

**Four Year Undergraduate Course in Physics
Semester - II**

Paper Name: Mathematical Physics & Electricity and Magnetism

Paper Code: PHY020104

Total number of lectures= 45

**Total credits = 4 (Theory 3 +Laboratory 1) (Total Marks 100: Internal-
25+External-75)**

Course objectives:

- *To introduce the methods of solving differential equations.*
- *To introduce various concepts of matrix algebra.*
- *Electric field from vector calculus point of view and use of potential formulation to solve electrostatic problems.*
- *Magnetic fields of current carrying conductors, torus, solenoids etc. Study magnetic properties of matter.*
- *Study and analysis of AC circuits like LCR, and use of network theorems in electrical circuits.*

Course outcome:

After the successful completion of the course, students will be able to understand methods of solving various differential equations appearing in physics. It will give an idea of how to study evolution of a physical system. Through matrix algebra students will be able to compute various matrix operations which are required for solving physical problems. They will be able to understand electric field and magnetic fields in matter, dielectric properties of matter, magnetic properties of matter, application of Kirchhoff's law in different circuits, and application of network theorem in different circuits. The students will also get accustomed to using multimeters and potentiometers, and they will be able to determine some of the important physical quantities related to electricity and magnetism for a better understanding of the topic.

Part A

Mathematical Physics (Theory)

Credit = 1

Unit - I: Differential equations (Lectures - 10)

First and second order ordinary differential equations (ODE). Homogeneous and inhomogeneous differential equations. Solutions of first order ODE – integrating factors (physical examples – radioactive decay, Newton's law of cooling, particle falling under gravity through a resistive medium). Concept of initial/boundary conditions. Solutions of second order ODE with constant coefficients - complementary function and particular integral (physical examples- simple harmonic oscillation, forced vibration). Wronskian- definition and its use to check linear independence of 2nd order homogeneous linear differential equation.

Partial differential equations (PDE) (physical examples – wave equation, diffusion equation, Laplace and Poisson equation – introduction only). Exact and inexact differentials. Concept of variable separation in a PDE.

Unit - II: Matrices (Lectures - 5)

Properties of matrices. Determinant and rank. Transpose and complex conjugate of matrices. Hermitian and anti-Hermitian matrices. Unitary and orthogonal matrices. Representation of linear homogeneous and inhomogeneous equations through matrix equation. Inverse of a matrix. Eigen values and eigen-vectors. Cayley-Hamilton Theorem (statement only), Diagonalisation of simple matrices.

Part B
Electricity and Magnetism (Theory)
Credit = 2

Unit - I: Electric field and electric potential (Lectures - 13)

Electrostatic field, electric flux. Gauss's law. Application of Gauss's law to charge distributions with planar, spherical and cylindrical symmetries. Conservative nature of electrostatic field. Electrostatic potential. Electrostatic energy of a system of charges. Electrostatic boundary conditions. Laplace's and Poisson's equations. Uniqueness theorem. Application of Laplace's equation involving planar, spherical and cylindrical symmetries. Potential and electric field of a dipole. Force and torque on a dipole. Capacitance of a system of charged conductors. Parallel plate capacitor. Capacitance on an isolated conductor.

Unit - II: Dielectric properties of matter (Lectures - 4)

Electric field in matter. Polarisation, polarisation charges. Electrical susceptibility and dielectric constant. Capacitor (parallel plate, spherical and cylindrical) filled with dielectric. Displacement vector, \vec{D} . Relation between \vec{E} , \vec{P} and \vec{D} . Gauss's law in dielectrics.

Unit - III: Magnetic field (Lectures - 6)

Magnetic force on a point charge, definition and properties of magnetic field \vec{B} . Curl and divergence. Vector potential, \vec{A} . Magnetic scalar potential. Magnetic force on (i) a current carrying wire and (ii) between two elements. Torque on a current loop in a uniform magnetic field. Biot-Savart's law and its simple application: straight wire and circular loop. Current loop as a magnetic dipole and its dipole moment (analogy with electric dipole). Ampere's circuital law and its application to (i) solenoid and (ii) torus.

Unit - IV: Magnetic properties of matter (Lectures - 2)

Magnetization vector, \vec{M} . Magnetic intensity, \vec{H} . Magnetic susceptibility and permeability. Relation between \vec{B} , \vec{H} and \vec{M} . Ferromagnetism. B-H curve and hysteresis.

Unit - V: Electrical circuits (Lectures - 5)

AC circuits: Kirchhoff's laws for AC circuits. Complex reactance and inductance. Series LCR circuits and parallel LCR circuits: (i) phasor diagram, (ii) resonance, (iii) power dissipation, (iv) quality factor, and (v) band width. Ideal constant-voltage and constant-current sources. Thevenin theorem and Norton theorem (only statements and solving of related problems).

Part C
Laboratory
Credit = 1

The students are required to perform at least four experiments from the following list.

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
2. To study the characteristics of a series RC circuit.
3. To determine an unknown Low Resistance using Potentiometer.
4. To determine an unknown Low Resistance using Carey Foster's Bridge.
5. To compare capacitances using De' Sauty's bridge.
6. Measurement of field strength \vec{B} and its variation in a solenoid (determine $\frac{dB}{dx}$).
7. To verify the Thevenin and Norton Theorems.
8. To verify the superposition and maximum power transfer theorems.
9. To determine the self-inductance of a coil by Anderson's bridge.
10. To study the response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
11. To study the response curve of a parallel LCR circuit and determine its (a) Anti- resonant frequency and (b) Quality factor Q.
12. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer.
13. Determine a high resistance by leakage method using Ballistic Galvanometer.
14. To determine the self-inductance of a coil by Rayleigh's method.
15. To determine the mutual inductance of two coils by the Absolute method.

Reference books:

- [1] Essential Mathematical Methods for the Physical Sciences; K. F. Riley and M. P. Hobson, Cambridge University Press.
- [2] Advanced Engineering Mathematics; E. Kreyszic, John Wiley & Sons (New York)
- [3] Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier
- [4] Mathematical Physics, H. K. Dass and Dr. Rama Verma, S. Chand Publication.
- [5] Mathematical Physics-I; Krishna K. Pathak and Sangeeta Prasher, Vishal Publishing Co, Jalalandhar (Delhi).
- [6] Introduction to Electrodynamics, D. J. Griffiths.
- [7] Electricity and Magnetism [With electromagnetic theory and special theory of relativity], D. Chattopadhyay and P. C. Rakshit, 2013, New Central Book Agency (P) Limited.
- [8] Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and S. R. Choudhury, 2012, Tata Mcgraw.
- [9] Schaum's outline of Theory and Problems of Electromagnetics, J. A. Edminister.
- [10] Electromagnetics, B. B. Laud, New Age International Publishers.
- [11] Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
- [12] Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education.
- [13] Elements of Electromagnetics, M. N. O. Sadiku, 2008. Pearson Education.

[14] Electricity and Magnetism, J. W. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.
