SIO229 – Gravity and Geomagnetism

Winter 2019. Mon/Wed/Fri 10:00~10:50 am
Revelle Conference Room, IGPP Room 4301

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This web page is a repository for class notes, assignments, and other items of possible interest for SIO229, a 4-unit graduate class on gravity and geomagnetism. Required course reading will be in the form of several sets of notes (authored by Adrian Borsa, Cathy Constable, and Bob Parker) with assigned sections for each lecture. Notes will be posted below in PDF format.

The class is an introduction to potential theory in the context of gravity and geomagnetism at a level suitable for the advanced nonspecialist in geophysics. The subtext is to get you familiar with spherical harmonics, which are ubiquitous functions in global geophysics. After a brief warm-up we are going to introduce spherical harmonics, derive some of their properties and apply them to various problems in potential fields, with emphasis on the geoid. Along the way we will meet some old topics, like the precession of the equinoxes and classical problems of potential theory, as well as some newer ones, like satellite-derived geoid and gravity models of other bodies in the solar system.

Theoretical topics include multipole expansions, spherical harmonics, Laplace's equation, boundary-value problems on a sphere, and Fourier methods. Applied topics include the global geoid, gravity anomalies, geomagnetic field modeling and sources, and paleomagnetic observations.

Grading for this class will be based primarily on homework assignments. Students may work together on assignments, but each student must turn in their own solutions based on their own work. Any code written to complete assignments (e.g. Matlab routines) should be submitted along with results. Short presentations of topics from the text or homework may be assigned, and a final exam may be given at the instructors' discretion. Prerequisite: graduate standing or consent of instructors.

Course Materials (Gravity)

- Lecture Notes #1
- Lecture Notes #2
- Lecture Notes #3
- Lecture Notes #4
- Lecture Notes #5
- Lecture Notes #6
- Lecture Notes #7
- Lecture Notes #8
- Lecture Notes #9
- Lecture Notes #10
- Lecture Notes #12
- Lecture Notes #13
- Lecture Notes #14
- Bob Parker Gravity Notes #1 (pages 1-16)
- Bob Parker Gravity Notes #2 (pages 17-26)
- Bob Parker Gravity Notes #3 (pages 27-36)
- Bob Parker Gravity Notes #4 (pages 37-50)
- Bob Parker Gravity Notes #5 (pages 51-65)
- Supplementary Notes on Orthogonal Functions
- Appendix B – Orthogonality of Spherical Harmonics
- Appendix P – Jean's Formula

Lecture 1 - 1/7/2019
Topics: Introduction to the gravity portion of the course; a brief look at gravity via the Earth and Moon.
Reading: None

Lecture 2 - 1/9/2019
Topics: Gravitational potential defined. Introduction to moments of inertia.
Reading: Bob Parker's Gravity Notes #1, Sections 0, 1

Reading: Lecture Notes #1, Lecture Notes #2 (start)

Lecture 3 - 1/11/2019
Topics: Moment of inertia for an arbitrary body.
Reading: Bob Parker's Gravity Notes #1, Sections 0, 1
Reading: Lecture Notes #2
Homework: Assignment 1 (due Wednesday, 1/23)

Lecture 4 - 1/14/2019
Topics: Principal axes of the inertia tensor. Angular momentum of Earth and the Chandler Wobble.
Reading: Bob Parker's Gravity Notes #1, Section 2
Reading: Lecture Notes #3

Lecture 5 - 1/16/2019
Topics: Multipole expansion of the gravitational potential of an arbitrary body (MacCullagh's Formula).
Reading: Bob Parker's Gravity Notes #1, Section 3
Reading: Lecture Notes #4

Lecture 6 - 1/18/2019
Topics: MacCullagh's Formula applied to Earth.
Reading: Bob Parker's Gravity Notes #1, Section 4
Reading: Lecture Notes #5

Lecture 7 - 1/23/2019
Topics: Earth's time varying J2. J2 from satellite orbits. A quick look at the solar system – mass, spin rates, J2s.
Reading: Bob Parker's Gravity Notes #1/#2, Section 5
Reading: Lecture Notes #6
Homework: Assignment 2 (due Friday, 2/1)

Lecture 8 - 1/25/2019
Topics: Measuring gravity with a pendulum. Newton's method for determining Earth's flattening. Intro to the geoid.
Reading: Bob Parker's Gravity Notes #1/#2, Section 5
Reading: Lecture Notes #7

Lecture 9 - 1/28/2019
Topics: A simplified geoid for a flattened, rotating Earth (Clairaut's Formula).
Reading: Bob Parker's Gravity Notes #1/#2, Section 5
Reading: Lecture Notes #8

Lecture 10 - 1/30/2019
Topics: Introduction to Potential Theory. Spherical harmonics as a general solution to Laplace's equation.
Reading: Bob Parker's Gravity Notes #2, Section 6 and Section 7
Reading: Lecture Notes #9

Lecture 11 - 2/1/2019
Topics: Spherical harmonics as an orthonormal basis on a unit sphere. A field guide to the spherical harmonics.
Reading: Bob Parker's Gravity Notes #2/#3, Sections 7 and 8 (Skip the S.H. Addition Theorem)
Reading: Lecture Notes #10

Lecture 12 - 2/4/2019
Topics: Table of Spherical Harmonic Lore
Reading: Bob Parker's Gravity Notes #3, Sections 8 (Skip the S.H. Addition Theorem)
Reading: Appendix P – Jean's Formula
Reading: Lecture Notes #12, #13
Homework: Assignment 3 (due Wednesday, 2/13)

Lecture 13 - 2/6/2019
Topics: Brun's Formula for calculating geoid height. The global geoid and global gravity.
Reading: Bob Parker's Gravity Notes #3/#4/#5, Sections 9, 10, 11, 15, 18

Reading: Lecture Notes #14

Lecture 14 - 2/9/2019
Topics: Reference ellipsoids (e.g. WGS84); global gravity models (e.g. EGM2008)
Reading: Bob Parker's Gravity Notes #3/#4/#5, Sections 10, 15
Reading: Lecture Notes #14

Supplementary References, Gravity

Physical Geodesy
W. Heiskanen and H. Moritz
W.H. Freeman and Company, San Francisco, 1967
A thorough treatment of much of the gravity material covered in the class notes.

Treatise on Geophysics, Volume 3, Geodesy
Volume Editor: T. Herring. Editor-in-Chief: G. Schubert
Elsevier, Amsterdam, 2007
Technical summaries of many current topics in gravity research, written by the best in the field.

Potential Theory in Gravity and Magnetic Applications
Richard J. Blakely
Cambridge University Press, New York 1995
Another look at potential theory, specifically in the context of gravity and geomagnetism.