Western Science

Department of Earth Sciences

Earth Sciences 3321a - PHYSICS OF THE EARTH'S INTERIOR I
Fall 2025

1. COURSE INFORMATION

Location: In person delivery

Time Zone: All times given are **Eastern Daylight Time (EDT)**

3 **Lectures** per week in person

PDF files of lectures will be available on the OWL course site before the lecture times given above.

1 **Tutorial** session per week will be scheduled and used as needed in person

The tutorial sessions will be used for the following purposes:
- for discussion of minor and major assignments
- to help guide you in choosing a topic and carrying out literature search for your major presentation (seminar)
- for lectures on occasion
- for seminar presentations by students at the end of term
- more tutorial details are available on the OWL course site under Resources

Contingency plan for an in-person class pivoting to 100% online learning
In the event there is cause that necessitates the course delivery moving away from face-to-face interaction, affected course content will be delivered entirely online, either synchronously (i.e., at the times indicated in the timetable) or asynchronously (e.g., posted on OWL for students to view at their convenience). The grading scheme will **not** change. Any remaining assessments will also be conducted online as determined by the course instructor.

1a. Prerequisites Earth Sciences 2220A/B or the former 2221A/B or special permission.

Unless you have either the prerequisites for this course or written special permission from your Dean to enrol in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in

the event that you are dropped from a course for failing to have the necessary prerequisites

Technical Requirements

In order to access the course materials (course-related information files, lecture files, seminar files, etc) and respond in a timely manner to email communications when required, a stable internet connection is required. For any Zoom meeting that may be required, computer with working microphone and webcam is required

2. INSTRUCTOR INFORMATION

Instructor: Prof. Rick Secco
Office: BGS Building Room 0178
Email: secco@uwo.ca
Phone: 519-661-4079
Office Hours: Email me to set up an appointment or come to my office. A Zoom meeting, with video on, may also be set up. The Zoom meeting will be recorded.

Students must use their Western (@uwo.ca) email addresses when contacting their instructor and to sign into any Zoom meeting.

3. COURSE SYLLABUS

An introduction to physics of the Earth's interior. Major topics are: Earth structure from seismic observations, heat flow, the physics of minerals under high temperatures and pressures, equations of state, seismological, thermal and compositional models.

Antirequisite(s):
Prerequisite(s): Earth Sciences 2220A/B or the former 2221A/B.
Corequisite(s):
Pre-or Corequisite(s):
Extra Information: 3 lecture hours, 2 tutorial hours, 0.5 course.

i. **Solar System – 9 lectures**
formation of planetary system
- **solar system** characteristics
- orbital **gravitation**al mechanics of gas
- building the planets
- **accretion**ary sequence, T-Tauri solar stage, Snow Line, accretion time estimates
- non-gravitational aspects of very small objects

meteorites

- **chondrites, achondrites, stony-irons, irons**
- **carbonaceous chondrites** - primitive composition
- irons - Widmanstatten structure, kamacite, taenite, cooling rates vs. parent body size

ii. **Global Seismology – 11 lectures**

elasticity and **equations of state**
Adams-Williamson equation, **density** models
earth structure from body wave data
free oscillations
PREM - Preliminary Reference Earth Model
internal constitution

- compositional Earth models from seismological models
- **mineralogy models** of the mantle
- **core** compositional models
- inner core **elastic anisotropy**, super-rotation

--- MIDTERM ---

iii. **Thermal State – 7 lectures**

thermal conduction (lattice and electronic)
heat flow density
heat conduction equation

- 1-d with/without heat production

surface temperature variation (propagation dependence on depth and time)

- sinusoidal (daily, annual)
- step function (impact, dike intrusion, deglaciation)
- arbitrary

heat transport
heat flow measurement
oceanic and continental heat flow
global heat flow map
geotherm

- upper mantle constraints: **peridotites, kimberlites, olivine-spinel, spinel - perovskite + magnesiowustite , periclase**
- lower mantle constraints: **adiabat, high P,T** melting experiments on perovskite and magnesiowustite
- core constraints: high P,T melting experiments on iron at inner core boundary conditions, adiabat

mantle convection

- layered vs. whole mantle

core convection

iv. **Physics of Minerals – 5 lectures**

transport properties overview

- driving force, flux, material properties

electrical conduction

- band theory concepts
- **metallic and semi-conduction**
- ionic, hopping (vacancy and intervalence charge transfer) conduction
- **ionic diffusion**, Nernst-Einstein equation

mantle electrical conductivity structure

- high P,T experiments
- lower mantle conductivity derived from geomagnetic variations (1969 Jerk)

core electrical conductivity

rheology

- types of rheology
- momentum carriers
- creep mechanisms
- mantle rheology

Course-Level Learning Outcomes : Upon successful completion of this course, students will be able to:

* Explain quantitatively the major processes responsible for planetary accretion as well as the observational evidence that supports the accepted accretion model.

* Describe the historical development of global seismology and use important equations to develop a model of Earth interior structure from travel time and free oscillation data that is consistent with a compositional model of the interior.

* Explain the sources of interior heat and using equations and the physics of heat transfer, describe quantitatively heat conduction and convection within the Earth as a basis for its heat engine behavior.

* Explain the physics of electrical conduction and rheology and its application to the geomagnetic field as well as the flow of matter in the mantle.

* Through practice in weekly exercises, capture and convey the main aspects of a published scientific article in Earth Physics by describing in less than one written page : the study purpose, method(s) used, results, application of results to the problem, and further study suggested.

* Through practice in a major oral presentation, communicate to a scientifically literate audience any major topic within the areas of solar system formation, earth interior structure, terrestrial heat flow and mineral physics.

4. COURSE MATERIALS

Course Materials / Course Website:

All course material will be posted to OWL: https://westernu.brightspace.com/

Students are responsible to check OWL (https://westernu.brightspace.com/) on a regular basis for news and updates. This is the primary method by which information (lectures, labs, announcements,

assignments, forum, etc) will be disseminated to all students in the class.

If students need assistance with OWL, they can seek support on the OWL Brightspace Help page. Alternatively, they can contact the Western Technology Services Helpdesk. They can be contacted by phone at 519-661-3800 or ext. 83800.

There is no text book for this course but the lecture material may be found in the general and more specific reference books listed below. Some of the books may be found on-line (including the titles in italics).

General Reference Books

FUNDAMENTALS OF GEOPHYSICS, W. Lowrie, Cambridge University Press, 1997.
PHYSICS OF THE EARTH 3rd ed., F. D. Stacey, Brookfield Press, 1992.
PHYSICS OF THE EARTH 4th ed., F. D. Stacey and P.M. Davis, Cambridge University Press, 2008.

THE SOLID EARTH C.M.R. Fowler, Cambridge University Press, 1990.
THE APPLICATION OF MODERN PHYSICS TO THE EARTH AND PLANETARY INTERIORS. S.K. Runcorn ed. Wiley, 1969.
THE INTERIOR OF THE EARTH, 2nd ed., M.H.P. Bott, Edward Arnold, 1982.
INTRODUCTION TO GEOPHYSICS, G.D. Garland, W.B. Saunders Co., 1979.
THE EARTH, H. Jeffreys, Cambridge University Press, 6th edition, 1976.

Specific Reference Books

Section 1

ORIGIN OF THE EARTH AND MOON, A.E. Ringwood, Springer Verlag, 1979.
METEORITES; THEIR RECORD OF EARLY SOLAR SYSTEM HISTORY, J.T. Wasson, Freeman, 1985.
AN INTRODUCTION TO PLANETARY PHYSICS, W.M. Kaula, Wiley, 1968.

Section 2

THE EARTH'S DENSITY, K.E. Bullen, Wiley, 1975.
DEEP INTERIOR OF THE EARTH, J.A. Jacobs, Chapman & Hall, 1992.
THE EARTH'S CORE, 2nd edition, J.A. Jacobs, Academic Press, 1987.

Section 3

THE INACCESSIBLE EARTH, 2nd ed., G.C. Brown and A.E. Mussett, Chapman & Hall, 1993.
THEORY OF THE EARTH, D.L. Anderson, Blackwell Sci. Pubs., 1989.

Section 4

INTRODUCTION TO THE PHYSICS OF THE EARTH'S INTERIOR, J-P. Poirier, Cambridge University Press, 1991.
INTRODUCTION TO THE PHYSICS OF ROCKS, Y. Gueguen and V. Palciauskas, Princeton Univ. Press, 1994.

Technical Requirements

In order to access the course materials (lectures and tutorial and seminar materials) and respond in a timely manner when required, a stable internet connection is required. For Zoom, a computer with working microphone and webcam is required.

5. METHODS OF EVALUATION

Assignments

Assignments on topics related to the above sections, though not necessarily specifically discussed in the lectures, will be set during term time. Some questions may require extra reading/study and you are therefore encouraged to refer to the books listed above (or any other book).

A deadline for submission of each completed MAJOR assignment will be indicated on the assignment. If the completed assignment is submitted within 72 hours after the deadline, there will be no penalty applied. After 72 hours following the deadline, marks will be reduced on late assignments at a rate of 20%/day. Missed assignments will receive a grade of zero. There will be 3 MAJOR assignments and you must submit any 2 of these.

A deadline for submission of each completed MINOR assignment will be indicated on the assignment. If the completed assignment is submitted within 48 hours after the deadline, there will be no penalty applied. After 48 hours following the deadline, marks will be reduced on late assignments at a rate of 20%/day. Missed assignments will receive a grade of zero. There will be 3 MINOR assignments and you must submit any 2 of these.

Seminar

Each student will be required to present a 20 minute Power Point presentation (10% of course grade) and hand in a written report (10% of course grade) of approximately 10 pages of text on an approved topic of her/his choice. Seminars will be given at a date to be determined near the end of term. Details will be provided on OWL. Deadlines for submission of the Power Point Presentation file and the written report will be indicated on OWL. If the Power Point Presentation file and/or the written report are/is submitted within 48 hours after the deadline, there will be no penalty applied. After 48 hours following the deadline, marks will be reduced on late submissions at a rate of 20%/day.

Midterm Test

A midterm test will follow soon after completion of the first two sections (Solar System, and Global Seismology … likely the second last or last week of October) of the course. The actual date will be announced at least two weeks prior to the midterm test. The test will be delivered and written in person. Formal supporting documentation (via an Academic Consideration) will be required by any student who misses the Midterm Test.

Final Exam

A final exam will be set by the university during the December exam period. The exam will be delivered and written in person.

Course Grade Evaluation
The final grade will be calculated with the following approximate distribution :

2 Major Assignments 10% : You must submit any 2 of 3 major assignments. If you choose to submit 3 major assignments, only the first 2 assignments will be graded.

2 Minor Assignments 5% : You must submit any 2 of 3 minor assignments. If you choose to submit 3 minor assignments, only the first 2 assignments will be graded.

Seminar oral presentation	10%
Seminar written report	10%
Midterm	30%
Final Exam	35%

6. STUDENT ABSENCES

General information about missed coursework
Students must familiarize themselves with the *University Policy on Academic Consideration – Undergraduate Students in First Entry Programs* posted on the Academic Calendar: https://www.uwo.ca/univsec/pdf/academic_policies/appeals/academic_consideration_Sep24.pdf,

This policy does not apply to requests for Academic Consideration submitted for **attempted or completed work**, whether online or in person.

The policy also does not apply to students experiencing longer-term impacts on their academic responsibilities. These students should consult Accessible Education.

For procedures on how to submit Academic Consideration requests, please see the information posted on the Office of the Registrar's webpage:
https://registrar.uwo.ca/academics/academic_considerations/
All requests for Academic Consideration must be made within 48 hours after the assessment date or submission deadline.

All Academic Consideration requests must include supporting documentation; however, recognizing that formal documentation may not be available in some extenuating circumstances, the policy allows students to make one Academic Consideration request **without supporting documentation** in this course. However, **the following assessments are excluded from this, and therefore always require formal supporting documentation:**

- **Midterm** (Designated by the instructor as the one assessment that always requires documentation when requesting Academic Consideration)

When a student *mistakenly* submits their one allowed Academic Consideration request **without supporting documentation** for the assessments listed above or those in the **Coursework with Assessment Flexibility** section below, the request cannot be recalled and reapplied. This privilege is forfeited.

7. ACCOMMODATION AND ACCESSIBILITY

Religious Accommodation
When conflicts with a religious holiday that requires an absence from the University or prohibits certain activities, students should request an accommodation for their absence in writing to the course instructor and/or the Academic Advising office of their Faculty of Registration. This notice should be made as early as possible but not later than two weeks prior to the writing or the examination (or one week prior to the writing of the test).

Please visit the Diversity Calendars posted on our university's EDID website for the recognized religious holidays:

https://www.edi.uwo.ca.

Accommodation Policies
Students with disabilities are encouraged to contact Accessible Education, which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The policy on Academic Accommodation for Students with Disabilities can be found at:

https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Accommodation_disabilities.pdf.

8. ACADEMIC POLICIES

The website for Registrar Services is https://www.registrar.uwo.ca/.

In accordance with policy,

https://www.uwo.ca/univsec/pdf/policies_procedures/section1/mapp113.pdf,

the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at their official university address is attended to in a timely manner.

No electronic devices will be permitted on tests and exams.

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:

https://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf.

All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (http://www.turnitin.com).

NOTE: At the time of writing, this course is planned for in person delivery of lectures, tutorials, midterm test and exam. Should there be a university-mandated switch to on-line course delivery at any time during this term, the following statements will apply.

Tests and examinations in this course will be conducted using a remote proctoring service. By taking this course, you are consenting to the use of this software and acknowledge that you will be required to provide **personal information** (including some biometric data) and the session will be **recorded**. Completion of this course will require you to have a reliable internet connection and a device that meets the technical requirements for this service. More information about this remote proctoring service, including technical requirements, is available on Western's Remote Proctoring website at:

https://remoteproctoring.uwo.ca.

Completion of this course will require you to have a reliable internet connection and a device that meets the technical requirements for this service. Information about the technical requirements are available at the following link:
https://www.proctortrack.com/tech-requirements/

Tests and examinations in this course may be conducted using Zoom. You will be required to keep your camera on for the entire session, hold up your student card for identification purposes, and share your screen with the invigilator if asked to do so at any time during the exam. The exam session will **not** be recorded.*

More information about the use of Zoom for exam invigilation is available in the Online Proctoring Guidelines at the following link:
https://www.uwo.ca/univsec/pdf/onlineproctorguidelines.pdf

Completion of this course will require you to have a reliable internet connection and a device that meets the system requirements for Zoom. Information about the system requirements are available at the following link:
https://support.zoom.us/hc/en-us

* Please note that Zoom servers are located outside Canada. If you would prefer to use only your first name or a nickname to login to Zoom, please provide this information to the instructor in advance of the test or examination.

Tests and examinations in this course may be conducted using both Zoom and a remote proctoring service, such as Proctortrack.

When Zoom is used for exam invigilation, you will be required to keep your camera on for the entire session, hold up your student card for identification purposes, and share your screen with the invigilator if asked to do so at any time during the exam. The exam session using Zoom will not be recorded.*

Proctortrack will require you to provide personal information (including some biometric data). The session will be recorded. By taking this course, you are consenting to the use of this software.
More information about remote proctoring is available in the Online Proctoring Guidelines at the following link:

https://www.uwo.ca/univsec/pdf/onlineproctorguidelines.pdf

Completion of this course will require you to have a reliable internet connection and a device that meets the system and technical requirements for both Zoom and Proctortrack. Information about the system and technical requirements are available at the following links:
https://www.proctortrack.com/tech-requirements/
https://support.zoom.us/hc/en-us

* Please note that Zoom servers are located outside Canada. If you would prefer to use only your first name or a nickname to login to Zoom, please provide this information to the instructor in advance of the test or examination.

9. SUPPORT SERVICES

Please visit the Science & Basic Medical Sciences Academic Advising webpage for information on adding/dropping courses, academic considerations for absences, appeals, exam conflicts, and many other academic-related matters: https://www.uwo.ca/sci/counselling/.

Students who are in emotional/mental distress should refer to Mental Health@Western (https://uwo.ca/health/) for a complete list of options about how to obtain help.

Western is committed to reducing incidents of gender-based and sexual violence and providing compassionate support to anyone who has gone through these traumatic events. If you have experienced sexual or gender-based violence (either recently or in the past), you will find information about support services for survivors, including emergency contacts at

https://www.uwo.ca/health/student_support/survivor_support/get-help.html.

To connect with a case manager or set up an appointment, please contact support@uwo.ca.

Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Accessible Education at

http://academicsupport.uwo.ca/accessible_education/index.html

if you have any questions regarding accommodations.

Learning-skills counsellors at Learning Development and Success (https://learning.uwo.ca) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

Western University is committed to a thriving campus as we deliver our courses in the mixed model of both virtual and face-to-face formats. We encourage you to check out the Digital Student Experience website to manage your academics and well-being: https://www.uwo.ca/se/digital/.

Additional student-run support services are offered by the USC, https://westernusc.ca/services/.