ASEN 6060: Advanced Astrodynamics Fall 2020

Course description:

This course focuses on studying multi-body gravitational environments via the circular restricted three-body problem. This dynamical model is derived in detail using multiple approaches. The complex solution space admitted by this dynamical model is explored through the numerical computation, characterization and analysis of fundamental dynamical structures and the application of dynamical systems theory. These solutions are used to construct a transfer and are transitioned into higher-fidelity software for further use.

Instructor Information

Instructor: Prof. Natasha Bosanac

Email: natasha.bosanac@colorado.edu

Office Hours: My office hours are Wednesdays 4pm-5pm MT and during lecture periods where no synchronous components are planned. All office hours will be held via Zoom.

Course Information

Instruction mode: Hybrid Remote/Online.

Course Schedule: T,Th: 2.50pm-4.05pm

Course webpage: canvas.colorado.edu (Please check that your settings in Canvas enable you to receive regular notifications and announcements)

Course format: This course will be divided into modules based on subject matter. Lecture content will be delivered asynchronously via videos that will be accessible through the course webpage. Selected lecture periods will be used for synchronous recitation-style discussions via Zoom; these designated lecture periods and the associated logistics for participation will be noted on the course webpage at the beginning of the semester. To ensure flexibility in your participation in this course, I will not monitor or mandate attendance during these synchronous discussions; parts of these sessions will be recorded and videos made available so that you can watch them later if you are unable to attend. Office hours will not be recorded.

Note: lecture videos and course materials may not be distributed publicly or shared with individuals who are not registered in the course this semester without instructor consent.

Prerequisites: ASEN 5050 or equivalent, or instructor permission required.

Student Learning Objectives

By the end of this course, students should be able to:

1. Describe the formulation of the circular restricted three-body problem and derive the equations of motion
2. Implement a numerical corrections procedure and examine the validity of the results
3. Compute, characterize and analyze equilibrium points and periodic orbits as well as their hyperbolic invariant manifolds
4. Transition solutions into STK or GMAT
5. Design simple transfers in the circular restricted three-body problem
6. Formulate technically precise and clear discussions of a solution to a problem and critically assess the corresponding results and observations.

Textbooks

There is no required textbook for this course. Any recommendations to useful, but optional, references will be provided on the course webpage for anyone who is interested.

Software

To implement numerical computations, please use either MATLAB (preferred), Python or C++. If you choose to use an alternative language or software, I will not be able to provide you with any useful feedback on your scripts or suggestions for addressing any problems.

To transition solutions into higher-fidelity software, you may use either GMAT or STK. Neither of these software may be accessible to users of assistive technology. If you use assistive technology to access the course material, please contact me as soon as possible to discuss.

To participate in the synchronous course components office hours, we will use Zoom. Please feel free to use Zoom in a manner that you feel comfortable with. For instance, while it would be nice for you to turn on your video, it is certainly not required; there are many reasons why you may be unable or uncomfortable with this and I will respect your decision.

Grading Policy

Homework: 75%

Final Project: 25%

Assessment Policies

Homework Assignments

There will be five homework assignments throughout the semester that will feature a combination of analytical derivations and developing numerical procedures. Homework submissions will be graded on both the accuracy of the answers and the accompanying working/discussion. Homework submissions – including those that require implementing numerical procedures – require a clear and technically precise discussion that may consist of the following elements: discussion of relevant theory and technical details, description of the solution to a problem, listing intermediate steps and quantities, description of the results, analysis of the results, and justification of the results. Where appropriate, the text of any computational scripts must be appended to the end of your homework submission; a script alone is not considered a sufficient homework submission. For any writeups, you are welcome to either hand-write or type your responses; please ensure they are clear and legible.

You are welcome to collaborate with your peers to discuss solution approaches, compare results and debug numerical procedures. However, you must write your own scripts, implement your own scenarios in STK or GMAT and write up your own responses.

Homeworks will be submitted electronically as a single pdf and will generally be due on Sunday evenings to accommodate students who need a flexible schedule due to their current location, work, carer or other commitments. You may consider submitting your homework before this deadline and during your preferred working hours to facilitate creating work/life boundaries during the semester. Once you submit your homework electronically, please double check that the file has uploaded correctly and is not corrupted; I cannot grade a homework if I cannot open the file.

If you need to request an extension on the homework, please send me an email. I would appreciate if you could send this no later than 3pm on the Friday before the deadline, where possible, so that I have an opportunity to respond during reasonable working hours. However, we are all trying to survive a global pandemic and unforeseen emergencies may very well arise. I will do my best to accommodate these requests with a solution that is both flexible for you and feasible for me.

If you believe that your homework has been graded incorrectly, you will have two weeks from the date that the homeworks are returned to request a regrade. Regrade requests must be submitted in writing via email and include an outline of the reason that you suspect an error.

Final Project

There will be one final project that is due in the last week of classes. This project will focus on numerically generating a transfer in the circular restricted three-body problem. Further information will be provided in the middle of the semester.

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, we do not have any in-person participation; however, if you are sick or quarantined, please let me know whenever you need any accommodations and/or extensions.

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 or injury, see Temporary Medical Conditions under the Students tab 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 who are 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 a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, intimate partner abuse (including 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, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

Religious Observances

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, please provide me with a list of these conflicts in the first two weeks of the semester.

See the campus policy regarding religious observances for full details.

Tentative List of Topics

*These topics may change throughout the semester

- Formulating the Circular Restricted Three-Body Problem
- Jacobi constant and zero velocity surfaces
- Equilibrium points
- Periodic orbits
- Orbital stability and the state transition matrix
- Numerical corrections and continuation
- Recreating periodic orbits in higher-fidelity software
- Manifolds
- Quasi-periodic orbits
- Poincaré mapping
- Designing transfers
- An overview of higher-fidelity models of multi-body systems