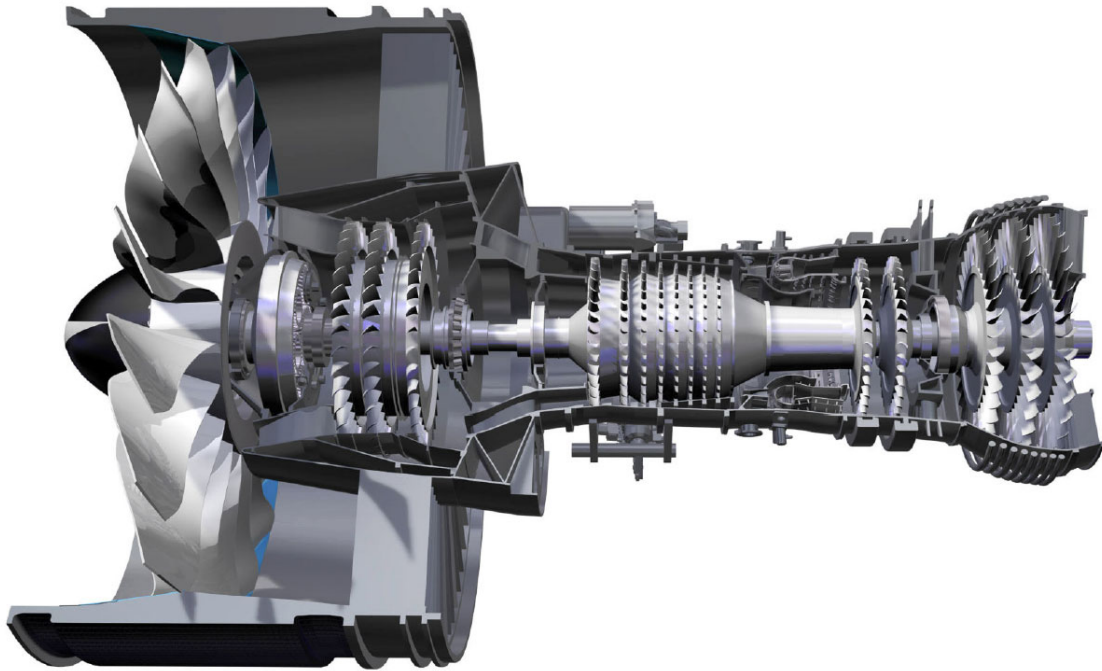


## ASEN 4013: Foundations of Propulsion



**CLASSROOM:** AERO 120 (MWF, 8:30-9:20 am)

**INSTRUCTOR:** Prof. James Nabity

Office: AERO N305

Phone: 303-492-3243

Email: james.nabity@colorado.edu

Office Hours: TBD

**Major Quizzes & Exams:**

See the Schedule

**Final Exam:** Project  
Report Due Wednesday,  
12/07/2022

**ASSISTANTS:**

TF: Gerald Yoho

[Gerald.Yoho@Colorado.EDU](mailto:Gerald.Yoho@Colorado.EDU)

TF: Alfredo Restrepo

[Alfredo.RestrepoJr@Colorado.EDU](mailto:Alfredo.RestrepoJr@Colorado.EDU)

TF: TBN

**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, 2<sup>nd</sup> Ed., Addison---Wesley (an excellent, albeit dated, reference on the subject)
  - c. Sutton, G. P. and O. Biblarz (2001). Rocket Propulsion Elements, 8<sup>th</sup> 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 3113 & APPM 2360

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

**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 aerodynamics, fluid mechanics, thermodynamics, structural/thermal systems, 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)
6. Rocket Project w/ solid rocket motor modeling & simulation with validation using experimental data

**COURSE ASSIGNMENTS:**

- Readings
- Lectures
- Homework
- Quizzes
- Term Exams
- Rocket Project Final Report

## 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 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	15%
Individual	Term Exams	50% (25% each)
Group	Rocket Project Final Report	25%
Group	Homework*	10%
<b>Total</b>		<b>100%</b>

\* 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:**

- Homework assignments are due at the start of class on the due date and quizzes may be given at any point during a class, so be sure to attend 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.
- 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.**
- 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 (10pts), while two randomly selected problems will be graded in detail for accuracy (10pts each, 20pts total). Thus the final score for each homework set will be out of a total of 30pts and computed based upon the numeric breakdown below:

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

Solutions will be provided to you for all the problems when the graded homework sets are returned.

4. Collaboration is permitted on homework. You may discuss the means and methods for formulating and solving problems and even compare answers, but you are not free to copy someone's assignment. Copying material from any resource (including solutions manuals) and submitting it as one's own is considered plagiarism and is an Honor Code violation. Remember, the less you think about the problems yourself, the less you actually learn, and the more difficult it will be to succeed on exams. ***Every student is expected to turn in their own individual assignment for grading!***
5. 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.

6. **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.**
7. **All homework and the project report must be completed on 8.5×11-inch paper. Submit via Canvas.** 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. Unacceptably messy work will be returned to you ungraded 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!

8. Always have a calculator and your textbook for lecture and office hours.
9. 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.

10. Lectures are an important part of your training as an engineer and is expected. Some of the material covered in class is not in the textbook. Online quizzes will draw from the lecture material. ***Like the exams, there are no unexcused make-ups for missed quizzes.***
11. 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 Hour may be recorded.***
12. 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.**
13. 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. 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.
  - Exams and quizzes provide a gauge to determine what *you* have learned.
  - The project helps you to learn how to synthesize and communicate the basic concepts, methods, and tools presented in the course curriculum.

## 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, but there is a limited amount of “curving” in the course. 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 in to 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 (65%) while homework and the rocket project (35%) are considered ‘group’ grades.

## SYLLABUS STATEMENTS

### CLASSROOM BEHAVIOR

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail 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, political affiliation or political philosophy. For more information, see the [classroom behavior](#) policy, the [Student Code of Conduct](#), and the [Office of Institutional Equity and Compliance](#).

### REQUIREMENTS FOR COVID-19:

As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. CU Boulder currently requires COVID-19 vaccination and boosters for all faculty, staff and students. Students, faculty and staff must upload proof of vaccination and boosters or file for an exemption based on medical, ethical or moral grounds through the MyCUHealth portal.

The CU Boulder campus is currently mask-optional. However, if public health conditions change and masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the Public Health Office ([contacttracing@colorado.edu](mailto:contacttracing@colorado.edu)). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the Public Health Office ([contacttracing@colorado.edu](mailto:contacttracing@colorado.edu)).

### **IF YOU ARE ILL OR QUARANTINED, PLEASE DO NOT COME TO AN IN-PERSON CLASS.**

- If quarantined and still able to do class work, then notify the instructor, participate remotely to extent practicable and turn in assignments on time.
- If illness or disability, then contact the instructor regarding missed work.

### ACCOMMODATION FOR DISABILITIES

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](mailto:dsinfo@colorado.edu) for further assistance. If you have a temporary medical condition, see [Temporary Medical Conditions](#) on the Disability Services website.

#### PREFERRED STUDENT NAMES AND PRONOUNS

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

#### HONOR CODE

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the [Honor Code](#). Violations of the Honor Code may include, but are not limited to: plagiarism, 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. All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution ([honor@colorado.edu](mailto:honor@colorado.edu); 303-492-5550). 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. Additional information regarding the Honor Code academic integrity policy can be found on the [Honor Code website](#).

#### 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 sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, protected-class discrimination and harassment, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these policies, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email [cureport@colorado.edu](mailto:cureport@colorado.edu). Information about university policies, [reporting options](#), and support resources can be found on the [OIEC website](#).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of any issues related to these policies regardless of when or where they occurred to ensure that individuals impacted receive information about their rights, support resources, and resolution options. To learn more about reporting and support options for a variety of concerns, visit [Don't Ignore It](#).

#### RELIGIOUS HOLIDAYS

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. 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 your professor should a conflict or need arise due to religious observance obligations.

See the [campus policy regarding religious observances](#) for full details.