Department of Earth Sciences/Faculty of Sciences
ERTH 4801/5701 – Physics of the Earth
Fall 2022 – September to December 2022

Course Description
This course provides an in-depth treatment of the various aspects of geophysics that are important to understand the physical properties, the theory of plate tectonics and the working of the Earth's deep interior. The Course will be delivered in a seminar and discussion form requiring the active participation of the students. We shall deal with the main fields of geophysics (gravity field and isostasy, seismicity and seismic wave propagation, heat flow and temperature distribution in the interior of the earth, plate tectonics, geodynamics and rheology of the Earth not by covering these sub- topics one by one, but by examining the present knowledge of the properties and dynamics of the Earth and the geophysical evidence upon which this knowledge is based. There will be strong emphasis on seismology as a tool in understanding the Earth's interior.

Prerequisites: ERTH 3405 or permission from the department/instructor. Some familiarity with calculus and physics is necessary.

Instructor: Wasiu Raji
Contact: E-mail: wasiuraji@cunet.carleton.ca;
Office: 2249 Herzberg – only by appointment

Teaching Assistants: Navid Saeidi
navidsaeidi@cmail.carleton.ca

Office hours: Tuesdays 11:25 pm – 14:35 pm at HP 2130

Lectures: In-person, 3 hours per week, Thursdays from 14:35PM – 17:25 PM, in HP2120

Link to Brightspace page for this course: https://brightspace.carleton.ca/d2l/home/144682

Email policy: All questions relating to this course should be sent to the course forum, not my email, so that everyone can benefit from the responses. The TA and I will respond to questions on 'Discussion' on Brightspace with 24 hours. Given the number of students on this course, I will not respond to emails asking questions about the course/lectures/announcements/deadlines, results, etc except they are very personal.

Suggested References

Ranalli, G. *Some problems of geodynamics*, lecture notes.
Fowler, C. M. R. (2005). *The Solid Earth*, 2nd edn. Cambridge University Press.
Ranalli, G. (1995). *Rheology of the Earth*, 2nd edn. Chapman & Hall, London.
Turcotte, D. L. & Schubert, G. (2002), *Geodynamics*, 2nd edn. Cambridge Uni. Press.

Learning Objectives:

- Learn the tools needed to understand the concepts underpinnings plate tectonics
- Understand the fundamental processes of Earth's interior deformation and touch on interactions between the interior and the plates through geologic time
- Build a solid foundation of the main geophysical features of the Earth such as gravity anomalies and isostasy, glacioisostatic rebound, surface heat flow and temperature distribution in the interior, etc.
- Use continuum mechanics to describe the lithosphere: stress, strain and strain rate tensors, rheological equations, brittleness and ductility, etc.
- Understand temperature profiles through the Earth
- Develop an understanding of the interior of the Earth (mantle and core) including physical properties and composition of the mantle
- Use seismological tools such as tomography to learn about the rheology of the mantle and seismic velocity distribution

Learning Outcome

Students who completed this course will achieve the following among others:

- Know the physical properties of the different layers of the earth.
- Understand how heat is generated in the earth interior, the process of heat flow, gravity and temperature profiles, and how these properties is used to explore the earth.
- Understand earth internal process, deformation, plate tectonic, and natural disaster.
- Know what account for the variation in seismic velocity, attenuation, and anisotropy in the earth and how they are used in study of the mantle and the core.

Grading Scheme:

Practical assignments	30%
Final project & Presentation	30%
Final Exam (take home)	30%
Attendance and Participation	10%

The **assignments** will be a combination of theoretical problems and practical applications solved on the computer. There will be 3 Assignments – one per month in September, October, and November. They will be posted on Brightspace and are due two weeks afterwards. Submission is through Assignment module in Brightspace. Submission will not be accepted by email, except otherwise stated. You are permitted to discuss assignments on this course with your classmates, but it is absolutely imperative that any work you submit for this class is your own. Plagiarism, defined as an *attempt by a person to represent the work of another as her or his own,* is strictly against the policies of academic fairness and integrity of Carleton University. This means you must clearly attribute sentences, quotations, or figures copies somewhere to the rightful owners (citing name + year + publication of any sources). You should always mention any classmates with whom you have collaborated (a brief marginal note will suffice), and it is not EVER permitted to copy another student's work. If you are found to be in violation of this policy, there are very serious consequences.

There will be one larger **project** focusing on a region of interest to you. This project will comprise the application of the concepts that we discuss in class to a particular locality (of your choosing). This project will be due at the end of the quarter, but you will be guided to work progressively on various aspects of it throughout the semester. Everyone will present their final projects in the last week of the course in a lively academic manner within a given time frame.

There will be a take-home **final exam** posted to the course Brightspace toward the end of the course or in the last class, and it will be due during the Final Exam Period, Submission is through the Brightspace.

For all labs and exams *always* show your full working for mathematical problems. As well as making it much easier to judge. Full mark will not be awarded if the logic and workflow of the answer is not very clear. Make sure to properly highlight your final answer to each problem. Answers should be mathematically *correct.* **Get in the practice of being meticulous with your mathematics!**

Missed Deadlines

If you foresee you might miss a deadline, you must inform the professor before the deadline. If you miss a due date for a task or exam due to unforeseen circumstances, then you must contact the course instructor within 3 days of the deadline and provide appropriate documentation in order to obtain an extension.

Course Requirements:

- The practical component of the course must be passed in order to pass the course.
- The final exam must be passed in order to pass the course.
- Assignments must be handed in on time. Late submission attracts deduction of 5 points per day up to a maximum of fifteen points. Late submission is acceptable without deductions in the instance of illness provided a medical note available.
- Lecture materials will be posted on Brightspace at least a week before the lecture. It is the student's responsibility to ahead of lectures, and attend classes prepared. Class attendance and participation attract 10% of final grade.
- Regularly log onto the course Brightspace to check for announcements, course information, assignments, lecture materials, and due dates.

Tentative Schedule (note: it is subject to change):

- ***Week 1 - Introductory class and meeting (Sept. 8)***
  Course outline, requirements and expectations, introduction to Geodynamics and the GeoMapApp (I suggest you download it sooner rather than later http://www.geomapapp.org/)

- ***Weeks 2-4 (Sept. 12 – Oct. 2): Introduction to Earth physics (review) & the Lithosphere*** Continuum mechanics description of the lithosphere; stress, strain, and strain rate tensors; rheological equations (elasticity; linear and nonlinear viscosity); equations of equilibrium and continuity; brittleness and ductility; conduction and advection of heat; conservation of energy; temperature in oceanic and continental lithosphere; high-temperature creep; rheology of the lithosphere.

- ***Weeks 5 - 7 (Oct. 3 – Oct. 23): Special topics in Seismology & Guest Lectures***
  Ray theory, global body waves, surface waves, normal modes, deep Earth seismology, attenuation, anisotropy, scattering, seismic structure of the lithosphere and internal structure of the Earth

- ***Week 8 (Oct 24 -29) Fall Reading Week***

- ***Weeks 9-10 (Oct. 31 – Nov. 13): The interior of the Earth – Rheology of the Mantle***
  Spherically symmetric Earth models; physical properties and composition on the mantle; temperature and solidus temperature; lateral variations: seismic tomography and its interpretation; rheology of the mantle: postglacial rebound and inferences on viscosity; thermal convection in the mantle: critical Rayleigh numbers; creep mechanisms, Newtonian and non-Newtonian viscosity.

- ***Weeks 11 – 12 (Nov. 14 – Nov. 27): Continental & Oceanic extension and Subduction*** Oceanic spreading transition, asthenospherization, time dependence of negative buoyancy and the subduction of continental lithosphere, initiation of subduction

- ***Week 13 (Nov. 28 – Dec. 4) Deep interior of the Earth***
  Convection in the core, generation of the Earth's magnetic field, PREM model, the Earth

density model

- ***Presentations (Dec. 5 – 9)***

- ***Dec. 10 – 22 – Final Exam Period***
  Take home final exam.

Academic Integrity
It is your responsibility to review Carleton's policy on Academic Integrity - Section 14 of the Calendar.
http://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/acadregsuniv14/

Plagiarism
The instructor is required to report all incidents (or suspected incidents) of plagiarism to the Dean. **All work handed in must be your own.** Plagiarism and cheating are viewed as being particularly serious and the sanctions imposed are accordingly severe. Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy. The Policy is strictly enforced and is binding on all students. Plagiarism and cheating – presenting another's ideas, arguments, words or images as your own, using unauthorized material, misrepresentation, fabricating or misrepresenting research data, unauthorized cooperation or collaboration or completing work for another student – weaken the quality of the graduate degree. Academic dishonesty in any form will not be tolerated. Students who infringe the Policy may be subject to one of several penalties including: expulsion; suspension from all studies at Carleton; suspension from full-time studies; a refusal of permission to continue or to register in a specific degree program; academic probation; or a grade of failure in the course.

Requests for academic accommodation

Please review the Carleton's Student Guide to Academic Accommodations at http://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf, and the websites therein.
For Students with Disabilities:
"The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your ***Letter of Accommodation*** *at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation*. After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website (www.carleton.ca/pmc) for the deadline to request accommodations for the formally-scheduled exam.

For religious observance:
1. *As soon as you receive your course syllabus*, identify any potential conflicts between your religious obligations and course requirements. **2.** Make a formal written request to your instructor indicating the nature of the religious obligation and suggest possible alternative dates and/or means of satisfying the academic requirements. *NOTE: Such request should be made*

during the first two weeks of the term, or as soon as possible after a need for accommodation is known to exist, but in no case later than the second last week of classes for that term. For detailed information on Religious Obligations please visit our website at: carleton.ca/equity/accommodation/academic.

For pregnancy:
A. For final exams, identify and discuss your needs for final examinations with your professors. When an agreement is reached fill out and submit the online **Pregnancy Accommodation Final Exam Request Form** at: carleton.ca/equity/ accommodation. Equity Services will forward the request to Exam Services to coordinate the accommodation. **B.** For in-class accommodations ONLY. If you anticipate you will only require in-class accommodations, discuss them directly with your course instructor. This request should be made in the first two weeks of the academic term. For detailed information on pregnancy and parental leave policies please visit the website at: carleton.ca/equity/accommodation/academic/

Equity and PMC Contact information:
• Department of Equity and Inclusive Communities
613-520-5622
3800 Carleton Technology & Training Centre
equity@carleton.ca
Website: carleton.ca/equity
• Paul Menton Centre for Students with Disabilities
613-520-6608
pmc@carleton.ca
500 University Centre
Website: carleton.ca/pmc

Statement on Student Mental Health

As a university student you may experience a range of mental health challenges that significantly impact your academic success and overall well-being. If you need help, please speak to someone. There are numerous resources available both on- and off-campus to support you. Here is a list that may be helpful:

Emergency Resources (on and off campus): https://carleton.ca/health/emergencies-and-crisis/emergency-numbers/

Carleton Resources:
• Mental Health and Wellbeing: https://carleton.ca/wellness/
• Health & Counselling Services: https://carleton.ca/health/
• Paul Menton Centre: https://carleton.ca/pmc/
• Academic Advising Centre (AAC): https://carleton.ca/academicadvising/
• Centre for Student Academic Support (CSAS): https://carleton.ca/csas/
• Equity & Inclusivity Communities: https://carleton.ca/equity/

Off Campus Resources:
• Distress Centre of Ottawa and Region: (613) 238-3311 or TEXT: 343-306-5550, https://www.dcottawa.on.ca/
• Mental Health Crisis Service: (613) 722-6914, 1-866-996-0991, http://www.crisisline.ca/
• Empower Me: 1-844-741-6389, https://students.carleton.ca/services/empower-me-counselling-services/

- Good2Talk: 1-866-925-5454, https://good2talk.ca/
- The Walk-In Counselling Clinic: https://walkincounselling.com