ASEN 6062: Celestial Mechanics

MW, 1:00-2:15 PM, AERO N250
Office Hours: Immediately after class

Instructor: Daniel Scheeres, scheeres@colorado.edu
AERO 454

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 motion of spacecraft subject to these gravitational systems. Emphasis will be given to solar system dynamics and astrodynamics.

Pre-requisite: ASEN 5050/5052 or equivalent

The course will be split into two main focus topics. First will be the N-Body problem and its variants, which describe the motion of gravitating bodies. Second will be the motion of spacecraft about these systems. Throughout the material will be focused on developing rigorous results and defining the pathways to realizing motion in these systems through simulations.

Topic 1: *The Full N-Body Problem*
This 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 may also be presented.

Topic 2: *Restricted 3- and 4-Body Problems*
Starting from the N-body systems defined in Topic 1, this topic will provide a review of classical mechanics: Newtonian, Lagrangian, and Hamiltonian. Then we will apply these models to study motion in the restricted 3- and 4-body problem, a topic central to astrodynamics and celestial mechanics today.

Each topic will have its own set of HW problems 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. The final computational project will be of a system of your own choosing.

Grading:

HW problems:	35%
Computational problems:	35%

Computational project: 30%

Textbooks (TBD):

H. Pollard, Celestial Mechanics, The Carus Mathematical Monographs #18, The Mathematical Association of America, 1976. eISBN 978-1-61444-018-5: Available for download ($17) at: https://www.maa.org/press/ebooks/celestial-mechanics

Excerpts from: D.J. Scheeres. “Orbital Motion in Strongly Perturbed Environments: Applications to Asteroid, Comet and Planetary Satellite Orbiters,” Springer-Praxis Books in Astronautical Engineering. 2012. ISBN 978-3-642-03255-4, e-ISBN 978-3-642-03256-1, DOI 10.1007/978-3-642-03256-1

Excerpts from: C.D. Murray and S.F Dermott, Solar System Dynamics, Cambridge, 1999

Additional Reference Books:
A.E. Roy, Orbital Motion 4th edition, Institute of Physics Publishing, 2005

V.I. Arnold, V.V. Kozlov, A.I. Neishtadt, Mathematical Aspects of Classical and Celestial Mechanics, 3rd edition, Springer, 2006.

A. Morbidelli, Modern Celestial Mechanics: Aspects of Solar System Dynamics, Advances in Astronomy and Astrophysics, Volume 5, Taylor & Francis, 2002: Available for download (free, gratis of the author) at: https://www-n.oca.eu/morby/celmech.pdf or https://www-n.oca.eu/morby/celmech.ps

D. Boccaletti and G. Pucacco, Theory of Orbits 1 & 2, Springer, 1996.

C. Marchal, The Three-Body Problem, Elsevier, 1990.

F.R. Moulton, An Introduction to Celestial Mechanics, 2nd edition, Dover, 1970.

J.M.A. Danby, Fundamentals of Celestial Mechanics, 2nd edition, Willmann-Bell, 1988

W.M. Kaula, Theory of Satellite Geodesy, Dover, 2000

On-Line References:
Prof. Rick Moeckel’s notes on the N-Body problem and Central Configurations:
http://www.math.umn.edu/~rmoeckel/notes/Notes.html

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

- Newtonian, Lagrangian and Hamiltonian formulations
- Basics of Hamiltonian dynamics and the properties of solutions
- Periodically-forced systems

Applications to Astrodynamics

- Circular Restricted 3-Body Problem
- Hill Restricted 4-Body Problem + other perturbed models
- Periodic and quasi-periodic solutions