty adviser form a supervising committee consisting of at least three members who are responsible for overseeing satisfactory progress toward the Ph.D. degree. At least two committee members must be Geophysics faculty members. The committee conducts the department oral examination, and meets thereafter annually with the student to review degree progress. The Geophysics faculty monitors progress of all students who have not yet passed their department oral examination by carrying out an annual performance appraisal at a closed faculty meeting.

Course requirements

1. *Geophysics*: 12 units, lecture courses numbered 200 and above, from 4 different Geophysics faculty with different research specializations. These units cannot be waived.
2. *Additional Geophysics*: 3 units, lecture courses numbered 150 and above

3. *School of Earth Sciences (non-Geophysics)*: 3 units, lecture courses numbered 100 or above
4. *Mathematics (numbered 100 or above), Science, and Engineering (non-School of Earth Sciences)*: 6 units, lecture courses numbered 200 or above
5. *Any of the above categories*: 6 units, lecture courses numbered 200 or above
6. *Total required units*: 30 units.

Ph.D. Department Examination Requirement

1. One research proposal (10-20 pages) with a completed component that outlines a plan of research for 2-3 years
2. Second scientific proposal or paper (4-10 pages) with a professor in another area
3. An oral presentation with the student's advising committee on both the research proposal (~30-40 min) and the second proposal/paper (~10 min), with questions by the committee constituting the qualifying exam.

Second Project

The purpose of the second research project is to add breadth to Ph.D. study and give the student the opportunity, ability and confidence to carry out research in multiple areas.

Description/Scope:

The second project should stand alone as a separate piece of work from the primary research project.

- The second project must be in Geophysics or a closely related discipline
- The topic must be substantially different from the topic of the Ph.D. thesis; i.e., it should not be the same method applied to a different problem, or a different method applied to the same problem.
- The second project should be supervised by a Stanford Geophysics faculty member (Academic Council or research faculty) who does not serve as the primary research adviser, and who must be in a separate research group. Exceptions allowing for second project advisers who are not Stanford Geophysics faculty must be approved by both the research adviser and the Director of Graduate Studies.
- Completion of the second project ideally results in a publication in the refereed literature, or a presentation at a scientific conference.
- Most students are expected to complete the second research project as part of their Ph.D. studies. However, the department allows an option of meeting academic breadth requirements through additional focused course work; see the Geophysics (<https://pangea.stanford.edu/departments/geophysics/academics/graduate-program/graduation-requirements>) web site for further information on program requirements and the coursework breadth option.

Chair: Howard Zebker

Associate Chair: Biondo Biondi

Professors: Greg Beroza, Biondo Biondi, Jerry M. Harris, Simon Klemperer, Rosemary J. Knight, Paul Segall, Norman H. Sleep, Howard Zebker,* Mark D. Zoback

Associate Professor: Eric Dunham

Assistant Professors: Tiziana Vanorio, Jenny Suckale

Professor (Research): Gerald M. Mavko

Associate Professor (Research): Tapan Mukerji***

Emeriti: Jon Claerbout, Antony Fraser-Smith,* Robert Kovach, Amos Nur, Joan Roughgarden,** George A. Thompson

Courtesy Professors: Stephan A. Graham, Wendy Mao, David D. Pollard

* Joint appointment with Electrical Engineering

** Joint appointment with Biological Sciences

*** Joint appointment with Energy Resources Engineering

Courses

GEOPHYS 20N. Predicting Volcanic Eruptions. 3 Units.

Preference to sophomores. The physics and chemistry of volcanic processes and modern methods of volcano monitoring. Volcanoes as manifestations of the Earth's internal energy and hazards to society. How earth scientists better forecast eruptive activity by monitoring seismic activity, bulging of the ground surface, and the discharge of volcanic gases, and by studying deposits from past eruptions. Focus is on the interface between scientists and policy makers and the challenges of decision making with incomplete information. Field trip to Mt. St. Helens, site of the 1980 eruption.

GEOPHYS 50N. Planetary Habitability, World View, and Sustainability. 3 Units.

Sustainability lessons from the geological past. Life on Earth has partially perished in sudden mass extinctions several times over the Earth's history. Threats include actions of our own volition, including fossil fuel burning as well as natural events, including the impact of large asteroids. The end Permian 250 million years ago and end Paleocene 55 million years ago extinctions involved natural burning of fossil fuels. The 65 million year ago end Cretaceous extinction involved the impact of an asteroid and possibly fossil fuel burning. Related sustainability topics in the popular press will be discussed as they arise. Student pairs lead discussions on topics on how humanity might avert these catastrophes. Offered occasionally.

GEOPHYS 60N. Man versus Nature: Coping with Disasters Using Space Technology. 4 Units.

Preference to freshman. Natural hazards, earthquakes, volcanoes, floods, hurricanes, and fires, and how they affect people and society; great disasters such as asteroid impacts that periodically obliterate many species of life. Scientific issues, political and social consequences, costs of disaster mitigation, and how scientific knowledge affects policy. How spaceborne imaging technology makes it possible to respond quickly and mitigate consequences; how it is applied to natural disasters; and remote sensing data manipulation and analysis. GER:DB-EngrAppSci.

Same as: EE 60N

GEOPHYS 70. The Water Course. 3 Units.

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.

Same as: EARTHSYS 104

GEOPHYS 80. The Energy-Water Nexus. 3 Units.

Energy, water, and food are our most vital resources constituting a tightly intertwined network: energy production requires water, transporting and treating water needs energy, producing food requires both energy and water. The course is an introduction to learn specifically about the links between energy and water. Students will look first at the use of water for energy production, then at the role of energy in water projects, and finally at the challenge in figuring out how to keep this relationship as sustainable as possible. Students will explore case examples and are encouraged to contribute examples of concerns for discussion as well as suggest a portfolio of sustainable energy options.

Same as: EARTHSYS 140

GEOPHYS 90. Earthquakes and Volcanoes. 3 Units.

Is the "Big One" overdue in California? What kind of damage would that cause? What can we do to reduce the impact of such hazards in urban environments? Does "fracking" cause earthquakes and are we at risk? Is the United States vulnerable to a giant tsunami? The geologic record contains evidence of volcanic super eruptions throughout Earth's history. What causes these gigantic explosive eruptions, and can they be predicted in the future? This course will address these and related issues. For non-majors and potential Earth scientists. No prerequisites. More information at https://pangea.stanford.edu/research/CDFM/CourseDescriptions/GP_113_announcement.pdf. Same as: EARTHSYS 113

GEOPHYS 100. Directed Reading. 1-2 Unit.
(Staff).**GEOPHYS 110. Earth on the Edge: Introduction to Geophysics. 3 Units.**

Introduction to the foundations of contemporary geophysics. Topics drawn from four broad themes in: whole Earth geodynamics, geohazards, natural resources, and environment/sustainability. In each case the focus is on how the interpretation of a variety of geophysical measurements (e.g., gravity, seismology, heat flow, magnetism, electromagnetics, and geodesy) can be used to provide fundamental insight into the behavior of the Earth's complex geosystems. Prerequisite: CME 100 or MA TH 51, or co-registration in either.

GEOPHYS 112. Exploring Geosciences with MATLAB. 1-3 Unit.

How to use MATLAB as a tool for research and technical computing, including 2-D and 3-D visualization features, numerical capabilities, and toolboxes. Practical skills in areas such as data analysis, regressions, optimization, spectral analysis, differential equations, image analysis, computational statistics, and Monte Carlo simulations. Emphasis is on scientific and engineering applications. Offered every year, autumn quarter.

GEOPHYS 118. Understanding Natural Hazards, Quantifying Risk, Increasing Resilience in Highly Urbanized Regions. 3 Units.

Integrating the science of natural hazards, methods for quantitatively estimating the risks that these hazards pose to populations and property, engineering solutions that might best ameliorate these risks and increase resilience to future events, and policy and economic decision-making studies that may increase long-term resilience to future events. Panel discussions by outside experts exploring the science, engineering, policy, and economics that underly the hazards, risks, and strategies for increasing resilience. Group assignments to evaluate the way in which natural hazards, and human population and developing interact in megacities to produce risk, and what strategies might be adopted in each area to reduce risks posed by the specific hazards faced by these urban areas. Same as: ESS 118, ESS 218, GEOPHYS 218, GS 118, GS 218

GEOPHYS 120. Ice, Water, Fire. 3-5 Units.

Introductory application of continuum mechanics to ice sheets and glaciers, water waves and tsunamis, and volcanoes. Emphasis on physical processes and mathematical description using balance of mass and momentum, combined with constitutive equations for fluids and solids. Designed for undergraduates with no prior geophysics background; also appropriate for beginning graduate students. Prerequisites: CME 100 or MATH 52 and PHYSICS 41 (or equivalent). Offered every year. Spring 2015-2016 and Winter 2016-2017.

Same as: GEOPHYS 220

GEOPHYS 130. Introductory Seismology. 3 Units.

Introduction to seismology including: elasticity and the wave equation, P, S, and surface waves, dispersion, ray theory, reflection and transmission of seismic waves, seismic imaging, large-scale Earth structure, earthquake location, earthquake statistics and forecasting, magnitude scales, seismic source theory.

GEOPHYS 141. Remote Sensing of the Oceans. 3-4 Units.

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. Same as: EARTHSYS 141, EARTHSYS 241, ESS 141, ESS 241

GEOPHYS 146A. Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation. 3 Units.

Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the atmospheric circulation. Topics include the global energy balance, the greenhouse effect, the vertical and meridional structure of the atmosphere, dry and moist convection, the equations of motion for the atmosphere and ocean, including the effects of rotation, and the poleward transport of heat by the large-scale atmospheric circulation and storm systems. Prerequisites: MATH 51 or CME100 and PHYSICS 41. Same as: EARTHSYS 146A, EARTHSYS 246A, ESS 146A, ESS 246A, GEOPHYS 246A

GEOPHYS 146B. Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation. 3 Units.

Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the large-scale ocean circulation. This course will give an overview of the structure and dynamics of the major ocean current systems that contribute to the meridional overturning circulation, the transport of heat, salt, and biogeochemical tracers, and the regulation of climate. Topics include the tropical ocean circulation, the wind-driven gyres and western boundary currents, the thermohaline circulation, the Antarctic Circumpolar Current, water mass formation, atmosphere-ocean coupling, and climate variability. Prerequisites: EESS 146A or EESS 246A, or CEE 164 or CEE 262D, or consent of instructor.

Same as: EARTHSYS 146B, EARTHSYS 246B, ESS 146B, ESS 246B, GEOPHYS 246B

GEOPHYS 150. Geodynamics: Our Dynamic Earth. 3 Units.

In this course we cover the dynamic forces acting upon the Earth. We will investigate how geophysical forces effect the bending of tectonic plates, the flow of heat, sea level topography, the breaking point of rocks, porous flow, and how faults store and release energy. Math 52 or CME 102. Offered every year, Spring quarter. Next Offered Spring 2016-2017.

GEOPHYS 160. D^3: Disasters, Decisions, Development. 3-5 Units.

This class connects the science behind natural disasters with the real-world constraints of disaster management and development. In each iteration of this class we will focus on a specific, disaster-prone location as case study. By collaborating with local stakeholders we will explore how science and engineering can make a make a difference in reducing disaster risk in the future. Offered every other year.

GEOPHYS 162. Laboratory Methods in Geophysics. 3-4 Units.

Lab. Types of equipment used in experimental rock physics. Principles and measurements of geophysical properties such as porosity, permeability, acoustic wave velocity, and resistivity through lectures and laboratory experiments. Training in analytical project writing skills and understanding errors for assessing accuracy and variability of measured data. Students may investigate a scientific problem to support their own research. Prerequisites: Physics 45 (Light and Heat); and CME 100 (Vector Calculus). Same as: GEOPHYS 259

GEOPHYS 170. Global Tectonics. 3 Units.

The architecture of the Earth's crust; regional assembling of structural or deformational features and their relationship, origin and evolution. The plate-tectonic cycle: rifting, passive margins, sea-floor spreading, subduction zones, and collisions. Case studies.

GEOPHYS 171. Tectonics Field Trip. 1-3 Unit.

Long weekend field trip to examine large-scale features in the crust. Destinations may include the San Andreas fault, Mendocino Triple Junction, Sierra Nevada, and western Basin and Range province.

GEOPHYS 181. Fluids and Flow in the Earth: Computational Methods. 3 Units.

Interdisciplinary problems involving the state and movement of fluids in crustal systems, and computational methods to model these processes. Examples of processes include: nonlinear, time-dependent flow in porous rocks; coupling in porous rocks between fluid flow, stress, deformation, and heat and chemical transport; percolation of partial melt; diagenetic processes; pressure solution and the formation of stylolites; and transient pore pressure in fault zones. MATLAB, Lattice-Boltzmann, and COMSOL Multiphysics. Term project. No experience with COMSOL Multiphysics required. Offered every other year, winter quarter.
Same as: GEOPHYS 203

GEOPHYS 182. Reflection Seismology. 3 Units.

The principles of seismic reflection profiling, focusing on methods of seismic data acquisition and seismic data processing for hydrocarbon exploration.
Same as: GEOPHYS 222

GEOPHYS 183. Reflection Seismology Interpretation. 1-4 Unit.

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: 222, or consent of instructor.
Same as: GEOPHYS 223, GS 223

GEOPHYS 184. Journey to the Center of the Earth. 3 Units.

The interconnected set of dynamic systems that make up the Earth. Focus is on fundamental geophysical observations of the Earth and the laboratory experiments to understand and interpret them. What earthquakes, volcanoes, gravity, magnetic fields, and rocks reveal about the Earth's formation and evolution. Offered every other year, winter quarter. Next offering Winter 2013-14.
Same as: GEOPHYS 274, GS 107, GS 207

GEOPHYS 185. Rock Physics for Reservoir Characterization. 3 Units.

How to integrate well log and laboratory data to determine and theoretically generalize rock physics transforms between sediment wave properties (acoustic and elastic impedance), 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. Offered every other year, spring quarter.
Same as: GEOPHYS 260

GEOPHYS 186. Tectonophysics. 3 Units.

The physics of faulting and plate tectonics. Topics: plate driving forces, lithospheric rheology, crustal faulting, and the state of stress in the lithosphere. Exercises: lithospheric temperature and strength profiles, calculation of seismic strain from summation of earthquake moment tensors, slip on faults in 3D, and stress triggering and inversion of stress from earthquake focal mechanisms. Offered every other year, winter quarter.
Same as: GEOPHYS 290

GEOPHYS 190. Near-Surface Geophysics. 3 Units.

Introduction to the integration of geophysical field measurements and laboratory measurements for imaging and characterizing the top 100 meters of Earth. Examples will focus on applications related to water resource management. The link between the measured geophysical properties of rocks, soils, and sediments, and their material properties. Forward modeling and inversion of geophysical data sets. Each week includes two hours of lectures; plus one two-hour lab that involves acquisition of field or lab data, or computer modeling/analysis of data. Pre-requisite: CME 100 or Math 51, or co-registration in either.

GEOPHYS 191. Observing Freshwater. 3 Units.

We will study estimates of the components of the land hydrological cycle using in-situ and satellite observations and model output. Hydrological variables are rainfall, snow, water vapor, soil moisture, stream discharge and groundwater; other variables are vegetation, surface temperature, soil types, land use and surface topography. We focus on observations and their role in the water balance of the land surface. In-class lab experience working with data. Group/individual term project & paper & presentation; no final. Pre-requisite: basic familiarity with MATLAB.

GEOPHYS 196. Undergraduate Research in Geophysics. 1-10 Unit.

Field-, lab-, or computer-based. Faculty supervision. Written reports.

GEOPHYS 197. Senior Thesis in Geophysics. 3-5 Units.

For seniors writing a thesis based on Geophysics research in 196 or as a summer research fellow. Seniors defend the results of their research at a public oral presentation.

GEOPHYS 198. Honors Program. 1-3 Unit.

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: department approval. Seniors defend the results of their research at a public oral presentation.

GEOPHYS 199. Senior Seminar: Issues in Earth Sciences. 3 Units.

Focus is on written and oral communication in a topical context. Topics from current frontiers in earth science research and issues of concern to the public. Readings, oral presentations, written work, and peer review.

GEOPHYS 201. Frontiers of Geophysical Research at Stanford: Faculty Lectures. 1 Unit.

Required for new students entering the department. Second-year and other graduate students may attend either for credit or as auditors. Department faculty and senior research staff introduce the frontiers of research problems and 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. Offered every year, autumn quarter.

GEOPHYS 202. Reservoir Geomechanics. 3 Units.

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. Course will have an online component in 2014-2015. Given alternate years.

GEOPHYS 203. Fluids and Flow in the Earth: Computational Methods. 3 Units.

Interdisciplinary problems involving the state and movement of fluids in crustal systems, and computational methods to model these processes. Examples of processes include: nonlinear, time-dependent flow in porous rocks; coupling in porous rocks between fluid flow, stress, deformation, and heat and chemical transport; percolation of partial melt; diagenetic processes; pressure solution and the formation of stylolites; and transient pore pressure in fault zones. MATLAB, Lattice-Boltzmann, and COMSOL Multiphysics. Term project. No experience with COMSOL Multiphysics required. Offered every other year, winter quarter.
Same as: GEOPHYS 181

GEOPHYS 204. Spectral Finite Element Method (SPECFEM) Seismograms. 3 Units.

This is a short course intended for graduate students, but senior level undergraduate students are welcome. The course will cover spectral finite element methods for generating synthetic seismograms. The course will emphasize application over theory, such that students will be able to generate synthetic seismograms by the end of the course. We will employ the SPECFEM code suite on the Center for Computational Earth and Environmental Science (CEES) cluster to generate synthetic seismograms. Bring your laptop to class! Pre-requisite: A working knowledge of differential equations, matrix algebra, unix/linux, and earthquake seismology.

GEOPHYS 205. Effective Scientific Presentation and Public Speaking. 2 Units.

The ability to present your work in a compelling, concise, and engaging manner will enhance your professional career. This course breaks down presentations into their key elements: the opening, body of the talk, closing, slide and poster graphics, Q&A, pacing, pauses, and voice modulation. We use clips from archived talks, slide sets and posters to illustrate the good, the bad, and the ugly. Each participant will use their upcoming conference talk or poster (e.g., AGU, SEG), or upcoming job talk or funding pitch, as their class project. The course will be 40% group meetings and 60% individual coaching. Everyone will come away a more skilled and confident speaker than they were before. Instructor: Ross S. Stein (USGS) The course syllabus is the third publication in <http://profile.usgs.gov/rstein>.

GEOPHYS 206. FLUID DYNAMICS OF THE SOLID EA. 3 Units.

Introduction to fluid dynamical processes in the interior and on the surface of the Earth. The main focus of this course are viscous flow systems with different rheologies. Topics include solid-mantle convection, lava flows, creep in ice sheets, flow instabilities in solid-fluid mixtures and basic principles of fluid percolation through porous media.

GEOPHYS 210. Basic Earth Imaging. 2-3 Units.

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/>. Offered every year, autumn quarter.

GEOPHYS 211. Environmental Soundings Image Estimation. 3 Units.

Imaging principles exemplified by means of imaging geophysical data of various uncomplicated types (bathymetry, altimetry, velocity, reflectivity). Adjoint, 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/>.

GEOPHYS 212. Topics in Climate Change. 2 Units.

This introductory classroom course presents Earth's climate system and explores the science and politics of global climate change. Students will learn how the climate system works, the factors that cause climate to change across different time scales, the use of models and observations to make predictions about future climate. The course will discuss possible consequences of climate change in the Earth, and it will explore the evidence for changes due to global warming. There are no prerequisites.

GEOPHYS 217. Numerical Methods in Engineering and Applied Sciences. 3 Units.

Scientific computing and numerical analysis for physical sciences and engineering. Advanced version of CME206 that, apart from CME206 material, includes nonlinear PDEs, multidimensional interpolation and integration and an extended discussion of stability for initial boundary value problems. Recommended for students who have some prior numerical analysis experience. Topics include: 1D and multi-D interpolation, numerical integration in 1D and multi-D including adaptive quadrature, numerical solutions of ordinary differential equations (ODEs) including stability, numerical solutions of 1D and multi-D linear and nonlinear partial differential equations (PDEs) including concepts of stability and accuracy. Prerequisites: linear algebra, introductory numerical analysis (CME 108 or equivalent).

Same as: AA 214A, CME 207

GEOPHYS 218. Understanding Natural Hazards, Quantifying Risk, Increasing Resilience in Highly Urbanized Regions. 3 Units.

Integrating the science of natural hazards, methods for quantitatively estimating the risks that these hazards pose to populations and property, engineering solutions that might best ameliorate these risks and increase resilience to future events, and policy and economic decision-making studies that may increase long-term resilience to future events. Panel discussions by outside experts exploring the science, engineering, policy, and economics that underly the hazards, risks, and strategies for increasing resilience. Group assignments to evaluate the way in which natural hazards, and human population and developing interact in megacities to produce risk, and what strategies might be adopted in each area to reduce risks posed by the specific hazards faced by these urban areas.

Same as: ESS 118, ESS 218, GEOPHYS 118, GS 118, GS 218

GEOPHYS 220. Ice, Water, Fire. 3-5 Units.

Introductory application of continuum mechanics to ice sheets and glaciers, water waves and tsunamis, and volcanoes. Emphasis on physical processes and mathematical description using balance of mass and momentum, combined with constitutive equations for fluids and solids. Designed for undergraduates with no prior geophysics background; also appropriate for beginning graduate students. Prerequisites: CME 100 or MATH 52 and PHYSICS 41 (or equivalent). Offered every year. Spring 2015-2016 and Winter 2016-2017.

Same as: GEOPHYS 120

GEOPHYS 222. Reflection Seismology. 3 Units.

The principles of seismic reflection profiling, focusing on methods of seismic data acquisition and seismic data processing for hydrocarbon exploration.

Same as: GEOPHYS 182

GEOPHYS 223. Reflection Seismology Interpretation. 1-4 Unit.

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: 222, or consent of instructor.

Same as: GEOPHYS 183, GS 223

GEOPHYS 224. Seismic Reflection Processing. 2-3 Units.

Workshop in computer processing of 2D and 3D seismic reflection data. Students individually process a seismic reflection profile (of their own choice or instructor-provided) from field recordings to migrated sections and subsurface images, using interactive software (OpenCPS from OpenGeophysical.com). Prerequisite: GEOPHYS 222 or consent of instructor.

GEOPHYS 229. Earthquake Rupture Dynamics. 3 Units.

Physics of earthquakes, including nucleation, propagation, and arrest; slip-weakening and rate-and-state friction laws; thermal pressurization and dynamic weakening mechanisms; off-fault plasticity; dynamic fracture mechanics; earthquake energy balance. Problem sets involve numerical simulations on CEES cluster. Prerequisites: GEOPHYS 287. Offered occasionally.

GEOPHYS 235. WAVES AND FIELDS IN GEOPHYSICS. 3 Units.

Basic topics and approaches (theory and numerical simulations) on acoustic, electromagnetic, and elastic waves and fields for geophysical applications: dispersion, phase and group velocities, attenuation, reflection and transmission at planar interfaces, high frequency and low frequency approximations, heterogeneous media. Prerequisites: UG level class on waves or consent of instructor.

GEOPHYS 240. Borehole Seismic Modeling and Imaging. 3 Units.

Borehole seismic imaging for applications to subsurface reservoir characterization and monitoring. Topics include data acquisition, data processing, imaging and inversion. Analysis and processing of synthetic and field datasets. Prerequisites: Waves class equivalent to GP 230, Matlab or other computer programming.

GEOPHYS 241A. Seismic Reservoir Characterization. 3-4 Units.

(Same as GP241) Practical methods for quantitative characterization and uncertainty assessment of subsurface reservoir models integrating well-log and seismic data. Multidisciplinary combination of rock-physics, seismic attributes, sedimentological information and spatial statistical modeling techniques. Student teams build reservoir models using limited well data and seismic attributes typically available in practice, comparing alternative approaches. Software provided (SGEMS, Petrel, Matlab). Recommended: ERE240/260, or GP222/223, or GP260/262 or GES253/257; ERE246, GP112.

Same as: ENERGY 141, ENERGY 241

GEOPHYS 246A. Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation. 3 Units.

Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the atmospheric circulation. Topics include the global energy balance, the greenhouse effect, the vertical and meridional structure of the atmosphere, dry and moist convection, the equations of motion for the atmosphere and ocean, including the effects of rotation, and the poleward transport of heat by the large-scale atmospheric circulation and storm systems. Prerequisites: MATH 51 or CME100 and PHYSICS 41.

Same as: EARTHSYS 146A, EARTHSYS 246A, ESS 146A, ESS 246A, GEOPHYS 146A

GEOPHYS 246B. Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation. 3 Units.

Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the large-scale ocean circulation. This course will give an overview of the structure and dynamics of the major ocean current systems that contribute to the meridional overturning circulation, the transport of heat, salt, and biogeochemical tracers, and the regulation of climate. Topics include the tropical ocean circulation, the wind-driven gyres and western boundary currents, the thermohaline circulation, the Antarctic Circumpolar Current, water mass formation, atmosphere-ocean coupling, and climate variability. Prerequisites: EESS 146A or EESS 246A, or CEE 164 or CEE 262D, or consent of instructor.

Same as: EARTHSYS 146B, EARTHSYS 246B, ESS 146B, ESS 246B, GEOPHYS 146B

GEOPHYS 251. Structural Geology and Rock Mechanics. 4 Units.

Quantitative field and laboratory data integrated with solutions to boundary value problems of continuum mechanics to understand tectonic processes in Earth's crust that lead to the development of geological structures including folds, faults, fractures and fabrics. Topics include: techniques and tools for structural mapping; differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; traction and stress analysis, conservation of mass and momentum in a deformable continuum; linear elastic deformation and elastic properties; brittle deformation including fracture and faulting; model development and methodology. Data sets analyzed using MATLAB. Prerequisites: GES 1, MATH 53, MATLAB or equivalent.

Same as: CEE 297R, GS 215

GEOPHYS 255. Report on Energy Industry Training. 1-3 Unit.

On-the-job-training for master's and doctoral degree students under the guidance of on-site supervisors. Students submit a report detailing work activities, problems, assignment, and key results. May be repeated for credit. Prerequisite: written consent of adviser.

GEOPHYS 257. Introduction to Computational Earth Sciences. 2-4 Units.

Techniques for mapping numerically intensive algorithms to modern high performance computers such as the Center for Computational Earth and Environmental Science's (CEES). Topics include computer architecture performance analysis, and parallel programming. Topics covered include pthreads OpenMP; MPI, Cilk++, and CUDA. Exercises using SMP and cluster computers. May be repeated for credit. Offered every other year, winter quarter.

GEOPHYS 258. Applied Optimization Laboratory (Geophys 258). 3-4 Units.

Application of optimization and estimation methods to the analysis and modeling of large observational data sets. Laboratory exercises using inverse theory and applied linear algebra to solve problems of indirect and noisy measurements. Emphasis on practical solution of scientific and engineering problems, especially those requiring large amounts of data, on digital computers using scientific languages. Also addresses advantages of large-scale computing, including hardware architectures, input/output and data bus bandwidth, programming efficiency, parallel programming techniques. Student projects involve analyzing real data by implementing observational systems such as tomography for medical and Earth observation uses, radar and matched filtering, multispectral/multitemporal studies, or migration processing. Prerequisites: Programming with high level language. Recommended: EE261, EE263, EE178, ME300 or equivalent.

Same as: EE 257

GEOPHYS 259. Laboratory Methods in Geophysics. 3-4 Units.

Lab. Types of equipment used in experimental rock physics. Principles and measurements of geophysical properties such as porosity, permeability, acoustic wave velocity, and resistivity through lectures and laboratory experiments. Training in analytical project writing skills and understanding errors for assessing accuracy and variability of measured data. Students may investigate a scientific problem to support their own research. Prerequisites: Physics 45 (Light and Heat); and CME 100 (Vector Calculus).

Same as: GEOPHYS 162

GEOPHYS 260. Rock Physics for Reservoir Characterization. 3 Units.

How to integrate well log and laboratory data to determine and theoretically generalize rock physics transforms between sediment wave properties (acoustic and elastic impedance), 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. Offered every other year, spring quarter.

Same as: GEOPHYS 185

GEOPHYS 262. Rock Physics. 3 Units.

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. Offered every year, autumn quarter.

GEOPHYS 265. Imaging Radar and Applications. 3 Units.

Radar remote sensing, radar image characteristics, viewing geometry, range coding, synthetic aperture processing, correlation, range migration, range/Doppler algorithms, wave domain algorithms, polar algorithm, polarimetric processing, interferometric measurements. Applications: surface deformation, polarimetry and target discrimination, topographic mapping surface displacements, velocities of ice fields. Prerequisites: EE261. Recommended: EE254, EE278, EE279.

Same as: EE 355

GEOPHYS 270. Electromagnetic Properties of Geological Materials. 2-3 Units.

Laboratory observations and theoretical modeling of the electromagnetic properties and nuclear magnetic resonance response of geological material. Relationships between these properties and water-saturated materials properties such as composition, water content, surface area, and permeability.

GEOPHYS 274. Journey to the Center of the Earth. 3 Units.

The interconnected set of dynamic systems that make up the Earth. Focus is on fundamental geophysical observations of the Earth and the laboratory experiments to understand and interpret them. What earthquakes, volcanoes, gravity, magnetic fields, and rocks reveal about the Earth's formation and evolution. Offered every other year, winter quarter. Next offering Winter 2013-14.

Same as: GEOPHYS 184, GS 107, GS 207

GEOPHYS 280. 3-D Seismic Imaging. 2-3 Units.

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. Offered every year, Spring quarter.

GEOPHYS 281. Geophysical Inverse Problems. 3 Units.

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 51.

GEOPHYS 284. Hydrogeophysics. 3 Units.

The use of geophysical methods for imaging and characterizing the top 100 meters of Earth for hydrogeologic applications. Includes material properties, forward modeling, data acquisition, inversion, and integration with other forms of measurement. Each week includes three hours of lectures; plus one three-hour lab that involves acquisition of data at campus or nearby sites, or computer modeling of data. Offered occasionally.

GEOPHYS 286. Global Seismology. 3 Units.

This course investigates how waves propagate through the whole Earth. This course examines the questions "How do body waves and surface waves behave within the Earth?" and "What does that tell us about the Earth?" The course delves into both theory and how we apply that theory to understand seismic observations. Requirements: Math 52 or CME 102, GP130 or permission from instructor.

GEOPHYS 287. Earthquake Seismology. 3-5 Units.

Seismic wave propagation (body waves and surface waves, reflection/transmission), Green's functions, seismic moment tensors and equivalent forces, representation theorem, finite-source effects. Prerequisites: GEOPHYS 130 or equivalent. Offered every other year, spring quarter.

GEOPHYS 288A. Crustal Deformation. 3-5 Units.

Earthquake and volcanic deformation, emphasizing analytical models that can be compared to data from GPS, InSAR, and strain meters. Deformation, stress, and conservation laws. Dislocation models of strike slip and dip slip faults, in 2 and 3 dimensions. Crack models, including boundary element methods. Dislocations in layered and elastically heterogeneous earth models. Models of volcano deformation, including sills, dikes, and magma chambers. Offered every other year, autumn quarter.

GEOPHYS 288B. Crustal Deformation. 3-5 Units.

Earthquake and volcanic deformation, emphasizing analytical models that can be compared to data from GPS, InSAR, and strain meters. Viscoelasticity, post-seismic rebound, and viscoelastic magma chambers. Effects of surface topography and earth curvature on surface deformation. Gravity changes induced by deformation and elastogravitational coupling. Poro-elasticity, coupled fluid flow and deformation. Earthquake nucleation and rate-state friction. Models of earthquake cycle at plate boundaries.

GEOPHYS 289. Global Positioning System in Earth Sciences. 3-5 Units.

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.

GEOPHYS 290. Tectonophysics. 3 Units.

The physics of faulting and plate tectonics. Topics: plate driving forces, lithospheric rheology, crustal faulting, and the state of stress in the lithosphere. Exercises: lithospheric temperature and strength profiles, calculation of seismic strain from summation of earthquake moment tensors, slip on faults in 3D, and stress triggering and inversion of stress from earthquake focal mechanisms. Offered every other year, winter quarter.

Same as: GEOPHYS 186

GEOPHYS 292. Magnetotellurics: Introduction, practical data analysis and inversion. 3 Units.

Geophys 292 approved, also can meet PhD requirement for 4 200-level classes. GEOPHYS 292 Magnetotellurics: introduction, practical data analysis and inversion. Designed for those with no knowledge of magnetotellurics or electromagnetic induction methods, this class will cover the theory and practice of the MT method with application to both commercial (mineral, oil/gas, and geothermal exploration) and academic (crustal and lithospheric studies). The second half of the class is a hands-on analysis and modelling workshop that will require use of a laptop and instructor-provided codes and data. The analysis will be using various methods to determine dimensionality and directionality, and testing the apparent resistivities and phases for internal consistency. The modelling will be 1D only, but knowledge and skills gained from understanding 1D inversion are equally applicable to 2D and 3D. Textbook is iquest; The Magnetotelluric Method: Theory and Practice iquest; (Chave and Jones, CUP, 2012).

GEOPHYS 385A. Reflection Seismology. 1-2 Unit.

Research in reflection seismology and petroleum prospecting. May be repeated for credit.

GEOPHYS 385B. Environmental Geophysics. 1-2 Unit.

Research on the use of geophysical methods for near-surface environmental problems. May be repeated for credit.

GEOPHYS 385D. Theoretical Geophysics. 1 Unit.

Research on physics and mechanics of earthquakes, volcanoes, ice sheets, and glaciers. Emphasis is on developing theoretical understanding of processes governing natural phenomena.

GEOPHYS 385E. Tectonics. 1-2 Unit.

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. May be repeated for credit.

GEOPHYS 385J. Global Seismic Techniques, Theory, and Application. 1-2 Unit.

Topics chosen from surface wave dispersion measurement, 1D inversion techniques, regional tomographic inversion, receiver functions, ray theory in spherical geometry, seismic attenuation, seismic anisotropy, seismic focusing, reflected phases, stacking, and interpretations of seismic results in light of other geophysical constraints. May be repeated for credit.

GEOPHYS 385K. Crustal Mechanics. 1-2 Unit.

Research in areas of petrophysics, seismology, in situ stress, and subjects related to characterization of the physical properties of rock in situ. May be repeated for credit.

GEOPHYS 385L. Earthquake Seismology, Deformation, and Stress. 1 Unit.

Research on seismic source processes, crustal stress, and deformation associated with faulting and volcanism. May be repeated for credit.

GEOPHYS 385N. Experimental Rock Physics. 1-2 Unit.

Research on the use of laboratory geophysical methods for the characterization of the physical properties of rocks and their response to earth stresses, temperature, and rock-fluid interactions. May be repeated for credit.

GEOPHYS 385S. Wave Physics. 1-2 Unit.

Theory, numerical simulation, and experiments on seismic and electromagnetic waves in complex porous media. Applications from Earth imaging and in situ characterization of Earth properties, including subsurface monitoring. Presentations by faculty, research staff, students, and visitors. May be repeated for credit.

GEOPHYS 385V. Poroelasticity. 1-2 Unit.

Research 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. May be repeated for credit.

GEOPHYS 385W. GEOPHYSICAL MULTI-PHASE FLOWS. 1-2 Unit.

Research on the dynamics of multi-phase systems that are fundamental to many geophysical problems such as ice sheets and volcanoes.

GEOPHYS 385Z. Radio Remote Sensing. 1-2 Unit.

Research applications, especially crustal deformation measurements. Recent instrumentation and system advancements. May be repeated for credit.

GEOPHYS 400. Research in Geophysics. 1-15 Unit.

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GEOPHYS 801. TGR Project. 0 Units.

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GEOPHYS 802. TGR Dissertation. 0 Units.

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