GEO 315L Earth From Lab to Planet (Course ID 27350)

Spring 2025

Summary:

This undergraduate course explores the physical laws that explain the dynamical changes we observe on the surface and interior of our planet, from tectonic to generational timescales. Our approach is based on "hands-on" experiments, in the lab and on the computer, to illuminate particular geodynamical processes or material behavior in isolation. We then use abstractions from these experiments to understand how those processes can be scaled up to understand the dynamics of Earth, from regional groundwater transport to global mantle convection. The course will be composed of five modules that explore different rock behavior. Based on the "toy models" that can be constructed, we will discuss basic theory to build our intuition for the controlling mechanisms for planetary evolution.

The course intends to provide a foundation for exploring geoscience problems from a quantitative, process-based, systems perspective, but there are no prerequisites. Any calculus or other math topics beyond basic algebra will be introduced on the fly and always with specific problems in mind. We likewise do not require any prior exposure to earth science and this class can be a first exposure to geoscience problems to students from physics, engineering, and related natural science fields.

Logistics

Instructors:

- Peter Flemings — pflemings@jsg.utexas.edu, JGB 5.318
- Thorsten Becker — twb@ig.utexas.edu, JGB JGB 5.226B
- Office hours: Becker: M, W 10:30-12:00 (or by appt.)
  Flemings: M, W 10:30-12:00 (or by appt.)
  Teaching Assistant - Mahmoud Mbarak (mbarak@utexas.edu) ,
  T 10:00-12:00 JGB 5.220E (or by appt)
  Course Assistant - Caroline Mackin (carolinemackin@utexas.edu):
  Th 10:00-12:00 (or by appt)

Lecture time & Location:

- EPS 1.126. M/W 9:00 a.m.-10:30 a.m.

Format: This course will be in person, including a mix of lectures, laboratory, and computer exercises.

Learning outcomes:

1. Apply Continuum Mechanics Concepts: Students will learn to apply fundamental principles of continuum mechanics to analyze and interpret experimental and computational data, gaining insights into the behavior of the solid Earth.
2. Conduct Tabletop Experiments: Through hands-on tabletop experiments, students will develop essential laboratory skills, including experimental design, data collection, and analysis, fostering a practical understanding of key concepts in introductory experimental physics.

3. Integrate Computer Simulations: Students will gain proficiency in using computational tools to simulate and model geophysical processes, allowing them to explore the application of theoretical concepts and compare results with experimental observations.
4. Link Laboratory Findings to Earth Sciences: Students will develop the ability to connect laboratory-based findings to real-world phenomena, establishing a bridge between the controlled environment of experiments and the broader understanding of Earth's dynamic processes.
5. Communicate Scientific Insights: Through written reports, presentations, and class discussions, students will enhance their communication skills, effectively conveying their scientific findings, interpretations, and the broader implications of their work in both experimental and computational aspects of the class.

Expectations & Grading:

Class attendance is required and attendance will be taken. If you miss more than 4 lectures, your grade will be reduced by a full grade (e.g. A>B). You are expected to take notes during class and your notes will be handed in.

Each student is responsible for having their own portable computer available for use in class

Grading is as follows:

A: 94 and above; A-: 90-93.99; B+: 87-89.99; B: 83-86.99; B-: 80-83; C+:77-79.99; C: 73-76.99; C-: 70-73

The relative weighting of each component of the course is listed below.

Component	course %
Module 1	5
Module 2	16
Module 3	13
Module 4	13
Module 5	13
Midterm 1	13
Midterm 2	13
Final	14
sum	100

Prerequisites

- None

Textbook:

- Reading assignments and lecture notes

Quantitative Reasoning:

- This course carries the Quantitative Reasoning flag. Quantitative Reasoning courses are designed to equip you with skills that are necessary for understanding the types of quantitative arguments you will regularly encounter in your adult and professional life. You should therefore expect a substantial portion of your grade to come from your use of quantitative skills to analyze real-world problems.

Writing:

- This course carries the Writing flag. Writing flag courses are designed to give students experience with writing in an academic discipline. In this class, you can expect to write regularly during the semester, complete substantial writing projects, and receive feedback from your instructor to help you improve your writing. You will also have the opportunity to revise one or more assignments, and you may be asked to read and discuss your peers' work. You should therefore expect a substantial portion of your grade to come from your written work. Writing Flag classes meet the Core Communications objectives of Critical Thinking, Communication, Teamwork, and Personal Responsibility, established by the Texas Higher Education Coordinating Board.
- AI policy: Should you decide to use AI tools, students shall give credit to AI tools whenever used, even if only to generate ideas rather than usable text or illustrations. When using AI tools on assignments, add an appendix showing an explanation of how the AI tools were used and an account of why AI tools were used. Students shall not use AI tools during in-class examinations, or assignments unless explicitly permitted and instructed. Overall, AI tools should be used wisely and reflectively with an aim to deepen understanding of subject matter.

Class topics

1. **Module 1: Python-Jupyter-Plotting WEEK 1**
    1. Achieve ability to use python in Jupyter notebook on personal computer
    2. Successfully load, plot, and model example data set.

1. **Module 2: Elasticity (stress-strain behavior) WEEKS 2-6**
    1. Laboratory Measurement: Perform stress-strain experiment. Loads will be incrementally applied to different materials and displacement will be measured. We will explore material behavior through these measurements. We will also study harmonic oscillation by examining the period of oscillation that results with different masses and different materials.
    2. Earth Application: Add inertia to Hooke's law, derive harmonic oscillator, and derive wave equation. Discuss attenuation, sensing of properties.
    3. Computer experiment: Solve an ODE. Oscillation. Damped Oscillation. Attenuation. Driven oscillator. Resonance.

2. **Module 3: Friction WEEKS 7-9**
    1. Laboratory Measurement: Measure static and dynamic friction. Determine relationship between friction coefficient and friction angle. Develop friction law.
    2. Earth Application: Friction: Calculate friction on a particular fault plane. Mohr Circle, Calculate orientation of faults at Coulomb failure. Transition from friction to plasticity/ductile behavior.
    3. Computer experiment: Rate-state friction with spring-slider. Transients and limit cycles, stick-slip earthquake sequence.

3. **Module 4: Viscosity WEEKS 10-12**
    1. Laboratory Measurement: Stoke's law settling lab. Students will learn both to interpret viscosity and to understand quantitatively settling rate as a function of viscosity, grain diameter, and fluid and solid densities.
    2. Earth Application: Derive Stokes settling velocity from balance of shear and gravity forces. Apply to river transport and settling as a function of grain size. Discuss visco-elasticity, post-glacial rebound, Maxwell time.
    3. Computer experiment: velocities and stress around a sinking sphere for different properties

5. **Module 5: Heat Conduction WEEKS 13-15**
    1. Fourier's Law: Measure steady state temperature across with different applied heat fluxes. Derive thermal conductivity.
    2. Earth Application: Earth geothermal gradient. Derive diffusion scaling (length ~ sqrt(time)), discuss half space cooling. Peclet number to balance advection and diffusion, leads to Rayleigh number when Stokes riser velocity is plugged in. Thermal Convection.
    3. Computer experiment: Lorenz convection equations, cycles, and deterministic chaos.

Disability notice:

Students with disabilities may request appropriate academic accommodations from the Division of Diversity and Community Engagement, Services for Students with Disabilities, 512-471-6259, diversity.utexas.edu

***Recordings**:*

Class recordings are reserved only for students in this class for educational purposes and are protected under FERPA. The recordings should not be shared outside the class in any form. Violation of this restriction by a student could lead to Student Misconduct proceedings.

Detailed Schedule

MODULE 1: Python-Jupyter-Plotting

January 13: WEEK 1

Monday: Class Introduction and Python/Jupyter fundamentals (PBF) (TWB out)

Wednesday: Stress/strain and Python/Jupyter fundamentals (PBF) (TWB out)

MODULE 2: Elasticity

January 20: WEEK 2

Monday: MLK Day - NO CLASSES

Wednesday: Experimental Measurements 1 (PBF)

January 27: WEEK 3

Monday: Experimental Measurements 2 (PBF)

Wednesday: Solving ordinary differential equations (TWB)

February 3: WEEK 4

Monday: Damped oscillators (TWB) (PBF out)

Wednesday: Driven oscillators (TWB) (PBF out)

February 10: WEEK 5

Monday: Driven oscillators (TWB)

Wednesday: Discussion of stress/strain and harmonic oscillator (TWB)

MODULE 3: FRICTION

February 17: WEEK 7

Monday: Lab Measurements 1 (PBF)

Wednesday: Lab Measurements 2 (PBF)

February 24: WEEK 8

Monday: Applications (stick slip, earthquakes, mohr circle) (PBF)

Wednesday: Computer experiment: Rate-state friction with spring-slider (TWB).

March 3: WEEK 9

Monday: Transients and limit cycles, stick-slip earthquake sequence (TWB).

Wednesday: Synthesis/wrap up (TWB)

Wednesday: Evening Exam

MODULE 4: Viscosity

March 10: **WEEK 10**

Monday: Experiments (PBF)

Wed: Experiments (PBF)

March 17-21: SPRING BREAK

March 24: **WEEK 11**

Monday: Experiments wrap-up (PBF)

Wed: Stokes flow experiment (TWB)

March 31: **WEEK 12**

Monday: Stokes flow experiment II (TWB)

Wed: Stokes Flow. (TWB)

MODULE 5: Heat Flow

April 7: **WEEK 13**

Monday: Lab (PBF)

Wed: Lab (PBF)

April 14: **WEEK 14**

Monday: Heat Flow Applications (PBF)

Wed: Mantle Convection (TWB)

Wed. Mantle Convection (TWB)

Evening ExamMonday:

April 21: **WEEK 15**

Wed: Mantle Convection (TWB)

Wed. Mantle convection (TWB)

April 28

Monday: Last class day

April 29 & April 30 Study days (no-class days)

May 1 & May 2: Final Exam, EPS 1.126, 8-10 am

Saturday, May 10 University commencement (official graduation date)

Useful Links:

https://www.youtube.com/watch?v=2WL-XTl2QYI Introduction to Jupyter/Python

Accessible/Compliant Statement:

If you are a student with a disability, or think you may have a disability, and need accommodations please contact Disability and Access (D&A). You may refer to D&A's website for contact and more information: http://disability.utexas.edu/. If you are already registered with D&A, please deliver your Accommodation Letter to me as early as possible in the semester so we can discuss your approved accommodations.

Accessible, Inclusive, and Compliant Statement:

The university is committed to creating an accessible and inclusive learning environment consistent with university policy and federal and state law. Please let me know if you experience any barriers to learning so I can work with you to ensure you have equal opportunity to participate fully in this course. If you are a student with a disability, or think you may have a disability, and need accommodations please contact Disability and Access (D&A). Please refer to D&A's website for contact and more information: http://disability.utexas.edu/. If you are already registered with D&A , please deliver your Accommodation Letter to me as early as possible in the semester so we can discuss your approved accommodations and needs in this course.