



## Department of Astronautical Engineering

### ASTE 280 Spring 2023: Foundations of Astronautical Engineering

#### Syllabus

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3 units

Lectures Mondays and Wednesdays 3:30-4:50 PM, SOS B2

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#### Instructor:

Dan Erwin, OHE 500W, 213-740-5358, [erwin@usc.edu](mailto:erwin@usc.edu).

Office Hours: Wednesdays 12-3 PM; Thursdays 2-4 PM

#### TA:

TBA

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#### 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.

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#### 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

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#### 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, on Wednesday of Week 6 and Week 11 respectively. The exams will be in the regular classroom, during the regular class time.
- ✦ **Final Exam:** The final exam will be two hours, in the regular classroom, Friday May 5, 2-4 PM.

### Grading Breakdown

Homework, 15%

1st Midterm Exam, 25%

2nd Midterm Exam, 25%

Final Exam, 35%

Week	Date	Topics	Notes
1	01/09 & 01/11	Class organization. Introduction to spacecraft. Length scales: Solar system and astronomical unit. Types of coordinate systems. Spherical trigonometry laws and applications.	Ch. 1
2	01/16 & 01/18	Rotations and rotation matrices. Spherical polar coordinates. Proofs and applications of spherical trigonometry laws.	Ch. 1
3	01/23 & 01/25	ECI to ECEF transformation. Azimuth and elevation of planets in sky. Universal time and Julian date. Solar and sidereal time. Gravitational parameter. Solar system data. Circular orbits.	Ch. 1, 2
4	01/30 & 02/01	Two-body motion: angular momentum; energy and velocity on orbit. Conic sections. Time since periapsis for elliptical orbits. Classical orbital elements. Proof of Kepler's laws. Flight path angle. Geostationary and Molniya orbits. Orbital perturbations: Regression of nodes.	Ch. 2
5	02/06 & 02/08	Rotation of apsides. Perturbations due to Sun and Moon. Ground track.	Ch. 2
6	02/13 & 02/15	Review of last year's first midterm exam. FIRST MIDTERM EXAM.	
7	02/20 & 02/22	Hyperbolic orbits. Oberth maneuver. Determining orbital elements from position and velocity. Spacecraft field of view. Orbital maneuvers. Instantaneous Delta-V.	Ch. 2, 3
8	02/27 & 03/01	Hohmann transfers. Plane changes. Bielliptic transfers. Fast transfers. Gravity assist. Interplanetary trajectories. Synodic period. Launch windows.	Ch. 3
9	03/06 & 03/08	Intro to rocket vehicles. Rocket equation. Momentum and pressure thrust. Specific impulse. Liquid-fueled rockets. Thrust coefficient and characteristic velocity.	Ch. 4
		SPRING BREAK	
10	03/20 & 03/22	Optimal nozzle exit area. Solid-fueled rocket motors. Performance of rocket vehicles. Atmospheric drag.	Ch. 4
11	03/27 & 03/29	Review. SECOND MIDTERM EXAM.	
12	04/03 & 04/05	Stability of solid rocket combustion. Gravity turn.	
13	04/10 & 04/12	Staging. Launch sites. Attitude and orbital control system. Moment of inertia. Parallel axis theorem. Angular velocity and angular momentum. Moment of inertia tensor. Principal axes. Transformation of time derivatives between rotating and inertial frames. Euler's equations. Stability of spin about a principal axis.	Ch. 4

14	04/17 & 04/19	Rate of change of Euler angles and quaternion. Full equations of motion for rigid body rotation. External torques on spacecraft. Attitude sensing. Gravity-gradient stabilization. Attitude control: Thrusters and reaction wheels. Angular momentum dumping. Gyroscopic forces. Control-moment and rate gyros. Magnetic torque rods.	Ch. 4
15	04/24 & 04/26	Space environment. Review.	Ch. 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 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](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.