ASTE 280

Spring 2019

Foundations of Astronautical Engineering

Mon/Wed, 3:30 - 4:50 PM, SOS B2

Paul N. Giuliano, Ph.D.

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RRB 201
Office Hours: Mon/Wed, 60 minutes before/after class, Fri, TBD
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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.

Co-requisites: 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 13, regular class time. Wednesday, March 27, regular class time.

Final Exam: Fri, May 3, 2:00 - 4:00 PM, SOS B2.

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.

Instructor Biography:

Professor Paul Giuliano is a Systems Engineer at the NASA Jet Propulsion Laboratory in Pasadena, CA, focusing on integration and test of advanced systems and instrument concepts for special applications. He holds an Adjunct Faculty position within the Department of Astronautical Engineering at the University of Southern California in Los Angeles, CA, teaching undergraduate programs in Astronautics and Space Technology.

In his spare time, Professor Giuliano volunteers in the community by teaching elementary, middle, and high school level classes in science, technology, engineering, and math as well as consults for the film industry on matters of science and space technology. Prior to joining NASA-JPL, Professor Giuliano was a Lead Systems Engineer within the Advanced Missions and Programs group of the Boeing Satellite Development Center in El Segundo, CA, working new business, technology development, strategy, and special projects for space technology.

He received his Ph.D. and M.S.E. in Aerospace Engineering and Plasma Science and Engineering from the University of Michigan, Ann Arbor, MI, specializing in the high-performance computation of plasma physics transport phenomena using statistical methods as applied to advanced in-space propulsion systems. Prior to that, he received a B.S. in Astronautical Engineering at the University of Southern California where he led teams in rocket propulsion and experimental plasma physics and held temporary research positions at Princeton University and Caltech/NASA-JPL.

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	1/7 & 1/9	Class organization. Introduction to spacecraft. Length scales: Solar system and astronomical unit. Types of coordinate systems. Spherical trigonometry laws and applications. Rotations and rotation matrices.	Ch. 1
Week 2	1/14 & 1/16	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. HW1 due.	Ch. 1
Week 3	~~1/21~~ (MLK) & 1/23	Intro to STK. Universal time. Julian date. Intro to spacecraft orbits. Solar and sidereal days. Newtonian gravitation, circular orbits, escape velocity. HW2 due.	Ch. 2
Week 4	1/28 & 1/30	Two-body motion: angular momentum; energy and velocity on orbit. Conic sections. Time since periapsis for elliptical orbits. Classical orbital elements. HW3 due.	Ch. 2
Week 5	2/4 & 2/6	More COE's. Common Earth orbits: LEO, GEO, Molniya. Derivation of Kepler's laws. Flight path angle. Orbital perturbations: regression of nodes, apsidal rotation. HW4 due.	Ch. 2
Week 6	2/11 & 2/13	Previous MT1 Review. Take MT1.	Last year's exam
Week 7	~~2/18~~ (President's) & 2/20	Pass back MT1. Ground track. Spacecraft Field of View.	Ch. 2
Week 8	2/25 & 2/27	Orbital maneuvers. Hohmann transfers. Plane changes. Bielliptic transfers. Fast transfers. Interplanetary launch opportunities. Planetary departure. Launch window. HW5 due.	Ch. 3

Week 9	3/4 & 3/6	Hyperbolic orbits. Velocity in hyperbolic orbit. Oberth maneuver. Time since periapsis for hyperbolic orbit. Determination of orbital elements from position and velocity vectors. HW6 due.	Ch. 3
	3/11 & 3/13	SPRING BREAK	
Week 10	3/18 & 3/20	Patched conics for interplanetary transfers. Gravity assist. HW7 due.	Ch. 3
Week 11	3/25 & 3/27	Previous MT2 Review. Take MT2	Last year's exam.
Week 12	4/1 & 4/3	Intro to rocket vehicles. Rocket equation. Momentum and pressure thrust. Specific impulse. Liquid-fueled rockets.	Ch. 4
Week 13	4/8 & 4/10	Solid-fueled rockets. Advanced space propulsion: electric, nuclear, solar, FTL. HW8 due.	Ch. 4
Week 14	4/15 & 4/17	1-d compressible flow. Optimal nozzle expansion. Vehicle performance in gravity field. Staging. HW9 due.	Ch. 4
Week 15	4/22 & 4/24	Launch into orbit: Programmed turn, gravity turn. Thrust vector control. Launch sites. Brief discussion of Final Exam. HW10 due.	Ch. 4