PHYC 550 Electricity and Magnetism I

Course Description

Application of vector analysis to electrostatics, dielectric theory, magnetostatics, dipole and multipole fields, currents, and Maxwell's equations. (3 credit hours)

Prerequisite: PHYC 122, MATH 267 or equivalent.

Not open to students who have credit in PHYC 450.

Course Objectives

The primary objective of the course is for students to gain a working knowledge of electric and magnetic fields, potentials, and their 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, including the del operator, gradient, divergence, and curl of vectors, as well as volume, surface and line integrals, to solve a variety of problems in electrostatics, magnetostatics, and electrodynamics.

Apply the above techniques to different coordinate systems, such as the Cartesian, cylindrical, and spherical coordinate systems.

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

Understand and calculate static charge, Coulomb's law, electric fields, and potentials. Examples involving direct integration and Gauss's law will be studied, and applications using energy and capacitance will be investigated.

Solve electrostatic boundary-value problems and Laplace's equation using techniques such as the method of images, separation of variables, and multipole expansion. Apply appropriate boundary conditions to such problems.

Study the effects dielectric materials have on electric fields and apply Gauss's law and electric displacement to a variety of examples. Study linear dielectric materials using polarization, susceptibility, permittivity, and the dielectric constant.

Develop an understanding of magnetostatics that includes the Lorentz force law, currents, magnetic fields, the Biot-Savart law, Ampère's law, and the magnetic vector potential. Examples and applications involving direct integration and Ampère's law will be studied.

Study magnetization in materials and investigate the causes of diamagnetism, paramagnetism, and ferromagnetism. Apply bound currents and the auxiliary magnetic field to materials that are linear or nonlinear.

Develop the concepts of electromotive force and Ohm's law. Understand electromagnetic induction and Faraday's law and apply these to inductors and energy in magnetic fields.

Derive Maxwell's equations and use them to solve problems in electrodynamics. Develop these equations for use in materials and apply the appropriate boundary conditions.

Course Rationale

The purpose of the course is to offer the student a rigorous development of the concepts of classical electricity and magnetism, and to develop a sufficient background for students to understand current research and to prepare them for the workplace. Topics, such as the search for magnetic monopoles and high-temperature superconductivity, are examples of current research that may be presented and discussed.

The course is designed primarily for graduate students in physics and astronomy. Other graduate students who have a sufficient mathematical and physics background 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

> Throughout the course, vector algebra and calculus will be used to solve a variety of problems in electrostatics, magnetostatics, and electrodynamics. Examples include: the del operator, gradient, divergence, and curl of vectors. Volume, surface and line integrals will also be used in numerous calculations. The above quantities and techniques may be applied to different coordinate systems, such as the Cartesian, cylindrical, and spherical coordinate systems. Other useful mathematical tools will be presented that will aid in solving a variety of problems in the course.

Electrostatics

> Topics that will be discussed include: static charge, Coulomb's law, electric fields, and potentials. Methods used to determine these quantities will also be presented. Examples involving direct integration and Gauss's law will be studied, as well as applications using energy and capacitance. Techniques to solve electrostatic boundary-value problems and Laplace's equation, such as the method of images, separation of variables, and multipole expansion, will be discussed. Electric fields in matter will be studied, as well as topics such as bound charges, polarization, susceptibility, permittivity, and linear dielectric materials.

Magnetostatics

> Topics that will be discussed include: the Lorentz force law, currents, magnetic fields, the Biot-Savart law, Ampère's law, and the magnetic vector potential. The mathematical treatment will emphasize

vector methods used to calculate fields and potentials. Magnetization in materials will be studied, and the causes of diamagnetism, paramagnetism, and ferromagnetism will be discussed.

Electrodynamics

The concepts of electromotive force and Ohm's law will be presented, along with a treatment of electromagnetic induction and Faraday's law. These ideas will be applied to inductors and energy in magnetic fields. Maxwell's equations, which are the foundation of all electrodynamics, will be derived and applied to problems. These equations will be modified for use in materials.

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 0-13-05326-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.