SIO229 – Gravity and Geomagnetism

Winter 2020. 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 notes (authored by Bob Parker and Cathy Constable) posted below in PDF format, with assigned sections for each lecture.

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)

Gravity Notes #1 (pages 1-16)
Gravity Notes #2 (pages 17-26)
Gravity Notes #3 (pages 27-36)
Gravity Notes #4 (pages 37-50)
Gravity Notes #5 (pages 51-65)
Supplementary Notes on Orthogonal Functions
Appendix B – Orthogonality of Spherical Harmonics
Appendix P – Jean's Formula

Lecture 1
Topics: Introduction to the gravity portion of the course; a brief look at the Moon.

Lecture 2
Topics: Moments of inertia for an arbitrary body.
Reading: Gravity Notes #1, Sections 0, 1

Lecture 3
Topics: Principal axes of the inertia tensor. Angular momentum of Earth and the Chandler Wobble.
Reading: Gravity Notes #1, Section 2

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

Lecture 5
Topics: MacCullagh's Formula applied to Earth.
Reading: Gravity Notes #1, Section 4

Lecture 6
Topics: Earth's time varying J2. J2 from satellite orbits. A quick look at the solar system – mass, spin rates, J2s.
Reading: Gravity Notes #1, Section 4

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

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

Lecture 9
Topics: Introduction to Potential Theory. Spherical harmonics as a general solution to Laplace's equation.
Reading: None for class. After class, read Gravity Notes #2, Section 6 and Section 7

Lecture 10
Topics: Orthogonal Functions. Spherical harmonics as an orthonormal basis on a unit sphere.
Reading: Supplementary Notes on Orthogonal Functions

Lecture 11
Topics: A field guide to the spherical harmonics.
Reading: Gravity Notes #2/#3, Sections 7 and 8 (Skip the S.H. Addition Theorem)

Lecture 12
Topics: The Table of Spherical Harmonic Lore.
Reading: Gravity Notes #2/#3, Sections 7 and 8 (Skip the S.H. Addition Theorem)

Lecture 13
Topics: Introduction to the global geoid and global gravity.
Reading: Gravity Notes #3/#4, Sections 9 and 10

Lecture 14
Topics: Brun's Formula for calculating geoid height; the gravity anomaly
Reading: Gravity Notes #3/#4/#5, Sections 10, 11, 15, 18

Lecture 15
Topics: Reference ellipsoids (e.g. WGS84); global gravity models (e.g. EGM2008)
Reading: Gravity Notes #3/#4/#5, Sections 10, 15

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.