Syllabus – PHYS 627 – Spring 2024

Course Information:

PHYS 627:	Advanced Plasma Physics, 3 credits, Spring 2024
Meeting Times:	Tues, Thurs 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, 1:30pm to 4:00pm or by appointment

Prerequisites: Fundamentals of Plasma Physics (PHYS626), 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 kinetic plasma theory waves and instabilities, take a closer look at MHD equilibria/discontinuities and MHD instabilities, and explore nonlinear plasma waves and turbulence. The goal is to provide an advanced survey of plasma physics. The specific topics that will be covered (not necessarily in order) are:

- Vlasov Equation/Waves
- Bernstein Waves
- Kinetic/inertial Alfven waves
- Pressure anisotropy (EMIC waves, Mirror modes, Firehose instability)
- Multi-species plasma waves/instabilities (e.g., two-stream, Farley-Buneman, bi-ion waves, EMIC waves)
- Mode conversion
- Fluid Instabilities, (Kelvin-Helmholtz, Rayleigh-Taylor, Sausage, Kink)
- MHD Equilibria, entropy
- Reconnection, tearing instability
- Radio waves, maser instability
- Nonlinear plasma physics/turbulence.

Approach: The course will revisit topics from "Fundamentals of Plasma Physics" (PHYS626), providing a more detailed understanding for students pursuing research in plasma physics and/or space plasma physics. Roughly half of the course will follow a standard lecture/homework format, with the remaining half geared toward developing basic research skills and inquiry. The latter will involve researching the literature when textbooks are insufficient as well as conducting a semester research project.

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

- Understand plasmas from both kinetic and fluid approaches.
- Assess plasma stability

- Identify all kinetic/fluid waves and instabilities.
- Evaluate conditions associated with turbulence and other nonlinear aspects of plasmas.
- Research the literature effectively and with confidence.

Semester Projects: The semester project will require research based on scientific articles in space or laboratory plasma physics. The project can be analytical and/or numerical, but must follow a focused science question. Research topics must be selected by **March 3, 2020**. More ambitious projects can be tackled by groups of 2 or 3 students. An in-class presentation (15 minutes per person) will be made during class on April 21 and 23. Written reports will be due on April 23 (5-10 pages per person). Due to the math-intensive nature of the course, students are encouraged to typeset the reports in LaTeX.

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).

Baumjohann and Treumann, *Advanced 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.

Typesetting: Students are encouraged to typeset semester projects and selected homework problems in LaTeX.

Grading:

Homework	30%
Midterm Exam	15%
Project	30%
Final Exam	25%

Letter grades will be evaluated on a curve; however, to satisfy university requirments, above 95% will be at least an A, above 85% will be at least a B above 75% will be at least a C, above 65% will be at least a D (in most cases the actual curve is significently lower!).

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").

COVID-19 statement: Students should keep up-to-date on the university's policies, practices, and mandates related to COVID-19 by regularly checking this website: https://sites.google.com/alaska.edu/coronavirus/uaf?authuser=0 Further, students are expected to adhere to the university's policies, practices, and mandates and are subject to disciplinary actions if they do not comply.

Student protections statement: UAF embraces and grows a culture of respect, diversity, inclusion, and caring. Students at this university are protected against sexual harassment and discrimination (Title IX). Faculty members are designated as responsible employees which means they are required to report sexual misconduct. Graduate teaching assistants do not share the same reporting obligations. 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/.

Disability services statement: I will work with the Office of Disability Services to provide reasonable accommodation to students with disabilities.

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:

- Speaking Center (907-474-5470, uaf-speakingcenter@alaska.edu, Gruening 507)
- Writing Center (907-474-5314, uaf-writing-center@alaska.edu, Gruening 8th floor)
- UAF Math Services, uaf-traccloud@alaska.edu, Chapman Building (for math fee paying students only)
- Developmental Math Lab, Gruening 406
- The Debbie Moses Learning Center at CTC (907-455-2860, 604 Barnette St, Room 120, 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/lr/SKM_364e19011717281.pdf)

Student Resources:

- Disability Services (907-474-5655, uaf-disability-services@alaska.edu, Whitaker 208)
- Student Health & Counseling [6 free counseling sessions] (907-474-7043, https://www.uaf.edu/chc/appointments.php, Gruening 215)
- Center for Student Rights and Responsibilities (907-474-7317, uaf-studentrights@alaska.edu, Eielson 110)
- 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

Additional syllabi statement for courses including off-campus programs and research activities:
University Sponsored Off-Campus Programs and Research Activities
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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/equity/title-ix/student-placement-guidelines/.

Tentative Schedule:

Topic	Week	Dates
Review, Vlasov Equation	1	Jan 16, 18
Vlasov Equation	2	Jan 23, 25
Kinetic waves/instabilities	3	Jan 30, Feb 1
Dispersive Alfvén waves	4	Feb 6, 8
Pressure anisotropy (waves/instabilities)	5	Feb 13, 15
Multi-species plasma waves	6	Feb 20, 22
No class (or possible guest lecture)	7	Feb 27, 29
Radio waves	8	Mar 5
Midterm Exam	8	Mar 7
Spring break–no class	9	Mar 12, 14
Fluid instabilities, MHD equilibria	10	Mar 19, 21
Reconnection	11	Mar 26, 28
Nonlinear plasma physics	12	April 2, 4
Turbulence	13	April 9, 11
Waves in inhomogeneous plasma/Mode conversion	14	April 16, 18
Review + In-class presentations	15	April 23, 25
Final exam	16	8–10 a.m., Thursday, May 2