ME 51500: Orbital Mechanics

Course (Catalog) Description

The two-body problem. Lagrangian dynamics. Hamiltonian equations. Perturbations. Satellite orbits and ballistic trajectories. Effects of drag on satellite orbits. The general three-body problem. Coordinate transformations. Computational methods. Design project. Prereq.: ME 24700. 3 class hrs./wk.; 3 credits.

Instructor: Peter Ganatos, Professor of M.E.

Course Materials

Textbooks: *Orbital Mechanics for Engineering Students*, H. Curtis, Elsevier, fourth edition, 2021 (ISBN 978-0128240250) (required).

Orbital Mechanics, J. E. Prussing and B. A. Conway, Oxford University Press, second edition, 2012 (ISBN 978-0199837700) (optional).

Fundamentals of Astrodynamics, R. R. Bate, D. D. Mueller, J. E. White and W. W. Saylor, Dover Publications, second edition, 2020 (ISBN 978-0486497044) (optional).

References: NASA General Mission Analysis Tool (GMAT) Documentation, available online at: https://documentation.help/GMAT/

Systems Tool Kit (STK) Tutorial, Analytical Graphics, Inc., available online at: http://help.agi.com/stk/11.0/index.htm#training/TutorialOverview.htm

Course Structure / Grading

This course is conducted using the web-enhanced course format. This means that you are required to attend all lectures in person and participate on Blackboard which may be accessed through the CUNY website http://www.cuny.edu and clicking on the login link on the upper right hand corner of the page. Here you will find weekly assignments which are due on the indicated date. Certain assignments will be collected and graded or there may be a quiz based on the homework on the date due. No makeups will be given for missed quizzes and no additional time will be given if you are late. There will also be two 75-minute in-class exams and a final exam which will also be in person. All exams are closed book, but original handwritten notes and homeworks will be allowed. Your final grade for the course will be determined as follows:

Exam 1	20%
Exam 2	20%

Final Exam	30%
Collected Homeworks and Quizzes	20%
Design Project	10%

The work you submit is expected to be your own. Anyone caught cheating during an exam or submitting an assignment bearing any resemblance to another student's work will receive a grade of negative 100%. Six absences in lectures will result in a letter grade reduction. Three late arrivals or leaving before the end of class are equivalent to one absence. To preserve grading fairness for all students, the course grade breakdown and grade assignment as specified in the course syllabus will be strictly followed. No individual exception to the grading policy will be allowed.

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Course Outcomes

a. Specific Outcomes of Instruction

1) Knowledge of Newton's law of gravitation and formulation of the N-body problem.
2) Knowledge of the two-body problem, satellite orbits and ballistic trajectories.
3) Knowledge of orbital maneuvers, interception and rendezvous.
4) Knowledge of the effect of atmospheric drag on satellite orbits.
5) Knowledge of the three-body problem and libration (Lagrange) points.
6) Knowledge of interplanetary trajectories, sphere of influence and the patched conic method.

b. Student Outcomes in ABET Criterion 3 or Other Outcomes Addressed by the Course

The course contributes to the following Student Outcomes:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Course Outline

Topics:

1) Introduction, the history of spaceflight, projectile motion, Newton's law of gravitation, formulation of the N-body problem, the ten known integrals and their meaning. (1 week)
2) The two-body problem. (1.5 weeks)
3) Ballistic trajectories, minimum energy trajectory. (1 week)

4) Orbit determination, orbital elements, equatorial and ecliptic systems, the hodographic plane, Lagrangian coefficients. (1.5 weeks)
5) Orbital maneuvers, interception and rendezvous, impulsive maneuvers, relative motion between vehicles, linearized orbit theory, the Clohessy-Wiltshire equations (2 weeks)
6) Orbit perturbations, Lagrange's planetary equations. (1 week)
7) Effect of atmospheric drag on satellite orbits. (1 week)
8) The three-body problem, specialized solutions, libration points. (1.5 weeks)
9) Interplanetary trajectories, sphere of influence, patched conic method, direct and gravity assisted interplanetary trajectories. (1.5 weeks)
10) Mechanics of powered flight, specific impulse and exhaust velocity, energy considerations, spacecraft motion under continuous thrust. (1 week)
11) Tests (1 week)

Design Project: Students are assigned a problem to design a trajectory or sequence of maneuvers needed for a specific space mission under a given set of constraints. Students are required to perform all necessary calculations, and create a computer simulation. A written report is required.