Geology/Civil Engineering/Environmental Science 413/513
Applied and Environmental Geophysics
Spring 2023

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, W. W. Norton & Company, 2006, ISBN 0-393-92637-0 **Additional**: *An Introduction to Geophysical Exploration* (3rd edition), P. Kearey, M. Brooks, and I. Hill, Blackwell Science, 2002, ISBN 0-632-04929-4
Prerequisites:	Introductory geology, algebra and trigonometry
Course Fee:	$70 (equipment use, materials, field trip)

COURSE DESCRIPTION

Learning objectives and philosophy

The course introduces the principles of standard geophysical techniques applied to the investigation of the geological and physical structure of the subsurface: the seismic, electrical, electromagnetic, radar, and gravity methods.

There are three specific learning objectives:

(1) Understand the physics behind the geological applications of the respective physical fields: what does a geophysicist really see?

(2) Learn the main techniques used to map the details of the subsurface structure through each method, to be ready to apply them to practical work.

(3) Gain experience in operating geophysical-interpretation software.

I start with the premise that all course material should be given in the classroom setting. That is why I prefer to explain it during the actual lecturing at a slow pace; in my view, a live blackboard presentation is the best way to follow the underlying logic and see how the material is happening. Taking notes is highly encouraged. I also believe that it is instructive to derive some of the mathematical expressions used, instead of providing them "cut-and-dried": this helps understand the inner workings and see the beauty of the geophysical techniques. The mathematics is kept at a simple level; only knowledge of algebra and trigonometry is required to complete the homework.

Using the textbooks

I try to follow the main text by Burger *et al*. The parts of the course that are not covered by this book are based on Kearey *et al*. (the induced-polarization and electromagnetic methods). However, the design of the course is such that, if notes are taken, the text is usually not needed. The lectures are meant to be self-sufficient.

Problems and labs (all students)

Problem-set assignments will conclude the presentation of the blocks of material. All students will complete three-four problem sets; in addition, graduate students will prepare two-three article reviews (see below). All assignments are due one-two weeks after they have been handed out; grades will be lowered at the rate of 5 percentage points per day for late returns.

When working on a problem assignment, please keep these simple rules in mind:

(1) Carefully explain all your work and the steps taken in arriving at the final solution. No problem will be considered complete if only the final answer is provided.

(2) Make the final result clearly seen.

During the labs, we will sample some real-world geophysical-interpretation software. When the weather permits, we will undertake a field survey with the seismic- and electrical-imaging systems, as well as will see how the ground-penetrating radar works. The field data will be analyzed during the labs. The survey will take place some time in April. The trip will take 4-5 hours and will not necessarily coincide with the regular class time.

Article critiques (graduate students)

The purpose of journal readings is to learn some typical procedures and case histories in shallow geophysics, refine the technical-writing skills, and strengthen the ability to view the work of others critically. There will be two-three reviews, alternating with problem-set assignments. The following rules will apply:

(1) The review should represent an analysis of the content of the article, not a simple recitation of what the authors did. I will be looking for your own 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. You are advised to put the article aside when finished reading and start writing about your 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) The critiques will be evaluated according to both *comprehension and style*.

(3) Generally, limit yourself to two double-spaced pages, excluding figures, although there is no penalty for exceeding this limit. Be concise and write to-the-point. *Important:* sometimes students fill their reviews with the excerpts pulled directly from the article. This is unacceptable and will significantly lower the grade. Please write in your own words, reflecting *your* understanding of the subject.

(4) 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 mid-term exams and one final exam. The exams will include questions requiring short answers and problems; the problems will be similar to those given as homework and will cover only the lecture material. All exams require 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.

Public health

If you are not feeling well, you should stay home and focus on your health. Should you miss class due to illness, it is your responsibility to work with the instructor to arrange for accommodations and to make up coursework.

You may choose to wear a face mask and/or receive the COVID-19 vaccine and boosters, as well as other vaccines such as influenza, but those options are not required. Thielen Student Health Center will continue to provide COVID-19 vaccinations free-of-charge to students. The university will continue to offer free masks and COVID-19 test kits during the fall 2022 semester. Other wellbeing resources for students are available at: www.cyclonehealth.iastate.edu/wellbeing-resources/.

Public-health information for the campus community continues to be available on Iowa State's public-health website (health.iastate.edu/public-health/). All questions should be directed to publichealthteam@iastate.edu.

Schedule

Date	Topic
Week 1 / January 16-20	Introduction. Goals of exploration geophysics. Forward and inverse problems. Wave terminology. Elastic properties of rocks. The wave equation.
Week 2 / January 23-27	Plane and spherical waves. Types of seismic waves. Seismic velocities in rocks. Snell's law for reflection and refraction. Critical refraction.
Week 3 / January 30-February 3	Waves recorded at the surface. Wave attenuation. Reflection and transmission coefficients. Lab: Seismograms and seismic-wave travel times
Week 4 / February 6-10	The seismic-refraction method. Head-wave travel-time

	curves for horizontal and dipping boundaries. Seismic-refraction interpretation.
Week 5 / February 13-17	Hidden layers in the refraction method. Seismic equipment: the geophone. The seismic-reflection method. Reflection travel-time curves for a horizontal and dipping boundaries. Lab: Preparation of input data for automated refraction interpretation. Computer package SIPWIN.
Week 6 / February 20-24	Multiples. Reflection surveying of stacks of horizontal layers: the Dix approximation. Lab: Refraction travel-time curves. Computer package SIPWIN.
Week 7 / February 27-March 3	Static corrections. Time sections and the common-depth-point method. Lab: Refraction interpretation using SIPWIN
Week 8 / March 6-10	Migration of time sections. **Exam 1** Basic electricity. Electrical-current flow in a homogeneous half-space.

March 13-17 **Spring Break**

Week 9 / March 20-24	Depth of penetration vs. electrode separation. Apparent resistivity. Reflection and transmission of the current flow. Resistivity patterns over two- and three-layer media. Lab: forward and inverse seismic problems using computer program REFLECT
Week 10 / March 27-31	Resistivity patterns over two- and three-layer media (cont.). Resistivity field procedures. Electrical properties of rocks. Quantitative interpretation by curve matching. Equivalence and resolution.
Week 11 / April 3-7	Examples of field applications of resistivity surveys. Induced-polarization method. Lab: Inverse problems of resistivity surveys. Interpretation by curve matching
Week 12 / April 10-14	Principles of electromagnetic (EM) surveying. Phase-measuring EM systems. Ground-penetrating radar (GPR), including work with the radar device. Lab: Resistivity-modeling and interpretation computer package RINVERT
Week 13 / April 17-21	Gravity field and its measurement. The normal gravity

	field of the Earth. Adjustments of observed gravity. Gravity anomaly. **Exam 2** Lab: Field work with portable seismic-imaging system StrataView (exact time depending on weather)
Week 14 / April 24-28	Gravity adjustments: latitude, free-air, Bouguer, terrain corrections. Lab: Inversion of collected seismic-refraction and resistivity data using computer programs SIP and RES2DINV. Obtaining combined subsurface image.
Week 15 / May 1-5	Gravity adjustments (cont.). The Bouguer anomaly and its interpretation. Densities of rocks. Gravity effects of simple geometric shapes. Applications of gravity surveys. Lab: forward and inverse gravity problems using computer package GeoModel

Week of May 8-11 **Final Exam**