

ASEN 4013 -- Foundations of Propulsion – Sp 2023 – TuTh 10:00-11:15 am – Aero 120

Instructor: Prof. Timothy K. Minton
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TA: Ethan Leong

TFs: Alfredo Restrepo, Brianna Gagliardi

TA/TF Office Hrs. Mondays, 5:00 pm – 6:00 pm; Aero N353 (starting Jan. 23)
Tuesdays, 12:00 pm – 1:00 pm; Aero 203 (starting Jan. 24)
Wednesdays, 5:00 pm – 6:00 pm; Aero N353 (starting Jan. 18)
Thursdays, 9:00 am – 10:00 am; Aero N253 (starting Jan. 19)
Fridays, 1:00 pm – 2:00 pm; Aero N253 (starting Jan. 20)

Web Page: This course uses Canvas and Slack.

Overview: Basic one-dimensional flows: isentropic; area change; heat addition. Overall performance characteristics of propellers, ramjets, turbojets, turbofans, rockets. Performance analysis of inlets and exhaust nozzles, compressors, burners, and turbines. Rocket flight performance, single and multi-stage chemical rockets, liquid, and solid propellants.

Course Materials: Lecture notes and relevant supplementary materials will be posted on Canvas. Access to the on-line course textbook (or a print version) is expected. Lecture notes take precedence over the course textbook.

Course Textbook: S. Farokhi, *Aircraft Propulsion: Cleaner, Leaner, and Greener, 3rd Edition*, Wiley, 2021.

On-line access to zyBook version of textbook:

1. Sign in or create an account at learn.zybooks.com
2. Enter zyBook code: COLORADOASEN4013Winter2023
3. Subscribe (subscription cost \$39 for semester)

Optional Textbooks: J. D. Mattingly and K. M. Boyer, *Elements of Propulsion: Gas Turbines and Rockets*, AIAA, 2nd Edition, 2016.

P. G. Hill and C. R. Peterson, *Mechanics and Thermodynamics of Propulsion*, Addison Wesley, 2nd Edition, 1992.

Ahmed F. El-Sayed, *Fundamentals of Aircraft and Rocket Propulsion*, Springer-Verlag London, 2016. [PDF downloadable from CU Library]

T. A. Ward, *Aerospace Propulsion Systems*, John Wiley & Sons (Asia) Pte Ltd, 2010.

A. M. Kuethe and C.-Y. Chow, *Foundations of Aerodynamics: Bases of Aerodynamic Design 5th Edition*, Wiley, 1997.

Related Aerodynamics Textbook: J. D. Anderson, Jr., *Fundamentals of Aerodynamics*, McGraw-Hill, 1991. [PDF file available online]

Approximate Course Outline:

Introduction

I. Thermodynamics of Gases

- properties of gases
- gas mixtures
- thermodynamic systems

Prob. Set 1

II. Aerodynamics

- quasi one-dimensional flow with area change
- shock waves and expansions
- converging/diverging nozzle flows
- quasi one-dimensional flow with heat addition

Prob. Set 2

EXAM 1

III. Air-Breathing Engines

- thrust, efficiency, and range
- Brayton cycle
- turbojets
- afterburners

Prob. Set 3

- turbofans
- propeller theory, turboprops
- ramjets, scramjets

Prob. Set 4

EXAM 2

IV. Engine Component Analysis

- inlets – supersonic, subsonic
- combustors, afterburners
- axial flow compressors
- axial flow turbines

Prob. Set 5

V. Rocket Propulsion

- rocket equation
- thrust and efficiency
- multi-staging
- chemical rocket propulsion
- liquid propellant rockets
- solid propellant rockets
- nozzles
- electric propulsion

Prob. Set 6

EXAM 3

Grading:

- 25% Problem Sets (6)
- 25% Exam 1 (75 min) – During regular lecture time
- 25% Exam 2 (75 min) – During regular lecture time
- 25% Exam 3 (75 min) – During regular lecture time

Grades will be assigned to indicate a student's level of competency in the course material. Accordingly, adjustments may be made in the assignment of final grades to reflect students' performance with respect to the current and historical average of the class. It is anticipated that the average grade (regardless of the absolute score) will be approximately a B-. The final grade indicates the student's achievement in the course according to AES Department standards based on experience, interactions with industry, government laboratories, others in academia, and according to the criteria established by the ABET accreditation board.

Office Hours:

- Office hours shall be used as a time for students to ask the TA, TFs, or each other questions about problem sets, exams, concepts presented in the lecture, etc. Students are expected to come to office hours with targeted questions.
- The office hour periods shall not be used as a time/place for students simply to study or work on their homework when they are not actively using the time to ask questions, participate in discussions, or listen to explanations provided by the TA, TFs, or student peers.

Problem Sets:

- The purpose of the problem sets is to aid the student in learning by working on problems related to the course material.
- Six problem sets of equal weights will be assigned.
- Students shall scan (or photograph) their problem sets and submit them *through Canvas* by **5:00 pm on their due dates. Late problem sets will not be accepted – no exceptions.** It is expected that students will upload their problem sets with sufficient time to overcome any problems with the upload, including potential problems with internet access. Furthermore, it is expected that students will verify that their problem sets have been successfully uploaded. Insufficiently legible work, **including corrupted files**, will not be graded and a score of zero will be recorded. Partially completed problem sets will be graded; therefore, if a student is not able to fully complete the problem set by the deadline, then submitting a partially completed problem set is better than submitting no problem set at all. Questions about the problem sets should first be directed to the TA or the TFs as soon as the questions arise.
- Problem set solutions will be posted on Canvas. For questions regarding the grading of a problem set, students should first discuss the issue with the TA or a TF, who will then decide whether the issue needs to be escalated to Prof. Minton.
- Collaboration is permitted on problem sets, but efforts are individual. **Every student is expected to turn in his/her/their own individual problem set for grading.** This means that students may discuss the means and methods for solving problems and even compare answers, but they are not free to copy someone's work or find solutions on the internet or in a solutions manual. Copying material from any resource and submitting it as one's own work may be considered plagiarism and an Honor Code violation.

- Use of MATLAB or other computer codes is permitted, but not always desirable. A computer code will not suffice for problem set solutions without prior permission from a TA/TF or Prof. Minton. Work shall be typed or written in legible handwriting (we will not try to decipher a student's code), and sufficient work must be shown to indicate to a grader that the student understands how the problem is solved. All graphs shall be legible and have meaningful axes and legends.
- For students who use a computer programming environment to solve a problem:
 - The script must be included in the student's submission, in PDF format.
 - The student must include a printout, in PDF format, of the command window which prints out the answer(s) to the question.
 - Do not screenshot code from the user interface and do not submit the source code file. Instead, copy and paste the code into the problem set submission. The TA or TFs must be able to run your code in order to properly assign points. Do not wait until the last hour to submit a problem set involving the use of a computer code. After submission, make sure the included code is able to be copy/pasted.
- Students should bear in mind that thinking independently about problems will enhance both learning and success on exams.

Exams:

- Exams 1, 2, and 3 will be given in the regular classroom (AERO 120) during the normal class time (10:00 am – 11:15 am) on the scheduled exam days. None of the exams will be cumulative. In other words, each exam will focus primarily on the material presented since the start of the course or since the previous exam, whichever applies. Prof. Minton will provide a list of topics to be covered on each exam prior to the exam.
- Each student will be allowed to bring a single note sheet to each exam. The note sheet shall be turned in with the student's completed exam and will be returned when the graded exam is returned. The attributes of a **note sheet** are as follows:
 - **A single sheet of physical paper, 8.5"x11" or A4.**
 - **Notes must be physically written onto the sheet by student's own hand, using an ink pen or lead pencil.**
 - **Notes may be written on the front and back of the sheet.**
 - **No electronic reproduction of any kind.**
 - **Examples of a non-compliant note sheet:**
 - **Two sheets with writing on one side each.**
 - **Two sheets stapled, glued, or taped together.**
 - **Printout from note sheet(s) prepared on a tablet or computer.**
 - **Sheet made of material other than standard paper, such as cardboard or cloth.**
 - **Sheet that is larger or smaller than 8.5"x11" or A4.**
- Students should make no assumptions about any deviations from the note-sheet policy and ask Prof. Minton if a clarification is desired.
- Exams turned in without a note sheet or with a non-compliant note sheet will be penalized during the grading process.
- A hand ("scientific") calculator is permitted during an exam. With the exception of note sheets, as described above, all other materials (e.g., textbooks, notebooks) will not be permitted during the exams. Electronic devices are not permitted during exams and must be turned off and put away during the exam – electronic devices include, but are not limited to: mobile phones, computers, tablets, Kindles, smart watches, and AR headsets. If a

student's electronic device is audible at any time during an exam, then that student shall be obliged to turn in his/her exam and exit the room immediately.

- Solutions to the exams will be posted on Canvas. For questions regarding the grading of an exam, students must first discuss the issue with the TA or one of the TFs **within one week following receipt of the graded exam**. The TA or TF will then decide whether the issue needs to be escalated to Prof. Minton.
- Make-up exams will only be approved under extraordinary situations for students with a legitimate excuse. If the make-up exam has not been approved by Prof. Minton at least 18 hours before the scheduled time of the exam, then the student will forfeit that exam and a grade of zero will be assigned. There are no unexcused make-up exams. [Note that Prof. Minton may not be able to receive the make-up exam request if it is made with too short notice.]
- A student who requires accommodations because of a disability shall submit an accommodation letter from Disability Services to the instructor in a timely manner (**minimum of two weeks in advance of the first exam**) so that the student's needs can be addressed. Furthermore, that student shall contact Prof. Minton and receive verification that the request has been received and shall work with Prof. Minton and/or the TA/TFs in good faith on any scheduling required to meet the accommodation.
- If in-person classroom instruction is not in effect during a scheduled exam time, then the exam shall be taken remotely, and instructions will be given if this becomes relevant. These instructions will supersede the exam policy above.

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 the student's performance and provides a major portion of the process that 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.

Behavioral Expectations:

- Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in-person, remote, or online. This includes respectful and courteous behavior, as well as ensuring a quiet work atmosphere without noise distractions (e.g., talking and audible sounds from electronic devices). 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. Those who fail to adhere to behavioral standards may be subject to discipline. For more information, see the [classroom behavior](#) policy, the [Student Code of Conduct](#), and the [Office of Institutional Equity and Compliance](#).
- Students are requested to use both title and name (i.e., “Professor Minton”, “Prof. Minton”, or “Dr. Minton”) when addressing Prof. Minton in electronic correspondence or during in-person conversations. The use of “Professor” without a following name, “Hello” without a following title and name, the word, “Hey,” and no name or salutation at all, are considered by Prof. Minton to be impolite.

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 a student requires accommodation because a disability prevents the student from fulfilling these safety measures, the student shall follow the steps in the “Accommodation for Disabilities” statement on this syllabus.
- Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must isolate and follow the guidance of the Public Health Office (contacttracing@colorado.edu). If a student is fully vaccinated and has been in close contact with someone who has COVID-19, then the student does not need to isolate; rather, the student should self-monitor for symptoms and follow the further guidance of the Public Health Office (contacttracing@colorado.edu). *In this class*, a student who is sick or quarantined should obtain lectures and other course materials on Canvas and contact the instructor to discuss any potential need for special consideration on an exam. There will be no special consideration for problem sets. If a student has been sick or quarantined with COVID-19 during the course, then the instructor will take this into consideration when assigning the student’s final grade.

Accommodation for Disabilities:

If a student qualifies for accommodations because of a disability, the student shall submit his/her accommodation letter from Disability Services to the instructor in a timely manner (**minimum of two weeks before a timed exam; otherwise as soon as the disability requires immediate attention/action**) so that the student's needs can be addressed. Furthermore, that student shall contact Prof. Minton and receive verification that the request has been received and shall work with Prof. Minton in good faith in any scheduling required to meet the accommodation. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](#). For assistance, Disability Services may be contacted at 303-492-8671 or dsinfo@colorado.edu. A student with a temporary medical condition should 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. Students are also encouraged to notify Prof. Minton directly of their preferred pronouns. 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: 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 the Honor Code (honor@colorado.edu; 303-492-5550). Students who are 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 a positive 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 concerns, and individuals who believe they 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 can be found on the [OIEC website](#).
- Faculty and graduate instructors have a responsibility to inform OIEC when 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, students should 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. The instructor will make every effort to accommodate a student's religious obligations provided that the student gives notification well in advance of the scheduled conflict (**minimum of two week's advance notice**). See the [campus policy regarding religious observances](#) for full details.

COURSE SCHEDULE ON NEXT PAGE

ASEN 4013 – SPRING 2023 SCHEDULE (subject to change *with notification*)

TUESDAY	THURSDAY
<u>Jan. 17</u>	<u>Jan. 19</u>
<u>Jan. 24</u>	<u>Jan. 26</u> Prob. Set 1 due, Friday, Jan. 27, 5:00 pm
<u>Jan. 31</u>	<u>Feb. 2</u>
<u>Feb. 7</u>	<u>Feb. 9</u> Prob. Set 2 due, Friday, Feb. 10, 5:00 pm
<u>Feb. 14</u> EXAM 1	<u>Feb. 16</u>
<u>Feb. 21</u>	<u>Feb. 23</u>
<u>Feb. 28</u>	<u>Mar. 2</u> Prob. Set 3 due, Friday, Mar. 3, 5:00 pm
<u>Mar. 7</u>	<u>Mar. 9</u>
<u>Mar. 14</u>	<u>Mar. 16</u> Prob. Set 4 due, Friday, Mar. 17, 5:00
<u>Mar. 21</u> EXAM 2	<u>Mar. 23</u>
<u>Mar. 28</u> SPRING BREAK no class	<u>Mar. 30</u> SPRING BREAK no class
<u>Apr. 4</u>	<u>Apr. 6</u>
<u>Apr. 11</u>	<u>Apr. 13</u> Prob. Set 5 due, Friday, Apr. 14, 5:00 pm
<u>Apr. 18</u>	<u>Apr. 20</u>
<u>Apr. 25</u>	<u>Apr. 27</u> Prob. Set 6 due, Friday, Apr. 28, 5:00 pm
<u>May 2</u>	<u>May 4</u> EXAM 3