ASTE 280

Spring 2018

Foundations of Astronautical Engineering

Mon/Wed, 4:00 - 5:20 PM, GFS 106

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NOTE: This syllabus may be updated throughout the course.
Refer to the online version as most up-to-date.

Course Description: This course is a broad introduction to basic topics in astronautics. It has four major topics: Mathematics of coordinate systems and transformations; spacecraft orbits and orbital maneuvers; rocket engines and rocket vehicles; rigid body rotation and spacecraft attitude dynamics. A brief introduction to the space environment is given at the end; while ASTE students will have more material on this in later courses, this is the only space course required for AE and many AE students will not see space environment in any other course. This course is required for the B.S. degrees in Aerospace Engineering (AE) and Astronautical Engineering (ASTE), and is typically taken in the second year.

Catalogue Description: Coordinate systems and transformations. Spherical trigonometry. Orientation angles. Spacecraft orbits and orbital maneuvers. Introduction to rocket propulsion, spacecraft attitude dynamics and control, and space environment.

Prerequisites: MATH 226 and PHYS 152L. Recommended skill in MATLAB programming.

Units: 3

What you should already know: Calculus through differential equations. Physics: mechanics, electromagnetism, a little optics. Enough about *MATLAB* to write simple programs and make plots.

Text: *Course Notes* to be posted in PDF form on Blackboard

Additional Text (Optional):

Space Mission Engineering: The New SMAD, Wertz, Everett, and Puschell, eds., Microcosm Press, 2011, ISBN: 978-1881883-15-9

Introduction to Space Flight, Francis J. Hale, Prentice Hall, 1994

Course Objectives:

At the completion of this course, students will be able to:

1. Understand the most common coordinate systems used in astronautics: geocentric vs. heliocentric, inertial vs. body-fixed, and when each one is appropriate. Transform between these systems using rotational and translational matrices.
2. Understand Keplerian orbits and orbital perturbations. Design spacecraft trajectories such as Hohmann transfers, plane changes, and interplanetary escape and capture.
3. Understand the fundamentals of rocket propulsion, and know the basic characteristics of the different kinds of rockets: solid, liquid, electric. Understand rocket vehicle dynamics: Earth launch, trajectories in the atmosphere, delta-V for orbital maneuvers.
4. Understand the basics of rigid body rotations: Euler's equations; orientation angles and quaternions; precession of cylindrical spinners; attitude control using reaction wheels and control moment gyros.

Midterm Exams: Wednesday, February 7, regular class time. Wednesday, March 21, regular class time.

Final Exam: Wed, May 2, 4:30 PM-6:30 PM, GFS 106.

Homework: Assigned weekly. Due on Wednesdays in class.
NOTE: Late homeworks will be accepted up to one week past the due date but will be reduced in grade by 50%. Exceptions to this must be approved by the instructor in advance of the due date.

Grade Distribution:

Homework	25%
Midterm Exam #1	20%
Midterm Exam #2	20%
Final Exam	35%

NOTE: Letter grade distributions are based on a curve and vary per semester.

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism presenting someone else's ideas as your own, either verbatim or recast in your own words is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Section 11, Behavior Violating University Standards. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and University policies on scientific misconduct.

Discrimination, sexual assault, and harassment are not tolerated by the University. You are encouraged to report any incidents to the Office of Equity and Diversity or to the Department of Public Safety. This is important for the safety of the whole USC community. Another member of the University community such as a friend, classmate, advisor, or faculty member can help initiate the report, or can initiate the report on behalf of another person. The Center for Women and Men provides 24/7 confidential support, and the sexual assault resource center webpage describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the American Language Institute, which sponsors courses and workshops specifically for international graduate students. The Office of Disability Services and Programs provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, USC Emergency Information will provide safety and other updates, including ways in which instruction will be continued by means of Blackboard, teleconferencing, and other technology.

Tentative Course Outline:

The weekly coverage might change as it depends on the progress of the class. However, you should keep up with the reading assignments.

Week	Date	Content	Reading
Week 1	1/8 & 1/10	Class organization. Length scales: Solar system and astronomical unit. Types of coordinate systems. Spherical trigonometry laws and applications. Rotations and rotation matrices.	1.1 - 1.4
Week 2	1/15 & 1/17	Spherical polar coordinates. Proofs and applications of spherical trigonometry laws. Translations and homogeneous coordinates. Three-angle sets for specifying orientation: Roll-pitch-yaw, Euler angles. Euler parameters.	1.5 - 1.10
Week 3	1/22 & 1/24	Universal time. Julian date. Intro to spacecraft orbits. Solar and sidereal days. Newtonian gravitation, circular orbits, escape velocity. Two-body motion: angular momentum; energy and velocity on orbit. Tidal forces. Conic sections. Time since periapsis for elliptical orbits.	2.1 - 2.6
Week 4	1/29 & 1/31	Classical orbital elements. Derivation of Kepler's laws. Flight path angle. Common Earth orbits: LEO, GEO, Molniya. Orbital perturbations: regression of nodes, apsidal rotation.	2.7 - 2.13
Week 5	2/5 & 2/7	Review. 1st MIDTERM EXAM.	Last year's exam
Week 6	2/12 & 2/14	Ground track. Hyperbolic orbits. Velocity in hyperbolic orbit. Oberth maneuver. Time since periapsis for hyperbolic orbit. Determination of orbital elements from position and velocity vectors. Field of view.	2.14 - 2.17
Week 7	2/19 & 2/21	Orbital maneuvers. Hohmann transfer. Plane changes. Fast transfers. Gravity assist. Interplanetary launch opportunities. Planetary departure. Launch window.	Chapter 3
Week 8	2/26 & 2/28	Intro to rocket vehicles. Rocket equation. Momentum and pressure thrust. Specific impulse. Liquid-fueled rockets.	4.1 - 4.4

Week 9	3/5 & 3/7	Solid-fueled rockets. Optimal nozzle expansion. Vehicle performance in gravity field. Atmospheric drag.	4.5 - 4.9
	3/12 & 3/14	SPRING BREAK	
Week 10	3/19 & 3/21	Intro to methods of numeric computation. Rootfinding methods: Bisection, regula falsi, Newton. Launch into orbit: Programmed turn, gravity turn, Hohmann transfer to parking orbit. Thrust vector control. Staging. Launch sites.	4.10 - 4.14
Week 11	3/26 & 3/28	Review. 2nd MIDTERM EXAM (possibly moved here)	Last year's exam.
Week 12	4/2 & 4/4	Intro to attitude dynamics and control. Gravity-gradient stabilization. Thrusters and reaction wheels. Moment of inertia. Parallel axis theorem. Principal axes. Transformation of time derivatives between frames. Euler's equations of rigid body dynamics.	5.1 - 5.9
Week 13	4/9 & 4/11	Torque-free rotational motion: Stability of spin; derivatives of Euler angles; derivatives of Euler parameters; precession of axisymmetric body. Realignment of spinning spacecraft.	5.10 - 5.12
Week 14	4/16 & 4/18	Gyroscopic motion. Damped harmonic oscillator. Impulse response. Control moment gyros; gyroscopes as rotation sensors.	5.13 - 5.16
Week 15	4/23 & 4/25	Intro to space environment. Sun and solar wind. Earth's atmosphere. Ionosphere and communications. Geomagnetic field. Review.	Chapter 6