Syllabus – PHYS 627 – Spring 2016

Course Information:

PHYS 626:	Advanced Plasma Physics, 3 credits, Spring 2016
Meeting Times:	Tues, Thurs 9:45-11:15
Meeting Location:	Reichardt 138

Instructor Information:

Instructor:	Peter Delamere, Associate Professor of Space Physics
Office:	708E Elvey (Geophysical Institute)
Email:	padelamere@alaska.edu
Phone:	(907) 474-6442
Office Hours:	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, 2016**. 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 26 and 28. Written reports will be due on April 28 (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%

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 – including 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").

Students with Disabilities Notice: The University of Alaska Fairbanks is committed to equal opportunity for students with disabilities. Students with disabilities are encouraged to contact the coordinator of Disability Services (Mary Matthews) at the Center for health & Counseling (x7043). See section on Disability Services of the UAF Class Schedule (http://www.uaf.edu/schedule/).

Tentative Schedule:

Topic	Week	Dates
Review	1	Jan 14
Vlasov Equation	2	Jan 19, 21
Kinetic waves/instabilities	3	Jan 26, 28
Kinetic/inertial Alfvén waves	4	Feb 2, 4
Pressure anisotropy (waves/instabilities)	5	Feb 9, 11
Multi-species plasma waves	6	Feb 16, 18
Mode conversion	7	Feb 23, 25
Review week	8	Mar 1, 3
Midterm Exam	8	Mar 3
Fluid instabilities	9	Mar 8, 10
Spring break–no class	10	Mar 15, 17
MHD Equilibria	11	Mar 22, 24
Reconnection	12	Mar 29, 31
Reconnection	13	April 5, 7
Radio Waves	14	April 12, 14
Nonlinear plasma physics/turbulence	15	April 19, 21
In-class presentations	16	April 26, 28
Final exam	17	Friday, May 6, 8-10 a.m.