ASEN 5053
ROCKET AND SPACECRAFT PROPULSION

Tuesdays and Thursdays 11:30 AM – 12:45 PM

Aerospace Building N240

Course Description:

This course is designed to teach you the theory, analysis and design of modern rocket and spacecraft propulsion systems. We start from the basics of rocket propulsion, including some orbital mechanics to delineate the requirements. We will then discuss thermodynamics of rocket propulsion and nozzle flow theory, followed by in-depth study of various types of rocket propulsion: cold gas, monopropellant and bipropellant liquid rockets, solid and hybrid rockets, electric propulsion, nuclear rockets, and solar sails. If time permits, other exotic propulsion technologies will be dealt with. The goal is to provide you with a broad overview of this fast-changing field, including latest developments at NASA, ULA and SpaceX, as well as in-depth knowledge of rocket and spacecraft propulsion systems. The course is designed to be self-sufficient so that students who may not have taken the prerequisite undergraduate course on propulsion can successfully navigate it, albeit with some more effort, and benefit from it. ULA-sponsored graduate projects in the department, such as HySOR (Hybrid Sounding Rocket) and currently on-going AMARCS (Additively Manufactured Aerospike Reaction Control System), build upon the knowledge you gain in this course. Many of my students have also ended up working for major corporations such as ULA, SpaceX, Orbital ATK, Boeing and Lockheed Martin.

Instructor:

Dr. Lakshmi Kantha
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Office Hours: Tuesdays 2:00 PM to 4:00 PM (plus lunch hour on any weekday).

In addition, you can e-mail me any time for an appointment at a mutually convenient time. Please don't be hesitant to come see me, even if it is to chat about latest events in the field or on any relevant issue or topic.

Course Assistants:

TBD

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

Grading: Homeworks (8) – 40%, Quizzes (5) – 10%, Exams (1) – 20%, Final Project (or Exam) – 30%

Course Outline:

1. Introduction – History, Classification – Chemical, Electric, Nuclear. Examples
2. Principles of Jet and Rocket Propulsion, Ideal Rocket Equation, Single and Multi-Stage Rockets.
3. Basics of Orbital Mechanics, Space Flight, Orbit Perturbations, Orbit Maneuvers
4. Thermodynamics of Rocket Propulsion, Nozzle Theory, Over and Under-expanded Nozzles. Cold Gas Rockets
5. Heat Transfer, Regenerative and Radiative Cooling
6. Solid Propellant Rocket Motors, Burning Rate, Performance Analysis and Design. Examples.
7. Liquid Propellant Rockets - Monopropellant and Bipropellant. Combustion Thermodynamics. Pressure-fed and Pump-fed Systems. Analysis and Design. Examples.
8. Electric Propulsion Systems, Electrothermal, Electrostatic and Electromagnetic. Analysis and Design. Emerging and Exotic Systems.
9. Hybrid Rockets, Analysis.
10. Nuclear Propulsion, Principles and Analysis

Over the past 16 years of teaching this course, I have prepared an extensive set of notes I will be following. I will post each set of notes on D2L, well before we discuss the topics in the class. However, the following books are useful. The first of them is required.

Books:

1. ***Rocket Propulsion Elements*** by G. P. Sutton and O. Biblarz, 9th Edition, John Wiley and Sons, 2001 (ISBN 0-471-32642-9) (**Required Text,** *this version is extensively updated - an excellent reference on the subject. Contains some topics I do not cover in my notes*). Eigth edition is also acceptable.
2. ***Space Propulsion Analysis and Design***, Revised Edition, by R. W. Humble, G. N. Henry and W. J. Larson, McGraw Hill, 1995 (ISBN 0-07-031320-2). **Call # TL782.S62 1995** (**Recommended,** *more details on elementary aspects than can be found in Sutton's book*).
3. ***Spacecraft Propulsion*** by C. D. Brown, AIAA Education Series, 1996 (ISBN 1-56347-128-0). **Call # TL782.B68 1996** (*compact, concentrating mostly on spacecraft propulsion systems, unfortunately uses British units*).
4. ***Mechanics and Thermodynamics of Propulsion*** by P. Hill and C. Peterson, Second Edition, 1992, Addison-Wesley (ISBN 0-2011-46592). **Call # TL709.H5 1992** (***Classic*** *text on propulsion, one third dealing with rockets – an excellent reference*).

5. ***Rocket and Spacecraft Propulsion: Principles, Practice and New Developments*** by M. J. L. Turner, Third Edition, Springer, 2009 (ISBN 978-3-540-69202-7) **Call # TL782.T87 2009** (***Recommended,*** *written for the non-specialist - very readable, nice chapter on nuclear rockets*)
6. ***Elements of Spacecraft design*** by C. D. Brown, AIAA Education Series, 2002 (ISBN 1-56347-5243). **Call # TL875.B76 2002** (*Good discussion of orbital mechanics*).
7. ***Introduction to Rocket Science and Engineering*** by T. S. Taylor, CRC Press, 2009 (ISBN 978-1-4200-7528-1) **Call # TL782.T395 2009** (Rather elementary book but has a good chapter on rocket testing).
8. ***Astronuatics*** by U. Walter, Wiley-VCH Press, 2008 (ISBN 978-3-527-40685-2) **Call # TL791.W35 2008** (Excellent treatment of astronautical aspects of rocket propulsion).
9. ***Fundamentals of Electric Propulsion (Ion and Hall Thrusters)*** by D. M. Gobel and I. Katz, John Wiley, 2008 (ISBN 978-0-470-42927-3) **Call # TL783.63.G64 2008** (detailed discussion of electric thrusters)
10. ***Solar Sailing*** by C. R. McInnes, Springer 1999 (ISBN 1-85233-102-X) **Call # TL783.9.M39 1999** (Good discussion of solar sails)
11. ***Propellants and Explosives*** by N. Kubota, Second Edition, Wiley-VCH, 2007 (ISBN 978-3-527-31424-9) (*very good book on thermochemistry of propellants*)
12. ***International Launch Site Guide*** by S. R. Strom, Aerospace Press, 2005 (ISBN 1-884989-16-0) **Call #** TL4020.I58 2005 (Good description of launch sites, their history and facilities available as well as contact information)

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.

The preferred programming language of 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.