Syllabus – PHYS 626 – Fall 2025

Course Information:

PHYS 626:	Fundamentals of Plasma Physics, 3 credits, Fall 2025
Meeting Times:	T/Th 9:45-11:15
Meeting Location:	Reichardt 203

Instructor Information:

Instructor:	Peter Delamere, Professor of Space Physics
Office:	708E Elvey (Geophysical Institute)
Email:	padelamere@alaska.edu
Phone:	(907) 474-6442
Office Hours:	Tuesday 1:30-4:30

Prerequisites: Undergraduate E&M, undergraduate differential and partial differential equations, experience in programming, or permission of the instructor.

Course Description: Plasma physics is the study of ionized and partially ionized gases and their collective interaction with electromagnetic fields. The dynamics of a plasma requires a self-consistent solution of the particle dynamics and the electromagnetic field equations. The objective of this course is to systematically develop analytical tools for understanding plasma physics. Specifically, we will start with single particle motion in prescribed electric and magnetic fields to understand the kinetic underpinnings of plasmas. Utilizing the tools of statistical mechanics, we will develop a kinetic theory for studying the self-consistent interaction between a collection of particles and the electromagnetic fields. Eventually, a kinetic approach can be "simplified" to a set of fluid equations – or magnetohydrodynamic equations– that serve as a convenient framework for understanding macroscopic plasma dynamics and equilibria. While certain phenomena (e.g., waves) can be understood with linear theory, plasmas are intrinsically nonlinear, exhibiting nonlinear plasma waves and instabilities. The specific topics that will be covered (not necessarily in order) are:

- Single charge particle motion in the electromagnetic fields
- Plasma kinetic theory
- Vlasov equations for collisionless plasmas
- Magnetohydrodynamic equations
- MHD Shocks and Discontinuity
- Linear plasma waves and instabilities
- Nonlinear plasma waves and instabilities

Approach: The course is intended to provide a basic understanding of plasma physics and its application to space physics. While detailed application of the mathematical tools developed in this course are generally reserved for other elective courses (e.g., Space Physics, Magnetospheric Physics, Aeronomy and Auroral Physics), several space physics applications will be highlighted to promote physical insights and intuition whenever possible. Due to convenience of the fluid (magnetohydrodynamic) equations for developing macro-scale intuition, we will initially streamline the coverage of kinetic theory to access the fluid equations, and then revisit kinetic theory in greater depth later in the semester.

Student learning outcomes Upon completion of this course, students should be able to:

- Qualitatively and quantitatively describe the motion of charged particles in a dipole magnetic field.
- Derive the fluid equations
- Analyze the conditions for MHD equilibria
- Describe MHD wave propagation in a magnetized plasma with particular emphasis given to momentum and energy transport by Alfvén waves.
- Analyze the jump conditions at MHD shocks and discontinuities.
- Understand the origin of plasma waves from two fluid equations and the Vlasov equation.
- Understand the origin of plasma instabilities.

Textbook: There is no textbook requirement for this course. But the following textbooks are highly recommended:

D. R. Nicholson, *Introduction to Plasma Theory*, John Wiley & Sons Inc (June 1, 1983), ISBN-10: 047109045X, ISBN-13: 978-0471090458 (Unfortunately this book is out of print but it is available in the GI-IARC Library).

George Parks, *Physics of Space Plasmas: An Introduction, Second Edition*, Westview Press (2003), ISBN-10: 0813341302.

D. A. Gurnett and A. Bhattacharjee, *Introduction to Plasma Physics*, Cambridge, 2005 (ISBN 0 521 36730 1 paperback).

Francis F Chen, *Introduction to Plasma Physics and Controlled Fusion, Volume 1: Plasma Physics*, Plenum Press, 2nd Edition, 1984.

Tom Cravens, *Physics of Solar System Plasmas*, Cambridge University Press, 1997.

Krall and Trivelpiece, *Principles of Plasma Physics*, San Francisco Press (1986).

Baumjohann and Treumann, *Basic Space Plasma Physics*, Imperial College Press (1997).

Fletcher, *Computational Techniques for Fluid Dynamics, I and II*, Springer (1988):

Potter, *Computational Physics*, John Wiley (1973)

Birdsall and Langdon, *Plasma Physics via Computer Simulation*, IOP (1995, based on 1985 original)

Stephan Jardin, *Computational Methods in Plasma Physics*, Chapman & Hall/CRC Computational Science Series:

Programming languages: Students are welcome to submit programming solutions in the language of their choice. Recommended languages for this course are Matlab, IDL, and Python.

Grading:

Homework	50%
Midterm Exam	20%
Final Exam	30%

Course Policies:

(a) Attendance and participation in class is expected of all students.

(b) Assignments are due at the beginning of class on the due date.

(c) Students are encouraged to work together on homework problems, but the final written solutions must be individual work.

(d) Students must acknowledge all sources of information – included fellow students – used in homework solutions and final projects. The UAF catalog states: "The university may initiate disciplinary action and impose disciplinary sanctions against any student or student organization found responsible for committing, attempting to commit or intentionally assisting in the commission of . . . cheating, plagiarism, or other forms of academic dishonesty. . . "

(e) All UA student academics and regulations are adhered to in this course. You may find these in the UAF catalog (section "Academics and Regulations").

(f) A large component of the assessments in this course requires critical thinking and synthesis of ideas in writing. Artificial Intelligence (AI) platforms such as ChatGPT could easily be used as a "student proxy" for this work. The danger in letting an AI platform do the synthesis and writing is that the student will not develop these important skills as part of the course learning objectives. Additionally, AI platforms such as ChatGPT are notorious for making things up, and it is difficult to ascertain if the information is correct or not. Therefore, the course policy is for students not to use AI platforms at all in this course (unless explicitly encouraged by the instructor). It is critical for students to develop core research and writing skills first before adding AI and other technological tools to their research toolbox.

Student protections statement: The university respects and upholds the principles of due process and a fair and equitable process as specified in the Board of Regents' Policy 09.02 Student Rights and Responsibilities. For more information regarding the rights and responsibilities of students, refer to the Office of Rights, Compliance and Accountability website. You are encouraged to read the Board of Regents' policy carefully to fully understand your responsibilities to our community.

We strive to create a safe and respectful environment for all members of our community. If you have questions about expectations of you as a student or believe your rights are being violated, we encourage you to reach out to the Office of Rights, Compliance and Accountability for help. UAF reserves the right to suspend, expel or take other necessary and appropriate action in cases where a student is unable or unwilling to uphold community standards and campus safety.

For more information on your rights as a student and the resources available to you to resolve problems, please go to the following site: https://catalog.uaf.edu/academics-regulations/students-rights-responsibilities/.

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ASUAF advocacy statement: The Associated Students of the University of Alaska Fairbanks, the student government of UAF, offers advocacy services to students who feel they are facing issues with staff, faculty, and/or other students specifically if these issues are hindering the ability of the student to succeed in their academics or go about their lives at the university. Students who wish to utilize these services can contact the Student Advocacy Director by visiting the ASUAF office or emailing asuaf.office@alaska.edu.

Student Academic Support:

- Communication Center (907-474-7007, uaf-commcenter@alaska.edu, Student Success Center, 6th Floor Room 677 Rasmuson Library)
- Writing Center (907-474-5314, uaf-writing-center@alaska.edu, Student Success Center, 6th Floor Room 677 Rasmuson Library)
- UAF Math Services (907-474-7332, uaf-traccloud@alaska.edu)

Drop-in tutoring, Student Success Center, 6th Floor Room 672 Rasmuson Library)
1:1 tutoring (by appointment only), 6th Floor Room 677 Rasmuson Library
Online tutoring (by appointment only) available
https://www.uaf.edu/dms/mathlab/, available at the Student Success Center

- Developmental Math Lab (Gruening 406, https://www.uaf.edu/deved/math/)
- The Debbie Moses Learning Center at CTC (907-455-2860, 604 Barnette St, Room 102, https://www.ctc.uaf.edu/student-services/student-success-center/)
- For more information and resources, please see the Academic Advising Resource List https://www.uaf.edu/advising/students/index.php

Student Resources:

- Disability Services (907-474-5655, uaf-disability-services@alaska.edu, 110 Eielson Building)

- Student Health & Counseling [free counseling sessions available] (907-474-7043, https://www.uaf.edu/chc/appointments.php, Whitaker Building, Room 206, Health, Safety & Security Bldg - same building as Fire and Police)
- Office of Rights, Compliance and Accountability (907-474-7300, uaf-orca@alaska.edu, 3rd Floor, Constitution Hall)
- Associated Students of the University of Alaska Fairbanks (ASUAF) or ASUAF Student Government (907-474-7355, asuaf.office@alaska.edu, Wood Center 119)

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UAF Department of Equity and Compliance
1692 Tok Lane, 3rd floor, Constitution Hall, Fairbanks, AK 99775
907-474-7300
uaf-deo@alaska.edu

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- There are supportive measures available to individuals that may have experienced discrimination.
- University of Alaska's Board of Regents' Policy & University Regulations (UA BoR P&R) 01.02.020 Nondiscrimination and 01.04 Sex and Gender-Based Discrimination Under Title IX, go to: http://alaska.edu/bor/policy-regulations/.
- UA BoR P&R apply at all university owned or operated sites, university sanctioned events, clinical sites and during all academic or research related travel that are university sponsored.

For further information on your rights and resources go to https://www.alaska.edu/accountability.

Schedule:

Topic	Week	Dates
Plasma Basics	1	Aug 26
Single Particle Motion	1	Aug 26 - Aug 28
Kinetic Theory I: phase space and distribution functions	2	Sept 2-4
Derivation of the fluid equations	3	Sept 9-11
Magnetohydrodynamic (MHD) equations	4	Sept 16-18
Properties of MHD (Frozen in condition, entropy)	5	Sept 23-25
MHD equilibria	6	Sept 30 - Oct 2
MHD stability and waves	7	Oct 7 - 9
Midterm Exam	8	Oct 14
MHD shocks and discontinuities	8	Oct 16
Magnetic reconnection	9	Oct 21 - 23
Fluid instabilities	10	Oct 28 - 30
Two-fluid equation and waves	11	Nov 4 - 6
Kinetic theory II: Klimontovich Equation	12	Nov 11 - 13
Kinetic theory II: Liouville & Lenard-Balescu equations	13	Nov 18 - 20
Vlasov Equation and waves	14	Nov 25
Thanksgiving break–no class	14	Nov 27
Vlasov Equation and waves	15	Dec 2
Review	15	Dec 4
Final exam	16	10:15 am - 12:15 pm, Thurs, Dec. 11