**Geophysics**

Courses offered by the Department of Geophysics are listed under the subject code GEOPHYS on the [ExploreCourses web site](http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=GEOPHYS&filter-catalognumber-GEOPHYS=on) of the Stanford University Bulletin. Courses are offered for a letter grade and are expected to lead to the degrees of Master of Science and Doctor of Philosophy. The Department of Geophysics provides 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 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" 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**

**Geophysics Core Courses (31-35 units)**

Students must take all of the following:
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:
   - GEOPHYS 182 Reflection Seismology
   - GEOPHYS 183 Reflection Seismology Interpretation
   - GEOPHYS 185 Rock Physics for Reservoir Characterization
   - ENERGY 120 Fundamentals of Petroleum Engineering
   - GES 130 Soil Physics and Hydrology
   - GES 131 Hydrologically-Driven Landscape Evolution
   Total Units 3

2. Whole-Earth Geophysics

   Select one of the following:
   - EESS 141 Remote Sensing of the Oceans
   - GEOPHYS 170 Global Tectonics
   - GEOPHYS 184 Journey to the Center of the Earth
   - GEOPHYS 186 Tectonophysics
   Total Units 3

3. Numerical and computational methods

   Select one of the following:
   - GEOPHYS 187 Environmental Soundings Image Estimation
   - GEOPHYS 281 Geophysical Inverse Problems
   - EARTHSCI 2 Introduction to Programming for Scientists and Engineers
   - ENERGY 160 Modeling Uncertainty in the Earth Sciences
   - EE 102A Signal Processing and Linear Systems
   - CS 106A & CS 106B Programming Methodology and Programming Abstractions
   - PHYSICS 113 Computational Physics
   Total Units 3-4

4. Geophysical fluid dynamics

   Select one of the following:
   - GEOPHYS 144 Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation
   - GEOPHYS 144 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 Physical Hydrogeology
   Total Units 3

5. Physics

   Select one of the following:
   - CEE 101A Mechanics of Materials
   - EE 141 Engineering Electromagnetics
   - ME 80 Mechanics of Materials
   - PHYSICS 110 Advanced Mechanics
   - PHYSICS 112 Intermediate Electricity and Magnetism I
   Total Units 4

6. Geology

   Select one of the following:
   - GES 102 Earth Materials: Introduction to Mineralogy
   - GES 110 Structural Geology and Tectonics
   - GES 111 Fundamentals of Structural Geology
   - GES 151 Sedimentary Geology and Petrography: Depositional Systems
   Total Units 3-5

Supporting Mathematics Courses

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

- GES 1A Introduction to Geology: The Physical Science of the Earth 4-5
- or GES 1B Introduction to Geology: California Desert Geology
- or GES 1C Introduction to Geology: Dynamic Earth
Curriculum

1. Required course:
   - GEOPHYS 110 Earth on the Edge: Introduction to Geophysics

2. Plus three additional approved electives, typically chosen from:
   - GEOPHYS 1Fcalc, Water, Fire
   - GEOPHYS 13Introductory Seismology
   - GEOPHYS 1GGeodynamics: Our Dynamic Earth
   - GEOPHYS 1Laboratory Methods in Geophysics
   - GEOPHYS 1HGlobal Tectonics
   - GEOPHYS 1Journey to the Center of the Earth
   - GEOPHYS 1Near-Surface Geophysics

3. Supporting science:

Optional Field Class

GES 105 Introduction to Field Methods

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.

Coterminal B.S./M.S. 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.

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.

University requirements for the coterminal M.A. are described in the "Coterminal Bachelor’s and Master’s Degrees (http://exploredegree.stanford.edu/archive/2013-14/cotermdegrees) " section of this bulletin. For University coterminal degree program rules and University application forms, see the Stanford Undergrad Coterm Guide (http://undergrad.stanford.edu/advising/student-guides/coterm) .

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<th>Units</th>
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<td>4-5</td>
<td>GES 1A  Introduction to Geology: The Physical Science of the Earth</td>
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<td>GES 1B  Introduction to Geology: California Desert Geology</td>
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<td>GES 1C  Introduction to Geology: Dynamic Earth</td>
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<td>5</td>
<td>CME 100 Vector Calculus for Engineers</td>
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<td>5</td>
<td>or MATH 51 Linear Algebra and Differential Calculus of Several Variables</td>
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<td>PHYSICS 21 Mechanics and Heat</td>
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<td>or PHYSICS 22 Mechanics and Heat Laboratory</td>
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<td>or PHYSICS 41 Mechanics</td>
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Stanford University
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. 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 (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, and turn in a thesis/report to adviser.
7. 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 ability and confidence to carry out research in multiple areas.

- 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 PhD thesis; i.e. it cannot be the same method applied to a different problem, or a different method applied to the same problem.
• The second project must be supervised by a faculty member who does not serve as the primary research adviser, and who must be in a separate research group, in any department at Stanford University. Non-Geophysics faculty serving as second project advisers must be approved by both primary adviser and graduate adviser.
• The expected level of work on the second project should be about one academic quarter of full time effort.

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

Chair: Greg Beroza
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

Assistant Professors: Eric Dunham, Jesse Lawrence

Professor (Research): Gerald M. Mavko

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

Consulting Professors: Dimitri Bevc, Antoine Guitton, Peter Hennings, Dave Nichols, Shuki Ronen

Consulting Associate Professor: Stewart Levin

Blaustein Visiting Assistant Professor: Associate Professor Chandong Chang

Cox Visiting Assistant Professor: Adam Pidlisecky

Senior Research Scientists: Robert Clapp, Jack Dvorkin, Tiziana Vanorio

Research Associate: Youli Quan

* Joint appointment with Electrical Engineering
** Joint appointment with Biological Sciences