ASEN 3700 ORBITAL MECHANICS/ATTITUDE DYNAMICS & CONTROL

Syllabus, Fall 2024

Lectures: T & Th 4:00pm-5:15pm, AERO 120

Instructors:
Dr. Daniel Scheeres:
Dr. Steve Nerem:

Teaching Facilitators:
Anthony La Barca:
Anirudh Etagi:
Tanner Holmes:

Office hours: TBA, See Canvas page

Final Exam: Monday, December 16, 4:30-7:00PM in AERO 120

Textbooks:
Required:

Howard D. Curtis, *Orbital Mechanics for Engineering Students*, 4th Edition, Elsevier Aerospace Engineering Series 2021. Electronic edition available for free through CU Libraries.

Supplementary (not required)

- Bedford and W. Fowler, Engineering Mechanics: Dynamics, 5th Edition Pearson Prentice Hall, Upper Saddle River, NJ, 2008. See Chapter 20 and Appendix C.
- H. Schaub and J. L. Junkins, *Analytical Mechanics of Space Systems*, 4th Ed, AIAA Ed Series, Reston, VA, 2014.
- Larson and Wertz, *Space Mission Analysis and Design. Provides useful hardware information*
- Vallado, D. A., *Fundamentals of Astrodynamics and Applications*, 4th Ed Microcosm, Hawthorne, CA 2013.

Prerequisites: ASEN 2703, ASEN 2704, and APPM 2350 or MATH 2400

Course Web Page: http://canvas.colorado.edu

Overview and Goals:
In the sophomore ASEN2703 and ASEN2704 courses, students developed an understanding of the motion of particles and rigid bodies in 2D as well as the basics of orbital mechanics and satellite design. In ASEN 3700, we break free of the planar motion bounds to explore full 3D motion of space platforms.

The first half of the course focuses on dynamics and control of spacecraft orientation or attitude. Nearly all spacecraft must be accurately pointed to accomplish their mission, yet the natural behavior in orbit is typically uncontrolled tumbling. We will develop a fundamental understanding of these natural 3D rigid body kinematics and dynamics, using this to discuss common methods of passive and active attitude control. Attitude sensor and actuator technology will be investigated, as well as common ways of representing and determining attitude. On the topic of rigid body kinematics, the goal is for students to become comfortable with a small sub-set of attitude representations such as the DCM, 3-2-1 and 3-1-3 Euler angles, and get some experience working with quaternions. On the topic of rigid body dynamics, the goal is for students to understand the use of Euler's equations and the angular momentum vector to describe the motion of a rigid body. On the topic of control, the goal is for students to gain experience working with simple open-loop and closed-loop flow diagrams can be created, and how to use transfer function methods to develop single-input-single- output linear controls. This is applied to 1-D constrained rotational motion only.

In the second half of the course, students will study and describe the characteristics of the motion of a particle in space and relative to a single celestial body; this particle could approximate a spacecraft or a celestial object. By the end of this section, students should be able to:

1. Formulate and derive the equations of motion for the two-body problem, approximating the dynamics governing a spacecraft or celestial object in the vicinity of a single celestial body that is modeled with the same gravity field as a point mass.
2. Derive and use the analytical solution to the two-body problem to calculate the state of the object at any location along an orbit that follows a conic section.
3. Derive, numerically solve, and use Kepler's equation to relate the location of the object along its orbit to time.
4. Describe and calculate Keplerian orbital elements that capture the size, shape, and orientation of an orbit in three-dimensional space.

5. Describe and assess the influence of the orbit size, shape, and orientation on the groundtrack formed by the projection of its path onto the surface of a nearby celestial body.
6. Calculate the influence of an impulsive maneuver on the state of a spacecraft and design foundational transfers that connect two distinct orbits.
7. Derive and describe an analytical approximation of the relative motion between two nearby spacecraft with near-circular orbits about a common celestial body.
8. Describe additional perturbing forces that may influence the path of the spacecraft. Use analytical approximations of the impact of the oblateness of a celestial body to design orbits with special characteristics.
9. Describe and use a foundational preliminary orbit determination method to extract the state of an object from successive estimates of its position vector.

Class Format:

The first half of the course is devoted to attitude dynamics and is led by Dr. Scheeres. The second half will focus on orbit mechanics, led by Dr. Nerem. Each section has a similar format:

- Lectures are held Tuesdays and Thursdays. Attendance is expected.
- We expect, but do not require, in-person attendance and participation during class. However, lectures will be recorded via classroom capture and automatically posted to Canvas so that students who are not able to attend a class can access the material they missed. If the professor is not able to attend in person, the class may be delivered via recording or on Zoom.
- Reading and homework assignments are given weekly. Reading assignments are expected to be completed before the class for which they are assigned.

Exams and Finals:

- There are total of 3 exams in this course.
- Exams will be closed book with students allowed to bring a pre-specified number of note sheets. Additional exam policies will be provided ahead of each exam and must be followed.
- One exam will be given near the end of each of the two sections and will be held during the class period.
- At the end of the semester a final exam is scheduled which will have questions from the entire course (both sections). The current schedule for the final is on Monday, December 16 from 4:30-7:00PM.
- The exams are currently scheduled for:

  - Attitude dynamics and control: in-class on Thursday October 10.
  - Orbit mechanics: in-class on Thursday, November 21.
  - Comprehensive final: 4:30-7:00pm on Monday, December 16.
  - Note: in the event of an emergency or campus closure, changes to these dates will be communicated promptly to the entire class.
- The instructors will provide information for timing or logistics of exams to students with accommodations.
- If you cannot take an exam at the scheduled time due to a foreseen and excusable reason, notify the instructor at least two weeks prior to the exam date to make arrangements for an alternate test date. It is up to the instructors to determine if an exam will be rescheduled. If you cannot take an exam due to illness or another emergency situation occurring on the exam date, notify the instructor as soon as possible so that an appropriate course of action can be arranged.
- Exams are to be completed independently. Any type of collaboration or copying on an exam or final constitutes cheating and will result in an F for the course. An Honor Code violation report will also be filed.

Homework:

- Homework problems will be regularly assigned throughout the semester, including both problems from the textbook and more complex problems. These problems are designed to help you learn and practice the concepts covered in class.
- Collaboration is permitted on homework. You may discuss the means and methods for formulating and solving problems and even compare answers, but you are not permitted to copy someone's assignment. Copying material from any resource (including solution manuals) and submitting it as one's own is considered plagiarism and is an Honor Code violation. Honor code violations on homework will result in a grade penalty and a violation report being filed with the honor code office.
- Homework solutions must demonstrate an understanding of the principles involved by including diagrams, using correct mathematical notation and terminology, explaining the approach, showing the key mathematical steps to obtaining the solution, reporting important intermediate values, and outlining the answer with proper units. These problem-solving steps are critical for developing problem formulation skills and communicating your approach. Although you may use mathematical software to aid in computations, code (even when commented) may not be submitted solely as your solution. Full credit for a problem requires both an accurate written presentation of the working and a correct answer.
- Always submit professional and readable work.

- You are not allowed to use artificial intelligence (AI) or machine learning tools (e.g., ChatGPT or Dall-E 2) on any assessment for this course. Each student is expected to complete each assessment without assistance from AI. Use of AI will be treated as a form of academic dishonesty akin to plagiarism or cheating.
- Homework must be submitted via Gradescope by the listed deadline.
- Assignment due dates will be indicated on the schedule and the Canvas page. Students are responsible for ensuring that submitted documents are uploaded correctly, readable, and in the correct location. Corrupt files will not be graded.
- Late homework will not be accepted unless previously agreed upon, and will be assigned a grade of zero; however, we will drop each student's lowest two homework scores in computing final grades. We expect this allowance should be sufficient to cover accidentally missed deadlines, illness, or other personal reasons for missing a deadline.
- Although each homework assignment will have several problems, all problems may not be graded and/or may be weighted differently. However, solutions or answers will be provided to you for all the problems.
- If you believe that your homework was graded incorrectly, you have 1 week from when it is returned to request a regrade in Gradescope (except at the end of the semester). This request should include a brief description of the error and the relevant rubric item/s. These requests will be reviewed by a member of the instructional team.

Grading: Grades on individual assignments and for the overall course are set based on the following criteria.

A, A- Demonstrates superior understanding of the material, excellent technical work

B+, B Demonstrates comprehensive understanding of the material, very strong technical work

B-, C+ Demonstrates good understanding of the material, complete technical work

C Demonstrates sufficient understanding of the material to proceed to the next level; adequate technical work

C- Does not demonstrate sufficient understanding of the material to proceed to the next level

D Poor technical work

F Unsatisfactory performance

- If you believe that an error has been made in grading any of your submissions, you may submit a regrade request in Gradescope by the listed deadlines. Your regrade

request must list a precise and clear reason that a specific rubric item should be applied to the grading of a particular problem.
- Please note: the Canvas gradebook is a guide to ensure that your assignments have been graded and that the grade entered is consistent with the score that has been reported to you. The Canvas gradebook does not contain all information related to the final course grade calculation; the final course grade calculation will follow the procedure outlined in this syllabus.

Grading Policy

Assignments are graded to an absolute standard designed to indicate your level of competency in the course material. Minor adjustments may be made in the assignment of final grades, but there is a limited amount of "curving" in the course. The final grade indicates your readiness to continue to the next level in the curriculum.

The course grade is primarily dependent on individual demonstrated measures of competency. We mainly rely on exam scores to identify whether a student has achieved the basic level of competency of the material. Homework assignments are also important and are designed to enrich the learning experience and to enhance your individual performance, not to substitute for shortcomings in the exams.

Section	Description	Percentage
Attitude	Exam	20%
Attitude	Homework	15%
Orbits	Exam	20%
Orbits	Homework	15%
Combined	Final Exam	30%
Total		**100%**

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 notify both instructors 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 Observances

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 in a timely manner. In this class, please provide both instructors with a list of these conflicts in the first week of classes.
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.