ASEN 5063
AIRCRAFT PROPULSION

Tuesdays and Thursdays 10:05 AM to 11:20 AM

Course Description:

This course is designed to teach the principles and practice of modern aircraft propulsion. It builds on the principles taught in ASEN 4013 (Fundamentals of Aerospace Propulsion). Gas turbine engines, principally turbofans, form an overwhelming fraction of modern aircraft engines. So the focus will be on turbofans, especially for commercial aircraft, although turboprops and military turbofans will also be considered. The emphasis will be more on the current state of aircraft propulsion, how engine selections are made, and what is necessary for success in the highly competitive field of aircraft propulsion. We will start with a review of the current state of aircraft propulsion and a brief history of gas turbine engines. After a brief overview of the Brayton cycle and a review of the principles of gas turbine engines, we will deal with analysis and design of various components: centrifugal and axial compressors, axial and radial flow turbines, inlets and nozzles, and burners. Compressor-turbine matching will be discussed, followed by analysis of off-design performance of gas turbine engines. Finally, environmental aspects of modern gas turbine engines, noise and emissions, will be dealt with.

We will be following an extensive set of notes I have prepared over the years. These notes will be made available on Canvas and will be supplemented by material from a recent textbook on *Aircraft Propulsion* by Farokhi, and a monograph on *Jet Propulsion* by Cumpsty, as needed.

Instructor:

Dr. Lakshmi Kantha
Professor
Department of Smead Aerospace Engineering Sciences
Office: Aerospace Building Room 463. Cell phone: 720-891-1775 (Please note that because of Covid-19 impact, I will be teaching from home. So it is best to e-mail me. Call me only if you need to contact me on an urgent matter).
E-mail: kantha@colorado.edu.

Office Hours: Tuesdays 3:00 PM to 5:00 PM

In addition, you can e-mail me any time for an appointment at a mutually convenient time. You are also welcome to call me to chat about latest events in the field or on any relevant issue or topic of your interest, but first notify me by e-mail to make sure I am free and available.

Office hours will be conducted remotely and not in the office as per CU regulations. The same applies to office hours with the TA.

Course Assistant (Teaching Fellow):

TBD
Email: TBD
Office Hours: TBD

Prerequisites: ASEN 4013 Undergraduate Course on Propulsion or Instructor's consent

Grading: Homework (8) – 40%, Quizzes (5) – 10%, Mid-Term Exam (1) – 20%, Final Project (or Exam) – 30%

Course Outline:

1. Introduction to Current State of Aircraft Propulsion
2. Brief Overview of Jet Propulsion
3. Thermodynamic Cycles – Brayton Cycle
4. Engine Selection
5. Brief Overview of Ideal and Real Cycle Analyses
6. Centrifugal and Axial Flow Compressors
7. Axial and Radial Flow Turbines
8. Inlets and Nozzles
9. Combustion and Burners
10. Component Matching
11. Engine Performance Analysis
12. Environmental Aspects – Noise and Emissions

Books and References:

1. ***Aircraft Propulsion***, by S. Farokhi, 2nd Edition, Wiley, 2014 (ISBN 1-56347-779-3). (***Required Text*** – *This is a well-written book, an excellent reference as well as a text. We will be using this book for some reading and homework assignments*).

2. ***Jet Propulsion***, by N. A. Cumpsty, Cambridge University Press, 2005 (ISBN 0-521-541441). **Call # TL709.3.T83 C85 2003** (*Supplementary. This book written by a leading gas turbine engine designer gives a step-by-step practical design example of a modern gas turbine engine*).

3. ***Compressor Aerodynamics***, by N. A. Cumpsty, Krieger Publishing Co, 2004 (ISBN 1-57524-247-8). **Call # TJ267.5.C5C86 2004** (*A comprehensive treatment of the arguably most critical component of a gas turbine engine, compressors. Ideal for a 6000 level course on the topic*).

4. ***Elements of Propulsion – Gas Turbines and Rockets***, by J. D. Mattingly, AIAA Education Series, 2006 (ISBN 1-56347-779-3). **Call # TL709.M388 2006** (*This book has a comprehensive treatment of gas turbine cycle analysis*).

5. ***Fundamentals of Jet Propulsion with Applications***, by R. D. Flack, Cambridge University Press, 2005 (ISBN 0-521-81983-0). **Call # TL709.F5953 2005** (*This text is very well-written but notations are irksome making it unsuitable as a text for this course*).

6. ***Theory of Aerospace Propulsion***, by P. M. Sforza, Elsevier, 2012 (ISBN 978-1-85617-912-6). **Call # TL709.S38 2012** (*This book was used as the text for ASEN 4013 for the past few years*).

7. ***An Introduction to Aerospace Propulsion***, by A. R. Douglas and M. Saarlas, Prentice Hall, 1996 (ISBN 0-13-120496-3). **Call # TL709.A7 1996** (*This book covers both gas turbines and rockets, and has a chapter on thermodynamic cycles and environmental impacts such as noise and sonic boom*).

8. ***Aircraft Engine Design***, 2nd Edition, by J. D. Mattingly, W. H. Heiser, and D. T. Pratt, AIAA Education Series, 2002 (ISBN 1-56347-538-3). **Call # TL709.5.T87 M38 2002** (*This book deals with design of aircraft engines, with a specific example of an engine for an advanced air-to-air fighter*).

9. ***Aircraft Engines and Gas Turbines***, 2nd Edition, by J. L. Kerrebrock, MIT Press, 2001 (ISBN 0-262-11162-4). **Call # TL709.K46 1992 (***A 6000 level book by the ex-director of the Gas Turbine Laboratory at MIT. Well-written and includes some other important aspects of aircraft engines such as engine noise and hypersonic engines*).

10. ***Principles of Turbomachinery in Air-Breathing Engines*****,** E. A. Baskeharone. Cambridge University Press, 2006 (ISBN 978-0-521-85810-6). **Call # TJ778.B33 2006** (*Good book on turbomachinery*).

11. ***Aerospace Propulsion***, by T.-W. Lee, Wiley, 2014 (ISBN 978-1-118-30798-4) (*An elementary treatment better suited for a 4000 level course*).

12. ***Aircraft Propulsion***, by V. Babu, CRC Press, 2009 (ISBN 1-43981-271-3) (*An elementary treatment*).

13. ***Mechanics and Thermodynamics of Propulsion***, 2nd Edition, by P. Hill, and C. Peterson, Addison Wesley, 1992 (ISBN 0-201-14659-2). **Call # TL709.H5 1992 (***A classic but dated. Remains a valuable resource on aerospace propulsion. It devotes about 1/3 each to fundamentals, air-breathing and rocket propulsion*).

14. **Gas Turbine Theory,** 4th Edition, by H. Cohen, GFC Rogers and HIH Sravanamutto, T. J. Press, 1996 (ISBN 0-582-23632-0). **Call # TL778.C6 1996** (*Classic but somewhat dated).*

Journals:

AIAA Journal of Propulsion and Power
AIAA Journal of Aircraft
AIAA Journal
ASME Journal of Engineering for Gas Turbines and Power
ASME Journal of Turbomachinery

Logistics:

We will make use of Canvas, to which I will upload my lecture notes for you to download if you like, post homework, homework solutions, quizzes and grades. We will be using Canvas for all matters related to the course, including e-mail. Please try not to use my regular e-mail for class business, since it may get lost in other e-mails I receive, including junk mail. For access to Canvas, please contact OIT at help@colorado.edu or 303-735-help. Obviously, you need to be registered for the course and you will need your identikey. All homework and assignments should be submitted in electronic form (.pdf, .docx, .ppt, .xlsx formats) with following naming convention: HW#_LastName.pdf . The same goes for other assignments with HW replaced by QZ, Exam or Finals.

The preferred programming language in this course is MatLab. We will be using MatLab at various stages during this course and therefore you need to know how to use it. Please brush up, if you are rusty.

Campus-mandated 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 policies on classroom behavior and the Student Code of Conduct.

Requirements for COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements, and public health orders in place to reduce the risk of spreading infectious disease. Required safety measures at CU Boulder relevant to the classroom setting include:

- maintain 6-foot distancing when possible,
- wear a face covering in public indoor spaces and outdoors while on campus consistent with state and county health orders,
- clean local work area,
- practice hand hygiene,
- follow public health orders, and
- if sick and you live off campus, do not come onto campus (unless instructed by a CU Healthcare professional), or if you live on-campus, please alert CU Boulder Medical Services.

Students who fail to adhere to these 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 policies on COVID-19 Health and Safety and classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the "Accommodation for Disabilities" statement on this syllabus.

Before returning to campus, all students must complete the COVID-19 Student Health and Expectations Course. Before coming on to campus each day, all students are required to complete a Daily Health Form.

Classes for this course will be taught completely on-line, with lectures, homework, quizzes, exams and discussions conducted via Canvas, and so there is no need for students taking this course to be on campus. The only exception (TBD) may be Final Projects that may require access to Departmental facilities such as the Machine Shop and Rocket Testing Bunker, in which case above protocols must be obeyed.

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 stay home and complete the Health Questionnaire and Illness Reporting Form remotely.

In this class, if you are sick or quarantined, please let me know about your absence by e-mail. Because of FERPA student privacy laws, students are not required to state the nature of their illness when alerting me.

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 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 policy 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 found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.

Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

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, just let me know so that we can avoid any conflicts.*** See the campus policy regarding religious observances for full details.