Mechanical Engineering 446
Astronautics

Instructor:	Dr. David S. Rubenstein
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Class Hours:	Tuesdays, Thursdays, 11:00AM – 12:15PM
Location:	Remote via Adobe Connect Pro
Office Hours:	Through email and Adobe Connect meetings (Students can log on as if it were a class session) through special arrangement. Availability will be flexible.
Prerequisites:	MEE 270, MAT 258, COS 215 or 220
Text:	*Orbital Mechanics for Engineering Students*, Second Edition, H. D Curtis
Technical software:	MATLAB Student Version (includes Matlab and Simulink). Release TBD
Final Exam:	TBD
Course Homepage	TBD

Course description

This course provides an introduction to the design and operation of spacecraft systems. Topics will include kinematics and relative orientations of different coordinate systems as well as fundamental orbital mechanics – orbit design, maneuvers and transfers. Rigid-body dynamics, torque-free and forced motions due to external disturbances acting on the spacecraft, will be discussed in addition to basic propulsion concepts related to orbital design. Course material will be integrated into the development of a spacecraft simulation project, demonstrating a critical method of satellite system design and analysis. Specific examples, including the Global Positioning System (GPS) and the NASA Space Shuttle, will be described as applications in the context of the course material.

Educational Objectives: After completing this course, students will be able to:

I) Formulate and describe relative orientations and motions of different coordinate systems and their rates-of-change using three-dimensional kinematics and apply this to aerospace vehicle applications.
II) Apply three and six-dimensional dynamics to write equations-of-motion for analysis and simulation of the orbital and rigid-body attitude motions of aerospace systems.
III) Estimate propellant requirements for a variety of orbital maneuvers and transfers.
IV) Demonstrate vehicle modeling skills through implementation in numerical simulation and analysis.

Topics

1. What is Aerospace Engineering?
   - Astronautics
   - Aeronautics
   - Overview of Aerospace industry
   - Aerospace projects and subsystems
   - Aerospace technology applications
2. 3-D Kinematics
   - direction cosine matrices
   - vector components in different coordinate systems
   - Euler angles
   - angular rate (rotation rate) vector
   - velocity and acceleration in different reference frames
3. 3-D Particle Dynamics

- Newton’s laws of particle motion
- energy
- angular momentum
- systems of particles

4. Two-body Orbital Mechanics
   - Newton’s law of universal gravitation
   - orbit equation
   - conic sections and orbit terminology
   - Kepler’s equation (predicting future position)
   - classical orbital elements
   - representations of satellite position and velocity
5. Orbital Maneuvers and Transfers
   - impulsive maneuvers
   - Hohmann transfers
   - simple inclination changes
   - relative motion between spacecraft
6. Introduction to the Global Positioning System (GPS)
   - history and evolution
   - basic concepts
   - pseudo-ranges and pseudo-range-rates
   - error sources
   - Differential GPS (DGPS) and WAAS
   - basic orbit design
   - Navigation with GPS
   - Kalman Filters and Inertial Navigation Systems (INS) Basics
7. Rocket Performance
   - rocket equation
   - specific impulse
   - staging
   - estimating propellant requirements for a mission
8. Rigid-body Dynamics
   - angular momentum and energy
   - inertia matrix
   - principal-axis system
   - Euler’s equations of rigid-body motion
   - torque-free motion
   - effects of external torques

Special Topics as Time Permits

9. Reentry Dynamics
10. Interplanetary Trajectories
11. Aerospace Navigation Concepts
12. Attitude Control Methods

Additional References

1. Bate, R.R., Mueller, D.D., and White, J.E., *Fundamentals of Astrodynamics*, Dover Publications, New York, 1971.
2. Greenwood, D., *Principles of Dynamics*, Prentice-Hall, Englewood Cliffs, NJ, 1988.
3. Chobotov, V., *Spacecraft Attitude Dynamics and Control*, Krieger, Malabar, FL, 1991.
4. Kaplan, M. H., *Modern Spacecraft Dynamics and Control*, Wiley & Sons, New York, 1976

Class Time
Students are expected to attend the live lecture sessions.

Homework
- Homework problems will be assigned approximately every week. You are expected to do the homework assignments individually. The homework problems are the basis for the preliminary and final exams. You are responsible for submitting the assigned homework if you are absent from the class.
- Late homework will NOT be accepted.
- Please be very neat and clear on homework. Define CLEARLY variables, vectors, reference frames, etc. Nomenclature and convention can be pretty much as you please but you MUST be clear and consistent.

Preliminary Examinations
There will be two preliminary examinations.

Simulation Project
A spacecraft simulation project will be assigned mid to late semester.

Final Exam
A comprehensive final exam will cover all material up to and including the last lecture before the exam.

Grading

Homework	5%
Preliminary Exam #1	25%
Preliminary Exam #2	25%
Simulation Design Project	20%
Final Exam	25%

Disabilities (ADA) Statement

Students with disabilities who may need services or accommodations to fully participate in this class should contact Ann Smith, Director of Disability Services in 121 East Annex, (voice) 581-2319, (TTY) 581-2325 as early as possible in the semester. Any student requiring an accommodation due to a disability is also encouraged to speak to the instructor privately at the beginning of the semester. Appropriate arrangements will be made to accommodate the student.

Academic Integrity

Academic dishonesty includes cheating, plagiarism and all forms of misrepresentation in academic work, and is unacceptable at The University of Maine. As indicated in the University of Maine's on-line "Student Handbook," plagiarism (the submission of another's work without appropriate attribution) and cheating are violations of The University of Maine Student Conduct Code. An instructor who has probable cause or reason to believe a student has cheated may act upon such evidence, and should report the case to the supervising faculty member or the Department Chair for appropriate action.

Class Disruption:

In the event of an extended disruption of normal classroom activities, the format for this course may be modified to enable its completion within its programmed time frame. In that event, you will be provided an addendum to the syllabus that will supersede this version.