

Space Plasma Physics



EAS 4803/8803-SS, PHYS 4760/6760
Spring 2027

Lecture:

Tuesdays and Thursdays, 09:30-10:45, room TBA

Instructor:

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Office hours: at any time, especially Tuesdays and Thursdays after class

TBA

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Attendees:

This class is designed for undergraduate and graduate students in the fields of physics, geophysics, aerospace engineering, and electrical engineering. Although there will be no formal verification of attendance, students are expected to regularly attend the class sessions and take notes. Large parts of the class will involve derivations on the whiteboard, and it is each student's responsibility to obtain an accurate and complete writeup of these.

Prerequisites:

Students are required to possess basic knowledge of electromagnetism. Undergraduate students can meet this expectation by taking the class on "*Electro & Magnetostatics*" (PHYS 3122) or the class on "*Electrodynamics*" (PHYS 3123) before taking the class on "*Space Plasma Physics*". Students should also bring robust background knowledge in multi-variable calculus.

Scope of this Class:

This class will cover the theoretical foundations of plasma physics as well as their application to describe phenomena in the near-Earth space environment and the solar system. Starting from the definition of a plasma, we will introduce fundamental paradigms to describe plasma dynamics (single particle, kinetic, multi-fluid, and magnetohydrodynamic picture). We will then explore basic solutions of the underlying equations, leading to phenomena like plasma waves

and discontinuities. Lastly, we will apply this knowledge to describe the dynamics of the solar wind and its interaction with the planets and moons of our solar system.

Goals of this Class:

At the end of this class, students will be able to apply different theoretical paradigms (e.g., kinetic theory, multi-fluid and MHD pictures) to describe the dynamics of a plasma. The class will also enable them to use this knowledge to understand real-world phenomena, both in space/ astrophysical contexts and in a lab setting.

Textbook:

While there is no required textbook for this class, parts of the lectures are based on the book “*Basic Space Plasma Physics*” (Third Edition, 2022) by W. Baumjohann and R.A. Treumann:
<https://www.amazon.com/Basic-Space-Plasma-Physics-third/dp/9811254400/>

Evaluation Criteria:

Weekly homework assignments (33.3%)

Homework assignments will be handed out every Thursday at the end of class. Solutions to the weekly homework assignments are due the following Thursday at the beginning of class. **Late submissions without prior authorization are not permitted and automatically lead to a grade of 0% on the respective assignment. However, students can contact the instructor or the TA before the respective submission deadline and request an extension for their submission (without any reduction in grade).** Requests for extensions are evaluated on a case-by-case basis and are normally approved (unless the number of requests from a specific student becomes excessive).

Two written exams (33.3% + 33.3%):

Exam #1 on Thursday, 25 March 2027, Exam #2 during Finals Week

Exams are closed books/closed notes and cover concepts discussed in class and in the weekly homework assignments. **Exam #1 will cover only the first half of the course and exam #2 will cover only the second half.**

Grading Scale:

Graduate students	> 80%: A / > 67%: B / > 53%: C / > 40%: D
Undergraduate students	> 75%: A / > 62%: B / > 48%: C / > 35%: D

In addition to different grading scales, homework assignments and exams will include dedicated problems that need to be completed only by the graduate students, but not by the undergraduate students. These dedicated problems deal with advanced theoretical concepts that are not needed to understand the basic foundations of plasma physics. **Undergraduate students are still strongly encouraged to submit solutions to these problems (for extra credit).**

(Anticipated) Class Schedule:

Week	Topic	Exam I/II
1	Definition of a plasma; Debye length and plasma frequency	I
2	Single particle motion, $\mathbf{E} \times \mathbf{B}$ drift, gradient drift, curvature drift, adiabatic invariants	I
3	Kinetic theory, Vlasov's equation, examples of distribution functions	I
4	Moments of Vlasov's equation, multi-fluid theory	I
5	Magnetohydrodynamics I: basic equations	I
6	Magnetohydrodynamics II: frozen-flux theorem, diffusion vs. convection	I
7	Magnetohydrodynamic waves I: the Alfvén mode	II
8	Magnetohydrodynamic waves II: compressional modes, moon-plasma interactions	II
9	Cold plasma waves I: dispersion relation, Clemmow-Mullaly-Allis diagram	II
10	Cold plasma waves II: examples	II
11	Shocks and discontinuities: Rankine-Hugoniot relations, classification of solutions	II
12	The solar wind: Parker's model, interplanetary magnetic field	II
13	Planetary magnetospheres I: Overview	II
14	Planetary magnetospheres II: Reconnection, Dungey cycle, magnetic storms	---
15	Data analysis techniques for spacecraft observations, Minimum Variance Analysis	---

Plagiarism & Academic Integrity:

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. All students enrolled at Georgia Tech, and all its campuses, are to perform their academic work according to standards set by faculty members, departments, schools, and colleges of the university. Cheating and plagiarism constitute fraudulent misrepresentation for which no credit can be given and for which appropriate sanctions are warranted and will be applied. For information on Georgia Tech's Academic Honor Code, please visit:

<http://www.catalog.gatech.edu/policies/honor-code/> or <http://www.catalog.gatech.edu/rules/18/>.

Any student suspected of cheating or plagiarizing on an exam or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodations for Students with Disabilities:

If you are a student with learning needs that require special accommodation, please contact the Office of Disability Services at (404)894-2563 or <http://disabilityservices.gatech.edu/>, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail the instructor as soon as possible in order to set up a meeting to discuss your learning needs.

Student-Faculty Expectations:

Georgia Tech believes that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. Please see

<http://www.catalog.gatech.edu/rules/22/>

for an articulation of some basic expectations that students can have of their instructor and that your instructor can have of their students. In the end, simple respect for knowledge, hard work, and cordial interactions will help build a productive and comfortable learning environment. Therefore, students are encouraged to remain committed to the ideals of Georgia Tech while in this class.

Class Material Usage:

The instructor and students in this class, as members of the Georgia Tech community, are bound by the Georgia Tech Academic Honor Code. The instructor will make available copies of appropriate assignments, samples, and readings. Unauthorized use of any previous semester course materials, such as exams, homework, and any other coursework, is prohibited in this course. Using these materials will be considered a direct violation of academic policy and will be dealt with according to the GT Academic Honor Code.

The syllabus and course schedule may be subject to change. Changes will be communicated in class and via the *Canvas* announcement tool.