



Course ID and Title: AME 436 Automotive and Flight Propulsion

Units: 3 (through Spring 2026); 4 (from Spring 2027 onwards)

Spring: 110 minute lectures, twice weekly

Location: Tuesdays and Thursdays 9:00 – 10:50 am, ZHS 252

Zoom: <https://usc.zoom.us/j/99760321116>

Instructor: Paul Ronney

Office: OHE 400B

Office Hours: Thu 3 – 6 pm, OHE 406 and Zoom: <https://usc.zoom.us/j/99574350347>

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Course producer: Adam White

Office hours: by request

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Course Description

This course provides juniors, seniors, and graduate students with an understanding of combustion engines including reciprocating-piston, gas turbine, and rocket types along with their advantages and disadvantages compared to non-combustion source of shaft and motive power. This course is intended for seniors and master's students interested in applying the fundamentals of thermodynamics to practical vehicle propulsion systems and is required for undergraduate Aerospace Engineering majors. In addition to ideal cycle analysis and performance evaluation, students will learn how to estimate quantitatively the impact of nonideal effects including heat losses, friction, slow burn rates, viscous drag, shock waves, and compressibility. Pollutant formation and remediation and its impact on practical engine design is stressed.

Learning Objectives

After completing this course, students will be able to:

1. Explain the similarities and differences between the various types of internal combustion engines (premixed-charge reciprocating, non-premixed charge reciprocating, turbojet, turbofan, ramjet, scramjet, liquid- and solid-propellant rockets, etc.)
2. Assess the advantages and disadvantages of internal combustion engines for automotive, aircraft, and spacecraft applications compared to alternatives such as steam, electric, and solar power sources.
3. Calculate flame temperature for idealized fuel-air mixtures (constant specific heats, no dissociation, etc.)
4. Describe how ideal flame temperatures are affected by non-ideal factors such as variable specific heats, dissociation, heat losses, etc.
5. Explain the difference between laminar premixed flames, turbulent premixed flames, homogeneous reaction (knock) and non-premixed spray or droplet flames as they pertain to internal combustion engines
6. Describe how NO, CO, unburned hydrocarbons and soot emissions are formed in engines, explain how they are minimized, and estimate how changes in engine operating conditions affect these emissions.
7. Analyze an ideal engine cycle (for either reciprocating or steady-flow engines) using P-v and T-s diagrams

8. Analyze the performance (indicated mean effective pressure, thrust specific fuel consumption, thermal efficiency, etc.) of an ideal Otto, Diesel, Brayton, etc. thermodynamic cycle.
9. Estimate the performance (indicated mean effective pressure, thrust specific fuel consumption, thermal efficiency, etc.) of an Otto, Diesel, Brayton, etc. thermodynamic cycle using a chemical thermodynamics computer program such as GASEQ.
10. Estimate the effect of non-ideal processes (throttling, slow burn, heat losses, knock, compressor/turbine losses, etc.) on an engine cycle using P-v and T-s diagrams
11. Explain how these non-ideal processes affect engine design and performance.
12. Perform simple analyses on the performance of turbomachinery (compressors and turbines)
13. Analyze one-dimensional compressible flows (isentropic, Fanno, shocks, and heat addition at constant area, temperature, or pressure)
14. Analyze and compare the performance of hypersonic propulsion cycles (*e.g.*, constant-A, constant-T, constant-P)
15. Compute the specific impulse of liquid and solid rocket propulsion cycles

Prerequisite: AME 310 (Engineering Thermodynamics)

Recommended Preparation: AME 309 (Dynamics of Fluids)

Course Notes

Letter grade. Lecture notes will be posted on Piazza with homework submitted via Gradescope. Discussions regarding homework and exams will be hosted on Piazza.

Technological Proficiency and Hardware/Software Required

Several aspects of the course will require the use of GASEQ, a free Windows program for chemical equilibrium calculations. Familiarity with Excel functions will be needed; much of the analysis presented in class employs spreadsheet-type models.

Required Readings and Supplementary Materials

There is no required textbook; the lecture notes are the primary source of information. Optional readings from the optional texts are listed in the Course Schedule table.

Optional Readings and Supplementary Materials

- Heywood, J. B., Internal Combustion Engine Fundamentals, 2nd Ed., McGraw-Hill, 2018, ISBN-13: 9781260116106
- Mattingly, J. D. and Boyer, K. M., Elements of Propulsion: Gas Turbines and Rockets, 2nd Ed., AIAA Education Series, 2016, ISBN-13: 9781624103711
- Turns, S. and Haworth, D. C., An Introduction to Combustion: Concepts and Applications, 4th Ed., McGraw-Hill, 2021, ISBN-13: 9781260477696

Description and Assessment of Assignments

The course activities are

- Lectures (4 hours per week) with associated homework sets (7)
- Exams (2 in-class midterms, 1 final exam)

Grading Breakdown

Assessment Tool	% of Grade
Homework (7 assignments; lowest grade dropped)	35
Midterm exam 1	20
Midterm exam 2	20
Final exam	25
TOTAL	100

Assignment Submission Policy

Assignments will be posted on Piazza (for discussion) and submitted via Gradescope

Course Specific Policies

- Exams will be open book and notes. The two midterm exams will each be 110 minutes in duration. The final exam will be 120 minutes in duration.
- Late homework will be marked down 10% per day (1 second to 24 hours) late. Since everyone has some valid reason for missing or doing poorly on at least one homework assignment, your lowest homework score will be eliminated. Requests for extensions will be considered in special circumstances (attendance at student conferences, participation in athletic events, etc.) but **only if requested at least 3 days before the homework is due.**
- Since there will be 7 homework assignments (approximately one every two weeks), each assignment will be about twice as long as those in a class with weekly assignments.
- The deadline for disputing grading of homework or exams is two weeks from the day the graded material and solutions are returned.
- Electronic versions of homework and exam solutions will not be posted. Hard copies will be available for on-campus students; "ONLINE" students will have solutions emailed to them.
- There will be no "extra credit" assignments.
- Grading policy
 - The average course grade will be close to the Viterbi School undergraduate average of about 3.3/4.0
 - The two midterms and the final exam will be curved so that obtaining a class-average score on either will result in the same number of points earned toward the total course score.
 - History has shown that the vast majority of students receiving low grades in this course did not turn in homework assignments, which count for 35% of the total course grade. So, turn in every assignment, even if it's not complete or there are parts you know aren't fully correct.

Attendance

All students (except students registered in the "ONLINE" section) are expected to attend class in person. No attendance is enforced, but it is up to the student to make sure they make up for missed classroom time. Any planned absences require permission in advance from the instructor within the first 2 weeks of class. Exam dates (mid-term, final) are not movable and attendance must be in person (except Online students)

Tentative Course Schedule

“Plans are nothing – planning is everything” – Dwight D. Eisenhower

Week (Monday date)	Topics/Daily Activities	Optional supplemental readings	Assignment Due / Exams [Learning objectives assessed]
Week 1 (1/8)	Introduction – combustion engines & comparison with other prime movers		
Week 2 (1/15)	1 st law of thermodynamics applied to chemically reacting systems Chemical equilibrium	Heywood Ch. 3, 4; Turns 2	
Week 3 (1/22)	Chemical reactions and combustion I - flames	Turns 4, 5, 8, 9, 10	Homework 1: prime mover comparisons; chemical thermodynamics [1, 2, 3, 4]
Week 4 (1/29)	Chemical reactions and combustion II – pollutant formation and remediation	Heywood 11; Turns 15	
Week 5 (2/5)	Using P-v and T-s diagrams	Heywood 5.1 – 5.3	Homework 2: combustion and pollutant formation [5, 6]
Week 6 (2/12)	Reciprocating engines - ideal cycle analysis	Heywood 2, 5.4 – 5.7	Midterm 1 [2 – 6]
Week 7 (2/19)	Reciprocating engines - nonideal effects	Heywood 5.8	Homework 3: ideal cycle analysis of reciprocating engines [7, 8, 9]
Week 8 (2/26)	Combustion in reciprocating engines – knock, misfire, emissions	Heywood 9, 10	
Week 9 (3/4)	Thrust and aircraft range	Mattingly 4	Homework 4: nonideal cycle analysis of reciprocating engines [10, 11]
(3/11)	SPRING BREAK		
Week 10 (3/18)	Compressible flow – isentropic, shocks, Fanno, diabatic	Mattingly 3	Midterm 2 [7 – 11]
Week 11 (3/25)	Gas turbines - ideal cycle analysis	Mattingly 5.1 – 5.8	Homework 5: ideal cycle analysis of gas turbine engines [7, 8, 9, 13]
Week 12 (4/1)	Gas turbines - turbomachinery	Mattingly 9	
Week 13 (4/8)	Gas turbines – nonideal effects	Mattingly 5.9 – 5.11, 6, 7	Homework 6: nonideal cycle analysis of gas turbine engines [10, 11, 12]
Week 14 (4/15)	Hypersonic propulsion	Mattingly 8	
Week 15 (4/22)	Liquid and solid rockets	Mattingly 10	Homework 7: hypersonic propulsion & rockets [13, 14, 15]
FINAL	Final Exam (Tuesday May 7, 8:00 – 10:00 am)		Refer to the final exam schedule in the USC <i>Schedule of Classes</i> at classes.usc.edu .

The readings are optional, not required. You will not be responsible for material in these readings that is not covered in lectures or the lecture notes, however, you WILL be responsible for material covered in the lectures but not the lecture notes.

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the [USC Student Handbook](#). All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the [student handbook](#) or the [Office of Academic Integrity's website](#), and university policies on [Research and Scholarship Misconduct](#).

- You may
 - Work with others to find solutions to homework assignments
 - Study with others for exams
- You may NOT
 - Copy homework assignments from others – even if you work together, you must prepare and turn in assignments that were created by you only
 - Work together during exams

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Violation	USC - Recommended Sanction for Undergraduates*	AME - Recommended Sanction for Undergraduates and Graduates
Copying answers from other students on any course work.**	F for course.	First offense: F on assignment. Second offense: F for course.
One person allowing another to cheat from his/her exam or assignment.	F for course for both persons.	If assignment: First offense: F on assignment. Second offense: F for course. If exam: F for course.
Possessing or using material during exam (crib sheets, notes, books, etc.) which is not expressly permitted by the instructor.	F for course.	First offense: F on exam. Second offense: F for course.
Continuing to write after exam has ended.	F for course.	F on exam
Taking exam from room and later claiming that the instructor lost it.	F for course and recommendation for further disciplinary action (possible suspension).	F for course
Changing answers after exam has been returned.	F for course and recommendation for further disciplinary action (possible suspension).	F for course
Fraudulent possession of exam prior to administration.	F for course and recommendation for suspension.	F for course
Obtaining a copy of an exam or answer key prior to administration.	Suspension or expulsion from the university; F for course.	F for course
Having someone else complete course work for oneself.	Suspension or expulsion from the university for both students; F for course.	F for course
Plagiarism — Submitting other's work as one's own or giving an improper citation.	F for course.	First offense: F on assignment. Second offense: F for course.
Submission of purchased term papers or papers done by others.	F for course and recommendation for further disciplinary action (possible suspension).	F for course
Submission of the same assignment to more than one instructor, where no previous approval has been given.	F for both courses.	F for both courses
Unauthorized collaboration on an assignment.	F for the course for both students.	First offense: F on assignment. Second offense: F for course.
Falsification of information in admission applications (including supporting documentation).	Revocation of university admission without opportunity to reapply.	Revocation of university admission without opportunity to reapply.
Documentary falsification (e.g., petitions and supporting materials; medical documentation.)	Suspension or expulsion from the university; F for course when related to a specific course.	Suspension or expulsion from the university; F for course when related to a specific course.
Plagiarism in a graduate thesis or dissertation.	Expulsion from the university when discovered prior to graduation; revocation of degree when discovered subsequent to graduation.***	Expulsion from the university when discovered prior to graduation; revocation of degree when discovered subsequent to graduation.***

*Assuming first offense

**Exam, quiz, tests, assignments or other course work.

***Applies to graduate students

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

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

[988 Suicide and Crisis Lifeline](#) - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

[Relationship and Sexual Violence Prevention Services \(RSVP\)](#) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

[Office for Equity, Equal Opportunity, and Title IX \(EEO-TIX\)](#) - (213) 740-5086

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

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 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) 740-0411

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

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

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

Non-emergency assistance or information.

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

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) 442-2850 or otfp@med.usc.edu

Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.

Suggestions for how to do well in this class (applies to almost any class, really):

- 1. Come to lectures!** There IS a very good correlation between attendance and performance in the course. The lecture notes are a **supplement** to lectures, not a replacement. **Do not assume that you can learn everything by reading the lecture notes. If a topic is clarified or expanded upon in class but not in the lecture notes, it's fair game for homework and exam questions.** The fact that you “didn’t know” something that was discussed in class is not an excuse. Also, exams will mirror lectures ... obviously the stuff I discuss most in class is the stuff mostly likely to appear on exams.
- 2. Read the lecture notes!** Everything on the homework and exams is covered in class and in the lecture notes.
- 3. Pick up your graded homework and exams and their solutions.** It’s remarkable that many students don’t. How can you know what you did correctly or incorrectly without comparing your answers to the “correct” ones? And without such feedback, how can you do better on subsequent homeworks and exams?
- 4. Tips for studying for and taking exams**
 1. Do the posted sample exams, homework, and examples in lecture notes without looking at answers. Some students tend to spend too much time on the first problem and try to get it “just right” before moving on to the next one. If you’re particularly prone to that, after getting your graded exam back, try re-doing the exam backwards, i.e. last problem to first problem.
 2. Since electronic versions of the lecture notes are not allowed during exams, put hard copies of all the lecture notes into a 3-ring binder then (and here’s the important part) create a system of tabs or some type of indexing (e.g. where key topics like “burning velocity” “T-s diagrams” “knock” etc. are located) so you can find things quickly. Just the process of doing this organization will force you to ask yourself, “What are the important topics in this course? Where can I find them in the notes?”
 3. Work both independently and as part of a group. As much as you may think otherwise, you really don’t understand something until you have to explain it to someone else.
 4. During the exam, budget your time and pick the low hanging fruit.