EP 495C – Plasma Physics and Engineering
Embry-Riddle University
Spring 2011

Instructor:	M. Anthony Reynolds
email:	`reynodb2@erau.edu`
web:	`http://faculty.erau.edu/reynolds/ep495` (or Blackboard)
phone:	(386) 226-7752
office:	Lehman 313
office hours:	M-F, 2:15-3:30, Lehman 313

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

Percentage system:		*Grading scale*:	
1 final exam	20%	A	90% –
3 tests	60% (20% each)	B	75% – 89%
Problem sets	15%	C	60% – 74%
Quizzes	5%	D	50% – 59%

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!*).

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* This syllabus incorporates all existing University policies, especially those sections of the *Student Handbook* pertaining to academic integrity, civility, and respect. *

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

RULES
1. Arrive on time; depart on time.
2. Take notes, and bring calculator to each class.
3. No eating, no cell phones.

Final Exam

Comprehensive; two-hour; closed book; closed notes.
Tools: pen or pencil.
Date: Tuesday 3 May, 12:30 – 14:30.

Tests

One-hour; closed book; closed notes.
Tools: pen or pencil.
Dates: Wed 9 Feb, Fri 18 Mar, Fri 22 Apr.
Final exam will replace lowest test.

Problems

Approximately 10 problems each week; must be neat and stapled.
Due Dates: see schedule.
Graded on completeness and effort.

Quizzes

10-15 minutes every Friday – based on week's work.

All assignments are due at the *beginning* of class on the due date, after which they will be considered late and the score will be reduced by 50%. After the *beginning* of the *next* class period, they will not be accepted.

General study habits

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: read 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!).

Notes

Taking notes during lecture is important – but you must review and re-copy those notes after class (within a few hours) for them to be useful. Notes that are never reviewed are less than worthless: they give you a false sense of security. It is important that you get into the habit studying every day.

Study Groups

I strongly suggest that you form study groups. "For most individuals, learning is most effectively carried out via social interactions." (Ed Redish)

Problem Solving

Solving problems is **critical** to your success in this course. 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. Solve problems according to the following rules of coherence and readability:

- 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, and do not simply copy from the solutions manual, 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.

Final Exam and Tests

Three one-hour in-class tests, and one two-hour final exam will be given. All are closed book and closed notes. Calculators are NOT allowed on any exam. This course will hopefully teach you to think and increase your physics intuition. 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.

SCHEDULE

Week	Topics	Chapters in Chen
1-3	Plasmas	1 + handout
4-5	Single-particle trajectories	2
	Exam 1 – Wed 9 Feb	
6-7	Fluid theory	3
8-10	Linear waves	4
	Exam 2 – Fri 18 Mar	
11-12	Fusion devices	handouts
13-14	Electric propulsion devices	handouts
	Exam 3 – Fri 22 Apr	
	Final Exam – Tue 3 May – 12:30-14:30	All