ASEN 4013 -- Foundations of Propulsion – Sp 2025 – TuTh 10:00-11:15 am – Aero 120

Instructor: Prof. Timothy K. Minton
Office: AERO 371
E-mail: tminton@colorado.edu
Ofc. Hrs: by appointment

TAs: Sydney Alcaraz, Steven Latimer, Bhuvvaan Punukolu, Chris Ladaw
TA Office Hrs: Mondays, 5:30 pm – 6:30 pm; Aero N353 (starts Jan. 27)
Tuesdays, 11:30 am – 1:00 pm; Aero N353 (starts Jan. 21)
Wednesdays, 4:30 pm – 6:00 pm; Aero N353 (starts Jan. 15)
Thursdays, 5:30 pm – 7:00 pm; Aero N250 (starts Jan. 16)
Fridays, 1:00 pm – 2:30 pm; Aero N353 (starts Jan. 17)

Web Page: This course uses Canvas and Slack.

Overview: Review of relevant thermodynamics of gases. Basic one-dimensional flows: isentropic; area change; heat addition. Overall performance characteristics of turbojets, turbofans, ramjets, scramjets, propellers, 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. Overview of electric propulsion.

Course Materials: Lecture notes and relevant supplementary materials will be posted on Canvas. Note that, with the exception of the first lecture on January 14, recorded lectures will not be posted. 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*, John Wiley & Sons Ltd, 2022. ISBN 9781119718642 (physical book)

Most economical source (not endorsed by Prof. Minton):
https://ebooksbasic.com/product/aircraft-propulsion-cleaner-leaner-and-greener-3rd-edition-pdf-ebook/?gad_source=1&gclid=Cj0KCQiA4fi7BhC5ARIsAEV1YiYOtBDb2sgF_PKDjNnyA_zdpYkYqejn7Q_IGYtOPpXb5cb7uFxo324aAqBrEALw_wcB

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]

Course Outline:

Introduction

I. Thermodynamics of Gases
- properties of gases
- gas mixtures
- thermodynamic systems

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

III. Air-Breathing Engines
- thrust, efficiency, and range
- Brayton cycle
- turbojets
- afterburners
- turbofans
- propeller theory, turboprops
- ramjets, scramjets

IV. Engine Component Analysis
- inlets – supersonic, subsonic
- combustors, afterburners
- axial flow compressors
- axial flow turbines

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

Grading:

25% Problem Sets (12) – two problem sets with lowest scores will be dropped
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
25% Exam 4 (75 min) – During part of scheduled Final Exam time

Exam with lowest score will be dropped.

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 TAs 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 TAs 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.
- 12 problem sets of equal weights will be assigned, but only the scores of ten problem sets will count toward a student's grade. In other words, the two lowest problem set scores will be dropped.
- Students shall submit their problem sets ***through Gradescope*** by **5:00 pm on their due dates**. **Late problem sets will not be accepted – no exceptions!** If a student cannot properly upload a problem set by the due date and time, then a score of zero will be recorded. 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. 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 TAs 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 a TA, 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 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 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.
- **The use of generative artificial intelligence software** (e.g., ChatGPT) to assist in solving problems for problem sets **is not permitted**, and its use will be considered a violation of the Honor Code.
- Students should bear in mind that thinking independently about problems will enhance both learning and success on exams.

Exams:

- Four exams of equal weight will be given in the regular classroom (AERO 120) during the normal class time (10:00 am – 11:15 am for Exams 1, 2, and 3) or during the first portion of the scheduled final exam time (**Tuesday, May 6, 4:30 pm – 5:45 pm, for Exam 4**) on the scheduled exam days. Each exam will focus primarily on the material presented since the start of the course or since the previous exam, whichever applies. There is a minor exception for Exam 4, which will cover material that precedes the previous exam; however, that preceding material will be limited. Prof. Minton will provide a list of topics to be covered on each exam prior to the exam.
- Although four exams will be given, only the top three exam scores will count toward a student's grade. **No accommodations will be made for a student who misses an exam for any reason.** If a student is not able to take an exam, then a score of zero will be recorded for that exam. It is thus expected that all students will be able to take at least three of the four exams offered.
- 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 should 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 a TA **within one week following receipt of the graded exam**. The TA will then decide whether the issue needs to be escalated to Prof. Minton.
- A student who requires an accommodation because of a disability shall notify Prof. Minton that Disability Services has approved his/her/their accommodation request for the course. The student shall notify Prof. Minton **5 days in advance of the first exam, at a minimum,** 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 TAs in good faith on any scheduling required to meet the accommodation.

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 appropriate 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 and disrespectful.**

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation:

- 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 on 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. If a student has a temporary illness, injury, or required medical isolation, then the student shall contact Prof. Minton and discuss whether a special accommodation is needed.
- If a student has a required medical isolation, the student shall notify Prof. Minton by e-mail, and Prof. Minton will attempt to resolve potential issues related to ASEN 4013 as soon as possible. In may cases, the resolution may simply be the dropping of an exam or problem set score, as described under "Grading" on page 3 of this syllabus.

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 policy 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. All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution (StudentConduct@colorado.edu). 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 protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, 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 must 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 outreach from OIEC about resolution options and support resources. To learn more about reporting and support options for a variety of concerns, students should visit Don't Ignore It.

Religious Accommodations:
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. Prof. Minton 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.

Mental Health and Wellness:
The University of Colorado Boulder is committed to the well-being of all students. If a student who is struggling with personal stressors, mental health or substance use concerns that are

impacting academic or daily life should contact Counseling and Psychiatric Services (CAPS) located in C4C or call (303) 492-2277, 24/7. Free and unlimited telehealth is also available through Academic Live Care. The Academic Live Care site also provides information about additional wellness services on campus that are available to students.

COURSE SCHEDULE ON NEXT PAGE

ASEN 4013 – SPRING 2025 SCHEDULE (subject to change *with notification*)

TUESDAY	THURSDAY	
Jan. 14 Course intro; Review of thermo (1) [***Recorded Lecture – Prof. Minton on travel***]	Jan. 16 Review of thermo (2)	PS 1 due, Friday, Jan. 17. 5:00 pm
Jan. 21 Review of thermo (3)	Jan. 23 Review of thermo (4); Review of aero (1)	PS 2 due, Friday, Jan. 24, 5:00 pm
Jan. 28 Review of aero (2)	Jan. 30 Review of aero (3); normal shock example	PS 3 due, Friday, Jan. 31, 5:00 pm
Feb. 4 Oblique shock and expansion fan examples; Const. area heat addition (1)	Feb. 6 Const. area heat addition (2); Const. pressure heat addition	PS 4 due, Friday, Feb. 7, 5:00 pm
Feb. 11 **EXAM 1** [Jan. 14 – Feb. 6]	Feb. 13 Thrust and efficiency	
Feb. 18 Brayton cycle; Ideal turbojet (1)	Feb. 20 Ideal turbojet (2)	PS 5 due, Friday, Feb. 21, 5:00 pm
Feb. 25 Ideal turbojet (3); Real turbojet (1)	Feb. 27 Real turbojet (2); Afterburners	PS 6 due, Friday, Feb. 28, 5:00 pm
Mar. 4 Turbofans; Propeller theory (1)	Mar. 6 Prop theory (2); Turboprops; Ramjets (1)	PS 7 due, Friday, Mar. 7, 5:00 pm
Mar. 11 **EXAM 2** [Feb. 13 – Mar. 6; up through propellers and turboprops]	Mar. 13 Scramjets: ***Expert lecture – Dr. Tom West, NASA Langley Res. Center***	
Mar. 18 Ramjets (2); Inlets	Mar. 20 Combustors; Compressors (1)	PS 8 due, Friday, Mar. 21, 5:00 pm
Mar. 25 SPRING BREAK no class	Mar. 27 SPRING BREAK no class	
Apr. 1 Compressors (2)	Apr. 3 Turbines; Rocket intro	PS 9 due, Friday, Apr. 4, 5:00 pm
Apr. 8 Rocket eqn; Multistaging	Apr. 10 Multistaging optimization	PS 10 due, Fri., Apr. 11, 5:00 pm
Apr. 15 **EXAM 3** [Mar. 13 – Apr. 10]	Apr. 17 Char. velocity.; Thrust coeff.; Solid rocket analysis ***Substitute Lecture***	
Apr. 22 Rocket nozzles and efficien. (1) ***Substitute Lecture***	Apr. 24 Rocket efficiencies (2); Chemical propellants	PS 11 due, Fri., Apr. 25, 5:00 pm
Apr. 29 Chemical propellants (2); Electric propulsion (1)	May 1 Electric propulsion (2): ***Expert lecture***	PS 12 due, **Mon., May 5**, 5:00 pm
May 6 **EXAM 4: 4:30 – 5:45 pm** [Focus on Apr. 17 – May 1, but may cover rocket material from Apr. 4 onward]		