PHYC 673 Electrodynamics

Course Description

Electrodynamics. Advanced mathematical techniques for solving problems in electrostatics and magnetostatics; fundamental concepts of electrodynamics. Applications to EM fields in matter, waves, and radiation. Prerequisite: 3 credit hours PHYC 550 or permission of department head.

Course Objectives

The objectives of the course are:

a) to deepen students' understanding of the fundamental laws of electrodynamics.

b) to develop the mathematical tools of theoretical physics needed for doctoral-level research.

c) to develop professional habits of problem solving and research needed for success in a doctoral program.

Content-specific objectives include:

1. Use basic principles of electromagnetism to analyze physical systems, including systems of conductors, capacitors, wave guides, dielectrics, and current distributions.
2. Bring together ideas from other branches of physics, such as mechanics, when necessary to understand the behavior of a system.
3. Apply mathematical techniques such as separation of variables in the solution of boundary value problems in electromagnetism in rectangular, spherical and cylindrical geometries.
4. Use the Green's function method to solve Poisson's equation in rectangular, spherical and cylindrical geometries, and the wave equation in free space.
5. Use conservation principles to discuss the evolution of electromagnetic systems.
6. Use computer techniques to solve boundary value problems in electromagnetism.
7. Communicate ideas clearly, orally and in writing.

Course Rationale

This course is a logical extension of PHYC 671 in the study of theoretical physics at the graduate level. PHYC 673 emphasizes the theory of electric and magnetic fields, and the mathematical techniques for analyzing field equations that will be of use in all other areas of physics.

This is a graduate level course for students of physics, astronomy and astrophysics, and a core requirement for the master of science degree in physics.

Course Content, Format, and Bibliography

Content

This is spelled out in course objectives. One realization of the course is given below.

I. Maxwell's equations
   A. Overview/Fields and Particles
   B. Static and Electric Magnetic fields
   C. Scalar and Vector Potentials
   D. Faraday's law and Displacement current
II. Electromagnetic energy
   A. Energy and Capacitance
   B. Numerical methods for electrostatics (optional)
   C. Energy and Inductance
III. Methods for solving electrostatics, part I
   A. Boundary conditions and Green's Theorem
   B. Method of images
   C. Orthogonal functions
   D. 2D potential problems
IV. Methods for solving electrostatics, part II
   A. Separation of variables in spherical coordinates
   B. Legendre Functions/Spherical Harmonics
   C. Cylindrical Coordinates/Bessel Functions (optional)
   D. Green's functions in terms of orthogonal functions
   E. Eigenfunction expansions of Green's functions (optional)
V. Electromagnetic fields in matter
   A. Multipole moments and spherical harmonics
   B. Electric fields in matter

C. Magnetic fields in matter

VI. Waves (optional)

A. Time dependent vector potential

B. Wave equation

C. Waveguides

Format

This course focuses on advanced problem solving skills and development of individual ability to master complex concepts. Student performance is assessed on the basis of problem sets submitted, tests, class participation (solving problems at the blackboard, giving talks on specific topics) and individual projects.

Bibliography

No one book is recommended for this class – rather the student is urged to learn how to access a variety of texts and sources of information for their learning.

The standard textbook is

- *Classical Electrodynamics*, J. D. Jackson, (3rd ed., Wiley, 1999).

Other graduate-level texts used by students include:

- *Classical Electricity and Magnetism*, W. Panofsky and M. Phillips, (Addison-Wesley , 1962).
- *Classical Theory of Fields*, L. D. Landau and E. M. Lifshitz.
- *Modern Problems in Classical Electrodynamics*, Charles A. Brau (Oxford University Press, 2004).

Other resources for reading and homework assignments include:

- *Problems and Solutions on Electromagneticsm*, ed. by Yung-Kuo Lim (World Press, Singapore, 2003)
- *Classical Electromagnetic Theory*, Jack Vanderlinde. (New York, Wiley, 1993).
- *Feynman Lectures on Physics*, vol 2, Richard Feynman.
- *Mathematical Methods for Physicists*, G. Arfken. (Boston, Academic Press).