SIO 225: Physics of Earth Materials
Fall Quarter 2015

Instructor: Duncan Agnew

Munk Lab Conference Room
MWF 9:45 to 10:35 AM

Instructor Contacts

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Course Objectives

This course aims to provide students with a basic familiarity with the concepts of continuum mechanics, that is, the mathematical description of the behavior of fluids and solids. The course uses the concept of materials as continua, and does not (despite the course title) deal with the microphysics of materials. The goal is to bring the student's understanding to the level required to develop simple models, to learn the more specific tools needed to solve realistic problems, and to read the geophysical literature.

Prerequisites

The course is mathematical, and a background in vectors and vector calculus (or at least multivariate calculus), while not strictly required, is highly desirable. Some familiarity with linear algebra will also be helpful.

Reading, Class Activities, and Homework

The course is based on, and will be taught from, class notes provided by the instructor, which are sent to class members by email. The notes include a bibliography of suggested other books on the course topics, many going into more depth than is possible for a one-quarter course. Students are urged to purchase Mase (1967), an inexpensive text, still in print, that complements the notes by providing many worked examples.

There will be a weekly homework assignment, handed out at least a week before the due date. Students should collaborate on homework as little as possible, but as much as necessary. If possible, homework should be PDF files created from LaTeX, When computer code is needed, it should be included, with appropriate commenting.

In-class time will be spent, as much as possible, in discussions, which all students should be ready to contribute to by having done the appropriate reading from the course notes in advance. On the day that homework is due, students should expect to be asked to present their work to the class. The following class will be devoted to the topics covered by the next homework assignment, and the one after that to the same topics, but with questions based on initial examination of that homework.

The grade will be based on the performance on the homework.

Course Topics

The sequence of topics is as follows (*italics* for topics covered in the notes but only discussed if time permits):

1 MATHEMATICAL BACKGROUND This includes a brief treatment of vector algebra, but done using index notation, as this is efficient, commonly used, and usually unfamiliar. This is followed by an introduction to Cartesian tensors, particularly those (symmetric) ones frequently seen in this field, and a brief discussion of vector and tensor calculus, including how gradients produce tensors of higher rank, and Gauss' and Stokes' theorems.

2 MOTION The Langrangian and Eulerian descriptions of motion within a continuum. Rigid-body motion. The material derivative and convective terms for quantities varying within a moving material.

3 DEFORMATION This means primarily the theory of strain and rotation in a material, for small strains; also large homogeneous strains and rates of deformation. The theory includes how strain components transform under rotation, and different representations of strain, including Mohr's circle.

4 CONSERVATION LAWS This covers the mathematical principles for converting global conservation laws to local partial differential equations, which are applied to conservation of mass, linear and angular momentum, and energy. The momentum laws require the introduction of the stress tensor, which is discussed at this point.

5 FAILURE AND FRICTION Phenomenological laws, mostly involving Mohr's-circle descriptions, for frictional slip and brittle failure, especially the Mohr-Coulomb failure criteria, its application to Andersonian faulting theory, and Coulomb models for earthquake triggering.

6 ELASTICITY The elastic constitutive model for a material, including anisotropic and isotropic elasticity. Description of various elastic moduli, and their variation in the Earth. Navier's equation.

7 ELASTIC WAVES The wave-equation solutions to Navier's equation, including source terms (body-force equivalents).

8 ELASTICITY: SPECIAL CASES Equations of elasticity in plane stress and plane strain; two-dimensional dislocations and cracks as examples.

9 *Fracture Mechanics* Stress concentration due to an elliptical inclusion, Griffith crack theory, fracture energy, non-singular crack models.

10 VISCOELASTICITY Simple spring-dashpot models of viscoelastic behavior (Maxwell, Kelvin, standard linear solid). The correspondence principle for converting viscoelastic to elastic

models. Harmonic excitation and Q; attenuation of travelling waves, convolution relations.

11 THERMODYNAMICS Conservation of energy. The concept of entropy and the entropy inequality. Thermodynamic potentials and different types of energy of a system.

12 FLUIDS General constitutive relation for fluids. The Navier-Stokes equation and how approximate versions of it are used, including steady inviscid flow, steady one-dimensional viscous flow (Couette and Poisuelle), and creeping flow.

13 *Poroelasticity* Flow in porous media. The poroelastic equations and the concept of effective stress. Interpreting the poroelastic constants

14 *Finite Strain* General expressions for large strain; the Birch-Murnaghan equation.

References

Mase, G. (1967), *Schaum's Outline of Theory and Problems of Continuum Mechanics*, McGraw-Hill, New York.