SPACE 595 Magnetospheric Physics

Winter 2019 Syllabus

Instructors: Profs. James Slavin and Tuija Pulkkinen

Office: 1518 and 1517 Space Research Building

Phone: (240) 476 8009;

Email: jaslavin@umich.edu & tuija@umich.edu

Grader: Ryan Dewey

Office Hours: Space Research Building Lobby Outside Class; Monday 430-530

Email: rmdewey@umich.edu

Course Overview:

The solar wind that flows outward continuously from the Sun's corona interacts strongly with the magnetic fields and upper atmospheres of the planets. It gives rise to the magnetospheres that surround the Earth and other planets. These interactions can be greatly enhanced during solar flares and coronal mass ejections and produce space weather events inside planetary magnetospheres that can have deleterious effects on high latitude ground-based power grids, global telecommunications and GPS signals, satellites and astronaut safety. This course introduces core concepts in magnetospheric physics and the plasma processes responsible for space weather in Earth's magnetosphere. It is intended to instill useful knowledge and skills for individuals planning careers in magnetospheric physics, planetary and exoplanet science, and space engineers focused on next-generation space-based infrastructure and human exploration. The course will focus on the Earth's magnetosphere, but some lectures with be devoted to other bodies, including exoplanets. Overviews of the spacecraft-borne instrumentation used to measure in situ magnetic and electric fields and charged particle populations in space will be presented. It is expected that the course material will be of value not only to students pursing Space and Astrophysical Science degree programs, but also Engineering students interested in space systems and technologies.

Prerequisites:

• Undergraduate level electromagnetism and classical mechanics;

• Introductory plasma physics and fluid mechanics are desirable, but not required

• Undergraduate Mathematics for Engineering and Physics, especially, matrix arithmetic and vector calculus.

• Basic programming in Matlab and/or Excel.

Course Structure:

Lectures are structured around key topics in plasma physics, magnetospheric physics, space instrumentation, MHD and kinetic simulations, planetary and exoplanet science, space weather, and space environment hazards for spacecraft and humans.

Tentative Lecture Schedule:

• Introduction to Magnetospheric Physics (Weds January 9th)

• Overview of Plasma Physics (Friday Jan 11 to Friday Jan 18th)

• The Sun and its atmosphere (Weds Jan 23rd)

• Solar Wind, Flares and Coronal Mass Ejections (Fri Jan 25th and Mon Jan 28th)

• Dynamo Theory and Planetary Magnetic Fields (Weds Jan 30th)

• Magnetic and Electric Field Instruments (Fri Feb 1st)

• Charged Particle Instruments (Mon Feb 4th: Guest Lecturer: Jim Raines)

• Shocks and Discontinuities in MHD (Weds Feb 6th and Fri Feb 8th)

• Magnetosheath in Gas Dynamics and MHD (Mon Feb 11th)

• Magnetopause (Weds Feb 13th)

• Magnetic Reconnection (Mon Feb 18th)

• Analysis of Magnetic Structures (Wes Feb 20th and Fri Feb 22th; Guest Lecturer: Weijie Sun)

• Magnetotail (Mon Feb 25th)

• Charged Particle Acceleration (Weds Feb 27th; Guest Lecturer: Mojtaba Akhavan-Tafti)

• Magnetospheric convection (Fri Mar 1st; Guest Lecturer: Ryan Dewey)

• Magnetosphere – Ionosphere Coupling (Mon Mar 11th); Guest Lecturer: Shasha Zou)

• Radiation Belts (Weds Mar 13th)

• Substorms (Fri Mar 15th; Guest Lecturer: Tuija Pulkkinen)

• Magnetic Storms (Mon Mar 18th; Guest Lecturer: Tuija Pulkkinen)

• Global MHD Magnetospheric Simulations (Weds Mar 20th; Guest Lecturer: Xianzhe Jia)

• Space Environment and Radiation Effects (Fri Mar 22nd)

• Spacecraft Charging (Mon Mar 25th)

• Comets, Venus and Mars: Induced Magnetospheres (Weds Mar 27th)

• Mercury: Miniature Intrinsic Magnetosphere (Weds Mar 29th)

• Outer Planet Magnetospheres (Fri April 1st)

• Exoplanets (Weds April 3rd)

• Student Project Presentations (Fri Apr 5th to Fri Apr 19th)

Required Text: *None*

Instructor Provided Text for Reference: *Heliophysics Plasma Physics of the Local Cosmos*, edited by C. J. Schrijver and G. L. Siscoe, Cambridge University Press (Course will present material related to Chapters 3, 5-6, 10-11, and 13)

Research Paper:

In lieu of a final examination, students will explore an important topic of their choosing, with Instructor concurrence, in magnetospheric, space and astrophysics, space weather or space engineering and write a 25 page (Times New Roman, font size 12, double-spaced) research paper and present a 20 min summary to the class. The purpose of the paper is to "drill down" in these topics by preparing a brief overview of the subject, an critical assessment of the state of our understanding and a brief discussion of the opportunities for further scientific and/or technical advances. Outlines must be submitted to the Instructor for comment and concurrence by the Friday February 15th class. Each student will schedule at least two meetings with the Instructor to discuss their progress with their project. Final versions of these research papers are due to the Instructor no later than April 15th.

Partial List of Projects from Previous Semesters:

K-H driven Reconnection; Alfven Wings; Active Spacecraft Charge Control; Magnetic Fields for Radiation Shielding; Solar Wind Interaction with Comets; Atmospheric Drag-Free Satellite Systems; CME-driven Ground Induced Currents; Field-Aligned current generation; Radiation Belt hazard mitigation; Magnetic storms and substorms in Planetary Magnetospheres

Class Hours and Location:

Tuesday/Thursday 10:00 to 11:30 am

Room 2238 Space Research Building

Office Hours:

Monday and Wednesdays 10 am to Noon

Any other time by appointment

Honor Code:

The CoE Honor Code holds that students are honorable and trustworthy people and encourages them to behave with integrity in all phases of university life. The complete Honor Code is available at:https://ossa.engin.umich.edu/honor-council/ (Links to an external site.)Links to an external site.

Policy on Homework:

Homework will consist of specific questions about key magnetospheric processes usually involving the application of key physical concepts using analytical or straightforward numerical calculations. Homework must be handed in electronically before midnight on the due date. Three sets of homework problems will be assigned during course.

You are encouraged to form study groups to work on homework problems and to study in other ways. You are allowed to consult with other students during the conceptualization of a problem. However, all written work, whether in scrap or final form, is to be generated by you alone. You are not allowed to possess, look at, use, or in any way derive advantage from the existence of solutions prepared in prior years, whether these solutions were former students' work product or copies of solutions that had been made available by others.

Unless arrangements are made with me beforehand, late homework will be accepted but marked down 10%, until the time when the graded homework assignments are returned to the students. At this point, submissions for that assignment will no longer be accepted. If you see a violation of the Honor Code, then you are obligated to report it.

Late Homework Policy:

Grades will be reduced by at least 10% for any homework turned in after the due date. After the answer sheet is handed out (usually one week after the due date) 50% of the grade will be deducted from a late homework. It is absolutely *not* permitted to consult answer sheets for help. Some collaboration on doing homework is encouraged, but each student must work out the answers on their own and the solutions they hand in must be individually prepared. When in doubt, write an honest note at the top of your assignment saying who you worked with and how much. Rule of thumb: < ¼ of your effort may be jointly if you don't mention a collaborator, < ½ if you do mention the collaborator. The write-up must be entirely your own.

Final Grades: Your final grade will be based on the following components:

60% Homework Sets

40% Research Paper & Presentation

Score	**Grade**
90-100	A
80-90	B
65-80	C
50-65	D
< 50	E