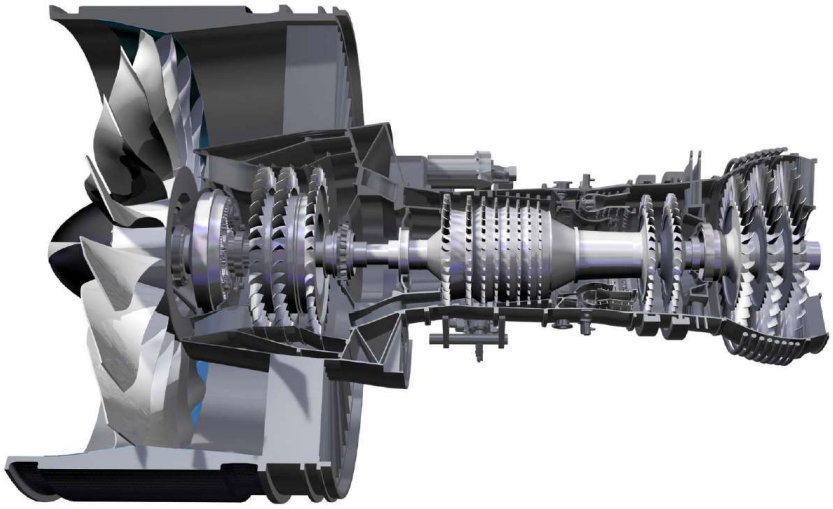
ASEN 4013: Foundations of Propulsion



CLASSROOM: AERO 120 (MWF, 1:55-2:45 am)

Homework & Exams: Please see the Schedule

Final Exam: Thursday, 11 Dec, AERO 120, 1:30pm-4pm

INSTRUCTOR: Prof. James Nabity
Office: AERO N305
Phone: 303-492-3243
Email: james.nabity@colorado.edu
Office Hours: AERO 302, W 9:30-10:30am
AERO N250, TuTh 5:30-7pm
Other days/times TBD

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WEB SITE: https://canvas.colorado.edu/

TEXTBOOK:
Required: Mattingly and Boyer (2016). **Elements of Propulsion Gas Turbines and Rockets, 2nd Ed.**, ISBN-13: 978-1-62410-371-1 (including supplementary material available by download)

Other Useful References:

1. Textbooks
    a. Oates, Aerothermodynamics of Gas Turbine and Rocket Propulsion, AIAA (A somewhat dated book on propulsion)
    b. Hill P., and C. Peterson (1992). Mechanics and Thermodynamics of Propulsion, 2nd Ed., Addison---Wesley (an excellent, albeit dated, reference on the subject)
    c. Sutton, G. P. and O. Biblarz (2001). Rocket Propulsion Elements, 8th Ed., Wiley (Classic text on rocket propulsion, extensively updated --- an excellent reference on the subject)
2. Journal articles, Conference papers and Technical reports
3. Personal notes

PREREQUISITES: ASEN 3713 & APPM 2360

REQUIRED EQUIPMENT: As needed for access to Canvas and Gradescope, lecture attendance, completion of assignments, and exams

COURSE OBJECTIVES: The goal of this course is to build an understanding of the different types of propulsion systems (both airbreathing and rocket), their relative performance trade-offs, and how they fit within the context of a vehicle "system". Specific emphasis will be placed on fundamental cycle analyses, component and propulsion system level understanding, and challenges with propulsion integration. Students will apply thermodynamics, aerodynamics/fluid mechanics, compressible and viscous gas flows, structural/thermal systems, physics and chemistry.

TOPICAL OUTLINE:

1. Introduction & Overview (Chapter 1)
2. Fundamentals (Chapters 2 & 3)
    a. Engineering solution method
    b. Thermodynamics
    c. Control volume analysis
    d. Perfect gas
    e. Chemical reactions
    f. Inviscid & compressible flows
    g. Normal shock
3. Compressible flows (Chapters 3)
4. Analysis and performance of airbreathing propulsion systems (Chapters 4-8, 11)
    a. Aircraft gas turbine engine
    b. Parametric cycle analysis of idealized engines
    c. Component performance - inlets, nozzles and combustors
    d. Parametric cycle analysis of real engines
    e. Engine performance analysis
5. Rocket Propulsion (Chapter 10, instructor provided material)
    a. Cold gas and monopropellant thrusters
    b. Liquid bi-propellant engines

c. Solid rockets and rocket motor modeling & simulation
d. Hybrid motors
e. Electric propulsion

COURSE ASSIGNMENTS:

- Readings
- Lectures
- Homework
- Quizzes
- Exams

ACADEMIC INTEGRITY AND GRADE SCHEDULE:

Evaluated Outcomes: The Department of Aerospace Engineering Sciences has adopted a policy of assigning grades according to "evaluated outcomes" in each course:

- O1 Professional context and expectations (ethics, economics, business environment, etc.)
- O2 Current and historical perspective
- O3 Multidisciplinary, systems perspective
- O4 Written, oral, graphical communication ability
- O5 Knowledge of key scientific/engineering concepts
- O6 Ability to define and conduct experiments, use instrumentation
- O7 Ability to learn independently, find information
- O8 Ability to work in teams
- O9 Ability to design
- O10 Ability to formulate and solve problems
- O11 Ability to use and program computers

Evaluation of these outcomes allows an assessment of your performance and provides a major portion of the process we (the Faculty) use for continuous assessment and improvement of the entire AES curriculum. The model for these outcomes derives from several sources including the "Desired Attributes of an Engineer" as defined by The Boeing Company, and "curriculum reviews" from major aerospace corporations including The Boeing Co., Lockheed Martin Corp., and Ball Aerospace Corp. These inputs were combined with the AES faculty vision of the desired attributes of an aerospace engineer and the requirements of the Accreditation Board for Engineering and Technology (ABET) to produce this list of evaluated outcomes. Each assignment is designed and graded to assess some combination of several or a few of the outcomes.

Grade Breakdown: Your final grade is determined according to the following percentage breakdown (see below for additional information regarding assignments and individual grade assessment).

Table 1. Grade Breakdown

Type	**Description**	**Percentage**
Individual	Quizzes	10%
Individual	Term Exams	75% (25% each)
Group	Homework*	15%
Total		**100%**

* *Although homework must be submitted individually, it can be discussed and therefore, counts as a 'group' grade.*

Table 2. Letter Grade Assignment for Final Student Grading

Letter Grade	Percent Grade	4.0 Scale
A	93-100	4.0
A-	90-92	3.7
B+	87-89	3.3
B	83-86	3.0
B-	80-82	2.7
C+	77-79	2.3
C	73-76	2.0
C-	70-72	1.7
D	60-69	1.0
F	Below 60	0.0

IMPORTANT NOTES AND CLASS POLICIES:

1. Homework assignments and quizzes are due at the start of class on the due date. Please be sure to attend class regularly and arrive on time! If you must miss class for an excused absence, you may submit your homework early. **Late homework submittals are not accepted** - this includes homework slipped under the professor's door after class has started. However, if you will not be attending class, you may submit your homework prior to class.
2. **In the case of homework, report, presentation, or exam conflicts, you must make arrangements with the professor at least two weeks in advance. There are no unexcused make-up assignments or exams.**
3. Each homework assignment will include a set of problems, which you are expected to completely solve using the Engineering Solution Approach. This approach entails the following elements:
    - **Problem statement** (*this will be given*)
    - **Sketch the system**: *diagram the problem* with given information
    - **Governing principles**: *state the governing principles applicable to this problem*
    - **Governing equations**: a mathematical formulation of physics (*describe the governing equation(s), e.g. the Navier-Stokes equations*)
    - **State Assumptions**: implications and influence on governing equations (*declare all simplifying assumptions*)
    - **Solve** using the simplified equation set and tools (*show your work!*)
    - **Critically assess** your solution. *Is the answer reasonable? Are the simplifying assumptions sound? Use the text, class notes, literature or other engineering rationale to defend your results.*

    Your assignment will be partially graded for completeness (10 pts), one randomly selected problem will be graded in detail for accuracy (10 pts) and each student will provide feedback on an instructor selected problem to two of your peers who will be randomly assigned for each HW assignment (10 pts). Thus, the final score for each homework set will be out of a total of 30 pts and computed based upon the numeric breakdown below:

$$HW\ Score = P1\ score + \ P2\ peer\ feedback + \ 10\ pts \cdot \frac{\#\ remaining\ problems\ completed}{\#\ remaining\ problems\ in\ the\ HW\ set}$$

Solutions will be provided for all problems shortly after the submission due date.

4. Group collaboration is permitted on homework, but efforts are individual. This means you may discuss the means and methods for solving problems and even compare answers, but you are not free to copy someone's work or the solutions manual. **The homework you submit must be your own.** ***Copying material from any resource (including solutions manuals) and submitting it as one's own work is considered plagiarism and is an Honor Code violation. Keep in mind that the more you think about the problems yourself, the more you will learn, and the easier it will be to succeed on exams.***

   Homework solutions must demonstrate an understanding of the principles involved by including diagrams, using correct notation and terminology, explaining the approach, showing the key steps to obtaining the solution, and outlining the answer with proper units. These problem---solving steps are critical for developing problem formulation skills.

5. **Collaboration on quizzes or exams, using another student's work as your own, or allowing another student to use your work as their own, is considered academic misconduct and will not be tolerated. If you are caught in any of these activities, you may receive a grade of "F" for the course and a report may be made to the Dean's office for further punitive action.**

6. **Complete homework on 8.5×11-inch paper or equivalent size if electronic. Submit via Gradescope.** You may use both sides of ruled notebook paper. However, use only the front side of engineering paper. Your name (last, first), assignment number, and due date should be visible on the outside in the upper portion of each page, to the right of the fold. Written work must be neat and readable with adequate spacing and margins. You are responsible for legibility – no reevaluation will be granted. Illegible work will not be graded and a score of zero recorded. Messy work will be docked points. **Final answers must be indicated with an arrow or box, or underlined.** Multiple answers (when only one is required) will be counted as incorrect.

   Always submit work with a professional appearance. Neatness, clarity, and completeness count in the work world!

7. Always have a laptop, tablet or calculator and your textbook for lectures and office hours.

8. Use of MATLAB is permitted, but not always desirable. MATLAB code will not suffice for homework solutions without prior permission, please write out your work in "human" readable format (we will not try to decipher your code). MATLAB figures should be legible, and have meaningful axes and legends.

9. Lectures are an important part of your training as an engineer. Some of the material covered in class is not in the textbook. Online quizzes proctored via Canvas will draw from the lecture material. ***Like the exams, there are no unexcused make-ups for missed quizzes.***

10. A cordial atmosphere is expected at all times within the classroom. Respect and be courteous to other students. Maintain a quiet work atmosphere; excessive noise distracts others. ***Please note, Lectures and Office Hours may be recorded.***

11. Expect new material to be presented in lecture/discussion periods. **Quizzes and exams can cover any material in the course including information from the textbook, lecture/discussions, homework, and supplemental handouts.**
12. Rationale for course assignments:

- Reading assignments are to be completed *before* the lecture/discussion since this material will be on the quizzes. The lecture/discussions should help to clarify and supplement what you have read.
- Homework reinforces classroom instruction such that you may become proficient in the field of propulsion. These help you to learn how to synthesize and communicate the basic concepts, methods, and tools presented in the course curriculum. In addition to the assigned homework, I encourage you to work additional problems for practice. Before beginning any homework assignment, you should read the text and review the examples in the text.
- Homework, quizzes and exams provide a gauge to determine what *you* have learned.

GRADING PHILOSOPHY

Assignments are graded to an absolute standard designed to indicate your level of competency in the course material. Minor adjustments may be made in the assignment of final grades, yet grading on a "curve" will be limited. The final grade indicates your readiness to continue to the next level in the curriculum. The AES faculty have set these standards based on our education, experience, interactions with industry, government laboratories, others in academe, and according to the criteria established by the ABET accreditation board.

The course grade is primarily dependent on individual measures of competency, i.e. exams and quizzes. The other course assignments are designed to enrich the learning experience and to enhance individual performance, not to substitute for sub-standard individual competency. Accordingly, group assignment grades are only incorporated into the final grade when the individual grade is a C or better. **In other words, if your individual average is below a C, the group-based grade fraction will not be averaged into your final grade, which will then be based solely on your individual score.** This policy makes it important to use the group assignments to enhance your own learning. If the work in the assignment is split up among group members, be sure that the learning is not also split up, but is shared among the whole group. For these purposes, exams and quizzes are considered 'individual' grades (85%) while homework assignments (15%) are considered 'group' grades.

SYLLABUS STATEMENTS

Please see the link below for syllabus statements.

HTTPS://WWW.COLORADO.EDU/ACADEMICAFFAIRS/ABOUT/POLICIES-CUSTOMS-GUIDELINES/REQUIRED-SYLLABUS-STATEMENTS

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, marital status, political affiliation, or political philosophy.

Additional classroom behavior information:
Student Classroom & Course-Related Behavior | Compliance, Ethics and Policy | University of Colorado Boulder
Honor Code and Student Code of Conduct | Student Conduct & Conflict Resolution | University of Colorado Boulder
Home | Office of Institutional Equity and Compliance | University of Colorado Boulder

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

If you have a temporary illness, injury or required medical isolation for which you require adjustment, please contact the instructor and/or TFs regarding missed work. Also see Temporary Medical Conditions on the Disability Services website.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. Understanding the course's syllabus is a vital part of adhering to the Honor Code.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: StudentConduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to

academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

Artificial Intelligence (AI)

Generative artificial intelligence tools—software that reproduces text, images, computer code, audio, video, and other content—have become widely available. Well-known examples include ChatGPT for text and DALL•E for images. This statement governs all such tools, including those released during our semester together. Keep in mind that the goal of gen AI tools is to reproduce content that seems to have been produced by a human, not to produce accurate or reliable content; therefore, relying on a gen AI tool may result in your submission of inaccurate content. It is your responsibility—not the tool's—to assure the quality, integrity, and accuracy of work you submit in any college course. If gen AI tool use is suspected in completing assignments for this course in ways not explicitly authorized, I will follow up with you. I may contact the Office of Student Conduct & Conflict Resolution to report suspected Honor Code violations. In addition, you must be wary of unintentional plagiarism or data fabrication. Please act with integrity, for the sake of both your personal character and your academic record.

Limited Gen AI Use: You may use gen AI tools for specific functions in this course that will augment your learning, but their use is limited to the following particular tasks:

- Grammar checks but not for rewriting text of the assignment.
- Generating key words and phrases or ideas or outlines for a report is acceptable, BUT the final work must be student-generated, summarizing or synthesizing content as outlined for the assignment.

You are not permitted to use Gen AI for problem-solving on your homework or exams, and you are not permitted to use Gen AI to generate text for any written assignment.

Should you use gen AI tools on an assignment in this class, document your usage with the Chicago Manual of Style (link below) or appropriate citation guidelines as specified in the problem assignment.

https://www.chicagomanualofstyle.org/qanda/data/faq/topics/Documentation/faq0422.html

Religious Accommodations

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments, or required attendance. Please communicate the need for a religious accommodation in a timely manner. In this class, the due dates for completion of assignments and the take home exam will be scheduled to avoid conflict with the observance of religious holidays. Please notify the instructor should a conflict or need arise due to religious observance obligations.

See the campus policy regarding religious observances for full details.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email cureport@colorado.edu.

Information about university policies, reporting options, and support resources including confidential services can be found on the OIEC website.

Please know that faculty and graduate instructors must inform OIEC when they are made aware of incidents related to these policies regardless of when or where something occurred. This is to ensure that individuals impacted receive outreach from OIEC about resolution options and support resources. To learn more about reporting and support for a variety of concerns, visit the Don't Ignore It page.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information does not always align with how they identify. If you wish to have your preferred name (rather than your legal name) and/or your preferred pronouns appear on your instructors' class rosters and in Canvas, visit the Registrar's website for instructions on how to change your personal information in university systems.