

ASEN6070 – Satellite Geodesy - Spring 2024

Instructor	Dr. R. Steven Nerem (Office: AERO 456, Ph. 492-6721, Email: nerem@colorado.edu)
Class Time	TTH 11:30 am – 12:45 pm
Class Location	AERO N250
Class Web Page	http://canvas.colorado.edu
Office Hours	Anytime door is open, or by appt, by email, Slack
Required Text (PDFs supplied)	<i>Geodesy: Treatise on Geophysics (Vol. 3)</i> by Tom Herring (editor), Elsevier, 2005 ISBN 978-0444534606
Optional Text	<i>Theory of Satellite Geodesy</i> , 2000 by William M. Kaula, Dover Publishing Co. ISBN 0-486-41465-5
Required Text (PDF supplied)	<i>Geodesy and Gravity</i> by John Wahr
Grading	Take Home Mid-Term (25%) Take Home Final Exam (25%) Homework (25%) (10 pts deducted for each day late!) Research Project (25%) 90-100 = A, 80-89 = B, 70-79 = C, 60-69 = D, < 60 = F
Schedule	March 7 – Take-Home Mid-Term Exam Passed Out (due 3/12) May 2 – Take Home Final Exam Passed Out (due 5/7)
Lecture Material	PDF files will be posted on the class website.
Course Overview	This course provides an overview of how artificial satellites are used to study the Earth's shape, rotation, and gravitational field, emphasizing Earth and space-based tracking of artificial satellites. Specific topics include satellite orbit perturbations due to the gravity field, satellite tracking systems (including SLR, GPS, DORIS, etc.), parameter estimation, Earth rotation and reference frames, time systems, ocean and solid Earth tides, and gravity field representations.

Syllabus – ASEN6070 – Satellite Geodesy (reading assignments – Herring, Wahr)

I. Introduction to Geodesy (HCh1)

II. Introduction to Geodetic Observation Techniques (HCh1, WCh2)

1. Ground-based gravity measurements (HCh2, HCh3)
2. Satellite Laser Ranging (SLR), Lunar Laser Ranging (LLR)
3. DORIS
4. The Global Navigation Satellite System (GNSS)
5. Very Long Baseline Interferometry (VLBI)
6. Satellite-to-Satellite Tracking / GRACE
7. Accelerometer Measurements
8. Gravity Gradiometer Measurements (GOCE)
9. Satellite Altimetry (HCh5)
10. Interferometric SAR (WCh12)

III. Potential Theory (WCh3, HCh2)

1. MacCullagh's Formula
2. Laplace's Equation
2. Spherical Harmonic Representation
3. Point Mass / Density Layer
4. The Geoid
5. Current Knowledge of the Earth's Gravity Field

IV. Interpretation of Observed Gravity Anomalies (WCh6)

V. Satellite Equations of Motion, Reference Frames, Time Systems

1. Coordinate Systems and Reference frames
2. Time Systems
3. Gravitational and non-gravitational forces
4. Introduction to orbital mechanics

VI. Satellite Orbital Perturbations Due to the Gravity Field (Kaula Book)

1. Kaula's Solution
2. Perturbation Spectrum

VII. Space-Based Geodetic Methods (HCh11)

1. Lunar Laser Ranging (LLR)

2. Satellite Laser Ranging (SLR)
3. Very Long Baseline Interferometry (VLBI)
4. GPS/GNSS
5. Geophysical Applications of Positioning

VIII. Earth Rotation Variations (HCh10, WCh9)

1. Nutation and Precession
2. Polar Motion Variations
3. Rotation Variations

IX. Applications of Satellite Altimetry (HCh5)

1. The Ocean Circulation
2. Geostrophic Currents
3. The Geoid and Dynamic Sea Surface Topography (DSST)
4. Satellite Altimeter Measurements of DSST
5. Sea Level change

X. Tidal Variations (HCh6, WCh8)

1. Solid Earth Tides
2. Ocean Tides
3. Tidal Loading
4. Tide Models Derived from Satellite Altimetry

XI. Non-Tidal Variations of the Gravity Field (HCh8)

1. Post-Glacial Rebound (WCh7, HCh7)
2. Melting/Accumulation of Polar/Glacial Ice
3. Mass Redistribution in the Ocean
4. Mass Redistribution in the Atmosphere
5. Redistribution of Continental Water Mass
6. Geocenter Variations

XII. Planetary Geodesy

1. Reference Frames
2. Rotation
3. Navigational systems
4. Gravity measurements
5. Topography Measurements
6. Focus on lunar geodesy

XII. Geodesy Using Interferometric SAR (HCh12)

References

- Anderson, A. J., and A. Cazenave, Eds., *Space Geodesy and Geodynamics*, Academic Press, 1986.
- Hofmann-Wellenhof, B., H. Lichtenegger, and J. Collins, *GPS Theory and Practice*, 4th Edition, Springer, 1997.
- Kaula, W. M., *Theory of Satellite Geodesy*, Dover, 2000.
- Lambeck, K., *The Earth's Variable Rotation*, Cambridge University Press, 1980.
- Lambeck, K., *Geophysical Geodesy: The Slow Deformations of the Earth*, Oxford, 1988.
- Leick, A., *GPS Satellite Surveying*, 2nd Edition, Wiley, 1995.
- Seeber, G., *Satellite Geodesy: Foundations, Methods, and Applications*, De Gruyter, 2nd Edition, 2003.
- Strang, G., and K. Borre, *Linear Algebra, Geodesy, and GPS*, Wellesley-Cambridge Press, 1997.
- Teunissen, P. J. G., and A. Kleusberg, Eds., *GPS for Geodesy*, 2nd Edition, Springer, 1998.
- Torge, W., *Geodesy*, de Gruyter, 1980.

University Policies

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy.

For more information, see the [classroom behavior policy](#), the [Student Code of Conduct](#), and the [Office of Institutional Equity and Compliance](#).

Requirements for Infectious Disease

Members of the CU Boulder community and visitors to campus must follow university, department, and building health and safety requirements and all applicable campus policies and public health guidelines to reduce the risk of spreading infectious diseases. If public health conditions require, the university may also invoke related requirements for student conduct and disability accommodation that will apply to this class.

If you feel ill and think you might have COVID-19 or if you have tested positive for COVID-19, please stay home and follow the [guidance of the Centers for Disease Control and Prevention \(CDC\) for isolation and testing](#). If you have been in close contact with someone who has COVID-19 but do not have any symptoms and have not tested positive for COVID-19, you do not need to stay home but should follow the [guidance of the CDC for masking and testing](#).

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](#). Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see [Temporary Medical Conditions](#) on the Disability Services website. If you have a required medical isolation for which you require adjustment, please contact Dr. Nerem to work out a plan as soon as possible.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the [Honor Code](#). Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: honor@colorado.edu, 303-492-5550. Students found responsible for violating the [Honor Code](#) will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit [Honor Code](#) for more information on the academic integrity policy.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits [protected-class](#) discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email cureport@colorado.edu. Information about university policies, [reporting options](#), and [support resources](#) can be found on the [OIEC website](#).

Please know that faculty and graduate instructors must inform OIEC when they are made aware of incidents related to these policies regardless of when or where something occurred. This is to ensure that individuals impacted receive outreach from OIEC about resolution options and support resources. To learn more about reporting and support for a variety of concerns, visit the [Don't Ignore It page](#).

Religious Accommodations

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please communicate the need for a religious accommodation with Dr. Nerem in a timely manner.

See the [campus policy regarding religious observances](#) for full details.

Mental Health and Wellness

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact [Counseling and Psychiatric Services \(CAPS\)](#) located in

C4C or call (303) 492-2277, 24/7.

Free and unlimited telehealth is also available through [Academic Live Care](#). The Academic Live Care site also provides information about additional wellness services on campus that are available to students.