EP 495C – Plasma Physics and Engineering
Embry-Riddle University
Spring 2004

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Required text: *Introduction to Plasma Physics and Controlled Fusion, 2nd ed*, by Chen
Recommended in the library: *Introduction to Plasma Theory*, by Nicholson
Introduction to Plasma Physics, by Thompson
Physics of Space Plasmas, by Parks

Grading:	20%	weekly homework
	60%	three one-hour exams (20% each)
	20%	two-hour final exam

Homework: Assigned weekly, and due at the beginning of class. Graded for correctness. Late homework will not be accepted. The lowest homework score will be dropped.
Exams: Three one-hour exams. No make-ups. The score on the final exam will replace the lowest score.
Final exam: Tue 27 Apr, 12:30 – 14:30. Two-hours. Comprehensive.

Holidays: Mon, Jan 19 (Martin Luther King day)
Mon, Feb 16 (President's day)
Mon-Fri, Mar 15-19 (Spring break)

IMPORTANT NOTE

Listening to lectures is not enough (*you retain only 10% of what you hear ...*). All processes of learning are somehow connected to active participation, and the learning of physics is no exception. Therefore, it is imperative that you work diligently at your own desk (*... 80% of what you practice ...*). However, this does not mean that you should only work alone. I encourage you to form study groups and collaborate with your classmates (*... and 90% of what you teach to others!*).

Course Description: Fundamentals of plasmas: Debye shielding, plasma frequency, plasma parameter. Motion of charged particles in electromagnetic fields: drifts, adiabatic invariants, diffusion. Two-fluid theory in unmagnetized and magnetized plasmas: electrostatic, electromagnetic, and hybrid waves and instabilities. Magnetohydrodynamics. Magnetic fusion devices: mirrors, tokamaks, stellarators. Electric propulsion devices: electrothermal, electrostatic, electromagnetic accelerators. Numerical design projects.
Prerequisites: PS 219 or PS 250, ES 206, MA 345.

Goals: This is an elective course in the Engineering Physics Program, and may be used as an "engineering elective." Other programs may also use it as an elective. Its purpose is to expose students to the basic physical principles of plasmas, both the single-particle approach and the fluid approach. Students will also learn about the application of plasma physics to magnetic fusion devices and electric propulsion devices. They will also learn about the design of tokamaks and various plasma engines.

Prerequisite Knowledge by Topic:

1. Integral form of Maxwell's equations
    a. Lorentz force
    b. Coulomb force
2. First and second order linear ordinary differential equations with non-constant coefficients
3. Behavior of fluids
    a. Bernoulli's law
    b. continuity equation
    c. momentum equation

Learning Outcomes: Gain a quantitative understanding of the following:

1. The Debye length and plasma frequency for various plasmas.
2. The motion of charged particles in nonuniform electric and magnetic fields
3. Collisions and diffusion
4. The derivation of normal modes and instabilities in a plasma
5. The stability of plasma configurations
6. The frozen in flux condition
7. The Lawson criterion for fusion
8. The magnetic geometry of tokamaks, stellarators, and mirrors
9. Heating mechanisms
10. Fundamentals of electric propulsion
11. Methods of acceleration

Code of Behavior

In order for learning to take place, we all must act with civility (formal politeness) and respect (polite consideration, courtesy) toward each other. My responsibilities include coming to class prepared and on time, and evaluating you in a fair and impartial manner. Your responsibilities include coming to class prepared and on time, not disrupting the class (for example, talking without being called on, eating, reading newspapers, shuffling papers, talking on cell phones, etc.), and treating your fellow students as colleagues (see the Student Handbook). Violations of this code can result in your removal from the class.

Academic Integrity

Issues of academic integrity are discussed on page 24 of the Student Handbook. They include plagiarism, cheating and fraud. Please read this section, and if you do not understand it, come see me. Some important passages are reproduced here:

"Sanctions [for academic dishonesty] may include failure of a test or assignment, failure of a course, suspension, or dismissal from the University."

"Plagiarism is recognized by the University as an act of academic dishonesty. It is defined as taking the ideas, writings, work, and/or words of another and representing them as one's own. Two common forms of plagiarism involve the use of written or oral work of another person without giving proper acknowledgment and the use of the oral work of another person as one's own."

Office hours

I am always in my office during my office hours, and this is your time to speak with me about any aspect of the course. Also, I am generally in my office between 9 am and 5 pm, and available at times other than my office hours. However, I may be teaching or doing research, and not available immediately. If you need to speak with me, drop by or call me and set up an appointment.

Attendance

Class attendance is mandatory although I will not take attendance. I will call on several of you each day to answer questions relating to the reading and the current material – not being present and prepared will affect your grade. Even though I will readily allow you to miss a class for a legitimate reason, you are still responsible for the material in lectures whether you are present or not.

Reading and Notes

The textbook is your primary source of information – not lecture. If you don't like the assigned text, find one that you do like (they are all essentially equivalent) – check one out of the library or buy one from a used bookstore. Reading the text is mandatory and is to be done *before* each class. It is extremely important that you come to class prepared to think and discuss the day's topic. Not knowing that topic is a serious detriment to learning. The schedule is listed at the end of this syllabus. *How* to read the textbook is suggested below.

Taking notes during lecture is also important – but you must review those notes after class (within a few hours). Notes that are never reviewed are less than worthless: they give you a false sense of security.

Repetition is critical for creating long-term memories. A good method for learning is the following sequence: read, listen, write, re-read, re-write, practice, and review. The textbook should be read THREE times: skim lightly once before class, read deeply (at least) once after class, and once as a review. In addition, you do not read textbooks as you would the newspaper. You must work through the examples, all mathematical steps should be confirmed, and you should write notes in the margins (it is your book, you can write in it!).

Homework

Problems will be assigned weekly, and are due at the beginning of the class period on the due date. Each problem will be graded on a scale of 0 to 10. These problem sets are **critical** to your success in this course. Not only are they worth 20% of your grade, but also because the exam problems will be very similar to the homework problems, doing the homework well will boost your exam performance. I suggest that you solve other problems as well, as practice for the exam, and my suggestions as to which extra problems to solve will be listed with the assigned problems.

In order to obtain full credit for each homework problem, you must solve the problem according to the following rules of <u>coherence</u> and <u>readability</u>:

- Describe *briefly*, but in clear and complete sentences, the basic principles used to solve the problem and explain the basic equations that are used in the solution [DO NOT simply rewrite the question]. This is the most important component of coherence and full credit will not be given for any problem solution that does not contain such a description.
- If a physical situation is discussed in the problem, draw an appropriate diagram.
- Identify in words, or by clear references to the diagram, all the symbols you use.
- Work through the problem symbolically, getting a simplified symbolic answer, and only substitute numbers (if appropriate at all) at the very end.
- If you obtain an explicit numerical solution, comment on whether the value you get is reasonable.
- Put boxes around your final answers.
- Write up the problem sets neatly.

Do not simply copy another student’s work (see the statement about plagiarism above), but I recommend that you form study groups and work together. This can help you through difficult sections and problems. I encourage you to discuss, argue, arm-wrestle, and finally master the problems. However, I expect you to write up your solutions individually, showing your own insights.

Exams

Three one-hour in-class exams, and one two-hour final exam will be given. All exams are closed book and closed notes. One 3”x5” card with your notes (on both sides) is allowed on the final (but not on the one-hour exams). Programmable calculators are NOT allowed on any exam (e.g., TI-80 and above). These rules will be strictly enforced.

An excellent method to prepare for the exams is to attempt problems at home in an exam-type environment. That is, once you have solved a group of problems, put aside the solutions and pretend that they are questions on an exam – attempt to solve them again, but without any help. If you can do this with several problems from each chapter, you should do fine on the exams. To help you, I have added extra problems from each chapter that can be used for this purpose. They are NOT to be turned in.

Grading System

From page 26 of the Student Handbook: "The following grades are used by the faculty to indicate the quality of work performed." (*I have added my own interpretations in italics – including the percentage score to attain this level.*)

A = Superior (*Performance of the student has been of the highest level, showing sustained excellence in meeting course responsibilities – 90%*)
B = Above Average (*Performance of the student has been good, though not of the highest level – 75%*)
C = Average (*Performance of the student has been adequate, satisfactorily meeting the course requirements – 60%*)
D = Below Average (*Performance of the student has been less than adequate – 50%*)
F = Failure (*Performance of the student has been such that course requirements have not been met.*)

Your success in this course depends on you alone. You must be self-critical and determine the method by which you study best. Whatever method you use, I believe that success requires a minimum of **six (6)** hours per week **outside** of lecture. Come see me if you desire suggestions on time management, study hints, or anything that will help you succeed in this course.

You also need adequate sleep and exercise. If you don't get these, your body will not be able to function well (even though your mind is willing).

SCHEDULE

Week	Topics	Chapters in Chen
1-3	Plasmas	1 + handout
4-5	Single-particle trajectories	2
	Exam 1 – Mon Feb 9	
6-7	Fluid theory	3
8-10	Linear waves	4
	Exam 2 – Fri Mar 12	
11-12	Fusion devices	handout
13-14	Electric propulsion devices	handout
	Exam 3 – Mon Apr 19	
	Final Exam – Tue Apr 27	All

Homework schedule

There will be 12 homework sets, due on Wednesdays. The due dates will be:

January 14, 21, 28
February 4, 18, 25
March 3, 10, 31
April 7, 14, 21