Mechanical Engineering 446
Astronautics

Instructor:  Dr. David S. Rubenstein, Boardman Hall
Email:  David.Rubenstein@umit.maine.edu
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
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
**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**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>5%</td>
</tr>
<tr>
<td>Preliminary Exam #1</td>
<td>25%</td>
</tr>
<tr>
<td>Preliminary Exam #2</td>
<td>25%</td>
</tr>
<tr>
<td>Simulation Design Project</td>
<td>20%</td>
</tr>
<tr>
<td>Final Exam</td>
<td>25%</td>
</tr>
</tbody>
</table>

*Any student requiring an accommodation due to a disability is encouraged to speak to the instructor privately at the beginning of the semester. Appropriate arrangements will be made to accommodate the student.*