ASEN 6060: Advanced Astrodynamics Fall 2022

Course description:

This course focuses on studying motion within multi-body gravitational systems via the circular restricted three-body problem. We will derive this dynamical model in detail. Then, we will explore the complex solution space through the numerical computation, characterization and analysis of fundamental dynamical structures and the application of dynamical systems theory. We will use these solutions to construct a transfer and transition them into higher-fidelity models using commercial software for further use. This course will involve a significant amount of numerical computation using scripts that students write on their own.

Instructor Information

Instructor: Prof. Natasha Bosanac

Email: natasha.bosanac@colorado.edu

Office Hours: My office hours are Wednesdays 2.30pm-3.30pm MT via Zoom.

Course Information

Assigned Lecture Periods: T,Th: 2.30pm-3.45pm in AERO N240

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

Course format: Selected lecture periods will be used for lectures and others will be used for small-group activities and discussions. Each group will need to have at least one laptop available in class (if in the -001 section). Please contact the instructor if this will be infeasible for you so that we can coordinate alternative options. The designated days for lectures and discussions appear on the course schedule. To ensure flexibility in your participation in this course during the ongoing pandemic, I will not monitor or mandate attendance during lecture or discussions. All lectures are recorded whereas only parts of the discussion sessions will be recorded. Recordings are available in Canvas so that you can watch them later if you are unable to attend or registered for the -001B section.

Note: 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 5050/5052 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. Approximately recover solutions in 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 might not be able to provide you with any useful feedback on your scripts or suggestions for addressing any problems.

To recover trajectories in higher-fidelity environments using commercial 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 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 in the early evening of the due date listed on the calendar 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 or accept a homework if I cannot open the file.

If you need to request an extension on the homework, please send me an email by no later than 3pm on the day before the deadline so that I have an opportunity to respond during reasonable working hours. If unforeseen emergencies arise after that, then please notify me as soon as possible. I will do my best to accommodate these requests with a solution that is both

flexible for you and feasible for me. Otherwise, late homework that does not have a prior approved extension will not be accepted.

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 on the last day of classes. This project will focus on numerically generating a transfer in the circular restricted three-body problem. The format for this submission will follow the expectations for the homework. Except in the case of unforeseen emergencies or illness, no extensions will be provided for this due date. Late projects without a prior approved extension will not be accepted.

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).

In this class, if you are sick or quarantined, please let me know as soon as possible 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, 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 policies, 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 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 trajectories in higher-fidelity environments in commercial software
- Manifolds
- Quasi-periodic orbits
- Poincaré mapping
- Designing transfers
- An overview of higher-fidelity models of multi-body systems