AAE 534 Spacecraft Electric Propulsion

Fall 2024

Tue./Thu. 3:00-4:15 PM, WANG 2579 (on-campus lecture section only)

Instructor: Alex Shashurin, ashashur@purdue.edu
Office hours: Tuesday, TBD Eastern Time in Zoom office at https://purdue-edu.zoom.us/j/7941406752

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Office hours: TBD

Text: R.G. Jahn, *Physics of Electric Propulsion* New York: McGraw-Hill, 1968.

Prerequisites: AAE334 or equivalent; PHYS 241 or equivalent; permission of instructor; Passing an undergraduate level electricity and magnetism course is a requirement, although fundamentals of the electromagnetic theory will be reviewed during the course.

Course description:
Spacecraft electric propulsion systems are intended to provide thrust for propelling spacecrafts in interplanetary missions, orbital maneuvers and attitude control. The course will start with reviewing material on mechanics and thermodynamics of propulsion, and identifying the niche occupied by the electric propulsion systems. The course will cover elements of plasma physics and electromagnetic theory essential for studying the electric propulsion systems. The core of the course will focus on studying various electric propulsion concepts which utilize electric power to generate thrust. Mechanisms of the utilization of the electric power to accelerate gas or plasma and produce thrust will be considered, including electrothermal, electrostatic, electromagnetic, and gasdynamic acceleration mechanisms.

By the end of the semester, successful students will be able to:

1. Demonstrate fundamental understanding of concepts and acceleration mechanisms utilized in electric propulsion systems (electrothermal, electrostatic, electromagnetic).

2. Perform analysis of electrothermal accelerator at given frozen flow fraction
3. Perform analysis of ion acceleration in space-charge limited electrostatic accelerators
4. Perform basic analysis of plasma acceleration in crossed-field electromagnetic thruster
5. Identify optimal electric propulsion system based on specific mission requirements

Course Website:

All course materials including course announcements, blank and filled lecture notes, homework assignments, etc. will be posted on the course Brightspace site. Hard copies of the notes will not be provided.

Homework:

Homework will be assigned once a week on Thursdays (with a few exceptions) and will be due one week later. Any homework assignments turned in after 1:00pm on the due date will not be accepted. Homework assignments will be turned in electronically in Brightspace (under Course Tools →Assignments).

Attendance

Students bear the responsibility of informing the instructor on the absences in a timely fashion, when possible. See more details in University Policies section below.

Course grading:

Homework	=	35%
Mid-term exam	=	30%
Final exam	=	35%
TOTAL	=	100%

Exam schedule:

Mid-term Exam (take-home): 10:00 am -12 noon on Saturday, October 14th
Final Exam: TBD, Finals Week

Grading schema: A+ (≥97), A (≥93), A- (≥90), B+(≥87), B (≥83), B- (≥80), C+ (≥77), C (≥73), C- (≥65), D (≥60), F (<60)

Collaboration Policy:

Students are permitted to discuss homework assignments with each other and may collaborate by discussing the theory and possible solution methods. However, each student is expected to turn in work that is entirely their own; if a student is found to have simply copied another student's work, there will be severe penalties.

Course Schedule and Reading Assignments:

#	**Topics covered**	**Duration/Reading**
1	Review of space propulsion and mission requirements. Electric propulsion.	1 week; Jahn Ch. 1
2	Fundamentals of electrodynamics. Maxwell equations in vacuum and matter.	2 weeks, Jahn Ch. 2
3	Elementary processes in plasmas. Thermal and non-thermal plasmas. Saha equation. Types of discharges: glow, arc, corona. Isotropic and magnetoactive plasmas. Particle motion in magnetic field. Ohm's law	2 weeks; Raizer Ch. 2-4, 8, 10, 12 & Jahn Ch. 3-5
4	Electrothermal acceleration: 1-D model and frozen flow losses. Resistojet thrusters. Arcjet thrusters.	2.5 weeks; Jahn Ch. 6
5	Electrostatic acceleration: Ion thruster. Electron neutralization. Electrospray thrusters.	2 weeks; Jahn Ch. 7
6	Electromagnetic acceleration: 1D cross-field accelerator. Hall thruster. Magnetoplasmadynamic (MPD) thruster. Pulsed Plasma Thruster (PPT).	3 weeks; Jahn Ch. 8,9
7	Gasdynamic acceleration: Vacuum arc fundamentals. Vacuum arc thruster.	1 week; Raizer Ch. 10
8	Electric power generation and storage for propulsion systems. Review of the advanced electric propulsion concepts.	1 week; Jahn Ch. 9 & Appendix

Additional Reading:

1. Y. P. Raizer, *Gas Discharge Physics* Springer, Berlin, 1991.
2. P. Hill and C. Peterson *Mechanics and Thermodynamics of Propulsion /2nd ed.*, Addison-Wesley Publishing Company, 1992.
3. G. P. Sutton and O. Biblarz, *Rocket Propulsion Elements/ 7th ed.*, John Wiley & Sons, 2001.
4. D. M. Goebel and I. Katz, *Fundamentals of Electric Propulsion: Ion and Hall Thrusters*, John Wiley & Sons, 2008.
5. R. W. Humble, G. N. Henry and W. J. Larson, *Space Propulsion Analysis and Design*, McGraw-Hill Inc, 1995.
6. R.G. Jahn, E.Y. Choueiri "Electric Propulsion," *Encyclopedia of Physical Science and Technology*, third edition, vol. 5, New York: Academic Press, 2002.
7. F. F. Chen, *Introduction to Plasma Physics and Controlled Fusion 2nd ed.*, Plenum Press, 1985.
8. J. D. Jackson *Classical Electrodynamics/ 3rd ed.*, John Wiley & Sons, 1999.
9. A special issue of the *Journal of Propulsion and Power* Vol. 14, No. 5, 1998.

University Policies and Student Resources:

Please refer to the corresponding material in Brightspace (under Table of Contents)

This syllabus is subject to change