EOSC 450: Potential Fields in Earth and Planetary Science, Fall 2018

Instructor: Manar Al Asad (malasad@eoas.ubc.ca, EOS-Main 302)

Meeting Times: Tues, Thurs: 2:00 – 3:30pm EOS-Main 105

Instructor office hours: just ask, right after class is best.

Text: See web site and "useful references" list for supplementary material

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Class webpage: https://www.eoas.ubc.ca/~malasad/EOSC450/

Summary

Potential theory is used widely to analyze problems involving gravity, magnetics, heat and fluid flow. Applications of potential methods in the Earth, ocean, atmospheric and planetary sciences include geophysical exploration, satellite altimetry, the mechanical properties of planetary lithospheres, the structure and secular variation of the Earth's magnetic field, the magnetic fields of other solar system planetary bodies, flow in the atmosphere, flow of groundwater, Milankovitch cycles (orbitally-forced ice ages), and the tidal triggering of earthquakes and moonquakes. In this class we will develop the theory of potential methods, along with the essential tools needed to analyze real data sets. We will address selected topics in class, as well as in homework problems and in final projects.

Course Outline

1. Introduction to potential theory
    a. Example problems
    b. Mathematical background for potential field analysis
    c. Introduction to gravity
    d. Introduction to magnetics
2. Overview of tools needed to analyze potential field data
    a. 1D and 2D Fourier transforms (review or new, as needed)
    b. Numerical approaches to Fourier analysis
    c. Spherical harmonics
    d. Upward and downward continuation
    e. Forward modeling versus inversion (discussion only)
3. Gravity, isostacy and flexure
    a. Gravity field of the Earth; establishing a Reference Earth Model
    b. Gravity and geoid measurements from space
    c. Various types of gravity anomalies & their use
    d. Gravity/geoid for Earth, Mars, Venus, Moon, Mercury.
    e. Mechanical properties of planetary lithospheres
    f. Elasticity and flexure
    g. Isostatic response functions and gravity/topography transfer function (admittance)
4. Magnetic fields and magnetization
    a. Introduction: The geomagnetic field – internal and external sources
    b. Electrodynamics review: Maxwell's equations, constitutive relations
    c. Magnetic field models: uniqueness, least squares, inverse theory
    d. Core fields (dynamos)
    e. Crustal magnetization: seafloor spreading and plate tectonics

f. Magnetic fields of other planets: Mars, Moon, Mercury. Why not Venus?

Assessment

Assigned problems (6-7 problem sets)	35%
Quizzes (4-5 quizzes)	35%
Capstone Assignments (1)	20%
Class participation	10%

Class Participation

It is essential that you come to class and are actively engaged. The participation grade will be based not only your actual participation in class but on how well prepared you are for each class, and whether your own participation facilitates participation by others. Some of the material (especially in the beginning) is heavily mathematical. I will ask you to read the material in *advance of class* and to come to class sufficiently well prepared to attempt to teach some of the material to your peers and/or to clearly elucidate anything that was difficult or confusing about the material. This way we can get the most out of class time in terms of building understanding, instead of devoting the class periods entirely to walking through every step of the underlying mathematics. I will call on you in-class to summarize the reading / work assigned for class. Sometimes I will ask you to turn in summary notes on the reading, prepared in advance of class.

Quizzes

Quizzes will address material from lecture and problem sets and are intended to help you build essential knowledge from the course as it develops. You can each bring 1 page (meaning 1 side of notes on 1 letter-sized page) of review notes to each quiz. There will be no midterm or final exam.

Capstone Assignments

We will have two capstone assignments, for which you can work alone or in pairs. You must submit your calculations and a written report, and make a 15-minute presentation on one of the topics (we may schedule an evening outside of class time for these). The goal of these assignments is to enable you to pursue a couple of topics that we have covered in greater detail. They are opportunities to do actual research and understand in depth how the mathematics, physics and the tools we develop in class can be applied to a real problem. It gives you a chance to be creative and even do cutting edge research. I will ask you to write your final report along the lines of articles submitted to a major journal in geophysics (e.g., *Geophysical Research Letters*). The talks will enable you to get critical evaluation and feedback from your peers, to share with them what you have researched, and to get experience in giving professional-level presentations.

Detailed Week-by-Week Schedule

This is posted on the course web site. Note, that it is subject to change. In particular, we often make some adjustments to the schedule in the second part of the course so make sure to check for updates, in particular if you have missed a class (and hence any in-class announcements).

Some Useful References

No single text incorporates the full range of subject matter we will encounter. Here are a few useful books. Most (or similar books) are available in the Geophysics reading room.

a. *Potential Theory in Geophysics and Magnetic Applications*, Blakely. This book is a good resource for establishing the basic tools of potential theory. The applications discussed are mainly problems in gravity and magnetics that are local or regional in geographic scale (in other words a "flat Earth" approximation is ok).
b. *Physics of the Earth,* Stacey. A classic text in geophysics. Currently out of print, but there should be plenty of copies around EOS if you ask the right people! We will use material from chapters 3 and 7. The appendix has a discussion of spherical harmonics.
c. *Isostacy and Flexure of the Lithosphere*, Watts. Thorough and modern approaches to the analysis of isostacy and flexure of planetary lithospheres.
d. *Advanced Engineering Mathematics*, Wyllie and Barrett. Or whatever your favorite upper level undergrad applied math text is.
e. *Div, Grad, Curl and All That*, Schey. Just what the title says.
f. *The Fourier Transform and its Applications*, Bracewell. And again, as the title says.
g. *The Magnetic Field of the Earth, Merrill,* McElhinny & McFadden. Parts of chs. 2,4,5

MATLAB

We will use MATLAB quite extensively during the course for the problem sets. A working knowledge of MATLAB is assumed to the level covered in EOSC 211. If you have not had experience with MATLAB please let me know at the beginning of the course.