ASTE 470: Spacecraft Propulsion

Units: 3
Fall 2022—Friday—5:00-7:40pm
Location: OHE 136, online via DEN@Viterbi

Instructor: Daniel Depew
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Office:
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Course Description

This course aims to provide a comprehensive introduction to the fundamentals of rocketry and spacecraft propulsion. Both the design and performance of rocket propulsion systems are covered and discussed in the context of mission requirements and recent industry trends. Students will gain exposure to both chemical and electric propulsion techniques, as well as current state-of-the-art propulsion technologies. Special emphasis is placed on the interplay of thermodynamics, compressible gas dynamics, and propellant chemistry in the thrust chamber and nozzle of conventional chemical propulsion systems. A primary goal of this course is to give students the tools and working knowledge necessary to transition immediately into a career as a propulsion engineer, though students with career aspirations in any aspect of the space industry will greatly benefit from this introduction to the field of propulsion.

Learning Objectives

By the end of this course, students will be able to:

- Be conversant in the nomenclature, components, and high-level design and operation of different spacecraft propulsion types
- Evaluate propulsion subsystems based on mission requirements and perform simple system sizing calculations
- Apply principles of compressible gas dynamics and heat transfer to rocket nozzle design
- Analyze propellant combustion/decomposition using chemical equilibrium models
- Characterize performance of thruster components in liquid, solid, and electric propulsion systems

Prerequisite(s): Senior or graduate standing.

Recommended Preparation: ASTE 305 or equivalent study in compressible gas dynamics is highly recommended. At a minimum, students should have a familiarity with thermodynamic concepts and a basic background in chemistry. Knowledge of calculus is assumed.

Course Notes

ASTE 470 is offered to both on-campus and remote students through Viterbi's Distance Education Network (DEN). All lectures will be webcast and all lecture materials will be posted on DEN@Viterbi's Course Management System, accessible at https://courses.uscden.net for all students.

Graduate students enrolled in the MS ASTE program should note that ASTE 575 has replaced ASTE 470 as a required course. ASTE 575 will be offered in Spring 2023. **Special permission is needed for MS ASTE students to take ASTE 470 in Fall 2022.** Contact department advisor Luis Saballos or MS ASTE program director Prof. Mike Gruntman for additional details.

Technological Proficiency and Hardware/Software Required

Basic proficiency in a high-level programming language (e.g. Matlab or Python) is assumed.

Required Readings and Supplementary Materials

Required Textbook:
Rocket Propulsion, S.D. Heister, W.E. Anderson, T.L. Pourpoint and R. J. Cassady, Cambridge, 2019.

Recommended Textbook:
Mechanics and Thermodynamics of Propulsion 2nd ed., P. Hill and C. Peterson, Pearson, 1991.

Additional References:
Rocket Propulsion Elements 9th ed., G.P. Sutton and O. Biblarz, Wiley, 2016.

Modern Compressible Flow: With Historical Perspective 4th ed., J.D. Anderson, McGraw-Hill, 2021.

Combustion Physics, C.K. Law, Cambridge, 2006.

Physics of Electric Propulsion, R.G. Jahn, Dover, 2006.

Description and Assessment of Assignments

The grade for this course is broadly broken down into two categories: out of class work (40%) and exams (60%). Out of class work consists of weekly homework and two short projects. The first project is an individual coding assignment to determine nozzle flow characteristics throughout the nozzle given certain input conditions. It can be viewed essentially as an extended homework assignment and will be due the week before the midterm. The second project may be individual or in small groups and asks students to complete a detailed design of a propulsion system component which uses an advanced technique covered in lecture but not otherwise assessed in weekly homework or the exams. This project will be assigned after the midterm. The final exam will be comprehensive. Exam format is subject to change and will be discussed the first week of class.

Grading Breakdown

Assignment	% of Grade
Homework	**20**
Project 1	**5**
Project 2	**15**
Midterm	**30**
Final	**30**
TOTAL	**100**

Assignment Submission Policy

Homework will be assigned weekly and is **due the following Friday at 12pm**. All homework must be submitted electronically to the assignment Dropbox folder on the class DEN website (https://courses.uscden.net). Late homework will receive a 20% grade deduction if submitted after the deadline and will receive zero credit if submitted after solutions are posted, without exception. Solutions will typically be posted a few days after the due date. The score for one homework assignment will be dropped at the end of the semester, but *only if all assignments* have been submitted by the final exam (whether on-time or late).

Additional Policies

Attendance is not required and students may come and go as they please. Any technology or other learning tools may be used during lectures so long as they do not disrupt the class—students are encouraged to utilize whatever resources help them learn best. No food is allowed in the DEN studios, but we will take a 10 minute break halfway through class.

Course Schedule: A Weekly Breakdown (SUBJECT TO CHANGE)

	Topics/Daily Activities	Deliverables
Week 1 8/26	Syllabus, History of Rocketry, Introduction to Spacecraft Propulsion	
Week 2 9/2	Tsiolkovsky Rocket Equation, Mission Analysis	HW1
Week 3 9/9	Compressible Gas Dynamics Review, Isentropic Nozzle Flow, Ideal Rocket	HW2
Week 4 9/16	Real Nozzles, Mach Diamonds, Method of Characteristics for Nozzle Design	HW3
Week 5 9/23	Chemical Thermodynamics, Combustion, Equilibrium Gas Composition	HW4
Week 6 9/30	Chemical Kinetics, Frozen and Equilibrium Nozzle Flow, Combustion Instability	HW5
Week 7 10/7	Rocket Heat Transfer, Cooling Systems, Midterm Review	HW6
Week 8 10/14	FALL RECESS – No Lecture	HW7 **Project 1 Due**
Week 9 10/21	**MIDTERM EXAM 5:00-7:00pm**	
Week 10 10/28	Liquid Rocket Systems: Propellants, Tanks, Injectors	HW8
Week 11 11/4	Solid Rockets, Hybrid Rockets, Launch Vehicles	HW9
Week 12 11/11	VETERAN'S DAY – Prerecorded Lecture: Review of Electricity and Magnetism, Plasma Physics	HW10
Week 13 11/18	Electric Propulsion Systems, Electrospray Thrusters	
Week 14 11/25	THANKSGIVING – No Lecture	
Week 15 12/2	Nuclear Thermal Propulsion, Advanced Propulsion and Interstellar Flight, Final Review	HW11 **Project 2 Due**
FINAL 12/9	**FINAL EXAM 4:30-6:30pm**	

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" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on Research and Scholarship Misconduct.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
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
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
eeotix.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
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
osas.usc.edu

OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.
USC Campus Support and Intervention - (213) 821-4710
campussupport.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
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
dps.usc.edu, 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) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
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.

*Occupational Therapy Faculty Practice - (323) 442-33*40 or otfp@med.usc.edu
chan.usc.edu/otfp
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.