Draft Syllabus

for

Four-Year (Eight Semester)

Undergraduate Program

in

Physics Major

(as per NEP 2020)

(Effective from Academic Session 2024-25)

University of Gour Banga

Malda-732103

West Bengal

Name of Major (Core) Papers

Semester	Course Code	Course Name
I.	PHS- DC-MJ-101	Mechanics
II.	PHS- DC-MJ-201	Mathematical Physics -I
III.	PHS- DC-MJ-301	Thermal Physics -I
	PHS- DC-MJ-302	Electricity & Magnetism
IV.	PHS- DC-MJ-401	Optics
	PHS- DC-MJ-402	Mathematical Physics -II & Acoustics
	PHS- DC-MJ-403	Elements of Modern Physics

Semester- I

Course Code: PHS-DC-MJ-101

Course Name : Mechanics

Learning Objectives:

This syllabus aims to equip students with a thorough understanding of fundamental principles of classical mechanics and dynamics, covering a range of topics from Newtonian dynamics, particle systems, gravitation, and rotational motion to non-inertial reference frames and elasticity. By the end of this course, students should be able to analyze various physical scenarios involving forces, motion, and energy and apply mathematical formulations to predict and interpret the behavior of dynamic systems. Emphasis is placed on developing problem-solving skills, understanding conservation laws, and mastering concepts related to both inertial and non-inertial systems, central forces, and material elasticity.

Learning Outcomes:

Upon successful completion of this syllabus, students will be able to:

1. Solve equations of motion for single particles and systems of particles in various force fields and recognize the importance of inertial frames.
2. Apply conservation laws for energy, linear momentum, and angular momentum to diverse physical situations.
3. Analyze gravitational and central forces, derive equations of motion for orbital bodies, and explain Kepler’s laws.
4. Distinguish between inertial and non-inertial reference frames, and understand the effects of fictitious forces, including centrifugal and Coriolis forces.
5. Solve problems in rotational dynamics, including calculating moments of inertia for different bodies and applying Euler's equations for rigid body motion.
6. Explain the basic principles of elasticity, including stress, strain, and material deformation, and apply these to beams and torsional systems.

Course Content

Mechanics (Theory) **Credits - 3**

Module1:

(a) Review of Newtonian Dynamics: Dynamics of a single particle. Concepts of Inertial frames. Solution of the equations of motion (E.O.M.) in simple force fields, Variable mass problem and rocket motion.

(b) Work and energy: Conservation of energy with examples. Conservative Forces. Force as the gradient of a scalar field - concept of Potential Energy. Qualitative study of one-dimensional motion from potential energy curve. Stable and unstable equilibrium. Other equivalent definitions of a conservative Force.

(c) Dynamics of systems of particles: Difficulty of solving the E.O.M. for systems of particles. External and internal forces. Torque acting on a system. Conservation of linear and angular momentum. Centre of mass of a system of particles and its properties. Energy of a system of particles.

Module 2:

(a)Newton's law of Gravitation. Gravitational potential energy. Potential and field due to spherical shell and solid sphere. Inertial and gravitational mass. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness.

(b) Central force. Reduction of the two-body central force problem to a one-body problem. Setting up the E.O.M. in plane polar coordinates. Motion of a particle in a central force field (motion is in a plane, angular momentum is conserved, areal velocity is constant). Kepler's laws of planetary motion and its application.

(c) Inertial frames of reference, Galilean transformations and Galilean invariance. Non-inertial frames of reference and idea of fictitious forces. E.O.M with respect to a uniformly accelerating frame. E.O.M with respect to a uniformly rotating frame - Centrifugal and Coriolis forces. Foucault's pendulum.

Module 3:

(a)The Rigid Body: Constraints defining the rigid body. Degrees of freedom for a rigid body.

(b)Rotational motion about an axis, Relation between torque and angular momentum, Rotational energy, Moment of inertia (M.I). Calculation of M.I of a rectangular lamina, disc, solid cylinder, Flywheel, etc. Theory of compound pendulum and determination of g. Principal axes transformation. Transformation to a body fixed frame. E.O.M for a rigid body with one point fixed (Euler's equations of motion).

(c) Hooke's law - Stress-strain diagram. Elastic constants and relation between them. Poisson's Ratio. Expression for Poisson's ratio in terms of elastic constants.

(d) Beams- Bending of beams. Internal bending moment. Cantilever. Torsion of a cylinder. Strain energy. Elasticity of liquid and gas.

Suggestive Readings:

- An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw- Hill.
- Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw- Hill.
- Classical Mechanics, 3rd Edn, H. Goldstein, C. P. Poole, J. Safko, 2011. Pearson.
- Classical Mechanics, N. C. Rana, P. S. Joag, 2018, McGraw Hill Education Pvt. Ltd.
- Introduction to classical mechanics., R. G. Takwale & P. S. Purnik, 2016, McGraw Hill Education Pvt. Ltd.
- Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley. Analyt- ical Mechanics, G.R. Fowles and G.L. Cassiday. 2005, Cengage Learning.
- Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education.
- University Physics, Ronald Lane Reese, 2003, Thomson Brooks
- Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000 University Physics.

Module 4 : **Mechanics(Practical)** **Credit-1**

List of Experiments:

1. To determine the height of a building using a Sextant.

2. To study the Motion of Spring and calculate, (a) Spring constant and (b) g.

3. To determine the Moment of Inertia of a regular shaped body.

4. To determine the Young’s Modulus of the material of a beam the Method of Flexure.

5. To determine the Modulus of Rigidity of the material of a Wire by Static method.

6. To determine the Modulus of Rigidity of the material of a Wire by dynamic method.

7. To determine the Young’s modulus of the material of a wire by Searle’s method.

8. To determine the value of g using Bar Pendulum.

9.To determine the value of g using Kater’s Pendulum.

General Topic:

1. Discussion on random errors in observations.

2. Measurements of length (or diameter) using slide calipers, screw gauge and travelling microscope.

Suggestive Readings:

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Og- born, 4th Edn, reprinted 1985, Heinemann Educational Publishers.
- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Edn, 2011, Kitab Mahal.
- Engineering Practical Physics, S. Panigrahi & B.Mallick, 2015, Cengage Learning India Pvt. Ltd.
- Advanced practical physics, volume-1, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.
- Advanced practical physics, volume-2, B. Ghosh, 2009. Sreedhar Publishers.
- Laboratory Manual of physics vol-1, M. Jana, 220. Books & Allied(P) Ltd.
- An advance course in practical physics, D. Chattopadhyay, P. C. Rakshit, 2009, New Central Book Agency (P) Ltd.

Semester- II

Course Code: PHS-DC-MJ-201

Course Name : Mathematical Physics – I

Learning Objectives:

Develop proficiency in differential equations by understanding and applying methods for solving first-order and second-order differential equations, including integrating factors, homogeneous equations, and the Wronskian concept. This involves learning to determine general and particular solutions for initial value problems and recognizing the conditions for the existence and uniqueness of solutions. Mastering multivariable calculus is also essential, as it includes a solid grasp of calculus with functions of multiple variables, such as partial derivatives, differentials, and constrained optimization using Lagrange multipliers, which can be applied in various mathematical and engineering contexts. Additionally, understanding vector operations and fields is important, which involves learning foundational vector concepts like vector addition, vector products, and scalar triple products, along with their geometric interpretations in terms of area and volume. Applying vector differentiation and integration entails performing vector differentiation by calculating gradients, divergences, and curls, as well as working with vector identities and vector field integrations, such as flux, and understanding the applications of Gauss' divergence theorem, Green's, and Stokes' theorems. Finally, exploring curvilinear coordinates and Dirac delta functions includes understanding orthogonal curvilinear coordinates, such as gradient, divergence, and curl derivations in various coordinate systems, and learning about the properties and representations of the Dirac delta function.

Learning Outcomes:

Upon completing this course, students will be able to:

1. Solve and interpret solutions to first-order and second-order differential equations using techniques like integrating factors and the Wronskian.

2. Perform partial differentiation, identify exact and inexact differentials, and apply Lagrange multipliers to optimize functions under constraints.

3.Calculate and interpret vector operations, including scalar and vector products, to model and solve area and volume problems in physics and engineering.

4. Apply vector calculus techniques such as calculating gradients, divergences, and curls, and use Gauss', Green's, and Stokes' theorems to solve problems involving vector fields.

5.Utilize orthogonal curvilinear coordinates to calculate vector field properties and explain the properties and applications of the Dirac delta function in theoretical contexts.

Course Content

Mathematical Physics - I (Theory) Credits – 3

Module 1:

a) First Order and second order differential equations: First order differential equations and integrating factor. Homogeneous equations with constant coefficients. Wronskian and general solution. Statement of existence and uniqueness theorem for initial value problems. Particular integral.

b) Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor with simple illustration. Constrained maximization using Lagrange multipliers.

Module 2:

a) Preliminaries of Vector: Vector addition. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.

b) Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities.

c) Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Line, surface, and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes theorems and their applications (no rigorous proofs)

Module 3:

a) Orthogonal curvilinear coordinates: Orthogonal curvilinear coordinates. Derivation of gradient, divergence, curl and Laplacian in Cartesian, spherical and cylindrical coordinate systems.

b) Dirac delta function and its properties: Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.

Suggestive Readings:

- Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber,F.E. Harris, 2013, 7th Edn., Elsevier.
- Vector analysis, S. Lipschutz, D. Spellman, M. R. Spiegel, 2009, McGraw Hill Education Pvt. Ltd.
- Theory and problems of Theoretical Mechanics, M. R. Spiegel, 2006, Tata McGraw Hill Education Pvt. Ltd.
- An introduction to ordinary differential equations, E.A. Codding- ton, 2009, PHI learning.
- Differential Equations, George F. Simmons, 2007, McGraw Hill.
- Mathematical Tools for Physics, James Nearing, 2010, Dover Pub- lications.
- Mathematical Methods for Scientists and Engineers, D.A. McQuar- rie, 2003, Viva Book.
- Mathematical Physics. B. Bhattacharyya, 2010, New Central Book Agency (P) Ltd.
- Mathematical Methods in the Physical Science. M. L. Boas, 2018. Willey.
- Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
- Mathematical Physics, Goswami, 1st Edition, Cengage Learning.
- Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
- Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
- Essential Mathematical Methods, K.F.Riley and M.P.Hobson, 2011, Cambridge Univ. Press

Module 4: Mathematical Physics-I (Practical) Credit-1

Introduction to programming in Python:

(a) Introduction to programming, constants, variables and data types, dynamical typing, operators and expressions, modules, I/O statements, file handling, iterables, compound statements, indentation in python, the if-else block, for and while loops, nested compound statements.

(b) Elementary calculations with different type of data e.g., area and volume of regular shapes using formulae. Creation and handling of one and two dimensional arrays, sum and average of a list of numbers stored in an array, finding the largest and lowest number from a list, simple calculation of matrices e.g., addition, subtraction, multiplication. Introduction to three dimensional arrays.

Graph Plotting: Introduction to plotting graphs with Matplotlib. Basic 2D graph plotting using data file and functions.

Note: Students need to execute simple python programs and generate plots.

Suggestive Readings:

- Introduction to Numerical Analysis, S.S. Sastry, 5th Edn. , 2012, PHI Learning Pvt. Ltd.
- Learning with Python-how to think like a computer scientist, J. Elkner, C. Meyer, and A. Downey, 2015, Dreamtech Press.
- Introduction to computation and programming using Python, J. Guttag, 2013, Prentice Hall India.
- Effective Computation in Physics- Field guide to research with Python, A. Scopatz and K.D. Hu , 2015, O’Rielly A first course in Numerical Methods, U.M. Ascher & C. Greif, 2012, PHI Learn- ing.
- Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
- Scientific computing in python, 2nd Edn, A. K. Gupta, 2021, Techno World.
- Numerical Methods for Scientists & Engineers, R.W. Hamming, 1973, Courier Dover Pub.
- An Introduction to computational Physics, T. Pang, 2nd Edn., 2006, Cambridge Univ. Press Computational Physics, Darren Walker, 1st Edn., 2015, Scientic International Pvt. Ltd.

Semester- III

Course code: PHS-DC-MJ-301

Course name- Thermal Physics-I

Learning Objective

This module aims to provide students with a comprehensive understanding of the fundamental principles of kinetic theory, heat conduction, and thermodynamics. By exploring concepts such as the Maxwell-Boltzmann distribution, specific heats, Fourier's law of heat conduction, and the laws of thermodynamics, students will gain insights into how energy and entropy govern physical processes. Additionally, students will examine key thermodynamic potentials and Maxwell's relations to understand the transformations in thermodynamic systems, further applying these to real-world phenomena like phase transitions, heat engines, and refrigeration.

Learning Outcomes

By the end of this module, students will be able to:

1. Explain the Maxwell-Boltzmann distribution law and its implications for particle velocities in an ideal gas, and calculate mean, RMS, and most probable speeds.

2. Apply the law of equipartition of energy to determine the specific heats of gases based on degrees of freedom.

3. Analyze the Fourier equation for heat conduction to solve problems related to thermal conductivity and heat diffusivity in rectilinear flow scenarios.

4. Describe and distinguish between extensive and intensive thermodynamic variables and state functions such as internal energy in relation to the Zeroth and First Laws of Thermodynamics.

5. Compare and contrast reversible and irreversible processes, and discuss the operation and efficiency of heat engines and refrigerators in terms of the Second Law of Thermodynamics.

6. Define entropy and apply the Clausius inequality to evaluate entropy changes in reversible and irreversible processes, including examples such as the entropy of a perfect gas and the concept of entropy in the universe.

7. Understand thermodynamic potentials and their applications, including enthalpy, Helmholtz free energy, and Gibbs free energy, along with the practical implications of adiabatic demagnetization.

8. Derive and apply Maxwell's thermodynamic relations to calculate properties such as heat capacities, the Joule-Kelvin coefficient, and temperature changes during adiabatic processes.

Course Content

Thermal Physics-I (Theory) **Credits – 3**

Module 1 :

(a) Kinetic Theory of Gases-I: Distribution of velocities: Maxwell- Boltzmann law of distribution of velocities in an ideal gas and its experimental verification. Mean, RMS and most probable speeds. Degrees of freedom. Law of equipartition of energy (no proof required). Specific heats of gases.

(b) Conduction of Heat: Thermal conductivity. Diffusivity. Fourier's equation for heat conduction and its solution for rectilinear flow of heat.

Module 2:

a) Zeroth and First law of Thermodynamics: Extensive and intensive thermodynamic variables. Thermodynamic equilibrium. Zeroth law of Thermodynamics & concept of temperature. Con- cept of work & heat. State functions. Internal energy and First law of Thermodynamics. Its differential form. First law & various processes. Applications of first law: General relation between C_P and C_V, Work done during isothermal and adiabatic processes. Compressibility and expansion co-efficient.

b) Second law of Thermodynamics: Reversible and irreversible process with examples. Conversion of work into heat and heat into work. Heat engines. Carnot's cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, Second law of Thermodynamics: Kelvin-Planck and Clausius statements and their equivalence.

c) Carnot's theorem. Applications of Second law of Thermodynamics. Thermodynamic scale of temperature and its equivalence to perfect gas scale.

d) Entropy: Concept of entropy. Clausius theorem. Clausius inequality, Second law of Thermodynamics in terms of entropy. Entropy of a perfect gas. Principle of increase of entropy. Entropy changes in reversible and irreversible processes with examples. Entropy of the universe. Third law of Thermodynamics. Unattainability of absolute zero.

Module 3:

a) Thermodynamic Potentials: Internal energy. Enthalpy. Helmholtz free energy. Gibb's free energy. Their definitions, properties and applications. Surface films and variation of surface tension with temperature. Magnetic work. Cooling due to adiabatic demagnetization. First and second order phase transitions with examples, Clausius-Clapeyron equation and Ehrenfest equations.

b) Maxwell's Thermodynamic Relations. Derivations and applications of Maxwell's relations. Determination of the following using Maxwell's relations: (i) Clausius Clapeyron equation (ii) values of $C_p - C_v$, (iii) $T - dS$ equations (iv) Joule-Kelvin coefficient for ideal and Van der Waal gases (v) Energy equations(vi) Change of temperature during adiabatic process.

Suggestive Readings:

- Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw- Hill.
- Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw- Hill.
- Modern Thermodynamics with Statistical Mechanics, Carl S. Hel- rich, 2009, Springer.
- Thermal physics (heat & thermodynamics), A. B. Gupta, H. P. Roy, 2009, Books and allied (P) Ltd.
- Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
- Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Edn., 2012, Oxford University Press.
- Thermodynamics and an introduction to thermo statistics, H. B. Callen, 1985, Wiley.
- Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Pub- lications.

Module-4: Thermal Physics-I(Practical) Credit - 1

List of Experiments:

1. To determine mechanical equivalent of heat J by Callender and Barne's constant flow method.

2. To determine the coefficient of thermal conductivity of glass in the form of tube.

3. To determine the coefficient of thermal conductivity of a bad con- ductor by Lee and Charlton's disc method.

4. To determine the temperature coefficient of resistance by platinum resistance thermometer (PRT).

5. To study the variation of thermo-emf of a thermocouple with difference of temperature at its two junctions.

6. To calibrate a thermocouple to measure temperature in a specified range using null method to determine neutral temperature

Suggestive Readings:

- Advanced Practical Physics for students, B. L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn., 2011, Kitab Mahal.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.
- Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.
- Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.
- Laboratory Manual of physics vol-I, M. Jana, 220. Books & Allied(P) Ltd.
- An advance course in practical physics, D. Chattopadhyay, P. C. Rakshit, 2009, New Central Book Agency (P) Ltd.

Semester III

Course code: PHS-DC-MJ-302

Course Name-Electricity and Magnetism

Learning Objective

This course module provides an in-depth study of electric and magnetic fields, electrostatics, dielectrics, magnetostatics, and electromagnetic induction. By exploring foundational principles such as Coulomb’s law, Gauss’s theorem, the Biot-Savart law, and Maxwell’s equations, students will understand how charges and currents generate electric and magnetic fields. Additionally, they will analyze the behavior of dielectrics and magnetic materials, apply key network theorems, and explore the principles underlying AC circuits. This module aims to equip students with both conceptual knowledge and practical problem-solving skills applicable to electrical circuits and various electrostatic and magnetostatic systems.

Learning Outcomes

By the end of this module, students will be able to:

1. **Apply Coulomb's law and the principle of superposition** to calculate electrostatic fields and understand the behavior of field lines around charges.

2. **Use Gauss’s theorem** to determine electric fields from charge distributions with spherical, cylindrical, and planar symmetry.

3. **Explain and calculate electric potential** in various configurations, including charged spherical shells and solid spheres, and solve for fields from potentials.

4. **Derive and solve Laplace's and Poisson's equations** in electrostatic contexts and apply the Method of Images for conductors.

5. **Analyze dielectric properties and polarization** by using the displacement vector and understanding the relationships among $\vec{E}$, $\vec{P}, and\ \overrightarrow{D}$ in dielectrics.

6. **Utilize Biot-Savart’s law and Ampere’s circuital law** to calculate magnetic fields around currents and in applications such as solenoids.

7. **Understand magnetic properties of materials** and relate $\vec{B}, \vec{H}$, and $\vec{M}$, while distinguishing between dia-, para-, and ferromagnetic materials.

8. **Apply Faraday’s and Lenz’s laws of electromagnetic induction** to solve problems involving self-inductance, mutual inductance, and energy storage in magnetic fields.

9. **Solve AC circuit problems using Kirchhoff’s laws,** understanding resonance, power dissipation, and quality factors in LCR circuits.

10. **Apply network theorems such as Thevenin’s and Norton’s** to analyze and simplify DC circuits for efficient problem-solving.

Course Content

Electricity and Magnetism (Theory) Credit-3

Module-1:

a) Coulombs law and Principle of superposition leading to the definition of electrostatic field and field lines. Divergence of an electrostatic field. Flux, Gauss's theorem of electrostatics. Applications of Gauss theorem to determine electric field due to charge configurations with spherical, cylindrical and planar symmetry.

b) Curl of an electrostatic field and its conservative nature. Electric potential. Potential for a uniformly charged spherical shell and solid sphere. Calculation of electric field from potential.

(c) Laplace's and Poisson equations. Uniqueness theorem. Method of Images and its application to: Point charge in front of an earthed conducting (i) infinite plane and (ii) sphere.

(d) Conductors: Electric field and charge density inside and on the surface of a conductor. Conductors in an electrostatic field. Force per unit area on the surface. Capacitance of a conductor. Capacitance an isolated spherical conductor. Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Energy per unit volume in electrostatic field.

(e) Electric potential and field due to an electric dipole. Electric dipole moment. Force and torque on a dipole.

(f) Electric fields inside matter: Electric Polarization. Bound charges. Displacement vector. Relations between E, P and D. Gauss's theorem in dielectrics. Linear Dielectric medium. Electric Susceptibility and Permittivity. Capacitor (parallel plate, spherical, cylindrical) with dielectric.

Module-2 :

a) Biot-Savart's law. Force on a moving point charge due to a magnetic field: Lorentz force law. Application of Biot-Savart's law to determine the magnetic field of a straight conductor, circular coil. Force between two straight current carrying wires. Divergence of the magnetic field - its solenoidal nature. Magnetic vector potential. Curl of the magnetic field. Ampere's circuital law and its application to (i) Infinite straight wire (ii) Infinite planar surface current(iii) Solenoid

b) Magnetic properties of matter: Potential and field due to a magnetic dipole. Magnetic dipole moment. Force and torque on a magnetic dipole in a uniform magnetic field. Magnetization. Bound currents. The magnetic intensity - H. Relation between B, H and M. Linear media. Magnetic Susceptibility and Permeability. Brief introduction of dia-, para- and ferro-magnetic materials. B-H curve and hysteresis.

c) Electro-magnetic induction: Ohms law and definition of E.M.F. Faraday's laws of electro- magnetic induction. Lenz's law. Self- Inductance and mutual inductance. Reciprocity theorem. Introduction to Maxwell's equations. Charge conservation. Displacement current and equation of Continuity. Energy stored in a magnetic field.

Module-3 :

a) Electrical circuits: AC circuits: Kirchhoff's laws for AC circuits. Complex reactance and impedance. Series LCR circuit: (i) Resonance, (i) Power dissipation (iii) Quality factor, and (iv) Band width. Parallel LCR circuit.

b) Network theorems: Ideal constant voltage and constant current sources. Thevenin's theorem. Norton's theorem.

c) Superposition theorem. Reciprocity theorem. Maximum power Transfer theorem and their applications to dc circuits.

Suggestive Readings:

- Introduction to Electrodynamics, D.J. Grifiths, 3rd Edn., 1998, Benjamin Cummings.
- Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw Hill.
- Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education.
- Feynman Lectures Vol.2, R.P. Feynman, R.B. Leighton, M. Sands, 2008, Pearson Education.
- Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford Uni- versity Press.
- Electricity and Magnetism, D. Chattopadhyay and P. C. Rakshit, New Central Book Agency, 2011.
- Foundation of electricity and magnetism, B. Ghosh, 2010. Books & allied (P) Ltd.
- Electricity and Magnetism, J. H. Fewkes & J. Yarwood. Vol.I, 1991, Oxford Univ. Press.

Module-4 :Electricity and Magnetism (Practical) Credit-1

List of Experiments:

1. To determine an unknown Low Resistance using Carey Foster's Bridge.

2. To verify the Thevenin's and Norton's theorems.

3. To verify the Maximum power transfer theorems.

4. To determine self-inductance of a coil by Anderson's bridge.

5. To study I -V characteristics of a series RC circuit with AC source.

6. To study response curve of a Series LCR circuit and determine its(a) Resonant frequency, (b) Band width, and (c) Quality factor.

7. To study the response curve of a parallel LCR circuit and determine its (a) Anti- resonant frequency and (b) Quality factor.

Suggestive Readings:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.

- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Edn., 2011, Kitab Mahal.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Og- born, 4th Edition, reprinted 1985, Heinemann Educational Pub- lishers.
- Engineering Practical Physics, S.Panigrahi and B.Mallick, 2015, Cengage Learning.
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.
- Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.
- Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.
- Laboratory Manual of physics vol-I, M. Jana, 220. Books & Allied(P) Ltd.
- An advance course in practical physics, D. Chattopadhyay, P. C. Rakshit, 2009, New Central Book Agency (P) Ltd.

Semester-IV

Course Code-PHS-DC-MJ-402

Course Name- Optics

Learning Objective

This course module explores the foundational concepts of geometrical and wave optics, focusing on principles that govern light behavior in optical systems, including Fermat's principle, interference, diffraction, and polarization. Students will study how light interacts with materials, observe dispersion, and understand aberrations. Through analysis of optical instruments, wave phenomena, and interferometric techniques, students will develop a comprehensive understanding of light's nature and behavior. This module aims to build students' skills in applying theoretical optics concepts to practical scenarios involving lenses, prisms, microscopes, telescopes, and diffraction gratings.

Learning Outcomes

By the end of this module, students will be able to:

1. **Apply Fermat's principle** to analyze and predict light reflection and refraction at both plane and curved boundaries, including cardinal points of optical systems.

2. **Identify and evaluate the field of view** and magnification for various optical instruments, including eyepieces, telescopes, and microscopes.

3. **Explain dispersion and chromatic aberration** in prisms and lenses, and describe methods for their reduction using achromatic lens combinations.

4. **Describe the wave nature of light** using Huygens' principle and understand the concepts of temporal and spatial coherence.

5. **Analyze and apply interference principles** to different experimental setups like Young's double-slit experiment, Fresnel's biprism, and thin-film interference.

6. **Understand interferometers** such as the Michelson and Fabry-Perot for precise measurements, including wavelength determination and refractive index evaluation.

7. **Examine diffraction patterns** from single and double slits, gratings, and circular apertures, and understand the principles behind the resolving power of optical instruments.

8. **Understand the Rayleigh criterion** and apply it to analyze and compare the resolving power of various optical devices, such as prisms, microscopes, and gratings.

Course Content

Optics(Theory) Credits – 3

Module-1 :

(a) Fermat's principle: Application of Fermat's principle to reflection and refraction at plane and curved boundaries. Cardinal points of an optical system. Thick lens. Two thin lenses separated by a distance. Equivalent lens. Different types of magnification. Helmholtz Lagrange equation. Paraxial approximation (matrix methods may be used).

(b)Optical Instruments: Field of view of optical instruments. Rams- den and Huygens eyepieces. Construction of high power immersion objectives. Telescope and microscope.

(c) Dispersion: Dispersive power of optical instruments. Dispersive power of prism. Chromatic aberration –methods of reduction, achromatic lens combination. Seidel aberrations (Only qualitative discussions), methods of reducing them.

Module-2

Wave optics: Wave nature of light. Wave front. Huygens Principle. Temporal and spatial coherence.

a) Interference: Coherent sources. Conditions for observing interference. Young's double slit experiment. Division of amplitude and wave front. Lloyd's Mirror and Fresnel's Bi-prism. Measurement of thickness of a thin film by Fresnel biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge- shaped films. Fringes of equal inclination (Haidinger fringes). Fringes of equal thickness (Fizeau fringes). Newton's rings: Measurement of wavelength and refractive index.

b) Interferometers: Michelson Interferometer: Idea of form of fringes (No theory required). Application of Michelson Interferometer: Determination of wavelength, Wavelength Difference, Refractive Index.Fabry-Perot interferometer: Working principle, construction and uses

Module-3 :

Diffraction:

(a) Fraunhofer diffraction: Single slit. Double slit. Plane diffraction grating. Diffraction in a circular aperture.

(b) Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Use of zone plate.

(c) Resolving Power of optical instruments: Rayleigh criterion, re- solving power of prism, telescope, microscope, grating.

Suggestive Readings:

- Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw- Hill.
- Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw- Hill.
- Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
- Optics, Ajoy Ghatak, 2008, Tata McGraw Hill.
- A text on light. B. Ghosh & K. G. Mazumdar, 2006. Sreedhar Publishers.
- Optics, 4th Edn., Eugene Hecht, Pearson Education Limited, 2014.
- Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.
- A textbook of Optics; N Subramanyam, B. Lal and M.N. Avadhan- ulu; S.Chand. Publishing.

Module-4 :Optics(Practical) Credit-1

List of Experiments:

1. Familiarization with: Schuster‘s focusing; determination of angle of prism.
2. To determine refractive index of the Material of a prism using sodium source.
3. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
4. To determine the wavelength of sodium source using Michelson's interferometer.
5. To determine wavelength of sodium light using Fresnel bi-prism.
6. To determine wavelength of sodium light using Newton's rings.
7. To determine wavelength of (i) Na source and (ii) spectral lines of Hg source using plane diffraction grating.
8. To determine dispersive power and resolving power of a plane diffraction grating.

General Topic: In the practical classes, students should be thoroughly familiarized with Schuster's focusing for their general proficiency with spectrometers.

Suggestive Readings:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal.
- Advanced level Physics Practicals, Michael Nelson, and Jon M. Og- born, 4th Edition, reprinted 1985, Heinemann Educational Publish- ers.
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.
- Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.
- Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.
- Laboratory Manual of physics vol-I, M. Jana, 220. Books & Allied(P) Ltd.
- An advance course in practical physics, D. Chattopadhyay, P. C. Rakshit, 2009, New Central Book Agency (P) Ltd.

Course code-PHS-DC-MJ-402

Course name-Mathematical Physics-II and Acoustics

Learning Objective

This module introduces students to the essential principles of wave mechanics and oscillations, focusing on the mathematical tools and physical concepts needed to analyze wave behavior, vibrations, and resonance. Topics include solutions of partial differential equations in different symmetries, Fourier series, and various types of wave and oscillatory motion. Through the study of harmonic oscillations, wave superposition, and the Doppler effect, students will gain the analytical skills to describe and predict the dynamics of mechanical systems and wave phenomena in diverse physical settings.

Learning Outcomes

By the end of this module, students will be able to:

1. **Solve partial differential equations** (Laplace, wave, and diffusion equations) for problems with rectangular, cylindrical, and spherical symmetry using separation of variables.

2. **Expand periodic functions into** Fourier series, understanding orthogonality of sine and cosine functions, and apply Fourier coefficients to analyze even and odd functions.

3. **Analyze simple harmonic motion (SHM**), calculating kinetic and potential energy, as well as evaluating damped and forced oscillations, resonance, and quality factor.

4. **Apply the principle of superposition** to collinear and perpendicular harmonic oscillations, using graphical and analytical methods, including generating and interpreting Lissajous figures.

5. **Describe wave motion** in different media, differentiate between plane and spherical waves, and calculate wave intensity, energy transport, and particle velocities.

6. **Calculate the velocity of transverse and longitudinal** waves in various mediums, including stretched strings and fluid-filled pipes, using relevant physical formulas.

7. **Explain and analyze standing waves** in strings and pipes, including energy transfer, normal modes, and experimental setups like Melde's experiment.

8.**Calculate and interpret the Doppler effect**, understanding its implications in both stationary and moving sources and observers.

<u>Course content</u>

Mathematical Physics-II and Acoustics (Theory)   Credits – 3

Module-1:

a) Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical, and spherical symmetry. Wave equation and its solution for rectangular membrane. Diffusion Equation.

b) Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Even and odd functions and their Fourier expansions.

Module-2:

a) Oscillations: Simple Harmonic Motion (SHM). Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy, and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states. Resonance. sharpness of resonance. Power dissipation and quality factor.

b) Superposition of Harmonic Oscillations: Superposition of Collinear Harmonic oscillations: Linearity and Superposition Principle. Superposition of two collinear oscillations having (i) equal frequencies and (ii) different frequencies (beats). Superposition of N collinear Harmonic Oscillations with (i) equal phase differences and (ii) equal frequency differences. Superposition of two perpendicular Harmonic Oscillations: Graph- ical and analytical methods. Lissajous figures with equal an unequal frequency and their uses.

c) Wave motion: Plane and spherical waves. Longitudinal and transverse waves. Plane progressive (traveling) waves. Wave equation. Particle and wave velocities. Differential equation. Pressure of a longitudinal wave. Energy transport. Intensity of wave. Water Waves: Ripple and gravity waves**.**

Module-3:

a) Velocity of Waves: Velocity of transverse vibrations along a stretched string. Velocity of longitudinal waves in a fluid within a pipe. Newton's formula for velocity of sound. Laplace's correction.

b) Superposition of Harmonic Waves: Standing (Stationary) waves in a string: Fixed and free ends. Analytical treatment. Changes with respect to position and time. Energy of vibrating string. Transfer of energy. Normal modes of stretched strings. Plucked and struck strings. Melde's experiment. Longitudinal standing waves and normal modes. Open and closed pipes. Superposition of N harmonic waves. Phase and group velocities

c) Doppler Effect: Calculation of Doppler shift, Doppler effect and stationary waves.

Suggestive Readings:

- Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.
- Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.
- Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
- Differential Equations, George F. Simmons, 2006, Tata McGraw- Hill.
- Partial Differential Equations for Scientists & Engineers, S.J. Far- low, 1993, Dover Pub.
- Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press.
- Mathematical methods for Scientists & Engineers, D.A. McQuarrie, 2003, Viva Books.
- Principles of acoustics. B. Ghosh, 2010, Sreedhar Publishers.
- The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
- The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.

Module-4: Mathematical Physics-II and Acoustics (Practical) Credit - 1

List of Experiments:

1. Determine the frequency of an electrically maintained tuning fork by Melde's experiment.

2. To verify $\lambda^2 - T$ law by Melde's experiment.

3. To investigate the motion of coupled oscillators.

4. To verify the laws of transverse vibration in a string using sonometer.

5. To determine (i) the density of the material of a wire using sonometer (ii) the speed of transverse waves in the wire of the sonometer.

6. To study the Lissajous figures formed by superposition of two mutually perpendicular simple harmonic oscillations using CRO.

Suggestive Readings:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal.
- Advanced level Physics Practicals, Michael Nelson, and Jon M. Og- born, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.
- Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.
- Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.
- Laboratory Manual of physics vol-I, M. Jana, 220. Books & Allied(P) Ltd.
- An advance course in practical physics, D. Chattopadhyay, P. C. Rakshit, 2009, New Central Book Agency (P) Ltd.

Course code-PHS-DC-MJ-404

Course name- Elements of Modern Physics

Learning Objective

This module aims to provide students with a comprehensive foundation in quantum mechanics, atomic physics, and nuclear physics, covering core concepts like wave-particle duality, atomic structure, and nuclear forces. Through examining blackbody radiation, the photoelectric effect, and key experiments like the Millikan oil-drop and Davisson-Germer experiments, students will gain insight into quantum theory's experimental and theoretical underpinnings. Topics such as the Heisenberg uncertainty principle, Bohr atomic model, and nuclear stability equip students with the knowledge to analyze and interpret fundamental physical phenomena at the quantum level.

Learning Outcomes

By the end of this module, students will be able to:

1. **Explain fundamental quantum concepts**, including blackbody radiation, Planck's quantum theory, photoelectric effect, and Compton scattering, and their impact on modern physics.

2. **Describe wave-particle duality** using the de Broglie wavelength and analyze particle behavior as waves, including group and phase velocity relationships.

3. **Apply the Heisenberg uncertainty principle** to scenarios demonstrating measurement limitations and the concept of non-deterministic particle trajectories.

4. **Summarize atomic models** (Bohr, Bohr-Sommerfeld) and experiments like the Millikan oil-drop and Franck-Hertz experiments to understand electron properties and atomic structure.

5. **Analyze nuclear properties and stability**, discussing nucleus size, mass, charge, and the effects of forces within the nucleus, including implications of the NZ graph and magic numbers.

6. **Understand radioactive decay processes,** including alpha, beta, and gamma decay, the concept of half-life, and the prediction of neutrino emission in beta decay.

7. **Explain the significance of the Doppler effect** and stationary waves in various contexts, applying knowledge to problems in classical and quantum physics.

Course content

Elements of Modern Physics(Theory) Credits - 3

Module-1:

a)Blackbody Radiation, Planck's quantum, Planck's constant. Photo- electric effect and Compton scattering. Davisson-Germer experiment. De- Broglie wavelength and matter waves. Wave- particle duality. Wave description of particles by wave packets. Group and phase velocities and relation between them. Probability interpretation: Normalized wave functions as probability amplitudes.

b) Two-Slit experiment with photons and electrons. Linear superposition principle as a consequence.

c) Position measurement- gamma ray microscope thought experiment. Heisenberg- uncertainty principle (statement with illustrations). Impossibility of a particle following a trajectory.

Module-2:

a) Determination of electronic charge: Millikan oil-drop method. Determination of e/m by Thompson's method. Discovery and properties of positive rays. Thomson's parabola method. As- ton's mass spectrograph.

b) Bohr atom Model, Bohr's correspondence principle. Bohr Sommerfeld atomic model, Pauli exclusion principle. Qualitative discussions on quantum numbers. Franck & Hertz experiment.

Module-3:

a) Structure of the Nucleus: Size, mass, charge, spin of atomic nucleus and its relation with atomic weight. Impossibility of an electron being in the nucleus as a consequence of the un- certainty principle. Nature of nuclear force, NZ graph. Magic Number.

b) Radioactivity: stability of the nucleus. Law of radioactive de- cay. Mean life and half-life. Alpha decay and beta decay (brief qualitative discussions). Energy released spectrum and Pauli's prediction of neutrino. Gamma ray emission. Energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus.

Suggestive Readings:

- Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
- Atomic Physics, S. N. Ghoshal, 2011, S. Chand & Company Ltd.
- Nuclear Physics, S. N. Ghoshal, 2011, S. Chand & Company Ltd
- Primer of Quantum Mechanics; M. Chester; John Wiley & Sons, 1987.
- Introduction to Quantum Mechanics, David J. Griffiths, 2005, Pear- son Education.
- Physics for Scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.
- Modern Physics, G. Kaur and G.R. Pickrell, 2014, McGraw Hill.
- Modern atomic and nuclear physics. A. B. Gupta 2014. Books and allied (P) Ltd.
- Quantum Mechanics: Theory & Applications, A.K.Ghatak & S.Lokanathan, 2004, Macmillan Additional Books for Reference
- Modern Physics, J.R. Taylor, C.D. Za ratos, M.A. Dubson, 2004, PHI Learning.
- Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd Edn, Tata McGraw-Hill Publishing Co. Ltd.
- Quantum Physics, Berkeley Physics, Vol.4. E.H.Wichman, 1971, Tata McGraw-Hill Co.
- Basic ideas and concepts in Nuclear Physics, K.Heyde, 3rd Edn., Institute of Physics Pub.
- Nuclear Physics; S.N.Ghosal; S. Chand Publishing.

Module- 4 : Elements of Modern Physics(Practical) Credit - 1

List of Experiments:

1. Measurement of Planck's constant using black body radiation and photo- detector.

2. Photo-electric effect: study photo current versus intensity and wave- length of light; maximum energy of photo-electrons versus frequency of light.
3. To determine work function of material of filament of directly heated vacuum diode.
4. To determine the Planck's constant using LEDs of at least 4 differ- ent colours.
5. To determine the wavelength of H-alpha emission line of Hydrogen atom.
6. To determine the ionization potential of mercury.
7. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
8. To determine the wavelength of laser source using diffraction of single slit.
9. To determine the wavelength of laser source using diffraction of double slits.
10. To determine (a) wavelength and (b) angular spread of He-Ne or any type of laser source using plane diffraction grating

Suggestive Readings:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Og- born, 4th Edition, reprinted 1985, Heinemann Educational Pub- lishers.
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn, 2011,Kitab Mahal.
- Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.
- Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.
- Laboratory Manual of physics vol-I, M. Jana, 220. Books & Allied(P) Ltd.
- An advance course in practical physics, D. Chattopadhyay, P. C. Rakshit, 2009, New Central Book Agency (P) Ltd.