Electrodynamics-I

Programme: M.Sc. (Physics) Year: 1st Semester : 2nd
Course : Core Course Credits : 4 Hours (LTP) : 40+12+0

Course Overview:
Electromagnetic force is one of the four fundamental forces in nature and along with gravity it is the interaction which governs most of the phenomena on everyday scale. The theory, as enunciated by Maxwell in his equations, unified the apparently different fields of electricity, magnetism and light. This theory not only serves as a guide to build more advanced and sophisticated models of particle interactions but it also is at the foundation of a lot of technological advancements (electricity, communications etc.). Not only this, electrodynamics provided the theoretical motivation for the special theory of relativity. A sound understanding of electrodynamics is therefore necessary of physics majors and in this course we will try to cover the various aspects of this beautiful theory.

Prerequisite Courses:
Basic knowledge of classical mechanics, Mathematical Physics-I.

On completion of this course
CO1: The students will acquire an understanding of the concept of electric and magnetic fields along with techniques (especially Green's function) to calculate these fields (in various circumstances).
CO2: Students will also acquire an understanding of the very important concept of potential(s) which is useful in various areas of physics.
CO3: Students will acquire an understanding of the behaviour of electric and magnetic fields inside materials and the interlink between electric and magnetic phenomena.
CO4: Students will learn to use Maxwell's equations to describe electromagnetic fields in different situations including the propagation of electromagnetic waves. This is a basic prerequisite in various technological applications of electromagnetic fields (for instance, waveguides, antennas etc.).

Course Topics:

Topics	**Contact Hours**
Introduction: Particles versus fields, experimental motivation for electrodynamics, properties of electric charge, Scalar and vector fields, vector calculus, Helmholtz theorem.	2
Electrostatics: Coulomb's law, Electric field, electric potential, curl of electrostatic field, flux of electric field and Gauss law, Applications of Gauss's law, equilibrium in electrostatics.	2+1
Conductors: Basic properties, Induced charges, surface charge and force on conductor, boundary conditions for electrostatic fields. Limits on the validity of inverse square law.	2
Methods for solving electrostatic problem: Poisson equation and Laplace equation, properties of solution of Laplace equation, boundary conditions and uniqueness theorems, Solution of Laplace equation, Solution of Poisson equation – Green's function method and method of images, two dimensional potential problems (method of complex analysis), electric dipole moment, multipole expansion, Capacitors, Work and Energy in Electrostatics, energy of a capacitor, electrostatic field energy.	8+3
Electric field in matter: Dielectrics, Induced dipoles, atomic polarizability,	5+1

polarization, linear dielectrics, electric susceptibility and dielectric constant, alignment of polar molecules, Electric Displacement-Gauss law in dielectrics, dielectric constant of gases, Clausius-Mossotti equation.	
Magnetostatics: Lorentz force law, steady currents, current density, continuity equation, Maxwell equations for magnetostatics, applications of Ampere's law, solving magnetostatic equations – magnetic vector potential, boundary conditions in magnetostatics, Biot-Savart law, magnetic dipole moment, multipole expansion for vector potential, torque on a magnetic dipole.	5+2
Magnetic field in matter: diamagnets, paramagnets, magnetization and magnetization or bound currents, Auxiliary field H-Amperes law in magnetized materials, ferromagnets.	3+1
Electromotive force- EMF, Motional EMF, Electromagnetic induction – Faraday's law, Induced electric field, mutual inductance and self inductance, energy in magnetic fields.	2
Maxwell's equations: Maxwell's correction of Ampere's law, Maxwell's equations in free space and in matter, boundary conditions on the fields, potential formulation of Maxwell's equations - scalar and vector potential, gauge transformations - Coulomb and Lorentz gauge.	2+1
Electromagnetic waves: plane and spherical waves in vacuum, Field energy and field momentum, conservation laws and Poynting's theorem, EM waves in dielectrics and conductors, wave polarization, reflection and refraction of waves at boundary between two media, Fresnel's law, index of refraction, wave dispersion and attenuation.	9+3

Text Books:

1. D.J. Griffiths, Introduction to Electrodynamics (Pearson Edu.; 4 th edition, 2015).
2. J.D. Jackson, Classical electrodynamics (John Wiley; 3rd edition, 2007).

Additional References:

1. L.D. Landau and E.M. Lifshitz, Classical Theory of Fields, (BH; 4th edition, 1987).
2. W. K. H. Panofsky and M. Phillips, Classical Electricity and Magnetism (Addison-Wesley, 1962).
3. R.P. Feynman, R. Leighton and M. Sands, Feynman Lectures on Physics (Vol. 1 & 2): The New Millennium Edition (Pearson Education India, 1 st edition, 2012).

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.):

1. Lecture notes are available from MIT open courseware. The link is https://ocw.mit.edu/courses/physics/

Evaluation Method:

Item	Weightage
Assignments and/or quizzes	45
Midterm	20
Endterm	35

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