Term Information

Effective Term	Spring 2025

General Information

Course Bulletin Listing/Subject Area	Earth Sciences
Fiscal Unit/Academic Org	School of Earth Sciences - D0656
College/Academic Group	Arts and Sciences
Level/Career	Graduate, Undergraduate
Course Number/Catalog	5201
Course Title	Introduction to Seismology
Transcript Abbreviation	Intro Seismology
Course Description	This course will provide students with the fundamentals to understand seismic theory, wave propagation, earth structure, earthquake source physics, and seismic data analysis. This is meant to be a comprehensive introduction to seismology, providing students with the requisite skills to begin research in seismology.
Semester Credit Hours/Units	Fixed: 3

Offering Information

Length Of Course	14 Week
Flexibly Scheduled Course	Never
Does any section of this course have a distance education component?	No
Grading Basis	Letter Grade
Repeatable	No
Course Components	Lecture
Grade Roster Component	Lecture
Credit Available by Exam	No
Admission Condition Course	No
Off Campus	Never
Campus of Offering	Columbus

Prerequisites and Exclusions

Prerequisites/Corequisites	Math through Calculus III (MATH 2153) or graduate standing or permission of the instructor. Geophysical inverse theory relies heavily on linear algebra. A working knowledge of either Python or Matlab is essential for successful completion of some homework assignments. Python is preferred, with a basic understanding of I/O of data, use of Numpy/Pandas/Scipy for data manipulation, and basic plotting (e.g., matplotlib). Students wishing to form a solid base in Python should consider CSE 1224..
Exclusions	
Electronically Enforced	No

Cross-Listings

Cross-Listings

Subject/CIP Code

Subject/CIP Code	40.0601
Subsidy Level	Doctoral Course
Intended Rank	Junior, Senior, Masters, Doctoral

Requirement/Elective Designation

Required for this unit's degrees, majors, and/or minors

Course Details

Course goals or learning objectives/outcomes

- Basic understanding of wave propagation through Earth materials
- Understanding inverse methods for determining composition of the Earth
- Ability to download and manipulate seismic data to setup common seismology inverse problems
- Understanding of earthquake source dynamics and how events are commonly characterized with seismic data

Content Topic List

- seismic theory

wave propagation

earth structure

earthquake source physics

seismic data analysis

Sought Concurrence No

Attachments

- EARTHSC 5201 Intro to Seismology.docx: Syllabus

(Syllabus. Owner: Griffith,William ASHLEY)

- CURRICULAR MAP OF COURSES BS - EARTHSC 5201 Added.docx: Curricular Map

(Other Supporting Documentation. Owner: Griffith,William ASHLEY)

- CEGE Concurrence.txt: Concurrence from Civil Engineering

(Concurrence. Owner: Griffith,William ASHLEY)

- CoverLetter_EARTHSC5201.pdf: Cover letter

(Cover Letter. Owner: Griffith,William ASHLEY)

- Revised_Syllabus_Oct16_2024.pdf: Syllabus

(Syllabus. Owner: Sawyer,Derek)

- Response_Cover_Letter_Oct16_2024.pdf: Cover letter

(Cover Letter. Owner: Sawyer,Derek)

Comments

- 10/16/2024:

Thank you for the feedback from the Natural and Mathematical Sciences Subcommittee for the course Earth Sciences 5210 Introduction to Seismology.

We are pleased to submit the revisions here. Attached are a cover letter with detailed responses and the revised syllabus. *(by Sawyer,Derek on 10/16/2024 10:38 AM)*

- Please see Subcommittee feedback email sent 09/11/2024. *(by Hilty,Michael on 09/11/2024 02:41 PM)*

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Griffith,William ASHLEY	08/08/2024 02:17 PM	Submitted for Approval
Approved	Griffith,William ASHLEY	08/08/2024 02:23 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	08/08/2024 03:38 PM	College Approval
Revision Requested	Hilty,Michael	09/11/2024 02:41 PM	ASCCAO Approval
Submitted	Sawyer,Derek	10/16/2024 10:38 AM	Submitted for Approval
Approved	Sawyer,Derek	10/16/2024 10:50 AM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	10/20/2024 09:22 PM	College Approval
Pending Approval	Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Neff,Jennifer Vankeerbergen,Bernadette Chantal Steele,Rachel Lea	10/20/2024 09:22 PM	ASCCAO Approval

Dear Natural and Mathematical Sciences Curriculum Subcommittee,

This letter is in reference to a new course proposal, Introduction to Seismology (Earth Sciences 5201). I thank you for all of the helpful comments, which I address below:

1) There was some uncertainty about how the students can expect to learn about seismic data analysis in the course goals. The final sentence alluded to this, where both lectures and homework assignments would contain real world examples for seismic data analysis. Throughout lectures, where relevant, I will show some simple coding examples that pertain to the lesson that day. The homework assignments will contain expanded versions of these examples. I have slightly revised the final sentence to be more clear about this.
2) With regards to the homework assignments, I addressed some of this already in the Academic Misconduct section where I stated that 'students may collaborate on homework assignments, however, each student must turn in their own copy of work'. I reiterate this in the Assignment Schedule and Format Section. I also addressed the use of AI in this section, where they are not discouraged from using it, but the disclaimer is that you will often give you incorrect answers. In terms of the percentage for homework, I originally had this at 60% (6 homeworks each worth 10% of final grade). I think these homework assignments are far more diagnostic of their knowledge than midterms or finals since they will combine both theory and applications together, looking at real world seismology problems. I would be willing to drop the homework percentage to 40% (increasing the midterms to 20% each) if the subcommittee prefers.
3) In reference to software programs, all of the homework assignments can be performed with fully open source software packages in Python. The only requirement for a student is that they have a computer. For seismic data acquisition and analysis, obspy is a very powerful tool (https://docs.obspy.org/). I allow students to use Matlab since all of the homeworks can be done in Matlab and many lower level courses use Matlab. I cannot make a requirement for Matlab though since there are licensing restrictions.
4) I have modified the course requirements to remove the reference to linear algebra since it is superseded by Calc 3. I was simply trying to emphasize that they better brush up on their Calc 2; Calc 3 is still very much necessary for the course. I have modified the coding course line to state 'completion of CSE 1223 or permission of instructor is required' here.
5) I have added the course hours here to state either MWF for 55 minutes or T-Th for 80 minutes. There will be no lab section, the course will be just lectures.
6) I changed the course grading scale to a table

7) I copied the Student Life - Disability Services statement over from the website.

Feel free to reach out with any other comments of concerns.

Sincerely,

Brendan Crowell
Assistant Professor
School of Earth Sciences

Introduction to Seismology

Earth Sciences 5XXX (3 Credit Hours)
Meeting Time: TBA
Meeting Location: TBA
Course Lecture Times: TBA, either MWF for 55 minutes each day or T-Th for 80 minutes each day

Instructor
Dr. Brendan Crowell, Mendenhall Laboratory, Room 329, Phone TBD, crowell.97@osu.edu
Office Hours: TBA

Course Objectives/Description
This course will provide students with the fundamentals to understand seismic theory, wave propagation, earth structure, earthquake source physics, and seismic data analysis. This is meant to be a comprehensive introduction to seismology, providing students with the requisite skills to begin research in seismology. Lectures and homeworks will include seismic data analysis examples with real seismic recordings, using standardized workflows for data analysis from common archives (i.e., SAGE facility).

Modality
In-person

Course Format
In-person lecture with lecture materials provided in PPT or PDF format after classes. Homework assignments will be roughly due every other week and may include both problem sets and coding notebooks (i.e., Jupyter Notebooks). Will also include two midterm exams and one final exam.

Prerequisites

Math through Calculus III (MATH 2153) or graduate standing or permission of the instructor. A working knowledge of either Python or Matlab is essential for successful completion of some homework assignments. Python is preferred, with a basic understanding of I/O of data, use of Numpy/Pandas/Scipy for data manipulation, and basic plotting (e.g., matplotlib). Completion of CSE 1224 or permission of the instructor is required.

Grading Breakdown (% of final grade)
Homework assignments: 50%
Midterm 1: 15%
Midterm 2: 15%
Final Exam: 20%

Grading Scale

Grade	Course Percentage
A	>= 93
A-	>= 90, < 93
B+	>= 87, < 90
B	>= 83, < 87
B-	>= 80, < 83
C+	>= 77, < 80
C	>= 73, < 77
C-	>= 70, < 73
D+	>= 67, < 70
D	>= 60, < 67
E	< 60

Textbook

Introduction to Seismology, Peter Shearer
https://www.cambridge.org/highereducation/books/introduction-to-seismology/C1471C1B553C05997E2BC7EB26D4C26D#overview

Other potential useful texts (lessons will not be drawn from these texts)

Quantitative Seismology, 2nd Edition, Aki and Richards
An Introduction to Seismology, Earthquakes, and Earth Structure, Stein and Wysession

Topics:

1) History of Seismology (Week 1)
2) Linear algebra and calculus refresher (Week 1)
3) Stress and Strain relations (Week 2)
    a) Stress tensor

    b) Principal axes of stress
    c) Deviatoric stress
    d) Strain tensor
    e) Linear stress-strain relationship
    f) Elastic moduli
4) Seismic Wave Equation (Weeks 3-4)
    a) The wave equation in 1-D
    b) The momentum equation
    c) The full seismic wave equation
    d) Plane waves
    e) P and S wave polarization
    f) Spherical waves
    g) Synthetic seismograms
5) Travel time ray theory (Week 5)
    a) Snell's law
    b) Ray paths for 1-D layered Earth
    c) Travel time curves, tau(p) function
    d) Low velocity zones
    e) Spherical Earth ray tracing
    f) 3-D ray tracing
    g) Seismic phases
6) Inversion of travel time data (Week 6)
    a) 1-D velocity inversion
    b) Layer cake model
    c) Tau(p) Inversion
    d) Linear inverse models and regularization
    e) 3-D velocity inversion, tomography
    f) Earthquake locations
    g) Relative event locations
7) Amplitude and phase ray theory (Week 7)
    a) Seismic wave energy
    b) Geometrical spreading in 1-D
    c) Reflection and transmission coefficients
    d) Turning points
    e) Modeling plane waves
    f) Attenuation
8) Reflection seismology (Weeks 8-9)
    a) Zero-offset sections
    b) Midpoint stacking
    c) Sources and deconvolution
    d) Migration
    e) Velocity analysis
    f) Receiver functions
    g) Kirchhoff theory

9) Surface waves and Normal modes (Weeks 10-11)
    a) Love waves
    b) Rayleigh waves
    c) Dispersion
    d) Global surface waves
    e) Normal modes
10) Earthquake seismology (Weeks 12-14)
    a) Green's functions and the moment tensor
    b) Earthquake faults
    c) Non double couple sources
    d) Radiation patterns
    e) Pulse shapes and directivity
    f) Source spectra
    g) Empirical Green's functions
    h) Stress drop and self-similarity
    i) Radiated energy
    j) Earthquake magnitudes
    k) Slip modeling
    l) Aftershocks
11) Network Seismology (Week 15)
    a) Local monitoring
    b) Global monitoring
    c) Analysis platforms
    d) Magnitude saturation
    e) The W Phase
    f) Early warning
12) Instrumentation (Week 16)
    a) Strong-motion sensors
    b) Broadband seismometers
    c) Historical instrumentation
    d) Standard naming conventions, SNCLs
13) Introductory seismic data analysis (lessons interspersed throughout semester pertaining to downloading specific data sets related to lectures - all Python based)

Assignment Schedule and Format

Homeworks with coding exercises will be 3-5 questions that require writing simple scripts, to be completed in either Jupyter notebooks with Python3 or in Matlab. Homeworks will be assigned at the first lecture of the week shown and due the last lecture of the week shown. Students may collaborate on homework assignments, however, each student must turn in their own copy of work.

Homework 1 - assigned Week 1, due Week 3. An overview of common linear algebra problems in seismology

Homework 2 - assigned Week 3, due Week 5. Coding exercises on continuum mechanics and the seismic wave equation.

Midterm 1 - Week 6 - material up to travel time ray theory

Homework 3 - assigned Week 5, due Week 7. Coding exercises on travel time ray theory and inversion.

Homework 4 - assigned Week 7, due Week 9. Coding exercises on amplitude and phase ray theory.

Homework 5 - assigned Week 9, due Week 11. Coding exercises on reflection seismology and surface waves

Midterm 2 - Week 12 - Material between Inversion of travel time data and normal modes.

Homework 6 - assigned Week 12, due Week 15. Coding exercises on earthquake seismology.

Final Exam (Week 16) - Test on all material, with more focus on later material.

Expected Learning Outcomes

- Basic understanding of wave propagation through Earth materials
- Understanding inverse methods for determining composition of the Earth
- Ability to download and manipulate seismic data to setup common seismology inverse problems
- Understanding of earthquake source dynamics and how events are commonly characterized with seismic data

Measurement of these expected learning outcomes will come directly from coding exercises for the applied tasks and homework/tests for theoretical knowledge.

Academic Misconduct

Students may collaborate on homework assignments, however, each student must turn in their own copy of the work. I do not discourage the use of AI resources for your homework, but these resources will often give you the incorrect answer, so be forewarned that you will probably receive a lower grade.

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term “academic misconduct” includes all forms of student academic misconduct wherever committed;

illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct http://studentlife.osu.edu/csc/.

Disability Services

The university strives to maintain a healthy and accessible environment to support student learning in and out of the classroom. If you anticipate or experience academic barriers based on your disability (including mental health, chronic, or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion.

If you are ill and need to miss class, including if you are staying home and away from others while experiencing symptoms of a viral infection or fever, please let me know immediately. In cases where illness interacts with an underlying medical condition, please consult with Student Life Disability Services to request reasonable accommodations. You can connect with them at slds@osu.edu; 614-292-3307; or slds.osu.edu.

Religious Accommodations

Ohio State has had a longstanding practice of making reasonable academic accommodations for students' religious beliefs and practices in accordance with applicable law. In 2023, Ohio State updated its practice to align with new state legislation. Under this new provision, students must be in early communication with their instructors regarding any known accommodation requests for religious beliefs and practices, providing notice of specific dates for which they request alternative accommodations within 14 days after the first instructional day of the course. Instructors in turn shall not question the sincerity of a student's religious or spiritual belief system in reviewing such requests and shall keep requests for accommodations confidential.

With sufficient notice, instructors will provide students with reasonable alternative accommodations with regard to examinations and other academic requirements with respect to students' sincerely held religious beliefs and practices by allowing up to three absences each semester for the student to attend or participate in religious activities. Examples of religious accommodations can include, but are not limited to, rescheduling an exam, altering the time of a student's presentation, allowing make-up assignments to substitute for missed class work, or

flexibility in due dates or research responsibilities. If concerns arise about a requested accommodation, instructors are to consult their tenure initiating unit head for assistance.

A student's request for time off shall be provided if the student's sincerely held religious belief or practice severely affects the student's ability to take an exam or meet an academic requirement and the student has notified their instructor, in writing during the first 14 days after the course begins, of the date of each absence. Although students are required to provide notice within the first 14 days after a course begins, instructors are strongly encouraged to work with the student to provide reasonable accommodation if a request is made outside the notice period. A student may not be penalized for an absence approved under this policy.

If students have questions or disputes related to academic accommodations, they should contact their course instructor, and then their department or college office. For questions or to report discrimination or harassment based on religion, individuals should contact the Office of Institutional Equity. (Policy: Religious Holidays, Holy Days and Observances)