

# ROCKET AND SPACECRAFT PROPULSION

## ASEN 5053

**(Classroom – CAETE 1B14; Tuesdays and Thursdays 8:00 – 9:15 AM)**

### **Course Description:**

This course is designed to teach the theory, analysis and design of modern rocket and spacecraft propulsion systems. Starting from the basics of rocket propulsion and orbital mechanics, thermodynamics of rocket propulsion and nozzle flow theory will be discussed followed by in-depth study of cold gas, monopropellant and bipropellant liquid rockets, solid and hybrid rockets and electric propulsion. Finally, nuclear rockets, and if time permits, other exotic propulsion technologies will be dealt with.

### **Instructor:**

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**Office Hours:** Mondays 1:00 to 3:00 PM (plus lunch hour on any weekday)

**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 10 years of teaching this course, I have prepared an extensive set of notes I will be following. However, the following books are useful.

**Books:**

1. ***Rocket Propulsion Elements*** by G. P. Sutton and O. Biblarz, 8th 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*).
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. ***Astronautics*** 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)

Books #2 to #12 will be available on Reserve at the Engineering Library except #5, #9, #10 and #12, which I have borrowed. You don't need to purchase any of these.

### **Logistics:**

We will make use of CULearn, so that I may upload my lecture notes for you to download if you like, post homeworks, homework solutions and grades, and make the whole process a bit more efficient than the hard copy route. We will however, be selective in making use of the features available on CULearn. For example, we will use the e-mail and discussion board features, but not real-time chat sessions. Here is what you need:

### **Accessing CULearn**

Requirements:

1. Microsoft Internet Explorer 5+
2. Adobe acrobat reader plug-in
3. CU login and Identikey

Go to <http://www.microsoft.com> to obtain the latest Internet Explorer

Go to <http://www.adobe.com> to obtain the latest Acrobat Reader (free)

Go to <http://www.colorado.edu/its/docs/accounts/identikey.html> to set up your identikey