GEO 315L Earth From Lab to Planet (Course ID 27330)

Spring 2024

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 4.220AA
- Office hours: TBD

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.

Grading:

- Each course module will comprise 16% of the grade (80%)
- Midterm 1 (10%)
- Midterm 2 (10%)

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

Prerequisites

- None

Textbook:

- Reading assignments and lecture notes

Class topics

1. **Module 1: Elasticity (stress-strain behavior) WEEKS 1-4**
    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 2: Friction WEEKS 5-7**
    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 3: Viscosity WEEKS 7-9**
    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 (Matlab based FE model)

5. **Module 4: Heat Conduction WEEKS 10-12**
    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.

6. **Module 5: Flow Through Porous Media WEEKS 13-15**
    1. Laboratory Measurement: Darcy's Law: Measure volumetric flow rate as a function of hydraulic head for several different porous media. Develop Darcy's Law. Express Darcy's law as a function of both head and pressure.
    2. Earth Application: Develop consolidation equation and apply to stream flux. Discharge and recharge. Erosion laws, stream transport vs. hillslope erosion.
    3. Computer experiment: Landscape evolution modeling.

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: Elasticity

January 15: WEEK 1

Monday: NO CLASS-MLK

Wednesday: Class Introduction and Initial Measurements (PBF)

January 22: WEEK 2

Monday: Final Stress-strain measurements

Wednesday: Discussion of stress/strain and harmonic oscillator

Laboratory Write-up Due

January 29: WEEK 3

Monday: How to solve ODEs (TB & PBF)

Wednesday: Damped and driven oscillators (TB & PBF)

February 5: WEEK 4

Monday: Damped and driven oscillators continued

Wednesday: Damped and driven oscillators continued

MODULE 2: FRICTION

February 12: WEEK 5

Monday: Lab Measurements 1

Wednesday: Lab Measurements 2

February 19: WEEK 6

Monday: Computer experiment: Rate-state friction with spring-slider (TB).

Wednesday: Transients and limit cycles, stick-slip earthquake sequence (TB).

February26: WEEK 7

Monday: Mohr's Circles and other applications

Wednesday: Synthesis

MODULE 3: Viscosity

March 4: WEEK 8

Monday: Laboratory Measurements

Wed: Laboratory Measurements

March 11-15: SPRING BREAK

March 18: WEEK 9

Monday: Class Introduction

Wed: Computer Experiment: Becker

March 25: WEEK 10

Monday: Computer Experiment Becker

Wed: Synthesis: Flemings

MODULE 4: Heat Flow

April 1: WEEK 11

Monday: Lab

Wed: Lab

April 8: WEEK 12

Monday: Class Introduction

Wed:

MODULE 4: Permeability

April 22: WEEK 13

Monday: Class Introduction

Wed:

April 29: WEEK 14

Monday: Last Class Day

April 29:	**Last Class Day**
April 30 & May 1	**Study days (no-class days)**
May 2-4 & May 6	**Final exams**
May 11	**University commencement (official graduation date)**

Useful Links:

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