

**Geophysics 9572a - PHYSICS OF THE EARTH'S INTERIOR I*
Fall 2021**

1. COURSE INFORMATION

Location: In person delivery

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

3 Lectures per week (Mon Wed Fri 12:30-13:20PM) SSC 3018 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 (Tues 14:30 - 16:30) BGS 0184 in person

The TA will be available during the tutorial session for discussion on minor and major assignments, and to help guide you in choosing a topic and carrying out literature search for your major presentation (seminar). More tutorial details are available on the OWL course site under Resources. Some tutorial sessions at the end of term may be used for seminar presentations by students.

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.



**This is a draft course outline pending information from UWO regarding sections 6 and 7 below. An updated course outline will be provided once that information is available.*

TAs: To be determined

TA office hours will be posted on the OWL course site.

Students must use their Western (@uwo.ca) email addresses when contacting their instructors (course instructor and TA) and to sign in to 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):

Corequisite(s):

Pre-or Corequisite(s):

Extra Information: 3 lecture hours, 2 tutorial hours, 0.5 course.

i. Solar System

formation of planetary system

- **solar system** characteristics
- orbital **gravitational** mechanics of gas
- building the planets
- **accretionary** 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 - Widmanstätten structure, kamacite, taenite, cooling rates vs. parent body size

ii. Global Seismology

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

iii. **Thermal State**

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**

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

- high P,T experiments
- **geodynamo** constraints - magnetic Reynolds number, lower bound
- thermal constraints - estimate of outer core thermal conductivity, electrical conductivity calculation from Wiedemann-Franz Law

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

Students should check OWL (<http://owl.uwo.ca>) on a regular basis for news and updates. All course material including lectures and assignments will be posted on OWL. This is the primary method by which information will be disseminated to all students in the class. Students are responsible for checking OWL on a regular basis.

If students need assistance, they can seek support on the OWL 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). Marks will be reduced on late assignments at a rate of 20%/day. Missed assignments will receive a grade of zero. There will be an assignment after each major lecture section (i.e. a total of ~4 assignments or one approximately every 3 weeks) as well as short assignments approximately every week. Each lecture section will occupy approximately 25% of the total lecture time.

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) 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.

Midterm Test

A midterm test will follow soon after completion of the first two sections (Solar System, and Global Seismology ... likely the 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.

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.

Grade

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

Assignments	15%
Seminar	20%
Midterm	35%
Final Exam	30%

6. ACCOMMODATION AND ACCESSIBILITY

Accommodation Policies

Students with disabilities work with Accessible Education (formerly SSD) which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The Academic Accommodation for Students with Disabilities policy can be found at: [https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic Accommodation_disabilities.pdf](https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Accommodation_disabilities.pdf)

Academic Consideration for Student Absence

Students will have up to two (2) opportunities during the regular academic year to use an on-line portal to self-report an absence during the semester, provided the following conditions are met: the absence is no more than 48 hours in duration, and the assessment for which consideration is being sought is worth 30% or less of the student's final grade. Students are expected to contact their instructors within 24 hours of the end of the period of the self-reported absence, unless noted on the syllabus. Students are not able to use the self-reporting option in the following circumstances:

- for exams scheduled by the Office of the Registrar (e.g., December and April exams)
- absence of a duration greater than 48 hours,
- assessments worth more than 30% of the student's final grade,
- if a student has already used the self-reporting portal twice during the academic year

If the conditions for a Self-Reported Absence are *not* met, students will need to provide a Student Medical Certificate if the absence is medical, or provide appropriate documentation if there are compassionate grounds for the absence in question. Students are encouraged to contact their Faculty academic counselling office to obtain more information about the relevant documentation.

Students should also note that individual instructors are not permitted to receive documentation directly from a student, whether in support of an application for consideration on medical grounds, or for other reasons. **All documentation required for absences that are not covered by the Self-Reported Absence Policy must be submitted to the Academic Counselling office of a student's Home Faculty.**

For policy on Academic Consideration for Student Absences - Undergraduate Students in First Entry Programs, see:

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

and for the Student Medical Certificate (SMC), see:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf

Religious Accommodation

Students should consult the University's list of recognized religious holidays, and should give reasonable notice in writing, prior to the holiday, to the Instructor and an Academic Counsellor if their course requirements will be affected by a religious observance. Additional information is given in the Western Multicultural Calendar:

<https://multiculturalcalendar.com/ecal/index.php?s=c-univwo>

You may also be eligible to write the Special Exam if you are in a "Multiple Exam Situation" (see http://www.registrar.uwo.ca/examinations/exam_schedule.html).

If a student fails to write a scheduled Special Examination, the date of the next Special Examination (if granted) normally will be the scheduled date for the final exam the next time this course is offered. The maximum course load for that term will be reduced by the credit of the course(s) for which the final examination has been deferred. See Academic Calendar for details (under [Special Examinations](#)).

7. ACADEMIC POLICIES

The website for Registrarial Services is <http://www.registrar.uwo.ca>.

In accordance with policy, <http://www.uwo.ca/its/identity/activatenonstudent.html>, 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 his/her official university address is attended to in a timely manner.

Participants in this course are not permitted to record the sessions, except where recording is an approved accommodation, or the participant has the prior written permission of the instructor.

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:
http://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>).

Computer-marked multiple-choice tests and exams may be subject to submission for similarity review by software that will check for unusual coincidences in answer patterns that may indicate cheating.

Tests and examinations in this course may be conducted using the remote proctoring service, such as Proctortrack. 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**. More information about this remote proctoring service 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 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 the 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.

8. SUPPORT SERVICES

Please visit the Science & Basic Medical Sciences Academic Counselling webpage for information on add/drop courses, academic considerations for absences, appeals, exam conflicts, and many other academic related matters: <https://www.uwo.ca/sci/counselling/>

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 Student Accessibility Services (SAS) at (519) 661-2147 if you have any questions regarding accommodations.

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/>.

Learning-skills counsellors at the Student Development Centre (<http://www.sdc.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.

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

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