PHYS 480/580: Introduction to Plasma Physics – Fall 2015

Course Instructor: Frank Toffoletto
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Overall course objectives and expected learning outcomes

By the end of this course you should be able to have a working understanding of the elements of Plasma Physics on topics include including: Basic plasma properties; Motion of charged particles in magnetic field; Plasma waves; Magnetohydrodynamic and kinetic representation of plasmas.

Course Description

Plasma physics is an important subject for a large number of research areas, including space plasma physics, solar physics, astrophysics, controlled fusion research, high-power laser physics, plasma processing, and many areas of experimental physics. The primary learning outcome for this course is for the students to learn the basic principles and main equations of plasma physics, at an introductory level, with emphasis on topics of broad applicability.

A plasma may be generally defined as any statistical collection of mobile charged particles. Thus, statistical physics and electrodynamics provide the fundamental basis for the physics of plasmas. An undergraduate course in classical electrodynamics (such as PHYS 302) is the only prerequisite for the course; relevant aspects of statistical physics and mechanics are reviewed or introduced as needed.

The required text for the 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. The well-known text *Introduction to Plasma Physics and Controlled Fusion* by F. F. Chen is a recommended text for the course, and in many ways it complements and reinforces material covered in Dendy's book.

The 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 are presented, starting with a dielectric description of cold plasma and moving on to the magnetohydrodynamic and kinetic descriptions. Additional topics may be added as time allows.

General Information

Course Prerequisite: PHYS 302 Classical Electrodynamics, or equivalent
Credit: 3 semester hours
Meeting Time: Tuesdays and Thursdays, 2:30 pm–3:45 pm
Classroom: TBA
Website: Owlspace

Office Hours

Open door. I am available most times during the week, or by appointment.

Textbooks

Required: *Plasma Dynamics*, R. O. Dendy, Clarendon Press, Oxford, 1990.
Recommended: *Introduction to Plasma Physics and Controlled Fusion*, second edition, F. F. Chen, Plenum Press, 1984.

Homework and Grades

Homework Policy: Students are encouraged to discuss the problems with their classmates and with the instructor, but they must write up their homework solutions *independently*. You must not copy anyone else's solution.

Late Policy: The grade for late homework will be 10% off for each part of a day late up to 50% off.

Class Presentation/projects:
For students enrolled in PHYS 480: Students will be asked to make a short presentation to the class on some aspect of plasma physics to be given near the end of the semester. The topic will be chosen by the student and approved by the instructor.

For students enrolled in PHYS 580: Students will be asked to do a substantial computational project, on a topic related to some aspect of plasma physics and present their project to the class at the end of the semester. The topic will be chosen by the student and approved by the instructor.

Grading Weights:

- Homework and Assignments: 45%
- Midterm Exam: 20%
- End of course Exam: 20%
- Class Participation: 5%
- Class Presentation (480) / Project (580): 10%

Students with Disabilities

Any student with a disability requiring accommodations in this course is encouraged to contact the instructor after class or during office hours. Additionally, students will also need to contact Disability Support Services in the Allen Center.

PHYS 480 - Course Content

1. Introduction
    - Definition of a plasma
    - Units
    - Classification of plasmas, the *n*-*T* diagram
    - A review of classical electrodynamics and vector calculus
2. Basic Plasma Characteristics
    - The electron plasma frequency
    - The Debye length
    - Electrostatic plasma waves
    - Coulomb collisions
3. Motion of a Charged Particle in Magnetic Fields
    - Constant uniform magnetic field
    - Constant uniform magnetic field with non-magnetic forces
    - Guiding center motion in non-uniform magnetic fields
4. Waves in a Cold Plasma
    - General formulation
    - Waves in a cold unmagnetized plasma
    - The dielectric tensor for a cold magnetized plasma
    - Waves in a cold magnetized plasma
5. Magnetohydrodynamic Description of Plasma
    - What is magnetohydrodynamics?
    - The MHD equations
    - General properties of ideal MHD plasmas
    - MHD equilibrium
    - MHD waves
    - MHD stability
    - MHD shocks
6. Kinetic Description of Plasma
    - The Vlasov equation
    - Connections to fluid theories
    - Vlasov theory of electrostatic plasma waves
    - Landau damping
    - The Fokker-Planck equation and binary Coulomb collisions