Geology / Civil Engineering 439 / 539 – Seismic Methods in Geology, Engineering, and Petroleum Exploration

Spring 2024

Instructor: Igor Beresnev, 162 Science I, 4-7529, beresnev@iastate.edu

Class Time: Lecture: MW 9:55 - 10:45
Lab: F 9:55 - 11:50 (or Lecture 9:55 - 10:45)

Text: **Main**: *Introduction to Applied Geophysics*, H. R. Burger, A. F. Sheehan, and C. H. Jones, Cambridge University Press, 2024, ISBN 978-1-009-43312-9 Paperback
(contains the basic information needed for the course in simple and accessible form)

Exploration Seismology (2nd edition), R. E. Sheriff and L. P. Geldart, Cambridge University Press, 1995, ISBN 0-521-46826-4 Paperback
(a comprehensive and rigorous presentation of all seismic methods; to be used to go in-depth)

Additional: *An Introduction to Geophysical Exploration* (3rd edition), P. Kearey, M. Brooks, and I. Hill, Blackwell Science, 2002, ISBN 0-632-04929-4
(a good elementary introduction; excellent supplement for the Burger et al. text)

Prerequisites: Introductory geology and math

Course fee: $70 (materials, equipment, and field trip)

DESCRIPTION

Philosophy

My basic premise is that all of the course material should be taught in the classroom. That is why I prefer explaining the content during the actual lecture time, instead of using cut-and-dried PowerPoints or handouts that do not really get anyone involved. Taking notes is highly encouraged: you should not need anything else to complete the homework and pass the exams. In my view, the live "chalkboard" presentation in a small-room setting is the best way to follow and see how science happens. Also, I believe it is instructive to derive some of the mathematical expressions used; this helps understand the inner workings and see the beautiful quantitative underpinnings of the geophysical techniques. The math is nonetheless kept at a simple level; only the knowledge of high-school algebra and trigonometry is strictly required.

Problems (all students)

Problem assignments will conclude the presentation of the blocks of material. I anticipate three problems sets; graduate students will also prepare 2-3 article reviews (see details

below). All assignments are due the same day two weeks later; grades will be lowered at the rate of 5 % per day for late returns.

Please keep these simple rules in mind when working on a problem assignment:

(1) Explain all your work and the steps taken at arriving at the solution. No problem is considered complete with only the final answer given.

(2) Make the final result clearly seen.

Labs and field trip

During the labs, we will sample some real-world seismic-interpretation software. We will also go out to conduct a shallow geophysical survey using modern seismic-acquisition equipment (the StrataView 24-channel engineering seismograph). The trip will take place some time in March or April, when the weather warms up; the exact time will be announced. *Note* that the survey will take about 4 hours and will not necessarily coincide with the regular class time; we may have to set aside a time outside the normal class schedule.

Article critiques (graduate students)

The purpose of journal reading is to acquire familiarity with some typical case histories in seismic exploration, develop writing habits, and strengthen the ability to view the work of others critically. There will be approximately three reviews, alternating with problem assignments. The following rules will apply:

(1) The review should present an analysis of the contents of the article, *not* a recitation of what it is about. I will be looking for your thoughts on the quality of the paper, its strengths and weaknesses, and any issues left unresolved. Your critique should demonstrate that you have read and understood the paper. Ideally, put the article aside when finished reading and start writing about your own impressions in your own language. It helps if you picture yourself an external referee asked by a journal editor to provide an expert opinion on whether this research is innovative and well-presented enough to be worth publishing.

(2) I will evaluate the critiques according to both criteria of *comprehension and style*.

(3) Generally, limit yourself to two double-spaced pages, excluding figures. Do not overdo it, try to be concise and to-the-point. *Important*: sometimes students fill their reviews with excerpts taken directly from the article; this is unacceptable and will significantly lower the grade. You should write in your own words, showing *your* understanding of the subject.

(4) The reviews will be due the same day two weeks later. The same grade-reduction rule as for the problem sets will apply to late returns.

Written exams

There will be two intermediate exams and a final one. The exams will include problem solving and a matching exercise; the problems will be similar to those given in homework and will only cover the lecture material. All exams require a calculator and paper.

Final grading

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Exams (average)	60 %	50 %
Problems (average)	40 %	30 %
Article reviews (average)		20 %

Rules of mutually respectful business conduct

(1) Electronic devices unrelated to class content must be turned off

(2) No leisurely conversations or whispering during the class time

(3) Business attitude and posture must be observed

Freedom of expression

Iowa State University supports and upholds the First-Amendment protection of freedom of speech and the principle of academic freedom in order to foster a learning environment where open inquiry and the vigorous debate of a diversity of ideas are encouraged. Students will not be penalized for the content or viewpoints of their speech as long as student expression in a class context is germane to the subject matter of the class and conveyed in an appropriate manner.

Schedule

Date	Topic
Week 1 / January 15-19	Introduction. History of exploration seismology. Outline of the seismic methods. Elasticity.
Week 2 / January 22-26	Wave physics. Wave equation. Plane and spherical waves. Harmonic waves.
Week 3 / January 29-February 2	Types of seismic waves. Seismic velocities in earth materials. Wave energy and attenuation.
Week 4 / February 5-9	Reflection and refraction. Fermat's principle. Snell's law. Critical refraction and head waves. Travel-time curves. Diffraction. Lab. Wave modeling using program REFLECT.
Week 5 / February 12-16	Wave partitioning at an interface. Zoeppritz equations. Reflection and refraction coefficients. Normal and oblique incidence.
Week 6 / February 19-23	Amplitude variation with angle. Idea of the seismic-refraction method. Horizontal refractors.
Week 7 / February 26-March 1	Dipping refractors. Exploration methods based on refraction. **Exam 1** Lab. Refraction-interpretation package SIP. Preparation of input data for automated interpretation.
Week 8 / March 4-8	The hidden-layer problem in seismic refraction. The seismic-reflection method in the shallow environment. Horizontal and dipping reflectors. Normal move-out.

	Lab. Refraction-interpretation package SIP. Refraction travel-time curves.
March 11-15	**Spring Break**
Week 9 / March 18-22	Dip move-out. Overview of seismic equipment. Introduction to petrophysical models. Velocity in a pack of uniform spheres, Gassmann's model. Factors affecting seismic velocities in rock. Lab. Automated refraction interpretation using SIP.
Week 10 / March 25-29	Measurement of seismic velocities. The seismic-reflection method in the deep environment. Reflection from stacks of horizontal layers.
Week 11 / April 1-5	The Dix approximation. Static corrections. Multiple reflections. **Exam 2**
Week 12 / April 8-12	Resolution. Time sections. The common-depth-point (CDP) method. Lab. Reflection modeling and interpretation using program REFLECT.
Week 13 / April 15-19	Velocity analysis. NMO corrections. Stacking. The CDP method in case of dipping layers. Lab. Field refraction survey with the StrataView engineering seismograph (exact time to be announced).
Week 14 / April 22-26	Seismic migration. Geophone arrays. Calculation of array directivity. American Association of Petroleum Geologists' video "Introduction to seismic reflection surveying".
Week 15 / April 29-May 3	Geologic interpretation of reflection data.
Week of May 6-9	**Final Exam**