CGS Agenda Item: 21-14
Effective Spring 2023

Eastern Illinois University

New/Revised Course Proposal Format

(Approved by CAA on 4/3/14 and CGS on 4/15/14, Effective Fall 2014)

Banner/Catalog Information (Coversheet)

1. **_X_New Course or _____Revision of Existing Course**

2. **Course prefix and number:** __PHY 4780 cross listed as EEN 4780________________

3. **Short title:** _______Plasma Physics____

4. **Long title:** ______Introduction to Plasma Physics__________________________________

5. **Hours per week:** _3_ Class _0_ Lab _3_ Credit

6. **Terms:** ___ Fall _X_ (Odd Years)_ Spring ___ Summer ___ On demand

7. **Initial term**: ___ Fall _X_ Spring ___ Summer Year: _2023_

8. **Catalog course description:** ___Plasma is sometimes called the fourth state of matter. It occurs when the material is hot enough that thermal collisions can free electrons from the atoms. In this course the implications and applications of plasma will be studied. The course will cover many different interactions between plasmas and electric and magnetic fields._______

9. **Course attributes:**

   General education component: ____

   ___ Cultural diversity ___ Honors ___ Writing centered ___ Writing intensive ___Writing active

10. **Instructional delivery**
    Type of Course:

    _X_ Lecture ___ Lab ___ Lecture/lab combined ___ Independent study/research

    ___ Internship ___ Performance ___ Practicum/clinical ___ Other, specify: ________________

    Mode(s) of Delivery:

    _X__ Face to Face ___ Online ___ Study Abroad

    ___ Hybrid, specify approximate amount of on-line and face-to-face instruction__________________

11. Course(s) to be deleted from the catalog once this course is approved. _____None____

12. **Equivalent course(s):** _________None_______________________________________

    a. **Are students allowed to take equivalent course(s) for credit?** ___ Yes ___ No

13. **Prerequisite(s): _______PHY 2450, PHY 3410 ______________**

    a. **Can prerequisite be taken concurrently?** ___ Yes _X_ No

    b. **Minimum grade required for the prerequisite course(s)? _C__**

    c. **Use Banner coding to enforce prerequisite course(s)?** ___ Yes _X__ No

d. Who may waive prerequisite(s)?

___ No one _X_ Chair ___ Instructor ___ Advisor ___ Other (specify)

14. Co-requisite(s): ____

15. Enrollment restrictions

a. Degrees, colleges, majors, levels, classes which <u>may</u> take the course: _No Restrictions_

b. Degrees, colleges, majors, levels, classes which may <u>not</u> take the course: __None__

16. Repeat status: _X_ May not be repeated ___ May be repeated once with credit

17. Enter the limit, if any, on hours which may be applied to a major or minor: _N/A__

18. Grading methods: _X_ Standard ___ CR/NC __ Audit ___ ABC/NC

19. Special grading provisions: N/A

___ Grade for course will <u>not</u> count in a student's grade point average.

___ Grade for course will <u>not</u> count in hours toward graduation.

___ Grade for course will be removed from GPA if student already has credit for or is registered in: ____

___ Credit hours for course will be removed from student's hours toward graduation if student already has credit for or is registered in: ____________________________________

20. Additional costs to students: N/A
Supplemental Materials or Software_____________________________________

Course Fee ___No ___Yes, Explain if yes________________________________

21. Community college transfer:

___ A community college course may be judged equivalent.

_X_ A community college may <u>not</u> be judged equivalent.

Note: Upper division credit (3000+) will <u>not</u> be granted for a community college course, even if the content is judged to be equivalent.

Rationale, Justifications, and Assurances (Part I)

1. ___Course is required for the major(s) of ____________________

   ___Course is required for the minor(s) of ____________________

   ___Course is required for the certificate program(s) of ______________

   __X_ Course is used as an elective

2. **Rationale for proposal** : Plasma Physics is a subject that spans the disciplines of Physics and Electrical Engineering. As such, it is completely appropriate to offer this course in both programs as an elective. This leads to efficiencies in staffing. It is said that 99% of the Universe is in the plasma state (and we live in the 1% that isn't) so this subject applies in a variety of important ways. Plasma is the route to sustained controlled fusion energy as well as some laser technologies and even a rocket engine. So it will be an important topic for understanding the world as well as developing new technologies (both goals of PHY and EEN). Furthermore, the mathematics developed in this course will be applicable across many areas of EEN and PHY.

3. **Justifications for (answer N/A if not applicable)**

   Similarity to other courses: N/A

   Prerequisites: This course requires a high level of conceptual and mathematical competence that is developed in the prerequisites.

   Co-requisites: N/A

   Enrollment restrictions: N/A

   Writing active, intensive, centered: N/A

4. **General education assurances (answer N/A if not applicable)**

   General education component: N/A

   Curriculum: N/A

   Instruction: N/A

   Assessment: N/A

5. **Online/Hybrid delivery justification & assurances (answer N/A if not applicable)**

   Online or hybrid delivery justification: N/A

   Instruction: N/A

   Integrity: N/A

   Interaction: N/A

Model Syllabus (Part II)

1. Course number and title

Sample Syllabus: Spring 2023
Introduction to Plasma Physics
PHY 4780

2. Catalog description

Catalog Description: (3, 0, 3) Spring odd years. Plasma is sometimes called the fourth state of matter. It occurs when the material is hot enough that thermal collisions can free electrons from the atoms. In this course the implications and applications of plasma will be studied. The course will cover many different interactions between plasmas and electric and magnetic fields.

Prerequisites: PHY 2450, Classical Dynamics. PHY 3410, Electricity and Magnetism I. This means that a certain level of physical knowledge of Electricity and Magnetism and a significant amount of mathematical sophistication is assumed.

3. Learning objectives.

Learning Objectives:

A. Students will be able to calculate various parameters of a plasma.
B. Students will be able to describe current applications of Plasma Physics.
C. Students will be able to calculate various motions of charged particles in electric and magnetic fields.
D. Students will be able to calculate phase and group velocities for plasmas in different situations.
E. The student will be able to identify the equations of magnetohydrodynamics and show how they relate to various plasma instabilities.
F. The students will be able to critically evaluate issues and solutions related to technical applications of Plasma Physics such as fusion energy and rocket thrusters.
F. Students will be able to critically evaluate Plasma Physics word problems and write complete solutions to those problems.

4. Course materials.

Instructor: Dr. Steven Daniels
Office Hours: M 2:00 – 3:00, T 10:00 – 11:30, W 2:00 – 3:00, Th 10:00 – 11:00, F 9:00 – 10:00
Class Times: MWF 3:00 – 3:50
Location: Physical Sciences Building room 2153

Textbook: Francis F. Chen, *Introduction to Plasma Physics and Controlled Fusion, Volume I, Plasma Physics, 3rd Edition*, ISBN 978-3-319-22308-7 and ISBN 978-3-319-22309-4 (eBook). © Springer International Publishing Switzerland 2016, corrected publication 2018.

> This is the standard textbook for this level of Plasma Physics course. It is in its third edition partly because it is such a good textbook. The author has maintained that two guiding principles were followed in writing the book: Do not leave algebraic steps as an exercise for the reader, and Do not let algebra obscure the physics. These principles have led to a textbook that is at the right level and very readable for EIU students.

5. Weekly outline of content.

Weekly Schedule (tentative)

Week 1:

- Introduction
  - Definition of Plasma
- Concept of Temperature
- Debye Shielding
- The Plasma Parameter
  - Criteria for Plasmas
- Applications of Plasma Physics
  - Gas Discharges
  - Controlled Thermonuclear Fusion
    - Tokamak
    - Inertial Confinement
  - Space Physics
  - Modern Astrophysics
  - MHD Energy Conversion and Ion Propulsion
  - Solid State Plasmas
  - Gas Lasers
  - Particle Accelerators
  - Industrial Plasmas
  - Atmospheric Plasmas

Week 2

- Review of E&M Principles
- Single-Particle Motions
  - Uniform E and B Fields
  - E=0
  - Finite E
  - Gravitational Field
- Nonuniform B Field
  - Del B ⊥ B: Grad-B Drift
  - Curved B: Curvature Drift
  - Del B ∥ B: Magnetic Mirrors

Week 3

- Nonuniform E Field
  - Time-Varying E Field
  - Time-Varying B Field
- Adiabatic Invariants
  - The First Adiabatic Invariant, μ
  - The Second Adiabatic Invariant, J
  - The Third Adiabatic Invariant, ϕ

Week 4

- Plasmas as Fluids
- Further Review:
  - Maxwell’s Equations
  - Classical Treatment of Magnetic Materials
  - Classical Treatment of Dielectrics
- The Dielectric Constant of a Plasma

Week 5

- The Fluid Equation of Motion
  - The Convective Derivative
- The Stress Tensor
- Collisions

Week 6

- Equation of Continuity
- Equation of State
- The Complete Set of Fluid Equations
    - Fluid Drifts Perpendicular to B
    - Fluid Drifts Parallel to B
- The Plasma Approximation
- Midterm Exam

Week 7

- Fourier Transforms
    - Properties of the Dirac Delta Function
    - Gaussian functions
- Fourier Transforms applied to the Wave Equation

Week 8

- Waves in Plasmas
    - Representation of Waves
    - Phase Velocity
    - Group Velocity
    - Dispersion Relations
- Plasma Oscillations
    - Electron Plasma Waves
    - Sound Waves
    - Ion Waves
- Validity of the Plasma Approximation
- Comparison of Ion and Electron Waves

Week 9

- Experimental Applications
- Ordinary Wave, $E_1 \parallel B_0$
- Extraordinary Wave, $E_1 \perp B_0$
- Cutoffs and Resonances

Week 10

- Experimental Consequences
    - The Whistler Mode
    - Faraday Rotation
    - Hydromagnetic Waves
    - Magnetosonic Waves
- Summary of Elementary Plasma Waves
- The Clemmow–Mullaly–Allis (CMA) Diagram

Week 11

- Diffusion in a Plasma
    - Diffusion and Mobility in Weakly Ionized Gases
    - Collision Parameters
    - Diffusion Parameters
    - Decay of a Plasma by Diffusion
- Steady State Solutions
    - Constant Ionization Function
    - Plane Source
    - Line Source
    - Recombination
    - Diffusion Across a Magnetic Field
- Collisions in Fully Ionized Plasmas
    - Plasma Resistivity

Mechanics of Coulomb Collisions

Week 12

Resistivity in a Plasma

Physical Meaning of Plasma Resistivity, η

Numerical Values of η

The Single-Fluid Magnetohydrodynamics (MHD) Equations

Diffusion of Fully Ionized Plasmas

Solutions of the Diffusion Equation

Time Dependence

Time-Independent Solutions

Week 13

Equilibrium and Stability

Hydromagnetic Equilibrium

The Concept of β

Diffusion of Magnetic Field into a Plasma

Classification of Instabilities

Streaming instabilities

Rayleigh–Taylor instabilities

Universal instabilities

Kinetic instabilities

Week 14

Plasma Applications

Fusion Energy

Magnetic Fusion

Inertial Fusion

Lasers

Free-Electron Lasers

Glass Lasers

KrF Lasers

Semiconductor Etching

Spacecraft Propulsion

Types of Thrusters

Week 15

Present Papers and Review

Week 16: The Final Exam will be Thursday, May 5, 2023 at 2:45 to 4:45.

6. Assignments and evaluation, including weights for final course grade.

Introduction:

Welcome back. I want to explain some of my expectations and hopes for this course. Plasma Physics is an exciting topic and I plan for this to be a first rate course for all of us. We have a great deal of information to cover and very little time to do it. In addition, there is a significant amount of mathematics involved in understanding Plasma Physics. Mathematics cannot be learned by watching someone do it on the blackboard, therefore much of the responsibility for learning the material falls on your shoulders. You need to understand that 99% of the Universe is in the Plasma state (we just happen to live in a part of the 1% that isn't). A plasma is a gas of charged particles that is overall neutral but locally may have electric fields. These charged particles can interact with electric and magnetic fields and electromagnetic waves. It is these interactions that make the subject complex and interesting. There are many applications of plasma so the technical uses of plasma will also be considered in this course. As a survey course there will be a great deal of information that will be covered.

Problems will be assigned and collected for grading. You are encouraged and even expected to work together on the homework. You may use any reference that you wish on it, you may discuss it with faculty, you may discuss it with me. When you write the homework up you should do it in your own words. Each equation should have a sentence describing why you are writing that equation. Explain the algebra steps, explain where you got the equation to begin with, or explain what you are solving for, etc. If your solution is simply a series of equations with an answer you will not receive much credit. Also, if your solution is too similar to another student's solution neither of you will get full credit. The process of writing out the solution can help you to learn and understand each and every step which will help you in the exams.

You will be expected to write a paper for this course. It can cover a wide variety of topics but please make sure to check with me before you go too far with your research. A list of potential topics will be distributed separately. You will need to consider both the qualitative and the quantitative aspects of these topics. These papers will be due on April 6 so that we may discuss some of them in class in order to enlighten your classmates on what you found. Pick a topic that interests you and go into considerable detail and depth. The papers should cover the topic at an appropriate level for undergrad or grad depending on your situation (about 5 to 10 pages for undergrads and 8 to 12 pages for graduate students) and should include references. You should look up at least one journal article and use it as a reference. We will follow the EIU Student Code of Conduct which you can find here: https://www.eiu.edu/judicial/studentconductcode.php and all papers will be checked for plagiarism. The topics will be distributed on a first come, first served basis and you must have your topic approved so clear topics for these papers through me by February 9 so that we can avoid any possible duplication.

Exams will consist of one midterm and one final. It will be necessary to understand the material in class and in lab in order to do well on these exams. However, if you do all of the homework and labs and understand them, the exams should be reasonable.

Breakdown of grades:

Homework (regular problems)	20%
Paper	25%
Midterm	25%
Final	30%

7. Grading scale.

This course will follow the following grading scale: 100 – 92 is an A, 83 – 92 is a B, 74 – 83 is a C, 65 – 74 is a D, and below 65 is an F. It is possible that these grades will be curved as it isn't possible to design the perfect exam that yields that distribution. But any curve will only lower these ranges so it works in the student's favor. The semester grade is based on total points accumulated throughout the semester with the weights given above.

One of the advantages of Eastern is the chance to contact faculty. Please come to see me if you have any questions. My office hours will be honored but you can also make an arrangement to see me at other times. Most of the other faculty is also available at any time. So, if you're stuck or if you just want to know more about something, please stop by.

A review of safety and evacuation procedures will be included in this course. If you have a documented disability and wish to discuss academic accommodations, please contact the Office of Disability Services at 581-6583 https://www.eiu.edu/disability/accomservices.php

8. Correlation of learning objectives to assignments and evaluation.

Course Learning Objective	Undergraduate University Learning Goals	Graduate Learning Goals	Homework (20%)	Exams (25%)	Paper (25%)	Final (30%)
A. Students will be able to calculate various parameters of a plasma.	CT-2, 3, 5 WCR-5, QR-1, 2, 3	1, 2	X	X		X
B. Students will be able to describe current applications of Plasma Physics.	CT-3, 5, WCR-6, RC-4	1, 3	X	X	X	X
C. Students will be able to calculate various motions of charged particles in electric and magnetic fields.	CT-2, 3, 4, WCR-5, QR-1, 2, 5, SL-7	1, 2	X	X		
D. Students will be able to calculate phase and group velocities for plasmas in different situations.	CT-2, 3, 4, WCR-5, QR-1, 2, 5, SL-7	1, 2	X	X		X
E. The student will be able to identify the equations of magnetohydrodynamics and show how they relate to various plasma instabilities.	CT-2, 3, 4, 6, WCR-2, 5, SL-3, QR-1, 2, 4, 5	1, 2, 3	X			X
F. The students will be able to critically evaluate issues and solutions related to technical applications of Plasma Physics such as fusion energy and rocket thrusters.	CT-1, 6, WCR-2, 5, 6, SL-4, QR-4, RC-4	2, 3			X	X
F. Students will be able	CT-2, 3, 4, 5,	1, 2, 3	X	X		X

to critically evaluate Plasma Physics word problems and write complete solutions to those problems.	6, WCR-1, 3, 4, QR-1, 2,					

Date approved by the department or school: 12/18/2020
Date approved by the college curriculum committee: 1/20/2021
Date approved by the Honors Council *(if this is an honors course):*
Date approved by CAA: CGS: