**Earth Sciences 3321a - PHYSICS OF THE EARTH'S INTERIOR I**
**Fall 2017**

## 1. COURSE INFORMATION

3 Lectures per week (M W F 12:30-13:20PM in STVH 1119)
1 Lab/Tutorial per week (Tues 14:30 - 16:30) BGS 0184

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

Unless you have either the requisites 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

## 2. INSTRUCTOR INFORMATION

Prof. Rick Secco (BG Rm 0178) secco@uwo.ca
519-661-4079

**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 hour, 0.5 course.

i. **Solar System**

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**

**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 Weidemann-Franz Law

## 4. COURSE OBJECTIVES

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.

## 5. COURSE MATERIALS

Students should check OWL (http://owl.uwo.ca) on a regular basis for news and updates. Lectures as well as 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.
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.

### General Reference Books

FUNDAMENTALS OF GEOPHYSICS, W. Lowrie, Cambridge University Press, 1997.
PHYSICS OF THE EARTH 3rd ed., F. D. Stacey, Brookfield Press, 1992.
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.

## 6. 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 seminar and hand in a written report (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 follow.

**Midterm Test**

A midterm test will follow immediately after completion of the first two sections of the course.

**Final Exam**

A 3 hour final exam will be set during the December exam period.

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

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|---|---|
| Assignments | 20% |
| Seminar | 20% |
| Midterm | 25% |
| Final Exam | 35% |

## 7. ADDITIONAL STATEMENTS

### i. Accessibility
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 Services for Students with Disabilities (SSD) at 661-2111 ext. 82147 if you have questions regarding accommodation.

### ii. Support Services
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.
The website for Registrarial Services is http://www.registrar.uwo.ca.

It is Faculty of Science policy that a student who chooses to write a test or exam deems themselves fit enough to do so, and the student must accept the mark obtained. Claims of medical, physical, or emotional distress after the fact will not be considered.

### iii. Use of Electronic Devices.
Use of electronic devices (cell phones, music players and cameras) will not be permitted during class or during the midterm test or exam.

### iv. Use of Personal Response Systems (Clickers) - not applicable

### vi. Academic Offences
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 ).

**vi. Student's Responsibilities in the Event of a Missed Course Component**

If you are unable to meet a course requirement due to illness or other serious circumstances, you must provide valid medical or other supporting documentation to the Academic Counselling Office of your home Faculty as soon as possible and contact your instructor immediately. If you are a Science student, the Academic Counselling Office of the Faculty of Science is located in WSC 140, and can be contacted at 519-661-3040 or scibmsac@uwo.ca. Their website is http://www.uwo.ca/sci/undergrad/academic_counselling/index.html.

A student requiring academic accommodation due to illness must use the Student Medical Certificate (https://studentservices.uwo.ca/secure/medical_document.pdf) when visiting an off-campus medical facility.

For further information, please consult the university's medical illness policy at http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf. It is the student's responsibility to make alternative arrangements with their instructor once the accommodation has been approved and the instructor has been informed.

A student requiring academic accommodation due to illness, should use the Student Medical Certificate when visiting an off-campus medical facility or request a Records Release Form (located in the Dean's Office) for visits to Student Health Services.
The form can be found here: https://studentservices.uwo.ca/secure/medical_document.pdf

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.

If you miss the midterm test or the Final Exam, please contact your faculty's Academic Counselling Office as soon as you are able to do so. They will assess your eligibility to write a make-up midterm (if offered; and if not, a grade re-weighting may be applied) the Special Exam (the name given by the university to a makeup Final Exam). 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).