ASEN 6519-003, 004 Special Topics: Celestial Mechanics

MWF, 9:35-10:25 PM, AERO N250

Instructor: Daniel Scheeres, scheeres@colorado.edu
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Introduction to the N-body problem and the modeling of naturally gravitating dynamical systems. Dynamical coupling between translational and rotational motion. Perturbation theory applied to the dynamics of Hamiltonian dynamical systems, with an emphasis on solar system dynamics and astrodynamics.

Pre-requisite: ASEN 5050/5052 or equivalent

The course will be taught in two intertwined "streams", focused on different aspects of celestial mechanics.

Stream 1 (Peterson): *Restricted 3- and 4-Body Problems*
This stream will start with a review of classical mechanics: Newtonian, Lagrangian, and Hamiltonian. Then we will go over the mathematical foundations of dynamical systems theory via differential geometry. We will then apply these ideas to study normal forms, continuation of solutions, and bifurcations of periodic orbits in the restricted 3- and 4-body problems central to astrodynamics and celestial mechanics today.
Main texts: Giorgilli, Lee, Arnold

Stream 2 (Scheeres): *The Full N-Body Problem*
This stream will focus on the fundamentals of the N-body problem, including all known (simple) solutions and properties. It culminates in the extension of classical results from the interaction of point mass bodies to the interactions of rigid bodies with finite density. Tidal flexure and its implications are also presented.
Main texts: Pollard, Murray & Dermott

Each stream will have its own set of HW problems (ideally due at the end of the term, but assigned en masse early in the term), and will have its own computational projects that will be assigned.

The HW problems are generally formulated so that the answer is clear, so what you need to show is that you were able to figure out how to arrive at the answer.

The computational projects will lead you, step by step, to developing a basic computational capability for these dynamics. In general, I am not interested in seeing code, but am interested in seeing the results requested.

Syllabus:

The Full N-Body Problem

Introduction to the N-body problem
- Problem statement
- Integrals of motion
- Constraints on motion, i.e., Sundmann's inequality and related results
- Central configurations and general solutions
- Stability in Celestial Mechanics systems

Introduction to the Full N-body problem
- Generalization of the N-body problem to rigid mass distributions
- Total system energy, angular momentum, and exchange between spin and orbits
- Implications of finite density for stable motions and states
- Tides and tidal theories for mass distributions
- Spin-Orbit coupling and secular evolution

Restricted 3- and 4-Body Problems

Mathematical Methods
- Hamiltonian dynamics
- Manifold Theory
- Periodically-forced systems
- Normal Forms

Applications to Astrodynamics
- Circular Restricted 3-Body Problem
- Hill Restricted 4-Body Problem + other perturbed models
- Continuation of solutions
- Bifurcations of periodic orbits

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.