ASEN 3200 ORBITAL MECHANICS/ATTITUDE DYNAMICS & CONTROL

Syllabus, Spring 2023

Lectures: MWF 8:30am – 9:20am AERO 120

Labs: Section 011: Monday 10:35am – 12:25pm Co-PILOT Lab (AERO N100)
Section 012: Monday 12:50pm – 2:40pm Co-PILOT Lab (AERO N100)
Section 013: Friday 12:40pm – 2:30pm Co-PILOT Lab (AERO N100)

Instructors:
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Office hours: See Canvas page

Textbooks:
Required:

- Howard D. Curtis, *Orbital Mechanics for Engineering Students*, 4th Edition, Elsevier Aerospace Engineering Series 2021. (Online access through CU library website)

Supplementary (not required):

- H. Schaub and J. L. Junkins, *Analytical Mechanics of Space Systems*, 2nd Ed, AIAA Ed Series, Reston, VA, 2009.
- Bedford and W. Fowler, Engineering Mechanics: Dynamics, 5th Edition Pearson Prentice Hall, Upper Saddle River, NJ, 2008. (See Chapter 20 and Appendix C)
- Larson and Wertz, *Space Mission Analysis and Design.* (Useful hardware information)

Prerequisites: Requires prerequisite courses ASEN 2003 and ASEN 2004 and APPM 2350 or MATH 2400 and APPM 2360 or MATH 2130 & MATH 3430 (all minimum grade C). Restricted to Aerospace Engineering (ASEN) majors and Integrated Design Eng majors with an Aerospace emphasis.

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

Overview and Goals:

In the sophomore ASEN 2003 and ASEN 2004 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 3200 we break free of the planar motion bounds to explore full 3D motion of space platforms. By the end of the semester students will be able to model and analyze the orbital and attitude motion of satellites; to develop a near-Earth satellite mission concept; and to design a single axis spacecraft attitude control system.

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.

Lab experiments will be conducted to measure spacecraft mass properties, understand the operation of gyroscopic instruments, and design feedback control to achieve precise spacecraft pointing. In these labs the goal is for students to receive hands-on opportunities to see the complex dynamic interactions that can occur with spinning rigid bodies and gyroscopic systems.

In the second half of the course, students will learn the characteristics of the motion of a system of particles with emphasis on the two-body problem, a model that offers a good preliminary approximation for the dynamics governing the motion of a planetary orbiter or interplanetary transfer vehicle. We will study the motion of a spacecraft under the influence of gravitational perturbing forces and n-body perturbations from additional celestial bodies. Also, the perturbations caused by atmospheric drag, and solar radiation pressure will be considered. In addition to studying the motion, we will look at ways to determine the ephemeris or trajectory of a satellite from observations. Finally, we will study aspects of designing an Earth orbiting and/or interplanetary mission.

Class Format:

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

- Lectures are held Monday, Wednesday, and Friday. Attendance is expected.
- Lab sections are also held on Mondays and Fridays. Attendance is required.
- We expect in-person participation during class. However, lectures will be recorded via classroom capture or zoom, and 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 4 exams in this course.
- Halfway through each of the two sections a midterm exam will be held during the class period. Exams will be closed book with students allowed to bring a 1-page sheet of notes.
- At the end of each of the two sections a final exam is scheduled outside of the regular class time. Students will have 2.5 hours to take each of the final exams. Dates and times are shown on the schedule.
- The instructors will provide information for timing of exams to students with accommodations.
- If you cannot take an exam due to an unavoidable schedule conflict, notify the instructor at least one week prior to the exam date to make arrangements for an alternate test date. If you cannot take an exam due to illness or other 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 completely 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:

- For grading purposes, homework is considered part of the group grade and only contributes to the total grade when the individual work meets the minimum threshold described under grading policies.
- 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 free to copy someone's assignment. Copying material from any resource (including solutions 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 notation and terminology, explaining the approach, showing the key steps to obtaining the solution, and outlining the answer with proper units. These problem-solving steps are critical for developing problem formulation skills.
- Always submit professional work. Clarity and completeness count and will be accounted for in the grading scheme. Although you may use software to aid in computations, code may not be submitted solely as your solution.
- Although each homework assignment will have several problems, all problems may not be graded. However, solutions will be provided to you for all the problems.
- If you believe that your homework was graded incorrectly, you have 2 weeks from when it is returned to request a regrade in Gradescope (except at the end of the semester). Request should simply include a brief description of the error. These requests will be reviewed by a member of the instructional team.
- 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; 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.

Lab Projects

- Experimental exercises, design labs, and projects are conducted together with your team.
- A grading rubric will be provided with each lab.
- Team lab reports will be submitted, graded, and returned in Gradescope.

Class Attendance:

You are expected to participate in class, labs, and scheduled exams. If you need to miss a lecture, it is your responsibility to catch up on the material. If you need to miss a lab, it is your responsibility to notify both the instructor and your lab partners.

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

C	Demonstrates sufficient understanding of the material to proceed to the next level
C-	Insufficient 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.
- 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 rely on exam scores to identify whether a student has achieved the basic level of competency of the material. Accordingly, other assignment grades are only incorporated into a student's final grade when their individual grade is a C or better. In other words, if your exam average is below a C, the other assignment grades are not included in the final grade, as shown in the table below.

Other course assignments are designed to enrich the learning experience and to enhance individual performance, not to substitute for shortcomings in individual competency. This policy makes it important to use the homework and lab group assignments to enhance your own learning. If the work in the assignment is split up among group members, be sure that the learning is not also split up, but rather is shared among the whole group.

Final Grade Table

Type	Description	Percentage
Exams	Midterm Exams (2)	40%
	Final Exams (2)	60%
	Exam Total	**100%**
Other	Labs & Projects	70%
	Homework	30%
	Other Total	**100%**
Final Grade	If exam grade >= C	Final grade = 0.5*Exam Total + 0.5*Other Total
	If exam grade < C	Final grade = Exam Total

CLASSROOM BEHAVIOR

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail 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 COVID-19

As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. CU Boulder currently requires COVID-19 vaccination and boosters for all faculty, staff and students. Students, faculty and staff must upload proof of vaccination and boosters or file for an exemption based on medical, ethical or moral grounds through the MyCUHealth portal.

The CU Boulder campus is currently mask-optional. However, if public health conditions change and masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the Public Health Office (contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the Public Health Office (contacttracing@colorado.edu). Students should alert the instructor in writing as soon as reasonably possible to make arrangements for missed assignments or labs.

ACCOMMODATION FOR DISABILITIES

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.

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, 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. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

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 sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, protected-class discrimination and harassment, 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 believe they 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 have a responsibility to inform OIEC when they are made aware of any issues related to these policies regardless of when or where they occurred to ensure that individuals impacted receive information about their rights, support resources, and resolution options. To learn more about reporting and support options for a variety of concerns, visit Don’t Ignore It.

RELIGIOUS HOLIDAYS

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, students must submit a written request for accommodating religious holidays at least two weeks in advance.

See the campus policy regarding religious observances for full details.