FOUNDATIONS OF GEOPHYSICS FALL 2024 GEOS F431/631 Syllabus

4 Credits

INSTRUCTORS:

Revathy M. Parameswaran:

Tel: 907-347-3545
email: rmparameswaran@alaska.edu
Office: 413E Elvey (GI)
Office hours: Tuesdays 12-1 pm in person or via zoom
https://alaska.zoom.us/j/81461162532?pwd=nUmzc54iEOivI5st5cjjOsaf6mxORM.1
(Passcode: 040638)

Amy Jenson:

Tel: 218-242-2806
email: ajjenson@alaska.edu
Office: 401K Elvey (GI)
Office hours: Thursdays 4-5 pm in person or via zoom
https://alaska.zoom.us/j/6756253429?pwd=b1p2aHJ2YkkvL2NHZUZvYU5iSGJzUT09
(Passcode :aaMV4u)

TEACHING ASSISTANT:

Jackie Beight
Email: jbeight@alaska.edu
Office: 107 O'Neil
Office hours: Wednesdays 4:30-5:30 in person or via zoom

COURSE LOGISTICS:

This class is offered in synchronous in person format. Meetings are:

Lectures: W & F 2:30-4 pm; MURIE 103/105 (room reserved until 4:30)

Labs: M 3:30-6:30 pm; WRRB 004

OPEN SCIENCE LAB (OSL) USERNAMES:

Please access the following link to a slide that provides you with information to create your individual accounts in Open Science Lab (OSL).
https://docs.google.com/presentation/d/1TIcplIxoMoQmginu7I_GcnW5-CgXvyd7VFLQuAb2h40/edit?usp=sharing

Your labs will be run exclusively in this environment.
Once you have your usernames please share your usernames with us via the following Google Sheets link:
https://docs.google.com/spreadsheets/d/13KLtDcajmBzBL7hoOE8mjOvHCe7UuNP7Ox57G1B6xbI/edit?usp=sharing

In case you're stuck at some point while creating the account, we can always sort it out first thing Friday, Aug 30.

COMMUNICATIONS:

We provide several communication channels for this course. Please find the details on Canvas. We will use Canvas to post all materials related to the course. You will receive regular emails for updates on Canvas or for other updates or changes to activities related to the course. You are responsible for being aware of due dates or updated material on Canvas. Ask questions on slack, come to (virtual) office hours!

Join the slack channel at the link below.

https://join.slack.com/share/enQtNzU2NTEzODQyMDA2Ni04MThlNmMyNzBmMjkwODI3Mjc0NTY1MDRhOGQ1MjRkYjc3MzljZWRiMzdlZmQ5NDBlOGMxNzE4Zjg0MWU4NWFh

COURSE CATALOG TEXT:

GEOS F431/631 Foundations of Geophysics
4 Credits
Offered Fall

Applications of continuum mechanics, heat flow theory, and potential theory to geophysical, geologic and glaciological problems. Topics such as postglacial rebound, non-Newtonian fluid flow, thermal convection, stress-relaxation, rheology of earth materials, gravity, and magnetics will be discussed. Emphasis will be placed on methods and tools for solving a variety of problems in global and regional geophysics and the geophysical interpretation of solutions. Prerequisites: GEOS F418, MATH 302 and 314, permission of instructor, or graduate standing

COURSE GOALS:

1. The primary goal of **GEOS 631** is to train new graduate students in the fundamental problem-solving methods (including computational skills) used in a variety of geophysics problems. The focus is on the applications of the Conservation Laws for Mass, Momentum, and Energy to geophysical problems and to introduce modern views of plate tectonics and potential theory.
2. The primary goal of **GEOS 431** is to offer a solid foundation in the problem-solving

methods for undergraduate students concentrating in Geophysics. As the final (or "capstone") course undergraduate students will take, it is intended to set them up for success in graduate school or in the geophysics workforce.

COURSE DESCRIPTION:

This course is designed for incoming graduate students in geophysics and upper level undergraduate students. The overarching goal of the course is for you to be able to recognize and apply various approaches to solving geophysical problems.

This is a seminar-style class, there will be lecturing especially on heavily quantitative material, but generally you will be expected to read material ahead of time and be prepared for in class discussions.

After taking this course, you should be able to:

1. Describe the large-scale structure of the Earth, including the gravity and magnetic fields.
2. Discuss the current theories and research methods in plate tectonics and geodynamics.
3. Determine which conservation laws are the most important for a particular problem.
4. Recognize the properties of the materials and state equations that will be important to the solution.
5. Decide on the set of simplifying assumptions to use and be able to justify those assumptions.
6. Apply the specific mathematical techniques related to continuum mechanics.
7. Apply the specific mathematical techniques related to potential theory.

The first half of the semester will focus on fundamental principles of the three conservation laws and introduce concepts in continuum mechanics. The second half will look deeper into applications of the conservation laws and emphasize potential theory and its methods. The computational lab will allow you to deepen your understanding of the concepts and improve your skills at numerical methods and modeling. The computational lab will use the Python programming language, which is very common among geophysics researchers; these are skills you will need to succeed in graduate school and as a future geophysicist.

Because this course is teaching you problem solving skills in addition to geodynamic and geophysical fields content, you will spend a substantial amount of time solving problems (individually and in groups).

In order to succeed in this course, you will need to have an understanding and be able to apply

1. basic linear algebra, such as a basis transformation (for vector or matrix), orthogonality

2. vector calculus: grad, div, curl and all that (Cartesian global coordinates, x-y-z)
3. vector calculus: grad, div, curl and all that (spherical local coordinates, r-theta-phi)

If you do not have these skills, please discuss this with the instructors and with your graduate advisor.

We will meet twice per week for a 90 minute lecture, discussion, and problem solving session and once a week for a 3 hour computing lab session. Most homework is to be done *before* attending class, not after. This will include coming to class prepared by reading course material, outlining the key concepts. During class, we will discuss the material you have read (guided by your questions from the reading) and we will use team problem solving, small group discussions, and other in class activities to probe the material more deeply.

Assessment in this class will take the form homeworks, labs, and two take-home exams.

STUDENT LEARNING OUTCOMES:

The specific learning outcomes on which the assessments will be based include:

Problem Solving Methods

1. Define a Continuum and provide examples for geodynamic problems
2. Define a vector, define a tensor
3. Read and interpret equations written in index notation (in comparison with vector/matrix notation)
4. Describe and visualize the 6 components of stress and strain
5. Identify several special states of stress and provide multiple examples of each
6. Explain the Conservation of Momentum, Mass, and Energy and describe the physical process underlying each of the terms within the equations
7. Explain what an equation of state (constitutive equation) is and provide examples related to geodynamic problems
8. List the steps toward solving a general geodynamics problem (define geometry, list assumptions and boundary conditions, write conservation equations using appropriate terms, choose and write equations of state and constitutive laws to build a solvable system of X eqns and Y unknowns, solve the system of equations)
9. Apply the general process for solving geodynamics problems to specific problems (defining assumptions, boundary conditions, conservation laws, etc.)
10. Recognize and evaluate other scientists' approaches to geodynamics problems (using the general process)
11. Classify geodynamics example problems according to which conservation laws are most important and which solution techniques might be useful.
12. Apply concepts of Fourier Series
13. Explain the concept behind spherical harmonics and how it is useful for

describing gravity and magnetic fields of the earth

14. Understand relationship between vector and potential fields
15. Set up and solve differential equations for potential field problems

Geodynamics Content

1. Draw the 1D Earth and label the core, mantle, crust, important distances, and basic properties of each layer
2. Explain the fundamental concept behind plate tectonics
3. Understand the mathematical description of (plate) motion on a sphere (key: Euler vectors)
4. Explain the factors that affect the gravity field on Earth and how it varies in time
5. Describe the variability in the Earth's magnetic field through time and space
6. Discuss the sources of heat within the earth and the effect of these sources on processes in the mantle and crust such as radioactive heating, etc.
7. Show familiarity with different processes involved with local and global sea-level changes (e.g., isostatic rebound, changes in dynamic topography due to internal mass redistributions, orbital fluctuations, etc.)

COURSE MATERIALS:

Book:

1. Required: Geodynamics 3rd Ed. by Turcotte and Schubert (2014)
2. Recommended: Geophysical Continua by Kennett and Bunge (2018?)
3. Recommended: Div, Grad, Curl, and All That: An Informal Text on Vector Calculus by Schey (2004)
4. Recommended: Isostasy and Flexure of the Lithosphere by A.B. Watts (2001)
5. Recommended (Additional and optional): Mechanics of Materials, Roy R. Craig Jr., John Wiley & Sons, 3rd Ed. (2011)
6. Recommended (Additional and optional): Geodynamics of the Lithosphere: An Introduction, Kurt Stüwe, Springer, 2nd Ed. (2007)

Notes: We will supply instructor-written notes and outlines of key concepts to supplement the reading and guide your preparations for class. These will be handed out early in the semester, so that you can plan and read ahead as necessary (i.e., being in the field is not an excuse for being unprepared for class).

Access to Computer with Matlab License: We will not use Matlab as the primary language in this class, however, some of you may choose it to work with (expect minimal support). UAF provides networked Matlab licenses for all university computers, if you do not have a computer with Matlab, ask your graduate advisor or course instructors for the best solution. The Geology and Geophysics Computer Lab (Reichardt Room 316) has computers with Matlab for your use. You will need to login with your university ELMO password. During COVID-19 related shutdowns, it is most appropriate to access machines remotely via (VPN and) ssh, x2go etc.

Journal Articles and Supplemental Readings: These will be supplied as PDFs on Canvas as necessary with ample lead time before the respective class

COURSE CONTENT The course will be divided into six units.

Unit 1: Understanding Deformation in Continuum Mechanics

Unit 2: Conservation of Mass and Momentum and Fluid Flow

Unit 3: Conservation of Energy and Heat Transfer

Unit 4: Gravity and Potential Fields

Unit 5: Magnetics and Plate Tectonics

Unit 6: Elasticity and Lithospheric Flexure

For each unit, there will be related computing labs and one written homework problem set and reading assignments to be completed before the meeting (best in order given).

DRAFT SCHEDULE:

Please click the link below to view the tentative schedule for the semester. This schedule is going to change as the semester goes. Please continue to check this document regularly.

https://docs.google.com/document/d/1zA-LwBXrfsDtPfTKA7evMOtmp2-6AEgwiu4FweDQ5JE/edit?usp=sharing

Due times for labs are BEFORE the beginning of the next lab session. All other due times are 6PM of the day indicated.

All homework assignments are due through uploading a pdf file to Canvas. As a professional scientist (whether academic or industry), how you present your work is important. We expect typed (Latex is recommended to make equations easier), well-organized solutions (if they are not legible, or not organized in a logical way, we may not be able to give you complete credit). Lab submissions should be zip-archives including code, figures, write up (PDF)

ASSESSMENT: Students registered for 431 are expected to achieve essentially all of the primary learning outcomes for geophysical problem solving and content. The specific differences between 631 and 431 include

1. On all Lab assignments, 631 students will receive credit for all assignments, 431 students will be allowed to drop their lowest score.

2. On homework assignments, all problems are expected to be completed by 631 students. Some homework problems will be labeled only for 631 (graduate) students and do not need to be completed by 431 students.
3. The mid-term and final exams will have a 431/631 assessment structure similar to the homework assignments.

Computational Problems / Labs: You will have one introductory computational problem to help familiarize yourself with Python. Then, you will complete one computational problem each week. Most of the work towards completion of these will occur during the computational lab time, some work will be finished outside of that time interval. You can do these assignments with partners in the lab, but you will each submit your own solutions.

Homework Problem Sets: We will assign one problem set or short written assignment for each unit (6 total). Unless otherwise stated, these will be due at the beginning of class the following Tuesday.

Exams: There will be two take-home exams, which you will have to complete within 1 week.

Class Participation: This will be assessed by whether you have done the reading and prepared for class sufficiently to contribute to class activities (as part of this we may make random checks that you have taken notes or written questions as part of preparation for class).

Grading: Grades are composed of 35% labs, 35% homework, 10% midterm exam, 12.5% final exam, 7.5% regular discussion participation. Minimum percentages for each grade:

A: 90% **B: 80%** **C**: 65%** **D**: 50%**

**note graduate students must receive a C minimum in this course and maintain a B average for graduate level courses

COURSE POLICIES:

1. In all aspects of this course, you are expected to follow ethical behavior. We encourage working with fellow students on assignments; however you must hand in your own work: **you may not plagiarize (this includes ChatGPT) or copy another student's work**.
2. Late Homework / Lab Assignments: You will receive 5 percent off your assignment for each day your written assignment is late.
3. The mid-term and final exams will not be accepted late. Please plan your schedule accordingly.

SYLLABUS ADDENDUM:
The syllabus addendum contains non-academic information all students must be aware of. You can find the most recent version here:

https://www.uaf.edu/uafgov/faculty-senate/curriculum/syllabus-addendum.php

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