USC University of Southern California

USC Viterbi School of Engineering

Department of Astronautical Engineering

ASTE 280 Spring 2016: Syllabus

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3 units; 2:00-3:20 Monday and Wednesday, GFS 116

Instructor:

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Office Hours: Mondays 3:30 PM - 4:30 PM, Wednesdays 10:00 AM - 12:00 noon.

Grader: To be announced

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. *Prerequisite:* MATH 226 and PHYS 152*L*. *Recommended preparation:* Skill in MATLAB programming.

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 and Astronautical Engineering, and is typically taken in the second year.

Learning Objectives: After taking this course, you should 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.

Text: Course notes. To be posted in pdf form on this website.

Additional text (optional): *Space Mission Engineering: The New SMAD*, Wertz, Everett and Puschell, eds. Microcosm Press, 2011. ISBN 978-1881883-15-9.

Additional material which may be useful:

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

Midterm Exams: Wednesday, February 17, regular class time. Wednesday, March 30, regular class time.

Final Exam: Monday, May 9, 2:00 PM-4:00 PM.

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.

Grading: Homework, 25%; each midterm, 20%; final exam, 35%.

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.

Course Material:

The readings are from the posted class notes.

Week	Date	Topic	Reading
1	01/11 & 01/13	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
2	01/18 & 01/20	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
3	01/25 & 01/27	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
4	02/01 & 02/03	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
5	02/08 & 02/10	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
6	02/15 & 02/17	Review. 1st MIDTERM EXAM.	Last year's exam.
7	02/22 & 02/24	Orbital maneuvers. Hohmann transfer. Plane changes. Fast transfers. Gravity assist. Interplanetary launch opportunities. Planetary departure. Launch window.	Chapter 3.
8	02/29 & 03/02	Intro to rocket vehicles. Rocket equation. Momentum and pressure thrust. Specific impulse. Liquid-fueled rockets.	4.1-4.4
9	03/07 & 03/09	Solid-fueled rockets. Optimal nozzle expansion. Vehicle performance in gravity field. Atmospheric drag.	4.5-4.9
	03/14-03/18	SPRING BREAK	
10	03/21 & 03/23	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
11	03/28 & 03/30	Review. 2nd MIDTERM EXAM.	Last year's exam.
12	04/04 & 04/06	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

13	04/11 & 04/13	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
14	04/18 & 04/20	Gyroscopic motion. Damped harmonic oscillator. Impulse response. Control moment gyros; gyroscopes as rotation sensors.	5.13-5.16
15	04/25 & 04/27	Intro to space environment. Sun and solar wind. Earth's atmosphere. Ionosphere and communications. Geomagnetic field. Review.	Chapter 6.

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.