



Department of Astronautical Engineering

ASTE 280 Spring 2021: Foundations of Astronautical Engineering

3 units

Lectures Mondays and Wednesdays 3:30-4:50 PM, Online

Instructor:

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Office Hours: Mondays 12-3 PM; Wednesdays 1-3 PM

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.

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, the student will:

- ✦ 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 matrices and quaternions.
 - ✦ Understand basics and applications of spherical trigonometry.
 - ✦ Understand Keplerian orbits and orbital perturbations. Design spacecraft trajectories such as Hohmann transfers, plane changes, and interplanetary escape and capture.
 - ✦ 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.
 - ✦ Understand the basics of rigid body rotations: Euler's equations; orientation angles and quaternions.
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Prerequisites: MATH 226, PHYS 152L

Recommended preparation: Matlab programming

Required Texts

Course notes, to be published on the class website

Optional Materials

V. L. Pisacane, Fundamentals of Space Systems, 2nd edition. ISBN 978-0195162059

Description and Assessment of Assignments:

- ✦ **Homework:** Written homework assigned weekly and due in class on Wednesdays. Homeworks will be graded and returned, generally in one week. Homework solutions will be posted on the class website.
- ✦ **Midterms:** Two midterm exams will be given in class, on Wednesday of Week 6 and Week 12 respectively.
- ✦ **Final Exam:** The final exam will be two hours, in the regular classroom, at the time specified by the University schedule of final exams.

Grading Breakdown

Homework, 15%

1st Midterm Exam, 25%

2nd Midterm Exam, 25%

Final Exam, 35%

Week	Date	Topics	Notes
1	08/17 & 08/19	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
2	08/24 & 08/26	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. Quaternions.	Ch. 1
3	08/31 & 09/02	Start on attitude and orbital control system (AOCS). Quaternions. Converting between attitude representations: Euler, RPY, transformation matrix, quaternion. Moment of inertia tensor and principal coordinates. Parallel axis theorem. Similarity transform. Transformation of time derivatives between inertial and rotating frames. Euler's equations for rigid body rotation. Stability of spin about principal axis.	Ch. 2
4	09/07 & 09/09	Two-body motion: angular momentum; energy and velocity on orbit. Conic sections. Time since periapsis for elliptical orbits. Classical orbital elements.	Ch. 2
5	09/14 & 09/16	More COE's. Common Earth orbits: LEO, GEO, Molniya. Derivation of Kepler's laws. Flight path angle. Orbital perturbations: regression of nodes, apsidal rotation.	Ch. 2
6	09/21 & 09/23	Review of last year's first midterm exam. FIRST MIDTERM EXAM.	
7	09/28 & 09/30	Ground track. Spacecraft field of view.	Ch. 2
8	10/05 & 10/07	Orbital maneuvers. Hohmann transfers. Plane changes. Bielliptic transfers. Fast transfers. Interplanetary launch opportunities. Planetary departure. Launch window.	Ch. 3
9	10/12 & 10/14	Hyperbolic orbits. Velocity in hyperbolic orbit. Oberth maneuver. Time since periapsis for hyperbolic orbit. Determination of orbital elements from position and velocity vectors.	Ch. 3
10	10/19 & 10/21	Patched conics for interplanetary transfers. Gravity assist.	Ch. 3
11	10/26 & 10/28	Intro to rocket vehicles. Rocket equation. Momentum and pressure thrust. Specific impulse. Liquid-fueled rockets.	Ch. 4
12	11/02 & 11/04	Review of last year's second midterm exam. SECOND MIDTERM EXAM.	
13	11/09 & 11/11	Solid-fueled rockets. Advanced space propulsion: electric, nuclear, solar, FTL.	Ch. 4
14	11/16 & 11/18	1-d compressible flow. Optimal nozzle expansion. Vehicle performance in gravity field. Staging.	Ch. 4
15	11/23 & 11/25	Launch into orbit: Programmed turn, gravity turn. Thrust vector control. Launch sites. Review.	Ch. 4

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 Part B, 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](#).

Support Systems

Counseling and Mental Health — (213) 740-9355 — 24/7 on call

<https://studenthealth.usc.edu/counseling>

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline — 1-800-273-8255 — 24/7 on call

<https://www.suicidepreventionlifeline.org>

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship & Sexual Violence Prevention Services (RSVP) — (213) 740-9355(WELL), press "O" after hours — 24/7 on call

<https://studenthealth.usc.edu/sexual-assault>

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) — (213) 740-5086 | Title IX — (213) 821-8298

<https://equity.usc.edu>, <https://titleix.usc.edu>

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment — (213) 740-5086 or (213) 821-8298

https://usc-advocate.symplicity.com/care_report

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity | Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs — (213) 740-0776

<https://dsp.usc.edu>

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Campus Support and Intervention — (213) 821-4710

<https://campussupport.usc.edu>

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC — (213) 740-2101

<https://diversity.usc.edu>

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency — UPC: (213) 740-4321, HSC: (323) 442-1000 — 24/7 on call

<https://dps.usc.edu>, <https://emergency.usc.edu>

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety — UPC: (213) 740-6000, HSC: (323) 442-1200 — 24/7 on call

<https://dps.usc.edu>

Non-emergency assistance or information.

Office of the Ombuds — UPC: (213) 821-9556, HSC: (323) 442-0382

<https://ombuds.usc.edu>

A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.