PHYS 519: Plasma Kinetic Theory

Syllabus

Introduction

Fundamentally, a plasma is an N-body system of mobile charged particles and electromagnetic fields. The basic equations that describe the system classically are the Lorentz-force equation and the (microscopic) Maxwell equations. Unfortunately, for a macroscopic amount of plasma, a complete global simulation of such a large N-body system by direct integration of the Maxwell-Lorentz equations is impractical, even with the most powerful computers, and even if we could solve the system exactly we would have far more information than we would typically require. For these reasons a variety of statistical models of plasma dynamics have been developed.

Statistical models range from kinetic models which contain essentially all the relevant physical phenomena, but are still largely unsolvable (except for simple geometries and/or relatively small systems and short times), to fluid models which selectively remove small-scale physics, but are more tractable and yield very useful large-scale solutions. Hybrid kinetic-fluid plasma models are a useful and popular alternative for some applications. Methods to obtain and solve the best plasma model for a given situation are at the forefront of current plasma physics research. These methods require a thorough understanding of the basic equations of plasma physics and the physical content of those equations.

In this course we will begin from first principles with the fundamental microscopic equations and then systematically derive the major equations in current use in plasma physics research. This approach is in contrast to most introductory plasma physics courses (including some taught by the instructor of this course), in which various approximate plasma models are presented with a minimal discussion of their theoretical foundations and in which the overall logical structure of theoretical plasma physics is often obscured. While this introductory treatment is arguably the best way to economically present the main physics while avoiding too much mathematics, a more systematic and mathematically-sophisticated approach is appropriate for a more advanced course such as this. The physical content of the main equations will be discussed in terms of general properties of the equations and in terms of waves and instabilities for a given plasma model.

We will consider the plasma kinetic equations (Klimontovich, Liouville, BBGKY, Balescu-Lenard, Fokker-Planck, and Vlasov), the Vlasov theory of waves and instabilities (including a detailed treatment of Landau damping), and connections to fluid plasma models. We may also include other topics of special interest, such as an introduction to gyrokinetic theory or to phase-space Lagrangian guiding center theory, as time allows.

Course Content

Please note that this is a *tentative* list, topics may be added or removed as the course proceeds. I plan to spend approximately 1-2 weeks on each of the numbered sections.

- **The dielectric function and the electrostatic dispersion relation**
- **Electrostatic waves in unmagnetized Vlasov plasma**
- **Electromagnetic waves in unmagnetized Vlasov plasma**
- **Waves in magnetized Vlasov plasma**

8. **Phase-Space Lagrangian Guiding Center Theory**
   - **The phase-space Lagrangian formulation of mechanics**
   - **Guiding center orderings**
   - **Derivation of the guiding center phase-space Lagrangian**
   - **Equations of motion and adiabatic invariants**
   - **Extensions to low-frequency kinetic theory**

General Course Information

Course Prerequisites: There are no formal prerequisites, but experience in PHYS 480 Introduction to Plasma Physics, PHYS 515 Classical Mechanics, and PHYS 532 Classical Electrodynamics, or equivalent courses, is helpful.
Credit: 3 semester hours
Meeting Times: Tuesday and Thursday, 10:50am to 12:05pm
Classroom: Herman Brown Hall 22 (in the basement)
Course Web Page: http://aachan.web.rice.edu/phys519
Format: A lecture course with problem sets, a midterm exam, a class presentation, and a final exam.
Textbooks: There are no required textbooks. A reference list will be distributed and discussed in class.

Course Instructor:

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Office Hours: I am available at most times during the week, but you should email or telephone first to confirm that I will be in the office.

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

Homework and Grades

I plan to assign a homework set about every week and a half, usually due within one week of assignment. Homework sets will be distributed in class and they will also be available from the course web page.

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*. Of course, you must not look at homework solutions from previous years.

Late Policy: The grade for late homework will be multiplied by a decaying exponential with a time constant of five days. Late homework must be given directly to the grader, with the date and time written on the front page.

Grading Weights:	Homework:	50%
	Midterm Exam:	15%
	Class Presentation:	10%
	Final Exam:	25%

Class Presentation: A presentation on some aspect of basic plasma physics relevant to topics covered in this class. To be given near the end of the semester, on a topic chosen by the student and approved by the instructor.

Auditors: To receive a passing grade auditors must attend more than half of the lectures and give one class presentation. Auditors are encouraged, but not required, to do the homework sets.

Course Home Page