PHYS 626: Fundamentals of Plasma Physics Syllabus Fall 2017

Instructor: Prof. Hui Zhang
Office: 708D Elvey Building; Tel: (907)474-5914; E-mail: hzhang14@alaska.edu
Reichardt 108 (during office hours)
Time: Mondays, Wednesdays, and Fridays, 11:45am-12:45pm
Place: REIC 207
Office Hours: Mondays, Wednesdays, and Fridays 2:00pm-3:00pm, or by appointment.
Credits: 3 credits, 3 hours/week of lecture
Useful Books: (all on reserve in the GI-IARC Library)

Introduction to Plasma Theory, Author: D. R. Nickolson, Publisher: 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)

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

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

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

Dynamics of Magnetically Trapped Particles: Foundations of the Physics of Radiation Belts and Space Plasmas, Authors: Juan G. Roederer and Hui Zhang, Publisher: Springer, 2nd Edition, 2014, ISBN(ebook): 978-3642415302, ISBN (hard cover): 978-3642415296.

Course Description

A plasma is a quasi-neutral ionized gas which exhibits collective behavior. The plasma state is often described as the fourth state of matter. More than 99% of the known universe is in the plasma state. A plasma behaves very differently from a normal gas. While electrically neutral particles interact with magnetic fields very weakly, charged particles interact with magnetic fields through the Lorentz force, a long-range force typically many times stronger than gravity. The objective of plasma physics is to study how ionized particles interact among themselves and with electromagnetic fields. Electromagnetic fields and charged particles obey respectively, the fundamental Maxwell equations and the Lorentz equation of motion. Our objective is to study these equations in a systematic way in order to learn how electromagnetic fields and charged particles behave, with an emphasis on understanding the various electrodynamics phenomena observed in space.

This course provides an introduction to plasma physics, and its application to space physics, at the beginning graduate level. No prior knowledge of plasmas will be assumed, but mathematical tools and basic physical concepts learned as an undergraduate will be assumed. This course is recommended for students preparing for the comprehensive exams and/or students with research interests in space physics. Emphasis will be on physical insight, application, and problem solving rather than formal derivations.

Grades

60% of the grade will be based on problem sets (expect one every week), 15% on the mid-term exam (closed book), and 25% on the final exam (closed book).

The course will be graded approximately on the following scale:

> 85 %	A
80 % -- 85 %	A-
75 % -- 80 %	B+
70 % -- 75 %	B
65 % -- 70 %	B-
60 % -- 65 %	C+
55 % -- 60 %	C
50 % -- 55 %	C-
45 % -- 50 %	D+
40 % -- 45 %	D
35 % -- 40 %	D-
< 35 %	F

Course Policies

Problem sets will be given in class and are due in class on the due date stated in the problem sets. You are expected to show not only your answer but also steps leading to that answer. Your work should be clean and clear enough for me to understand.

High ethical standards are essential for maintaining credibility. Plagiarism is defined as appropriating passages or ideas from another person's work and using them as one's own. You may work with your classmates on problem sets, however, you should submit your own work, not a copy from another source. Keep in mind that you will be required to do similar problems on your own during an exam. Plagiarism on homework or on an exam will result in a failing grade.

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 Course Outline

I. Introduction

1. What is a plasma?
2. Characteristic Parameters of a Plasma
3. Approaches to plasma physics

II. Single Particle Motion

1. Uniform Magnetic Field (Gyro Motion)
2. Uniform Magnetic and Electric Field (E x B Drift)
3. General Force Drift
4. Nonuniform Magnetic Field (Gradient and Curvature Drift, Magnetic Mirror)

5. Motions in a Dipole Magnetic Field
6. Adiabatic Invariants

III. Kinetic Theory

1. The Distribution Function
2. Differential Flux
3. Velocity Distribution Functions
4. Vlasov Equation
5. Collisions
6. Landau Damping
7. Derivation of Fluid Equations

IV. Magnetohydrodynamics

1. The Equations of MHD Equations
2. Ideal MHD
3. Hydromagnetic Equilibria
4. Magnetic Pressure
5. Magnetic Field Convection and Diffusion
6. Magnetic Reconnection
7. MHD Shocks and Discontinuities

V. Waves and Instabilities

1. Electrostatic Waves
2. Electromagnetic Waves
3. Instabilities

Tentative Weekly Schedule

Week	Date	Lecture Subject	Problem Sets
1	M Aug 28	Introduction	Problem Set 1
	W Aug 30	Approach, Gyro Motion	
	F Sep 1	ExB Drift, Polarization Drift	
2	M Sep 4	**Labor Day (no classes)**	
	W Sep 6	Gradient Drift, Curvature Drift	Problem Set 1 is Due
	F Sep 8	Magnetic Mirror, Motion in a dipole field	
3	M Sep 11	Adiabatic Invariants, Violation of Adiabatic	
	W Sep 13	Invariants, Drift in the Magnetosphere,	Problem Set 2 is Due
	F Sep 15	Ponderomotive Force	
4	M Sep 18	Exact Phase Space Density, Klimontovich eq.	
	W Sep 20	the Distribution Function, Differential Flux,	Problem Set 3 is Due
	F Sep 22	Velocity Distributions, Pitch Angle Distributions	
5	M Sep 25	Generalized Distribution Function	
	W Sep 27	Energy Distribution, Boltzman eq.	Problem Set 4 is Due
	F Sep 29	Liouville eq., Vlasov Equation	
6	M Oct 2	BBGKY Hierachy, Lenard-Balescu Eq.	
	W Oct 4	Collisions	Problem Set 5 is Due
	F Oct 6	Vlasov Eq.	
7	M Oct 9	Landau damping	
	W Oct 11	Derivation of Fluid Equations	Problem Set 6 is Due

	F Oct 13	Derivation of Fluid Equations (cont.)	
8	M Oct 16	MHD Equations, Ideal MHD	
	W Oct 18	Review	Problem Set 7 is Due
	F Oct 20	Mid-term Exam	
9	M Oct 23	Hydromagnetic Equilibria	
	W Oct 25	Magnetic Pressure	
	F Oct 27	Plasma beta	Problem Set 8 is Due
10	M Oct 30	Magnetic Field Convection and Diffusion	
	W Nov 1	Magnetic Reconnection	
	F Nov 3	MHD Shocks and Discontinuities	Problem Set 9 is Due
11	M Nov 6	R-H condition, Discontinuity	
	W Nov 8	Shocks	
	F Nov 10	Electrostatic Waves-Electron waves	Problem Set 10 is Due
12	M Nov 13	Electrostatic Waves-Ion waves	
	W Nov 15	Comparison of electron and ion waves	
	F Nov 17	Upper Hybrid, Ion Cyclotron Waves, Lower Hybrid	Problem Set 11 is Due
13	M Nov 20	Light Waves, O-, X- Waves	
	W Nov 22	Right hand and left hand waves	
	F Nov 24	**Thanksgiving Holidays (no classes)**	
14	M Nov 27	MHD Waves	
	W Nov 29	Wave-Particle Interactions	Problem Set 12 is Due
	F Dec 1	Two-Stream Instabilities, Drift waves	
15	M Dec 4	K-H Instability, Interchange Instability	
	W Dec 6	Mirror Instability, Penrose Criterion	
	F Dec 8	Review	
16	F Dec 15	10:15am-12:15pm, Final Exam	