PHYS 480/580 – Introduction to Plasma Physics
Fall 2019

Instructor:	**Prof. Stephen Bradshaw (302 Herman Brown Hall, ext. 4045)**
Email:	**stephen.bradshaw {at} rice.edu**
Class Website:	**N/A**
Lectures:	**Tuesday & Thursday, 9:25am – 10:40am, Location: HBH 21**
Office Hours:	**After each class and by email appointment**

Course Description

Plasma may be generally defined as any statistical collection of mobile charged particles. Statistical physics and electrodynamics provide the fundamental basis for the physics of plasmas, which is an important subject for a large number of research areas, including: space plasma physics; solar physics; astrophysics; controlled fusion research; and high-power laser physics.

This course begins with a description of various types of plasmas and a discussion of some basic plasma parameters, such as the Debye length and the plasma frequency. Following a discussion of charged particle motion in electromagnetic fields, progressively more detailed models of plasmas and their associated phenomena are presented, starting with a dielectric description of cold plasma and then moving on to the magnetohydrodynamic description.

Learning Outcomes

- Qualitatively and quantitatively describe basic plasma properties and processes such as the plasma frequency, Debye length, and binary coulomb collisions.

- Qualitatively and quantitatively describe the motions (e.g. drifts) of charged particles in different kinds of magnetic and electric fields (e.g. constant, uniform, time-varying, non-uniform, with an external body force).

- Understand the importance, utility, and application of invariant quantities.

- Derive dispersion relations and find solutions for a range of waves in magnetized and unmagnetized plasmas using the dielectric description.

- Apply the magnetohydrodynamic (MHD) equations in their conservative and non-conservative forms to describe a variety of ideal and non-ideal plasma phenomena (e.g. waves, instabilities, reconnection) that can be treated in the fluid limit.

- Understand and appreciate the ranges of applicability and the limits of the single particle and fluid-based treatments of plasmas, and why such approximations are necessary.

- (Undergraduate students) Confidently review the published literature for a plasma physics topic of contemporary interest and deliver a presentation accessible to peers.

- (Graduate students) Simulate a plasma phenomenon either discussed during the course or selected from individual research interests by developing a code (using lab. software such as Matlab or a suitable programming language) to solve the underlying equations (e.g. partial differential equations) and deliver a presentation accessible to peers.

Prerequisites

An undergraduate course in classical electrodynamics (such as PHYS 302) is the only prerequisite. Relevant aspects of statistical physics and mechanics are reviewed or introduced as needed.

Course Textbook

Title: Plasma Dynamics
Author: R. O. Dendy
Publisher: Oxford University Press (22 Feb. 1990)
ISBN: 978-0198520412

The primary text for this course is “Plasma Dynamics” by R. O. Dendy. This book contains a good balance between mathematical formulations and physical principles, it is clearly written, and it uses an appealing logical organization of the subject which provides an excellent framework for a first course in plasma physics. Additional material will be drawn from other sources and made available as needed.

Communication

All course materials including problem sets, links to relevant websites, supplementary material, and class updates and announcements will be provided via email. It is the responsibility of the student to check their email regularly for the most recent information concerning the class.

Special Needs

If you have a documented disability that requires special consideration for this class then please contact the professor as soon as possible to discuss your needs. Students with disabilities should also contact the Disability Support Services Office in the Ley Student Center (http://dss.rice.edu).

Assessment

Homework problem sets: There will be weekly problem sets with questions that will be based on the material covered during the previous week. A problem set will be emailed out after each Tuesday class and will be due in class the following Tuesday. You are encouraged to discuss general concepts with your classmates before attempting the questions, but your answers must be the result of your own understanding of the material and you should therefore write up the solutions to each problem set by yourself.

PHYS 480: To strengthen understanding of modern plasma physics, and to allow the student to delve a little more deeply into a particular subject area than would otherwise be possible, students will present a topic of current interest in plasma physics to the class. The presentations will be approximately 15 minutes (depending upon eventual number enrolled) in duration and will be given towards the end of the semester. Presenting scientific material in an accessible and understandable manner to your peers is an extremely important skill to develop during scientific training. Therefore, students will grade each other's presentations.

PHYS 580: Science at the graduate level is not a spectator sport and a computational modeling project based on some aspect of plasma physics will be undertaken by the student. The topic will be chosen by the student and approved by the Professor. The student may choose any suitable programming language to implement the model, but the code must be comprehensively commented / documented. The project will be written up by the student (maximum 10 sides of Letter-sized paper in single-spaced, 12 point, Times New Roman font, including figures) and presented to the class towards the end of the semester.

Midterm and final exams: The midterm and final exams will be based on material covered in roughly the first and second halves of the semester, respectively. The dates/times/locations of these exams will be confirmed later but tentative dates are listed in the final section of this syllabus on page 5.

It is expected that each student will attempt each of the assessment tasks on their own. However, active discussion of any difficulties with classmates and the professor is perfectly acceptable to attain a clearer understanding of the issues, once the task has been attempted to the best of each student's ability.

The Honor Code applies to all assessment tasks. You can review Rice's Honor Council documentation online at: http://honor.rice.edu/index.cfm

Plagiarism will not be tolerated and the professor has no discretion about whether to report it. The procedure for dealing with cases of suspected plagiarism is manifestly unpleasant and stressful (for student and professor), and emphatically not worth the risk to your academic career and to your future. Your work should be clearly distinguishable from its sources and be a direct result of your own understanding of the material. For a guide to what constitutes plagiarism and how to avoid it please consult the Honor Council's document concerning academic fraud: http://honor.rice.edu/bluebook.cfm?doc_id=10355

Grading

Task	Weighting
Homework problem sets	50%
Presentation (PHYS 480)	10%
Computational project (PHYS 580)	10%
Midterm exam	20%
Final exam	20%

The overall grade will be calculated from the grade awarded for each task, with the appropriate weighting applied. Percentage grades are converted into letter grades as follows:

$A\pm \geq 90\%$; $80\% \leq B\pm < 90\%$; $70\% \leq C\pm < 80\%$; $60\% \leq D\pm < 70\%$; $F < 60\%$

Course Content

1. Introduction

- Classification of plasmas
- Review of classical electrodynamics and vector calculus

2. Basic Plasma Characteristics

- The electron plasma frequency
- The Debye length
- Electrostatic plasma waves
- Binary Coulomb collisions

3. Motion of a Charged Particle in a Magnetic Field

- Motion in a constant, uniform magnetic field
- Motion in a time-varying, uniform magnetic field
- Motion in a uniform magnetic field with a non-magnetic force (gravity)
- Motion in a non-uniform magnetic field
- Adiabatic invariants

4. Waves in Cold Plasma

- Waves in cold, un-magnetized plasmas
- Introduction to the dielectric description of plasma
- The dielectric tensor of cold, magnetized plasma
- High-frequency waves in cold, magnetized plasma
- Low-frequency waves in cold, magnetized plasma

5. Magnetohydrodynamic Description of Plasma

- What is magnetohydrodynamics?
- The MHD equations
- General properties of ideal MHD plasmas
- MHD equilibrium
- MHD waves
- Magnetic reconnection

Summary of Important Dates

August

Tuesday	27th	-	First class

September

Tuesday	3rd	-	Problem set 1 released
Tuesday	10th	-	Problem set 1 due. Problem set 2 released
Tuesday	17th	-	Problem set 2 due. Problem set 3 released
Tuesday	24th	-	Problem set 3 due. Problem set 4 released

October

Tuesday	1st	-	Problem set 4 due. Problem set 5 released
Tuesday	8th	-	Problem set 5 due.
Tuesday	**15th**	**-**	**MIDTERM RECESS.** Problem set 6 released
Thursday	17th	-	Midterm exam (tentative)
Tuesday	22nd	-	Problem set 6 due. Problem set 7 released
Tuesday	29th	-	Problem set 7 due. Problem set 8 released

November

Tuesday	5th	-	Problem set 8 due. Problem set 9 released
Tuesday	12th	-	Problem set 9 due. Problem set 10 released
Tuesday	19th	-	Problem set 10 due. Problem set 11 released
Tuesday	26th	-	Problem set 11 due. Problem set 12 released
Thursday	**28th**	**-**	**THANKSGIVING RECESS**

December

Tuesday	3rd	-	Problem set 12 due. Presentations (tentative)
Thursday	5th	-	Presentations (tentative)
Wednesday	11th	-	Start of final exams
Wednesday	18th	-	End of final exams