Geophysics

Courses offered by the Department of Geophysics are listed under the subject code GEOPHYS on the [ExploreCourses website](http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&g=GEOPHYS&filter-catalognumber-GEOPHYS=on) and in Stanford Bulletin’s [ExploreCourses website](http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&g=GEOPHYS&filter-catalognumber-GEOPHYS=on) and the [ExploreCourses website](http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&g=GEOPHYS&filter-catalognumber-GEOPHYS=on). The department expects undergraduate majors in the program to be able to identify the physical processes governing the behavior of common geophysical systems.

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

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. understand the physics and geology that form the basis for geophysical observation and measurement.
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.
Geophysics Core Courses (22-34 units)

Students must take all of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOPHYS 110</td>
<td>Earth on the Edge: Introduction to Geophysics</td>
<td>3</td>
</tr>
<tr>
<td>GEOPHYS 120</td>
<td>Ice, Water, Fire</td>
<td>3-5</td>
</tr>
<tr>
<td>GEOPHYS 130</td>
<td>Introductory Seismology</td>
<td>3</td>
</tr>
<tr>
<td>GEOPHYS 150</td>
<td>Geodynamics: Our Dynamic Earth</td>
<td>3</td>
</tr>
<tr>
<td>GEOPHYS 160</td>
<td>Introduction to SES Computing (or equivalent knowledge)</td>
<td>2-3</td>
</tr>
<tr>
<td>GEOPHYS 190</td>
<td>Near-Surface Geophysics</td>
<td>3</td>
</tr>
<tr>
<td>GEOPHYS 196</td>
<td>Undergraduate Research in Geophysics</td>
<td>1-10</td>
</tr>
<tr>
<td>GEOPHYS 199</td>
<td>Senior Seminar: Issues in Earth Sciences</td>
<td>3</td>
</tr>
<tr>
<td>GEOPHYS 201</td>
<td>Frontiers of Geophysical Research at Stanford: Faculty Lectures</td>
<td>1</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>22-34</td>
</tr>
</tbody>
</table>

Geophysics Breadth Courses (12-14 units)

Choose four upper-level courses, one from each of the following four areas:

1. **Resources, hazards, and the environment**

   Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOPHYS 182</td>
<td>Reflection Seismology</td>
<td>3</td>
</tr>
<tr>
<td>GEOPHYS 183</td>
<td>Reflection Seismology Interpretation</td>
<td></td>
</tr>
<tr>
<td>GEOPHYS 185</td>
<td>Rock Physics for Reservoir Characterization</td>
<td></td>
</tr>
<tr>
<td>ENERGY 120</td>
<td>Fundamentals of Petroleum Engineering</td>
<td></td>
</tr>
<tr>
<td>GES 131</td>
<td>Hydrologically-Driven Landscape Evolution</td>
<td></td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

2. **Whole-earth Geophysics**

   Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOPHYS 184</td>
<td>Journey to the Center of the Earth</td>
<td>3</td>
</tr>
<tr>
<td>GEOPHYS 170</td>
<td>Global Tectonics</td>
<td></td>
</tr>
<tr>
<td>GEOPHYS 186</td>
<td>Tectonophysics</td>
<td></td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

3. **Numerical and computational methods**

   Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOPHYS 187</td>
<td>Environmental Soundings Image Estimation</td>
<td>3-4</td>
</tr>
<tr>
<td>GEOPHYS 281</td>
<td>Geophysical Inverse Problems</td>
<td></td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Supporting Mathematics Courses

Students must take one of the following series (15 or 20 units):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOPHYS 181</td>
<td>Fluids and Flow in the Earth: Computational Methods</td>
<td>3-4</td>
</tr>
<tr>
<td>CEE 164</td>
<td>Introduction to Physical Oceanography</td>
<td></td>
</tr>
<tr>
<td>EESS 146A</td>
<td>Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation</td>
<td></td>
</tr>
<tr>
<td>EESS 220</td>
<td>Physical Hydrogeology</td>
<td></td>
</tr>
<tr>
<td>ENERGY 121</td>
<td>Fundamentals of Multiphase Flow</td>
<td></td>
</tr>
<tr>
<td>GES 130</td>
<td>Soil Physics and Hydrology</td>
<td></td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>3-4</td>
</tr>
</tbody>
</table>

Supporting Science Courses

Students must take all of the following (27-40 units):

- CME 200: Linear Algebra with Application to Engineering Computations
- CME 204: Partial Differential Equations in Engineering
- CME 206: Introduction to Numerical Methods for Engineering
- CME 211: Introduction to Programming for Scientists and Engineers
- EE 102A: Signal Processing and Linear Systems I
- ENERGY 160: Modeling Uncertainty in the Earth Sciences
- MATH 51: Linear Algebra and Differential Calculus of Several Variables
- MATH 51M: Introduction to MATLAB for Multivariable Mathematics (recommended in addition to MATH 51) ¹
- MATH 52: Integral Calculus of Several Variables
- MATH 53: Ordinary Differential Equations with Linear Algebra
- MATH 54: Linear Algebra and Partial Differential Equations for Engineers
- CME 104: Linear Algebra and Partial Differential Equations for Engineers
- CME 108: Introduction to Scientific Computing
- GEOPHYS 112: Exploring Geosciences with MATLAB

¹ It is recommended that students take MATH 51M Introduction to MATLAB for Multivariable Mathematics (1 unit) if the MATH series is taken.
Select one of the following:  
<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
</table>
| 4-5   | GES 1A Introduction to Geology: The Physical Science of the Earth  
| GES 1B Introduction to Geology: California Desert Geology  
| GES 1C Introduction to Geology: Dynamic Earth  
| 0-10  | Select one of the following:  
| CHEM 31A Chemical Principles I  
| CHEM 31X Chemical Principles  
| A score of 4-5 on the Chemistry AP exam  
| PHYSICS 41 Mechanics  
| PHYSICS 43 Electricity and Magnetism  
| PHYSICS 45 Light and Heat  
| one additional PHYSICS class  
| 4     | PHYSICS 110 Advanced Mechanics  
| PHYSICS 120 Intermediate Electricity and Magnetism I  
| CEE 101A Mechanics of Materials  
| EE 141 Engineering Electromagnetics  
| ME 80  Mechanics of Materials  
| 3-5   | 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  
| 27-40 | Total Units  

**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), two electives (6 units), and prerequisites in mathematics and physics. Minors require no fewer than 20 units and no more than 36 units.

**Curriculum**

1. Required course:

**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 coterminous Geophysics program, and interested students are encouraged to discuss their own background with a Geophysics faculty member.

The requirements for entry into the coterminous 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. Contact the Department of Geophysics student services officer for additional information.

University requirements for the coterminous M.A. are described in the "Coterminous Bachelor’s and Master’s Degrees (http://exploredegrees.stanford.edu/archive/2012-13/cotermdegrees)" section of this bulletin. For University coterminous degree program rules and University application forms, see the Registrar’s Publications and Online Guides (http://studentaffairs.stanford.edu/registrar/publications/#Coterm) web site.

**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 (see the "Doctor of Philosophy in Geophysics (http://www.stanford.edu/dept/registrar/bulletin/5059.htm)" section of this Bulletin), 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 102M Technical/Professional Writing for Mechanical Engineers/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.

The purpose of the second research project is to add breadth to Ph.D. study, and give the student the ability and confidence to teach or advise work in multiple areas. Both research projects must be in Geophysics or related disciplines. The two projects should be clearly distinct: neither the same methodology applied to two different datasets, nor two distinct methodologies applied to the same fundamental problem. The second project should clearly stand alone as a separate piece of work. The two projects must be supervised by different faculty in separate research groups, except in rare cases, as approved by the departmental graduate faculty adviser. The quality of each research project should be consistent with publication of a short journal article (typically achieved by additional work beyond the qualifying exam); although occasionally an extensive term paper deserving of presentation to the second project research group may be approved. 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

**Consulting Professors:** Dimitri Bevc, Antoine Guittton, 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