ASEN 3200 ORBITAL MECHANICS/ATTITUDE DYNAMICS & CONTROL

Lectures: MW 4-5:15 pm on Zoom

Labs: 011 Tues 12:50-2:40 Aero 141, 013 Tues 12:50-2:40 Aero N100
012 Thur 12:50-2:40 Aero 141, 014 Thur 12:50-2:40 Aero 120
In-person or on Zoom

Office hours: TBD on Zoom

Instructors:
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Textbooks:
Required:

- Howard D. Curtis, *Orbital Mechanics for Engineering Students*, 3rd Edition, Elsevier Aerospace Engineering Check the Errata on Canvas

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 for an alternate and compressed version of the material in the first half of the course.
- Larson and Wertz, *Space Mission Analysis and Design. Provides useful hardware information*
- H. Schaub and J. L. Junkins, *Analytical Mechanics of Space Systems*, 3rd Ed AIAA Ed Series, Reston, VA, 2014.
- Vallado, D. A., *Fundamentals of Astrodynamics and Applications*, 4th Ed Microcosm, Hawthorne, CA 2013.

Logistics for Fall 2020 Hybrid Course Modalities/COVID-19 –

Lectures will be conducted remotely at the scheduled time or, in some cases, pre-recorded, via Zoom. Classroom capture and zoom recordings will be posted to Canvas. Students are expected, whenever possible to attend lecture, to engage in breakout discussions, and to answer follow up questions on Canvas. If you cannot attend a lecture it is fine to watch the recordings afterwards.

Lab sections are scheduled for in-person rooms. Zoom sessions will be run concurrently so that students who wish to participate remotely can do so. Students will be assigned to a team of 3-4 that will work together for half the semester. We will switch teams for the second half.

Students in general, but especially when attending class in-person, are expected to follow campus Protect Our Herd practices: https://www.colorado.edu/protect-our-herd/. Masks and social distancing are mandatory for in-person attendance of lab sections.

Overview and Goals:

In the sophomore ASEN2003 and ASEN2004 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 ASEN3200 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 and the 3-2-1 Euler angles, and aware of other sets of coordinates such as other Euler angle sequences and quaternions. On the topic of rigid body dynamics, the goal is to expose students to repeated uses of Euler's equation and the angular momentum vector to develop the system equations of motion. On the topic of control, the goal is to show students how 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.

In the orbital section 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.

The lab will involve a combination of MATLAB and Systems Tool Kit (STK), e.g. students will be asked to solve a problem with STK, verify the solution, and/or use data generated by STK in a follow-on application. The objective here is to teach students how to determine if a result from 'off the shelf software' is reasonable. A primary complaint of employers is that recent graduates often believe whatever comes out of 'blackbox software' even when results are obviously unreasonable. When completed with the orbit portion of the class the student should be somewhat proficient with STK and more skilled in the use of MATLAB. They will understand the basics of orbital motion and significant perturbations as well as mission design and preliminary orbit determination techniques. They will be able to solve problems on these subjects using both their analytical and computer skills.

Class Format:

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

- Twice-weekly lectures are held on Mondays & Wednesdays. Lab sections on Tuesday or Thursday. Lectures are available remotely/online with Zoom set up to allow for synchronous participation and Classroom Capture and/or Zoom recordings posted to CANVAS to allow students to access the materials afterwards. Students may participate in breakout sessions or online discussions of material presented in lecture.
- Due to the unique nature of this semester, the instructors may elect to pre-record lectures for students to view prior to the regularly scheduled class period. Then, the scheduled lecture period will be used for Q&A and working pertinent example problems. Advanced notice will be given regarding pre-recorded lectures so students will have adequate time to prepare.
- Attendance in lab sessions on Tues or Thur may be in-person or via Zoom. Guidelines for working with lab groups are provided in a separate document on Canvas. Please note that all in-person participants are required to wear masks and to follow social distancing protocols implemented in the classrooms, labs, and other spaces in and near the Aerospace building.
- Reading and homework assignments are given weekly.
- Office hours will be on zoom.

Exams and Finals:

- Exams will be distributed, submitted, and returned on Canvas/Gradescope. 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. Beginning at the class start time 4PM, students will have 75 minutes to take the exam + 30 minutes for logistics to submit solutions to Canvas. Exams will be open book, with computer access limited to only course materials.
- 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 + 30 minutes for logistics of submittal. Dates and times are shown on the schedule.
- Students with exam accommodations should start at specified exam start time and adjust the end time based on their specific accommodation conditions.
- 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.
- If you run into technical difficulties uploading your solutions to Canvas, please notify the instructor and use the CU Large File Transfer system to send the pdf to the appropriate instructor: https://filetransfer.colorado.edu. If necessary, you can email your solution to the instructor.
- 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 or accusation 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.
- 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 work with a professional appearance. Neatness, 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 handed back to ask for a regrade. To ask for a regrade, you must briefly outline via email what you think the error in grading was and submit it to the instructor.
- Assignment due dates will be indicated on the Canvas webpage. Students are responsible to ensure 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.

Labs

- Experimental exercises, design labs and the research report exercises are conducted together with your team.
- A grading rubric will be provided with each lab.
- Team lab reports shall be turned in as a PDF on Canvas.

Class Attendance:

You are expected to participate in class, labs, and scheduled exams. All activities can be performed remotely via Zoom. As much as possible, we will also offer in-person lab sections for students who wish to participate in this manner. 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, 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 to the instructor by email within two weeks of the grade being posted to Canvas. Please include a brief summary of the error and attach an annotated copy of the assignment (or use tools in Gradescope or Canvas to provide this information).
- Please note: the CANVAS gradebook is a guide to ensure that your assignments have been graded and that the grade entered is consistent with that reported to you. The CANVAS gradebook does not contain all information related to the final course grade calculation; so if you would like an estimate of your final course grade, consult with the instructor by email or in office hours.

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 sub-standard 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 is shared among the whole group.

Participation is based on contributions to lab activities, lab reports, and engagement in zoom and online class activities.

Final Grade Table

Type	Description	Percentage
Exams	Midterm Exams (2)	40%
	Final Exams (2)	60%
	Exam Total	**100%**
Other	Labs & Research Project	70%
	Homework	20%
	Participation	10%
	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

University Policies

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 policies on classroom behavior and the Student Code of Conduct.

Requirements for COVID-19
As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements, and public health orders in place to reduce the risk of spreading infectious disease. Required safety measures at CU Boulder relevant to the classroom setting include:

- maintain 6-foot distancing when possible,
- wear a face covering in public indoor spaces and outdoors while on campus consistent with state and county health orders,
- clean local work area,
- practice hand hygiene,
- follow public health orders, and
- if sick and you live off campus, do not come onto campus (unless instructed by a CU Healthcare professional), or if you live on-campus, please alert CU Boulder Medical Services.

Students who fail to adhere to these 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 policies on COVID-19 Health and Safety and classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the "Accommodation for Disabilities" statement on this syllabus.

Before returning to campus, all students must complete the COVID-19 Student Health and Expectations Course. Before coming on to campus each day, all students are required to complete a Daily Health Form. Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home and complete the Health Questionnaire and Illness Reporting Form remotely. In this class, if you are sick or quarantined please notify the instructor and your lab/homework partner.

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 policy may include: 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 the Honor Code (honor@colorado.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation
The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.

Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

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. For this class, you are expected to review the course schedule and let the instructor know within the first two weeks of the semester of any such conflicts so that we can work out an accommodation plan.

See the campus policy regarding religious observances for full details.