PHYC 552 Electricity and Magnetism II

Course Description

Electrostatic boundary-value problems, multipoles, dielectrics, magnetostatics, Maxwell's equation, EM waves and radiation, plasmas, relativistic kinematics and dynamics, and radiation of moving charges. (3 credit hours)

Prerequisite: PHYC 450 or 550 or equivalent.

Not open to students who have credit in PHYC 452.

Course Objectives

The primary objective of the course is for students to gain a working knowledge of electric and magnetic fields, potentials, radiation sources using the language and tools of mathematics and to obtain physical insights into their behavior. More detailed objectives are listed below:

Understand and use vector algebra and calculus to solve a variety of problems in electrostatics, magnetostatics, and electrodynamics.

Gain a working knowledge of other useful mathematical tools that will aid in solving a variety of problems in the course.

Derive and develop an understanding of Maxwell's equations and apply them to solve problems in electrodynamics. Modify Maxwell's equations for use in materials and apply the appropriate boundary conditions.

Understand and use Poynting's theorem and the Maxwell stress tensor, and describe how they may be used to develop conservation laws of charge, energy, momentum, and angular momentum.

Study the mathematical formulation and properties of electromagnetic waves, which includes reflection, transmission, and polarization. Describe the differences between electromagnetic waves in vacuum and in materials, and apply waves to optical systems.

Investigate the behavior of electromagnetic waves in conductors, including absorption and reflection. Study the effects of dispersion in materials.

Understand the behavior of electromagnetic waves within wave guides, and the properties and propagation of TE, TM, and TEM waves.

Develop vector and scalar potentials to generalize Maxwell's equations and investigate gauge transformations. Understand and apply retarded potentials and Liénard-Wiechert potentials to point charges and the fields of moving point charges.

Understand the causes of electromagnetic radiation, the dipole approximations, and radiation from point charges.

Develop an understanding of the special theory of relativity, which includes geometry, Lorentz transformations, and the structure of spacetime. Investigate the effects of relativistic kinematics and dynamics on systems.

Investigate the role of electrodynamics in relativity, such as how magnetism is a relativistic effect and how fields, potentials, and the field tensor transform.

Course Rationale

The purpose of the course is to offer the student a continuation in the rigorous development of the concepts of classical electricity and magnetism as introduced in the prerequisite course, and to develop a sufficient background for students to understand current research and to prepare them for the workplace.

The course is designed primarily for graduate students in physics and astronomy. Other graduate students who have a sufficient mathematical and physics background and knowledge to meet the necessary prerequisites may also take this course.

Course Content, Format, and Bibliography

Content

The course will cover several main topics, listed below, and more detail is provided under each topic:

Vector Analysis and Mathematical Tools

Vector algebra and calculus will be used to solve a variety of problems in electrodynamics. Other useful mathematical tools, such as tensor analysis and complex analysis, will be presented that will aid in solving classes of problems in the course.

Electrodynamics

Topics, such as electromotive force, Ohm's law, induction, and energy, and methods used to determine these quantities, will be discussed, and a treatment of Faraday's law and electromagnetic induction will be presented. Maxwell's equations will be developed and applied to a variety of problems. The Poynting theorem and Maxwell's stress tensor will be derived and applied to energy and momentum.

Electromagnetic Waves

The mathematical derivation of the wave equation and its application to electromagnetic waves will be presented. Properties of electromagnetic waves will be studied, along with the behavior of waves at the interface between media that result in reflection and transmission. The relationship between electromagnetic waves and optics will be explored. The behavior of electromagnetic waves in dielectric materials and conductors, including absorption and reflection, will be investigated. This leads to a study of electromagnetic waves within wave guides and the propagation of TE and TEM waves. The vector and scalar potentials will be used to develop the theory of the fields of moving charges.

Radiation

The causes of electromagnetic radiation, the electric and magnetic dipole approximations of radiation, and power radiated from a moving point charge will be discussed.

Electrodynamics and Relativity

An introduction to Einstein's special theory of relativity will be presented that includes effects on geometry, Lorentz transformations, and the structure of spacetime. Relativistic kinematics and dynamics on systems will be explored. Relativistic electrodynamics will be investigated, including magnetism and the effects on fields, potentials, and the field tensor.

Format

The course will be primarily a lecture course with no laboratory work. Several lecture demonstrations may be presented. Numerous problems will be assigned and a certain amount of outside reading will be expected. Students' progress will be monitored by graded problems and by several written examinations.

This course is taught as a dual undergraduate/graduate course. Students will be required to complete activities appropriate for the level of the course in which they are enrolled. Student performance on homework, exams and/or labs will be evaluated using different standards for undergraduate and graduate students.

Bibliography

Examples of standard texts in the subject that may be used in this course are listed below:

Introduction to Electrodynamics, Third Edition, by D. J. Griffiths, Prentice-Hall, 1999. ISBN 0-13-805325-X

Foundations of Electromagnetic Theory, Fourth Edition, by J. Reitz, F. Milford, and R. Christy, Addison-Wesley Longman, 1993.

Electromagnetic Fields and Waves, Second Edition, by P. Lorrain and D. Corson, Freeman, 1970.

Electromagnetism, by G. Pollack and D. Stump, Addison-Wesley, 2002.

These texts provide adequate background for the subject.