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

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<tr><td colspan="9">Students on exit shall be awarded Undergraduate Certificate after securing requisite 40 credits on completion of Semester II</td></tr>
<tr><td>III</td><td>DC-MJ-301 (4)
DC-MJ-302 (4)</td><td>MN-301 (4)</td><td>MDC-301 (3)</td><td>SEC-301 (3)</td><td>English Language-1 (2)</td><td>IAPC (2)</td><td></td><td>22</td></tr>
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<tr><td colspan="9">Students on exit shall be awarded Undergraduate Diploma after securing requisite 82 credits on completion of Semester IV</td></tr>
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DC-MJ-604 (4)</td><td>MN-601 (4)</td><td colspan="5">----------------------</td><td>20</td></tr>
<tr><td colspan="9">Students on exit shall be awarded Bachelor Degree after securing requisite 122 credits on completion of Semester VI</td></tr>
<tr><td>VII</td><td>DC-MJ-701 (4)
DC-MJ-702 (4)
DC-MJ-703 (4)
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DC-MJ-802 (4)
DC-MJ-803 (4)
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<tr><td colspan="9">Students on exit shall be awarded Bachelor Degree (Honours) after securing requisite 162 credits on completion of Semester VIII</td></tr>
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DC-MJ-702 (4)
DC-MJ-703 (4)
DC-MJ-704 (4)</td><td>MN-701 (4)</td><td colspan="5">----------------------</td><td>20</td></tr>
<tr><td>VIII (Hons with research)</td><td>DC-MJ-801 (4)
DRP-1 (12)</td><td>MN-801 (4)</td><td colspan="5">----------------------</td><td>20</td></tr>
<tr><td colspan="9">Students on exit shall be awarded Bachelor Degree (Honours with Research) after securing requisite 162 credits on completion of Semester VIII</td></tr>
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Marks Distribution for Major Course (Credit: 4)

Type of Evaluation	Marks	Distribution of Marks
Internal Assessment	25	Attendance: 05 Class Performance: 05 Project/Presentation*: 10 Viva*: 05 (* to be evaluated in presence of external examiner)
Theoretical Examination	30	$1 \times 6 = 6$ (6 out of 8 alternative questions) $3 \times 3 = 9$ (3 out of 5 alternative questions) $5 \times 3 = 15$ (3 out of 5 alternative questions)
Practical Examination (or Project)	20	L.N.B.: 03 Viva: 05 Examination: 12
Total	75	

Credit Hours per Course Component

Course Component	Credit	Hours per credit per week	Total hours in a 15-week semester
Lecture	3	1	45
Practicum	1	2	30
Seminar Internship / Studio Activities / Field Practice / Projects / Community Engagement and Service (IAPWC)	2	2	60
Skill Enhancement Course (SEC)	3	2	90

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:

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

Course Content

Mechanics (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 15)

(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:
(Total Lectures: 15)

(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:
(Total Lectures: 15)

(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:

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

Module 4:

Mechanics (Practical) **Credit: 1**

Total Lectures: 30

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:

1. *Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.*
2. *Advanced level Physics Practicals, Michael Nelson and Jon M. Og- born, 4th Edn, reprinted 1985, Heinemann Educational Publishers.*
3. *A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Edn, 2011, Kitab Mahal.*
4. *Engineering Practical Physics, S. Panigrahi & B.Mallick, 2015, Cengage Learning India Pvt. Ltd.*
5. *Advanced practical physics, volume-1, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.*
6. *Advanced practical physics, volume-2, B. Ghosh, 2009. Sreedhar Publishers.*
7. *Laboratory Manual of physics vol-1, M. Jana, 2020. Books & Allied(P) Ltd.*
8. *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:

- **Solve** and interpret solutions to first-order and second-order differential equations using techniques like integrating factors and the Wronskian.
- **Perform** partial differentiation, identify exact and inexact differentials, and apply Lagrange multipliers to optimize functions under constraints.
- **Calculate** and interpret vector operations, including scalar and vector products, to model and solve area and volume problems in physics and engineering.
- **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.
- **Utilize** orthogonal curvilinear coordinates to calculate vector field properties and explain the properties and applications of the Dirac delta function in theoretical contexts.

<u>Course Content</u>

Mathematical Physics-I (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 15)

(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:
(Total Lectures: 20)

(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:
(Total Lectures: 10)

(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:

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

Module 4:

Mathematical Physics-I (Practical) Credit: 1
Total Lectures: 30

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:

1. *Introduction to Numerical Analysis, S.S. Sastry, 5th Edn. , 2012, PHI Learning Pvt. Ltd.*
2. *Learning with Python-how to think like a computer scientist, J. Elkner, C. Meyer, and A. Downey, 2015, Dreamtech Press.*
3. *Introduction to computation and programming using Python, J. Guttag, 2013, Prentice Hall India.*
4. *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 Learning.*
5. *Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.*
6. *Scientific computing in python, 2nd Edn, A. K. Gupta, 2021, Techno World.*
7. *Numerical Methods for Scientists & Engineers, R.W. Hamming, 1973, Courier Dover Pub.*
8. *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 Objectives:

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:

- **Explain** the Maxwell-Boltzmann distribution law and its implications for particle velocities in an ideal gas, and calculate mean, RMS, and most probable speeds.
- **Apply** the law of equipartition of energy to determine the specific heats of gases based on degrees of freedom.
- **Analyze** the Fourier equation for heat conduction to solve problems related to thermal conductivity and heat diffusivity in rectilinear flow scenarios.
- **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.
- **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.
- **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.
- **Understand** thermodynamic potentials and their applications, including enthalpy, Helmholtz free energy, and Gibbs free energy, along with the practical implications of adiabatic demagnetization.
- **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) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 10)

(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:
(Total Lectures: 20)

(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:
(Total Lectures: 15)

(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:

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

Module 4:

Thermal Physics-I (Practical) **Credit: 1**
Total Lectures: 30

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:

1. *Advanced Practical Physics for students, B. L. Flint and H.T. Worsnop, 1971, Asia Publishing House.*
2. *A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn., 2011, Kitab Mahal.*
3. *Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.*
4. *A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Publishers.*
5. *Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.*
6. *Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.*
7. *Laboratory Manual of physics vol-I, M. Jana, 2020. Books & Allied(P) Ltd.*
8. *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 Objectives:

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:

- **Apply** Coulomb's law and the principle of superposition to calculate electrostatic fields and understand the behavior of field lines around charges.
- **Use** Gauss's theorem to determine electric fields from charge distributions with spherical, cylindrical, and planar symmetry.
- **Explain** and calculate electric potential in various configurations, including charged spherical shells and solid spheres, and solve for fields from potentials.
- **Derive** and solve Laplace's and Poisson's equations in electrostatic contexts and apply the Method of Images for conductors.
- **Analyze** dielectric properties and polarization by using the displacement vector and understanding the relationships among $E\rightarrow\longrightarrow$, $P\rightarrow\longrightarrow$, *and* $\longrightarrow D\rightarrow\rightarrow\longrightarrow$ in dielectrics.
- **Utilize** Biot-Savart's law and Ampere's circuital law to calculate magnetic fields around currents and in applications such as solenoids.
- **Understand** magnetic properties of materials and relate $B\rightarrow\longrightarrow$, $H\rightarrow\longrightarrow$, and $M\rightarrow\longrightarrow$, while distinguishing between dia-, para-, and ferromagnetic materials.
- **Apply** Faraday's and Lenz's laws of electromagnetic induction to solve problems involving self- inductance, mutual inductance, and energy storage in magnetic fields.
- **Solve** AC circuit problems using Kirchhoff's laws, understanding resonance, power dissipation, and quality factors in LCR circuits.
- **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**
Total Lectures: 45

Module 1:
(Total Lectures: 18)

(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:
(Total Lectures: 18)

(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:
(Total Lectures: 9)

(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:

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

Module 4:

Electricity and Magnetism (Practical) Credit: 1
Total Lectures: 30

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:

1. *Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.*
2. *A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Edn., 2011, Kitab Mahal.*
3. *Advanced level Physics Practicals, Michael Nelson and Jon M. Og- born, 4th Edition, reprinted 1985, Heinemann Educational Publishers.*
4. *Engineering Practical Physics, S.Panigrahi and B.Mallick, 2015, Cengage Learning.*

5. *A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.*
6. *Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.*
7. *Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.*
8. *Laboratory Manual of physics vol-I, M. Jana, 2020. Books & Allied(P) Ltd.*
9. *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-401
Course Name: Optics

Learning Objectives:

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:

- **Apply** Fermat's principle to analyze and predict light reflection and refraction at both plane and curved boundaries, including cardinal points of optical systems.
- **Identify** and evaluate the field of view and magnification for various optical instruments, including eyepieces, telescopes, and microscopes.
- **Explain** dispersion and chromatic aberration in prisms and lenses, and describe methods for their reduction using achromatic lens combinations.
- **Describe** the wave nature of light using Huygens' principle and understand the concepts of temporal and spatial coherence.
- **Analyze** and apply interference principles to different experimental setups like Young's double-slit experiment, Fresnel's biprism, and thin-film interference.
- **Understand** interferometers such as the Michelson and Fabry-Perot for precise measurements, including wavelength determination and refractive index evaluation.
- **Examine** diffraction patterns from single and double slits, gratings, and circular apertures, and understand the principles behind the resolving power of optical instruments.
- **Understand** the Rayleigh criterion and apply it to analyze and compare the resolving power of various optical devices, such as prisms, microscopes, and gratings.

<u>Course Content</u>

Optics (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 15)

(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:
(Total Lectures: 15)

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:
(Total Lectures: 15)

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:

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

Module 4:

Optics (Practical) Credit: 1
Total Lectures: 30

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:

1. *Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.*
2. *A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal.*
3. *Advanced level Physics Practicals, Michael Nelson, and Jon M. Og- born, 4th Edition, reprinted 1985, Heinemann Educational Publish- ers.*
4. *A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.*
5. *Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.*
6. *Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.*
7. *Laboratory Manual of physics vol-I, M. Jana, 2020. Books & Allied(P) Ltd.*
8. *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: Mathematical Physics-II and Acoustics

Learning Objectives:

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:

- **Solve** partial differential equations (Laplace, wave, and diffusion equations) for problems with rectangular, cylindrical, and spherical symmetry using separation of variables.
- **Expand** periodic functions into Fourier series, understanding orthogonality of sine and cosine functions, and apply Fourier coefficients to analyze even and odd functions.
- **Analyze** simple harmonic motion (SHM), calculating kinetic and potential energy, as well as evaluating damped and forced oscillations, resonance, and quality factor.
- **Apply** the principle of superposition to collinear and perpendicular harmonic oscillations, using graphical and analytical methods, including generating and interpreting Lissajous figures.
- **Describe** wave motion in different media, differentiate between plane and spherical waves, and calculate wave intensity, energy transport, and particle velocities.
- **Calculate** the velocity of transverse and longitudinal waves in various mediums, including stretched strings and fluid-filled pipes, using relevant physical formulas.
- **Explain** and analyze standing waves in strings and pipes, including energy transfer, normal modes, and experimental setups like Melde's experiment.
- **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) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 10)

(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:
(Total Lectures: 20)

(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: Graphical 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:
(Total Lectures: 15)

(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:

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

Module 4:

Mathematical Physics-II and Acoustics (Practical) Credit: 1
Total Lectures: 30

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:

1. *Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.*
2. *A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal.*
3. *Advanced level Physics Practicals, Michael Nelson, and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.*
4. *A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.*
5. *Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.*
6. *Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.*
7. *Laboratory Manual of physics vol-I, M. Jana, 2020. Books & Allied(P) Ltd.*
8. *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-403
Course Name: Elements of Modern Physics

Learning Objectives:

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:

- **Explain** fundamental quantum concepts, including blackbody radiation, Planck's quantum theory, photoelectric effect, and Compton scattering, and their impact on modern physics.
- **Describe** wave-particle duality using the de Broglie wavelength and analyze particle behavior as waves, including group and phase velocity relationships.
- **Apply** the Heisenberg uncertainty principle to scenarios demonstrating measurement limitations and the concept of non-deterministic particle trajectories.
- **Summarize** atomic models (Bohr, Bohr-Sommerfeld) and experiments like the Millikan oil-drop and Franck-Hertz experiments to understand electron properties and atomic structure.
- **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.
- **Understand** radioactive decay processes, including alpha, beta, and gamma decay, the concept of half-life, and the prediction of neutrino emission in beta decay.
- **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) **Credit: 3**

Total Lectures: 45

Module 1:
(Total Lectures: 15)

(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:
(Total Lectures: 15)

(a) Determination of electronic charge: Millikan oil-drop method. Determination of e/m by Thomson's method. Discovery and properties of positive rays. Thomson's parabola method. Aston'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:
(Total Lectures: 15)

(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:

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

Module 4:

Elements of Modern Physics (Practical) Credit: 1
Total Lectures: 30

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 different 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:

1. *Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.*
2. *Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.*
3. *A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn, 2011,Kitab Mahal.*
4. *Advanced practical physics, volume-I, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.*
5. *Advanced practical physics, volume-II, B. Ghosh, 2009. Sreedhar Publishers.*
6. *Laboratory Manual of physics vol-I, M. Jana, 2020. Books & Allied(P) Ltd.*
7. *An advance course in practical physics, D. Chattopadhyay, P. C. Rakshit, 2009, New Central Book Agency (P) Ltd.*

Semester – V
Course Code: PHS- DC-MJ-501
Course Name: Analog system and applications

Learning Objectives:

By the end of the course, students will be able to:
Understand the fundamental properties of semiconductors, PN junctions, transistors, FETs, and their applications in electronic circuits. Analyze the working principles, characteristics, and performance of diode and transistor-based circuits including rectifiers, regulators, and amplifiers. Gain knowledge of different biasing techniques, hybrid models, frequency response, and feedback mechanisms in amplifier design. Learn the characteristics and applications of operational amplifiers, including various signal conditioning and processing configurations. Design and evaluate waveform generators, multivibrators, and oscillators for practical electronic systems.

Learning Outcomes:

On successful completion of the course, students will be able to:

- **Explain** the operation of semiconductor devices (diodes, BJTs, FETs, OPAMPs) and their characteristics.
- **Design** and analyze rectifiers, voltage regulators, biasing circuits, amplifiers, and filters to meet specified requirements.
- **Evaluate** performance parameters such as ripple factor, efficiency, frequency response, stability, and gain for various circuits.
- **Implement** OPAMP-based applications (adders, comparators, integrators, differentiators, oscillators) in analog systems.
- **Develop** complete electronic circuits using semiconductor devices for signal processing, regulation, and waveform generation.

Course Content

Analog system and applications (Theory) Credit: 3
Total Lectures: 45

Module 1:
(Total Lectures: 10)

(a) Semiconductor diodes and applications: P and N type semiconductors. Energy level diagram. Conductivity and mobility, concept of drift velocity. PN junction fabrication (simple idea only). Barrier formation in PN junction diode. Static and dynamic resistance. Current flow mechanism in forward and reverse biased diode.

(b) Rectifier diode: Half-wave rectifiers. Centre-tapped and Bridge full-wave rectifiers, Calculation of Ripple Factor and Rectification Efficiency, L and C filter.
(a)Circuit and operation of clipping and clamping circuit; principle and structure of LEDs, photodiode, solar cell.

Module 2:
(Total Lectures: 10)

(a) n-p-n and p-n-p transistors, Characteristics of CB, CE and CC configurations. Physical mechanism of current flow, Relations between the current gains of the three modes. Active, cut-off and saturation regions. DC load line and Q-point.

(b) Field effect transistors: JFET and MOSFET (both depletion and enhancement type), Basic structure and principle of operations and their characteristics.

(c) Regulated power supply, Load regulation and line regulation. Zener diode as a voltage regulator.

Module 3:
(Total Lectures: 25)

(a) Transistor biasing and stabilization circuits: Fixed bias, voltage divider bias. Transistor as 2-port network. h-parameter equivalent circuit. Analysis of a single-stage CE amplifier using hybrid model. Input and output impedance. Classification of class A, B and C amplifiers with respect to placement to Q point. Frequency response of a CE amplifier. Role of series and parallel capacitors for cut off frequencies.

(b) Feedback amplifiers and OPAMP: Effects of positive and negative feedback. Voltage series, current series, voltage shunt and current shunt feedback and uses for specific amplifiers. Estimation of input impedance, output impedance, gain, stability; Operational Amplifiers (black Box approach): Characteristics of ideal and practical OP-AMP (IC 741), Open-loop and closed-loop voltage gain. Frequency response. CMRR. Slew rate and concept of virtual ground. Application of OP-AMP: DC application — inverting and non-inverting amplifiers, inverting and noninverting adder, subtractor, error amplifier, comparator, Schmidt trigger. AC applications: differentiator, integrator.

(c) Transistor as a switch, Explanation using CE output characteristics.

(d) Oscillators: Sinusoidal oscillators: Barkhausen's criterion for self-sustained oscillations. RC phase shift oscillator, Wien bridge oscillator.

Suggestive Readings:

1. *Circuits and Networks, Analysis and Synthesis, A Sudhakar, Shyammohan S Palli, 2017, Tata McGraw-Hill Education Private Ltd.*
2. *Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, 6th Edn.,2009, PHI Private Ltd.*
3. *Fundamental Principles of Electronics, B.Ghosh, 2nd ed, 2008, Books & Allied (P) Ltd.*
4. *Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata McGraw-Hill Education Private Ltd.*
5. *Electronic Devices and Circuits, S. Salivahanan, N. Suresh Kumar, 2022, McGraw Hill Education Private Ltd.*
6. *Learning OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition,2000, Prentice Hall India Private Ltd.*
7. *Electronic Devices, Thomas L. Floyd, 7/e 2008, Pearson India.*
8. *Fundamentals of Analog Electronics: Theory, Problems and Solutions, U.N. Nandi, 2022, Techno India.*

Module 4:

Analog system and applications (Practical) Credit: 1
Total Lectures: 30

List of experiments:

1. To construct and study the output characteristics of BJT in CE mode.
2. To construct and study the frequency response of BJT amplifier in CE mode.
3. To study the current voltage characteristics of a solar cell.
4. (a) To Study the characteristics of Zener diode.
   (b) To study load and line regulation using Zener diode.
5. Construction of a series regulated power supply from an unregulated power supply.
6. To study OP-AMP: inverting amplifier, non-inverting amplifier, adder, integrator, differentiator.
7. To design a Wien bridge oscillator for given frequency using an OP-AMP.

Suggestive Readings:

1. *Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, McGraw Hill.*
2. *Advanced Practical Physics (volume II), B. Ghosh, Shreedhar Publication.*
3. *An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency.*
4. *Laboratory Manual for Operational Amplifiers and Linear ICs, David A. Bell, 2006, Prentice Hall of India*

Semester – V
Course Code: PHS-DC-MJ-502
Course Name: Solid State Physics

Learning Objectives:

This course aims to provide students with a fundamental understanding of the structural, thermal, magnetic, dielectric, optical, and electronic properties of solids. It introduces the theoretical concepts and models of solid-state physics, including crystal structures, lattice dynamics, semiconductors, and superconductors, while developing analytical and problem-solving skills relevant to the study of materials and modern electronic devices.

Learning Outcomes:

After completing this course, students will be able to:

- **Differentiate** between crystalline and amorphous solids, and describe the concept of lattice, unit cell, Miller indices, and reciprocal lattice.
- **Apply** Bragg's law and interpret X-ray diffraction data to determine crystal structure and understand atomic/geometrical factors.
- **Analyze** lattice vibrations and explain the role of phonons in heat capacity using Dulong-Petit, Einstein, and Debye models.
- **Distinguish** between acoustic and optical phonons in monoatomic and diatomic chains.
- **Describe** and explain the magnetic properties of materials, including diamagnetism, paramagnetism, ferromagnetism, and the B-H curve.
- **Apply** classical and quantum theories to interpret magnetic susceptibility and Curie-Weiss behavior.
- **Explain** dielectric polarization mechanisms, calculate electric susceptibility, and apply the Clausius-Mossotti relation and Langevin-Debye model.
- **Analyze** light dispersion in materials using Cauchy and Sellmeier relations and understand complex dielectric constants.
- **Interpret** the band structure of solids using the Kronig-Penney model and distinguish between conductors, semiconductors, and insulators.
- **Understand** semiconductor behavior, including carrier mobility, Hall Effect, and measurement techniques like the 4-probe method.
- **Describe** key features of superconductivity, including critical temperature, Meissner effect, London equations, and the isotope effect.
- **Connect** theoretical models with real-world materials and develop problem-solving skills in solid state physics.

Course Content

Solid State Physics (Theory) **Credit: 3**

Total Lectures: 45

Module 1:
(Total Lectures: 15)

(a) Crystal Structure: Solids: Amorphous and Crystalline Materials. Unit Cell. Lattice, Basis. Miller

Indices. Reciprocal Lattice. Diffraction of X-rays by Crystals. Bragg's Law. Structure factor.

(b) Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Mono atomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law.

Module 2:
(Total Lectures: 15)

(a) Magnetic Properties of Matter: Dia, Para, Ferri and Ferromagnetic Materials. Classical Langevin Theory of Dia and Paramagnetic Domains. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss.

(b) Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius-Mosotti Equation. Normal and Anomalous Dispersion (qualitative idea).

Module 3:
(Total Lectures: 15)

(a) Elementary band theory: Kronig Penny model (Basic idea only). Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. & Hall coefficient.

Suggestive Readings:

1. *Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.*
2. *Solid-state Physics, H. Ibach and H. Luth, 2009, Springer Solid State Physics, Rita John, 2014, McGraw Hill.*
3. *Elementary Solid State Physics, M. Ali Omar, 1999, Pearson India.*
4. *Solid State Physics and Electronics, A.B.Gupta and N.Islam, Books and Allied (P) Ltd.*
5. *Solid State Physics, M.A. Wahab, 2011, Narosa Publications.*
6. *Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning.*
7. *The Oxford Solid State Basics, S.H. Simon, 2017, Oxford University Press.*
8. *Basic Solid State Physics, A. Raychaudhuri, 2014, Sarat Book House.*

Module 4:

Solid State Physics (Practical) Credit: 1
Total Lectures: 30

List of Experiments:

1. Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method).
2. To measure the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. To measure the Dielectric Constant of a dielectric Materials with frequency.
5. To study the PE Hysteresis loop of a Ferroelectric Crystal.
6. To draw the B-H curve of Fe using Solenoid & determine energy loss from Hysteresis.

7. Measurement of hall voltage by four probe method.

Suggestive Readings:

1. *Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.*
2. *Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.*
3. *Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice Hall of India.*
4. *A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal*
5. *Elements of Solid State Physics, J. P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India.*

Semester – V
Course Code: PHS- DC-MJ-503
Course Name: Quantum Mechanics and Applications

Learning Objectives:

To introduce undergraduate students to the fundamental principles of quantum mechanics, enabling them to understand and apply the Schrödinger equation, analyse the behaviour of particles in various potentials, generalized angular momenta and spin, and explore the origin of fine structure of spectral lines of hydrogen atom and alkali atoms.

Learning Outcomes:

Upon completing this course, students will be able to:

- **Understand** and apply the Schrödinger equation to simple quantum systems.
- **Analyse** the behaviour of particles in various potentials, including the square well potential and simple harmonic oscillator.
- **Describe** the quantum mechanics of hydrogen-like atoms and understand the concept of orbital angular momentum.
- **Explain** the concept of spin and its relation to magnetic moment and angular momentum.
- **Calculate** energy corrections and understand the fine structure of atomic spectra.
- **Describe** the behaviour of atoms in electric and magnetic fields, including the Zeeman and Stark effects.
- **Understand** the principles of many-electron atoms, including identical particles, symmetry, and spectral notation.

Course Content

Quantum Mechanics and Applications (Theory) Credit: 03
Total Lectures: 45

Module 1:
(Total Lectures: 15)

(a) Schrödinger Equation

Description of a particle using wave packets. Spread of the Gaussian wave-packet for a free particle in one dimension. Fourier transforms and momentum space wave function. Position momentum uncertainty.

(b) General discussion of bound states in an arbitrary potential

Continuity of wave function, boundary condition and emergence of discrete energy levels. Application to one dimensional problem-square well potential.

(c) Quantum mechanics of simple harmonic oscillator

Setting up the eigenvalue equation for the Hamiltonian. Energy levels and energy eigen functions in terms of Hermite polynomials (Solution to Hermite differential equation may be assumed). Ground state, zero point energy and uncertainty principle.

Module 2:
(Total Lectures: 18)

(a) Quantum theory of hydrogen-like atoms
Reduction of a two-body problem to a one-body problem. The time independent Schrödinger equation for a particle moving under a central force – the Schrödinger equation in spherical polar coordinates. Separation of variables. Angular equation and orbital angular momentum. Spherical Harmonics (Solution to Legendre differential equation may be assumed). Radial equation for attractive coulomb interaction-Hydrogen atom. Solution for the radial wave functions (Solution to Laguerre differential equation may be assumed). Shapes of the probability densities for ground and first excited states. Orbital angular momentum quantum numbers *l* and *m*; *s*, *p*, *d*, *f* shells.

(b) Generalized Angular Momenta and Spin
Generalized angular momentum. Magnetic moment of electron and spin angular momentum. Gyromagnetic Ratio and Bohr Magneton and the *g*-factor. Energy associated with a magnetic dipole placed in magnetic field. Larmor's Theorem. Stern-Gerlach Experiment.

(c) Addition of angular momenta - Statement only. Restriction of eigen-values from $|j_1 - j_2|$, $|j_1 + j_2|$.

Module 3:
(Total Lectures: 12)

Spectra of Hydrogen atom and its fine structure
(a) Formula for first order non-degenerate perturbative correction to the eigenvalue – statement only.
(b) Spin-orbit interaction and relativistic correction to the kinetic energy and Darwin term.
(c) Fine structure of the hydrogen atom spectrum.

Atoms in Electric and Magnetic Fields
(a) Zeeman Effect: Normal and Anomalous Zeeman Effect (Formula for first order perturbative correction to the eigen value to be assumed).
(b) Paschen Back effect and Stark effect (Qualitative Discussion only)

Many electron atoms
(a) Identical particles. Symmetric and anti-symmetric wave functions. Pauli's exclusion principle. Hund's rule. Periodic table.
(b) Fine structure splitting. L-S and J-J coupling scheme. Spectral notation for atomic states and term symbols. Spectra of Alkali atoms (Na etc.).

Module 4:

Quantum Mechanics and Applications (Project and Presentation) Credit: 1
Total Lectures: 30

Each student is required to complete a project work based on topics covered in the syllabus. A project paper should have the following components - Abstract, Introduction, Theory, Methodology, Result and Discussion (use graph and tables, Python implementation if required), Conclusion, Reference. The project must be presented in the form of a Power Point presentation during the semester-end examination in front of the examiners along with a write up around 1500 words, approximately.

Few suggested topics of Project **(Students may choose one or propose their own):**

1. Gaussian Wave Packet and its Spreading in Free Particle Motion
2. Fourier Transform in Quantum Mechanics
3. Uncertainty Principle and its Applications
4. Bound States in One-Dimensional Potentials: The Square Well Example
5. Quantum Harmonic Oscillator: Energy Spectrum and Zero-Point Energy
6. Hermite Polynomials in the Wave Functions of Harmonic Oscillator
7. Central Force Motion and Reduction of Two-Body to One-Body Problem in Quantum Mechanics
8. Angular Momentum in Quantum Mechanics and Spherical Harmonics
9. Hydrogen Atom Wave Functions
10. Orbital Angular Momentum Quantum Numbers
11. Spin Angular Momentum, Magnetic Moment, and Stern–Gerlach Experiment
12. Fine Structure of Hydrogen Atom: Spin–Orbit Coupling and Relativistic Corrections
13. Zeeman Effect: Normal vs. Anomalous Cases
14. Pauli's Exclusion Principle and Periodic Table Structure
15. Hund's Rule, Coupling Schemes (L-S, J-J), and Spectral Term Symbols

Suggestive Readings:

1 *Mathews, P. M., & Venkatesan, K. (2010). A Textbook of Quantum Mechanics (2nd ed.). McGraw Hill.*

2 *Eisberg, R., & Resnick, R. (2002). Quantum Mechanics (2nd ed.). Wiley.*

3 *Griffiths, D. J. (2005). Introduction to Quantum Mechanics (2nd ed.). Pearson Education.*

4 *Schiff, L. I. (2010). Quantum Mechanics (3rd ed.). Tata McGraw Hill.*

5 *Aruldhas, G. (2002). Quantum Mechanics (2nd ed.). PHI Learning of India.*

6 *Reed, B. C. (2008). Quantum Mechanics. Jones & Bartlett Learning.*

7 *Bransden, B. H., & Joachain, C. J. (2002). Quantum Mechanics (2nd ed.). Pearson Prentice Hall.*

8 *Bohm, A. (1993). Quantum Mechanics: Foundations and Applications (3rd ed.). Springer.*

9 *Miller, D. A. B. (2008). Quantum Mechanics for Scientists and Engineers. Cambridge University Press.*

Semester – V
Course Code: PHS- DC-MJ-504
Course Name: Classical Dynamics

Learning Objectives:

This course aims to:

Develop a deep understanding of the advanced concepts of classical mechanics using the Lagrangian and Hamiltonian formulations. Equip students with the ability to analyze mechanical systems with constraints using generalized coordinates. Introduce the mathematical formalism of canonical transformations and Poisson brackets. Enable students to understand and apply the principles of the Special Theory of Relativity and relativistic kinematics. Familiarize students with the concept of four-vectors and their use in relativistic dynamics and decay processes. Introduces the fundamentals of fluid dynamics.

Learning Outcomes:

Upon successful completion of the course, students will be able to:

- **Explain** generalized coordinates, constraints, and degrees of freedom.
- **Apply** Euler-Lagrange and Hamilton's equations to mechanical systems.
- **Analyze** systems using Lagrangian and Hamiltonian formalisms.
- **Understand** canonical transformations and Poisson brackets.
- **Use** conservation laws in central force problems.
- **State** and apply the postulates of Special Relativity.
- **Perform** Lorentz transformations and interpret space-time diagrams.
- **Explain** time dilation, length contraction, and the twin paradox.
- **Classify** and use space-like, time-like, and light-like four-vectors.
- **Apply** four-momentum and energy-momentum relations.
- **Analyze** the Doppler effect and particle decay using four-vector formalism.
- **Understand** the Principles of Fluid Dynamics

Course Content

Classical Dynamics (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 20)

(a) Classical Mechanics of Point Particles

Generalized coordinates and velocities, constraint and degrees of freedom. Hamilton's principle and Lagrangian formalism. Euler-Lagrange equations and their applications for Simple Harmonic Oscillations, Particle under uniform gravity, Coupled oscillators. Canonical momenta. Lagrange's equations for systems with semi-holonomic constraints.

(b) Hamilton's equations of motion. Hamiltonian for a harmonic oscillator and its solution. Canonical transformations and generating functions. Properties of canonical transformations and Poisson

brackets. Hamilton's equations and their use in solving mechanical systems.
(c) Particle in a central force field; conservation laws.

Module 2:
(Total Lectures: 18)

(a) Special Theory of Relativity:
Postulates of Special Theory of Relativity. Lorentz Transformations. Minkowski space. The invariant interval, light cone and world lines. Space-time diagrams, Time-dilation, length contraction and twin paradox. Simultaneity.

(b) Four-vectors: space-like, time-like and light-like. Four-velocity and acceleration. Four-momentum and energy- momentum relation. Doppler effect from the four-vector perspective. Concept of four-force and conservation of four-momentum. Relativistic kinematics. Application to two-body decay of an unstable particle.

Module 3:
(Total Lectures: 07)

(a) Fluid Dynamics
Kinematics of moving fluid. Poiseuille's equation for flow of a liquid through a capillary tube. Navier-Stokes equation and Reynolds number. Laminar and turbulent flow. Euler equation. Bernoulli's theorem, equation of continuity, venturi effect.

Module 4:

Classical Dynamics (Project and Presentation) Credit: 1
Total Lectures: 30

Each student is required to complete a project work based on topics covered in the syllabus. A project paper should have the following components - Abstract, Introduction, Theory, Methodology, Result and Discussion (use graph and tables, Python implementation if required), Conclusion, Reference**.** The project must be presented in the form of a Power Point presentation during the semester-end examination in front of the examiners along with a write up around 1500 words, approximately**.**

Few suggested topics of Project **(Students may choose one or propose their own):**

1. A Review of Hamiltonian Mechanics and Its Applications
2. Understanding the Lagrange equation of Motion
3. From Newtonian mechanics to Special Relativity
4. Coupled Oscillators – theory of normal modes and energy exchange
5. Canonical Transformations and Generating Functions
6. Poisson Brackets and Their Properties

7. Central Force Motion
8. Postulates of Special Relativity and Their Consequences
9. Lorentz Transformations and Minkowski Space – spacetime interval and causal structure
10. Time Dilation, Length Contraction, and the Twin Paradox
11. Energy–Momentum Four-Vector – relativistic energy-momentum relation
12. Relativistic Doppler Effect – four-vector approach and astrophysical significance
13. Relativistic Kinematics – two-body decay problem in special relativity
14. Navier–Stokes Equation and Reynolds Number – transition from laminar to turbulent flow
15. Bernoulli's Theorem and Applications – Venturi effect, equation of continuity

Suggestive Readings:

1. *Classical Mechanics, H. Goldstein, C.P. Poole, J.L. Safko, Pearson Education.*
2. *Mechanics, L. D. Landau & E. M. Lifshitz, Pergamon.*
3. *Classical Mechanics, P.S. Joag & N.C. Rana, McGraw Hill.*
4. *Classical Mechanics, R. Douglas Gregory, Cambridge University Press.*
5. *Classical Mechanics: An Introduction, Dieter Strauch, Springer.*
6. *Chaos and Non-linear Dynamics, R.C. Hilborn, Oxford.*
7. *Nonlinear Dynamics and Chaos, S.H. Strogatz.*
8. *Solved Problems in Classical Mechanics, O.L. Delange & J. Pierrus, Oxford Press.*

Semester – VI
Course Code: PHS-DC-MJ-601
Course Name: Electromagnetic Theory

Learning Objectives:

This course equips students to master electromagnetic theory, focusing on formulating Maxwell's equations using scalar/vector potentials and gauge transformations (Lorentz, Coulomb). Students will analyze EM wave propagation in unbounded media (vacuum, dielectrics, conductors – covering skin depth and relaxation time) and bounded media (reflection/refraction at interfaces using boundary conditions, Snell's law, and Fresnel's equations). It emphasizes comprehensive polarization studies: linear/circular/elliptical states, production methods (reflection, refraction, birefringence), waveplate analysis (quarter/half-wave), compensators (Babinet), and optical rotation (Biot's laws, Fresnel's theory). Theoretical principles are integrated with practical experiments (Malus' law, polarimetry, ultrasonic diffraction, PN junctions), ensuring rigorous theory-practice correlation.

Learning Outcomes:

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

- **Formulate** Maxwell's equations, scalar/vector potentials, and gauge transformations (Lorentz/ Coulomb).
- **Derive** EM wave equations and analyze plane-wave propagation in dielectrics/conductors (skin depth, relaxation time).
- **Apply** Poynting's theorem to compute energy flux and energy density.
- **Predict** wave behavior at interfaces: derive boundary conditions, Snell's law, Fresnel's equations, and Brewster's angle.
- **Analyze** total internal reflection, evanescent waves, and metallic reflection (normal incidence).
- **Characterize** polarization states (linear/circular/elliptical) and production methods (reflection, refraction, birefringence).
- **Operate** polarization tools: Nicol prisms, waveplates, Babinet compensators; verify Malus' law.
- **Explain** optical rotation via Biot's laws, Fresnel's theory, and specific rotation measurement (Laurent's/biquartz polarimeters).
- **Correlate** theory with experiments: Malus' law, sugar solution rotation, Babinet compensator, ultrasonic diffraction, polarization by reflection, and Boltzmann constant (PN junction).

Course Content

Electromagnetic Theory (Theory) Credit: 3
Total Lectures: 45

Module 1:
(Total Lectures: 14)

(a) Maxwell Equation

Review of Maxwell Equation, Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density.

(b) EM Wave Propagation in Unbounded Media

Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth.

Module 2:
(Total Lectures: 13)

EM Wave Propagation in Bounded Media

Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reaction (normal Incidence).

Module 3:
(Total Lectures: 18)

Polarization of EM Waves

(a) Description of Linear, Circular and Elliptical Polarization. Polarization by reflection. Polarization by refraction, Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Malus Law, Phase Retardation Plates: Quarter wave plates, Half Wave plates. Production and analysis of polarized light. Babinet Compensator and its uses.

(b) Rotatory Polarization, Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Specific rotation. Laurent's half-shade and biquartz polarimeters.

Suggestive Readings:

1. *Feynman's Lecture, Volume 2, R.P. Feynman, R.B. Leighton, M. Sands, 2008, Pearson Education.*
2. *Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.*
3. *Optics, E. Hecht, 2016, Pearson.*
4. *Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.*
5. *Fundamental of Optics, F.A. Jenkins & H.E. White, 1981, McGraw Hill.*
6. *Optics, Ajoy Ghatak, 7th Edition, 2020, Tata McGraw Hill.*
7. *Introduction to Electromagnetic Theory, T.L. Chow, 2006, Jones & Bartlett Learning.*

8. *Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill.*
9. *Electromagnetic eld Theory, R.S. Kshetrimayun, 2012, Cengage Learning.*
10. *Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.*
11. *Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.*
12. *Electromagnetic eld theory fundamentals, B. Guru and H. Hiziroglu, 2004, Cambridge University Press.*

Module 4:

Electromagnetic Theory (Practical) Credit: 1
Total Lectures: 30

List of Experiments:

1. To verify the law of Malus for plane polarized light.
2. To determine the specific rotation of sugar solution using a Polarimeter.
3. To analyze elliptically polarized Light by using a Babinet's compensator.
4. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
5. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.
6. To determine the Boltzmann constant using V-I characteristics of PN junction diode.

Suggestive Readings:

1. *Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.*
2. *Advanced level Physics Practical, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.*
3. *A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal.*
4. *Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer.*

Semester – VI
Course Name: Digital Electronics and Applications
Course Code: PHS-DC-MJ-602

Learning Objectives:

The aim of this course is to lay the foundation of Digital Electronics for students of undergraduate Physics. The course will provide an overall understanding of concepts of digital electronics so that the students gain an in-depth knowledge of the different number systems, logic gates and various types of logic circuits. The objective of the course is to enable the students to explain, analyse and design various logic circuits like adders, different types of Flip Flops, counters, shift registers digital multiplexers

Learning Outcomes:

- **Understand** and explain different types of number systems, Boolean Algebra and Logic Gates
- **Simplify** logical expression using both Boolean Algebra and Karnaugh Map
- **Understand** and explain the concepts and working mechanism of Combinational and Sequential logic circuits
- **Understand**, explain and implement different types of adders, Flip flops, shift registers and counters
- **Understand** the concepts of multiplexers, demultiplexers, encoders and decoders

<u>Course Content</u>

Digital Electronics and Applications (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 16)

Number System and Boolean Algebra

(a) Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. Binary Addition. Binary Subtraction using 2's Complement.

(b) (i) Concepts of different logical operations, Boolean Laws, De Morgan's Theorems, Simplification of Logic Circuit using Boolean Algebra.

(ii) Idea of Minterms, Maxterms, Sum of Products, Product of Sums in logical expression. Simplification of Logic Circuit using Karnaugh Map.

Logic Gates

AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers.

Module 2:
(Total Lectures: 16)

Digital Circuits:

(a) Difference between analog and digital circuits.

(b) Combinational Logic Circuit:

Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder / Subtractor.

(c) Sequential Logic Circuit:

SR, D, JK and T Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop.

Module 3:
(Total Lectures: 13)

Data Processing Circuits

Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders.

Registers and Counters

(a) Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).

(b) Counters (4 bits): Asynchronous counters, Ripple Counter, Decade Counter. Synchronous Counter Ring Counter.

Suggestive Readings:

1. *Digital Principles and Applications, A.P. Malvino, D. P. Leach and Saha, 7th Ed., 2011, Tata McGraw Hill.*
2. *Fundamentals of Digital Circuits, Anand Kumar, 2016, PHI Learning Pvt. Ltd.*
3. *Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.*
4. *Digital Electronics G K Kharate ,2010, Oxford University Press.*
5. *Digital Systems: Principles & Applications, R.J.Tocci, N.S.Widmer, 2022, Pearson Education International.*
6. *Logic circuit design, Shimon P. Vingron, 2012, Springer.*
7. *Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.*
8. *Digital Electronics, S.K. Mandal, 2018, Tata McGraw Hill*

Module 4:

Digital Electronics and Applications (Practical) Credit: 1
Total Lectures: 30

List of Experiments:

1. To verify and design AND, OR, NOT and XOR gates using NAND gates.
2. To convert a Boolean expression into logic circuit and design it using logic gate ICs.
3. To construct Half Adder and Full Adder using logic gates and verify the Truth Table.
4. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.

5. To build JK Master-slave flip-flop using Flip-Flop ICs/ trainer kit.
6. To build a 4-bit Counter using D-type/JK Flip-Flop ICs/ trainer kit and study timing diagram.
7. To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs/ trainer kit.

Suggestive Readings:

1. *Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 2001, Tata Mc-Graw Hill.*
2. *Modern Digital Electronics, R.P. Jain, 2009, Tata McGraw Hill.*
3. *Laboratory Manual of Physics, M. Jana, 2022, Books & Allied Pvt. Ltd.*
4. *Physics in Laboratory, P.K. Mandal, S. Chowdhury, S. Das, M. Das,2019, Santra Publication.*
5. *An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, 2016, New Central Book Agency.*
6. *Advanced Practical Physics, Volume 2, B. Ghosh, 2019. Sreedhar Publishers.*

Semester – VI
Course Code: PHS-DC-MJ-603
Course Name: Statistical Mechanics

Learning Objectives:

Statistical Mechanics deals with the derivation of the macroscopic parameters (internal energy, pressure, specific heat etc.) of a physical system consisting of large number of particles (solid, liquid or gas) from knowledge of the underlying microscopic behaviour of atoms and molecules that comprises it. The main objective of this course is to introduce the techniques of statistical mechanics which has applications in various fields including astrophysics, semiconductor physics, plasma physics, biophysics etc. and in many other directions. All the problems of different units should be done in the tutorial classes.

Learning Outcomes:

By the end of the course, students will be able to:

- **Understand** the concepts of phase space, macrostate, microstate, thermodynamic probability and partition function.
- **Understand** the use of thermodynamic probability and partition function for calculation of thermodynamic properties for physical systems (ideal gas, finite level system).
- **Understand** the difference between classical and quantum statistics and their applicability.
- **Understand** the properties and laws associated with thermal radiation.
- **Apply** the Fermi- Dirac distribution to model problems such as electrons in solids
- **Apply** the Bose-Einstein distribution to model problems such as blackbody radiation and liquid Helium.

Course Content

Statistical Mechanics (Theory) **Credit: 3**

Total Lectures: 45

Module 1:

(Total Lectures: 15)

Basics of Classical Statistical Mechanics

Basic concepts: Probability, Macrostate & Microstate, Concept of time averaging in a macroscopic measurement, Postulate of equal a-priori probabilities, Phase Space, Density of states, Ergodic Hypothesis (statement only), Entropy and thermodynamic probability– Boltzmann's relation, Liouville's theorem.

Ensemble Theory: Elementary Concept of Ensemble, Classification of ensembles Microcanonical ensemble: Density distribution, Entropy of an ideal classical gas

Canonical Ensemble: System in contact with heat reservoir, Partition function, Thermodynamics functions of an ideal gas, Classical Entropy Expression, Gibbs Paradox, Canonical ensemble average of physical quantities, Law of equipartition of energy (with proof) – applications to specific heat and its limitations.

Grand Canonical Ensemble: Chemical potential, grand canonical partition function and grand potential.

Module 2:
(Total Lectures: 10)

Classical Statistics

Maxwell -Boltzmann Statistics: Maxwell-Boltzmann (MB) distribution law, Assumptions of distinguishability and non-quantum nature, Derivation of the Maxwell-Boltzmann distribution function, Applications to specific heat of gases (monoatomic and diatomic), solids and its limitations.

Module 3:
(Total Lectures: 20)

Quantum Statistics

Bose-Einstein Statistics (10 lectures): B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas. Bose derivation of Planck's law.

Fermi-Dirac Statistics (10 lectures): Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Fermi temperature, Fermi momentum, Fermi velocity, Electron gas in a Metal, Specific Heat of Metals, Transition from quantum statistics to classical statistics.

Module 4:

Statistical Mechanics (Project and Presentation) Credit: 1
Total Lectures/Classes: 30

Each student is required to complete a project work based on topics covered in the syllabus. A project paper should have the following components - Abstract, Introduction, Theory, Methodology, Result and Discussion (use graph and tables, Python implementation if required), Conclusion, Reference**.** The project must be presented in the form of a Power Point presentation during the semester-end examination in front of the examiners along with a write up around 1500 words, approximately**.**

Few suggested topics of Project **(Students may choose one or propose their own):**

1. Probability, Macrostate and Microstate
2. Postulate of Equal A-priori Probabilities and Its Significance
3. Phase Space and Density of States in Classical Systems
4. Ergodic Hypothesis and Liouville's Theorem
5. Boltzmann's Entropy Relation and Thermodynamic Probability
6. Ensemble Theory – Microcanonical, Canonical and Grand Canonical Ensembles
7. Canonical Partition Function and Its Applications to Thermodynamics
8. Law of Equipartition of Energy
9. Gibbs Paradox and Its Resolution in Statistical Mechanics
10. Maxwell–Boltzmann Distribution Law and Its Applications to Gases
11. Limitations of Maxwell–Boltzmann Statistics in Explaining Heat Capacities
12. Bose–Einstein Statistics and Bose–Einstein Condensation
13. Radiation as a Photon Gas and Bose's Derivation of Planck's Law

14. Fermi–Dirac Distribution and Its Applications to Electron Gas in Metals
15. Fermi Energy, Fermi Temperature and Specific Heat of Metals

Suggestive Readings:

1. *Fundamentals of Statistical and Thermal Physics, Frederick Reif, Waveland Press, INC.*
2. *Fundamentals of Statistical Mechanics, B.B. Laud, New Age International Pvt. Ltd.*
3. *Statistical Mechanics by Satyaprakash.*
4. *A Textbook of Statistical Mechanics by Suresh Chandra and Mohit Kumar Sharma.*
5. *Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford Univ. Press.*
6. *Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill.*
7. *Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed.,1996, Oxford University Press.*
8. *An Introductory Course of Statistical Mechanics. P.B. Pal, 2008, Narosa.*
9. *Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall.*
10. *Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.*
11. *Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.*
12. *An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press.*

Semester – VI
Course Code: PHS-DC-MJ-604
Course Name: Nuclear and Particle Physics

Learning Objectives:

This course aims to provide undergraduate physics students with a comprehensive understanding of nuclear and particle physics, covering foundational concepts of nuclear structure and reactions, radiation interactions with matter, detection techniques, and an introduction to accelerators and elementary particles. Emphasis is placed on conceptual clarity, the role of conservation laws and symmetries, and the relevance of nuclear and particle physics in modern technology, medicine, and research. The course also highlights real-world applications to develop scientific awareness and critical thinking.

Learning Outcomes:

After completing this course, students will be able to:

- **Explain** the basic nuclear models and their implications for nuclear structure and stability.
- **Classify** and interpret various nuclear reactions and apply conservation laws to analyse them.
- **Describe** the principles of energy release in nuclear fission and fusion and outline their practical applications.
- **Explain** how different types of radiation interact with matter and interpret their effects qualitatively.
- **Identify** and describe the working principles of major radiation detectors and their applications.
- **Understand** the basic operating principles of particle accelerators and recognize key Indian research facilities.
- **Distinguish** between leptons, mesons, and baryons and understand the fundamental forces acting among them.
- **Apply** symmetry principles and conservation laws to predict particle interactions and decays.
- **Describe** the quark model, including quark types, color charge, and hadron composition.
- **Appreciate** the societal, medical, and industrial relevance of nuclear and particle physics, along with associated ethical considerations.

<u>Course Content</u>

Nuclear and Particle Physics (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 15)

1. Nuclear Models (5 lectures): Liquid Drop Model (conceptual), Shell Model (qualitative features: magic numbers, predictions)

2. Nuclear Reactions (4 lectures): Classification: direct, compound, resonance reactions, Conservation laws (mass-energy, momentum, charge, etc.), Q-value and reaction threshold, Reaction kinematics and cross-section (qualitative idea).

3. Applications of Nuclear Reactions (6 lectures): Nuclear fission and fusion (basic idea, no reactor physics), Nuclear energy production and safety, Radiocarbon dating and archaeological applications, Medical uses: radiation therapy, PET scans, Industrial applications: radiography, material testing, Indian contributions to nuclear research (e.g., BARC, VECC).

Module 2:
(Total Lectures: 15)

1. Radiation Interaction with Matter (6 lectures): Charged particles: Ionization and excitation, Bethe-Bloch formula (qualitative discussion), Gamma interactions- Photoelectric effect, Compton scattering, Pair production, Neutron interaction- basic concepts (elastic & inelastic scattering).

2. Radiation Detectors (5 lectures): Gas detectors, Ionization chamber (basic working), GM counter (principle only), Scintillation detectors- Working principle, Role of photomultiplier tube (PMT).

3. Accelerator Overview (4 lectures): Principles of particle acceleration, Cyclotron, Linear Accelerator, Synchrotron (basic operation), Overview of Indian facilities (BARC, VECC, RRCAT, etc.).

Module 3:
(Total Lectures: 15)

1. Fundamental Particles and Interactions (5 lectures): Leptons and hadrons (mesons and baryons), Fundamental forces- strong, weak, electromagnetic, gravitational.

2. Symmetries and Conservation Laws (5 lectures): Charge, energy, linear and angular momentum, Parity, lepton number, baryon number (conservation), Isospin (basic idea), strangeness (qualitative).

3. Quark Model (5 lectures): Quark types: u, d, s, c (mention b, t), Colour charge and gluons, Quark content of hadrons (proton, neutron, mesons).

Module 4:

Nuclear and Particle Physics (Project and Presentation) Credit: 1
Total Lectures: 30

Each student is required to complete a project work based on topics covered in the syllabus. A project paper should have the following components - Abstract, Introduction, Theory, Methodology, Result and Discussion (use graph and tables, Python implementation if required), Conclusion, Reference**.** The project must be presented in the form of a Power Point presentation during the semester-end examination in front of the examiners along with a write up around 1500 words, approximately**.**

Few suggested topics of Project **(Students may choose one or propose their own):**

1. Liquid Drop Model of the Nucleus
2. Nuclear Shell Model and the Concept of Magic Numbers

3. Classification of Nuclear Reactions
4. Conservation Laws in Nuclear Reactions
5. Q-value and Reaction Threshold in Nuclear Reactions
6. Nuclear Fission and Fusion
7. Applications of Nuclear Techniques in Medicine
8. Industrial Applications of Nuclear Reactions
9. Indian Contributions to Nuclear Research
10. Interaction of Radiation with Matter
11. Neutron Interactions with Matter
12. Principles and Working of Radiation Detectors
13. Particle Accelerators
14. Fundamental Particles and Forces
15. Quark Model of Hadrons

Suggestive Readings:

1. *Introductory Nuclear Physics – Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).*
2. *Concepts of Nuclear Physics – Bernard L. Cohen (Tata McGraw Hill, 1998).*
3. *Introduction to the Physics of Nuclei and Particles – R.A. Dunlap (Thomson Asia, 2004).*
4. *Introduction to High Energy Physics – D.H. Perkins (Cambridge University Press).*
5. *Introduction to Elementary Particles – David Griffiths (John Wiley & Sons).*
6. *Quarks and Leptons – F. Halzen and A.D. Martin (Wiley India, New Delhi).*
7. *Basic Ideas and Concepts in Nuclear Physics – An Introductory Approach – K. Heyde (IOP Publishing, 2004).*
8. *Radiation Detection and Measurement – Glenn F. Knoll (John Wiley & Sons, 2000).*
9. *Nuclear Physics – D.C. Tayal (Himalaya Publishing House).*
10. *Atomic and Nuclear Physics – S.N. Ghoshal (S. Chand Publishing).*

Semester – VII
Course Code: PHS-DC-MJ-701
Course Name: Mathematical Physics-III

Learning Objectives:

This course is designed to equip students with the advanced analytical tools necessary to solve complex physical problems through rigorous mathematical frameworks. Students will master the algebraic structures of matrices—including eigenvalue problems and diagonalization—and delve into complex analysis to handle contour integration and analyticity. The curriculum further extends into the Frobenius method for solving second-order differential equations, focusing on the derivation and properties of special functions like Legendre, Hermite, and Bessel polynomials. Finally, by exploring Fourier transforms and their application to wave and heat equations, learners will develop a robust mathematical foundation required for higher-level studies in quantum mechanics, electromagnetism, and thermodynamics.

Learning Outcomes:

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

- **Perform** advanced matrix operations, including calculating the rank, trace, and inverse of various matrix types (Hermitian, Unitary, Orthogonal).
- **Solve** systems of simultaneous linear equations and implement the Cayley-Hamilton theorem for matrix simplification and diagonalization.
- **Analyze** complex functions by applying Cauchy-Riemann conditions to determine analyticity and identifying various types of singularities and poles.
- **Evaluate** complex integrals using Cauchy's Integral Formula and expand functions into Taylor and Laurent series.
- **Apply** the Frobenius power series method to find solutions for linear differential equations around ordinary and singular points.
- **Utilize** special functions (Legendre, Hermite, and Bessel) by leveraging their generating functions, recurrence relations, and Rodrigues' formulas to solve physical boundary-value problems.
- **Execute** Fourier transforms on diverse functional forms and utilize their properties, such as translation and scaling, to simplify mathematical models.
- **Solve** partial differential equations, specifically the one-dimensional heat and wave equations, using Fourier transform techniques.

Course Content

Mathematical Physics-III (Theory) Credit: 3
Total Lectures: 45

Module 1:
(Total Lectures: 15)

1. Matrices:

(a) Matrix and its properties. Addition and Multiplication of Matrices. Null Matrices. Diagonal, Scalar and Unit Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of

a Matrix. Hermitian and Skew-Hermitian Matrices. Singular and Non-Singular matrices. Orthogonal and Unitary Matrices. Trace and Rank of a Matrix.
(b) Solutions of Simultaneous linear equations. Eigenvalues and Eigenvectors. Cayley-Hamilton Theorem. Diagonalization of Matrices. Rotation, Pauli matrices and their properties (basic algebra only).

2. Complex Analysis:
Complex Numbers and their properties. Cubic roots of unity. Euler's formula. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Laurent and Taylor's expansion. Elementary ideas of Contour Integration.

Module 2:
(Total Lectures: 20)

3. Frobenius Method and Special Functions:
(a) Ordinary and Singular Points of Second Order Linear Differential Equations. Frobenius method of series solution to differential equations. Legendre, Bessel and Hermite differential equations.
(b) Legendre Polynomial: Rodrigues Formula, Generating Function, Orthogonality, Recurrence relation, Expansion of a function in a series of Legendre Polynomials.
(c) Hermite Polynomial: Rodrigues Formula, Generating Function, Orthogonality, Recurrence relation.
(d) Bessel Functions of the First Kind: Generating Function, Orthogonality, Recurrence relation, Zeros of Bessel Functions [$J_0(x)$ and $J_1(x)$].

Module 3:
(Total Lectures: 10)

4. Fourier Transforms:
Definition. Fourier transform of trigonometric, Gaussian, finite wave train etc. Representation of Dirac delta function as a Fourier Integral. Properties of Fourier transforms: translation, change of scale and complex conjugation. Fourier transform of derivatives, Inverse Fourier transform. Application of Fourier Transforms to differential equations: one dimensional wave and heat flow equations.

Suggestive Readings:

1. *Mathematical Methods for Physicists: Arfken, Weber, Harris, Elsevier.*
2. *Mathematics for Physicists: P. Dennery and A. Krzywicki, Dover Publications.*
3. *Schaum's Outline of Complex Variables, 2ed.: M. R. Spiegel, S. Lipschutz, J. J. Schiller and D. Spellman.*
4. *Complex Variables: A. K. Kapoor, Cambridge Univ. Press.*
5. *Fundamentals of Mathematical Physics: A.B. Gupta, Books & Allied (P) Ltd.*
6. *Mathematical Physics: H.K. Dass, S. Chand.*

Module 4:

Mathematical Physics-III (Practical) Credit: 1

Total Lectures: 30

List of Experiments:

1. Classification of matrices based on symmetry properties (symmetric, skew-symmetric, Hermitian, skew-Hermitian) using computational methods.
2. Study of algebraic properties of Pauli matrices, including verification of commutation and anti-commutation relations.
3. Numerical techniques for matrix diagonalization, particularly for real symmetric matrices, using standard computational schemes (e.g., Jacobi rotation method) to obtain eigenvalues and eigenvectors.
4. Representation of complex numbers: computation and graphical visualization of roots of unity on the complex plane.
5. Generation, visualization, and analysis of special functions (such as Legendre polynomials, Hermite polynomials, and Bessel functions), including graphical representation and determination of their zeros using numerical methods.
6. Numerical integration methods (e.g., Trapezoidal rule and Simpson's rule) applied to verify orthogonality relations of special functions.
7. Fourier transform of functions (e.g., Gaussian functions) and analysis of their properties, including uncertainty relations.
8. Study of Gaussian functions and their limiting behavior approaching the Dirac delta function.

Suggestive Readings:

1. *Introduction to Numerical Analysis, S.S. Sastry, 5th Edn. , 2012, PHI Learning Pvt. Ltd.*
2. *Learning with Python-how to think like a computer scientist, J. Elkner, C. Meyer, and A. Downey 2015, Dreamtech Press.*
3. *Introduction to computation and programming using Python, J. Guttag, 2013, Prentice Hall India.*
4. *Scientific computing in python, 2nd Edn, A. K. Gupta, 2021, Techno World.*
5. *Mathematical Methods for Physicists: Arfken, Weber, Harris, Elsevier.*
6. *Mathematics for Physicists: P. Dennery and A. Krzywicki, Dover Publications.*
7. *Schaum's Outline of Complex Variables, 2ed.: M. R. Spiegel, S. Lipschutz, J. J. Schiller and D. Spellman.*
8. *Complex Variables: A. K. Kapoor, Cambridge Univ. Press.*
9. *Fundamentals of Mathematical Physics: A.B. Gupta, Books & Allied (P) Ltd.*
10. *Mathematical Physics: H.K. Dass, S. Chand.*

Semester – VII
Course Code: PHS-DC-MJ-702
Course Name: Communication Electronics

Learning Objectives:

The course on Communication Electronics is designed to develop a clear understanding of the fundamental principles of analog and digital communication systems. It aims to familiarize students with the basic components and functioning of communication systems, including transmitters, channels, and receivers. The course seeks to introduce various modulation and demodulation techniques and to explain their role in efficient signal transmission. It also focuses on building knowledge of the electronic circuits and devices used in communication, along with key concepts such as noise, bandwidth, and signal distortion. Additionally, the course intends to enhance the analytical ability of students to evaluate the performance of communication systems and to provide an introductory understanding of modern communication technologies such as optical and wireless communication.

Learning Outcomes:

After completing the course, students will be able to:

- **Understand** basic communication concepts: explain elements of a communication system (transmitter, channel, receiver).
- **Analyze** modulation techniques: describe and compare AM, FM, PM and digital modulation methods.
- **Apply** circuit knowledge: design and analyze simple communication circuits (modulators, demodulators, amplifiers).
- **Evaluate** system performance: calculate bandwidth, signal-to-noise ratio, and efficiency.
- **Understand** noise effects: explain different types of noise and their impact on communication systems.
- **Work** with digital communication basics: understand PCM, sampling theorem, and basic digital transmission.
- **Use** practical tools: perform basic experiments and interpret results using electronic instruments.
- **Explore** modern communication systems: gain introductory knowledge of fiber optics, satellite, and mobile communication.

<u>Course Content</u>

Communication Electronics (Theory) Credit: 3

Total Lectures: 45

Module 1:
(Total Lectures: 15)

1. Electronic Communication

Introduction to communication means and modes. Need for modulation. Block diagram of an electronic communication system. Brief idea of frequency allocation for radio communication system in India (TRAI). Electromagnetic communication spectrum, band designations and usage. Channels and base-band signals. Concept of Noise, signal-to-noise (S/N) ratio.

2. Analog Modulation

Amplitude Modulation, modulation index and frequency spectrum. Generation of AM (Emitter Modulation), Amplitude Demodulation (diode detector), Concept of Single side band generation and detection. Frequency Modulation (FM) and Phase Modulation (PM), modulation index and frequency spectrum, equivalence between FM and PM.

Module 2:
(Total Lectures: 15)

3. Analog Pulse Modulation

Channel capacity, Sampling theorem, Basic Principles- PAM, PWM, PPM, modulation and detection technique for PAM only, Multiplexing.

4. Digital Pulse Modulation

Need for digital transmission, Pulse Code Modulation, Digital Carrier Modulation Techniques, Sampling, Quantization and Encoding. Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK).

Module 3:
(Total Lectures: 15)

5. Introduction to Communication and Navigation systems

(a) Satellite Communication Introduction, need, Geosynchronous satellite orbits geostationary satellite advantages of geostationary satellites. Satellite visibility, transponders (C - Band), path loss, ground station, simplified block diagram of earth station. Uplink and downlink.

(b) Mobile Telephony System Basic concept of mobile communication, frequency bands used in mobile communication, concept of cell sectoring and cell splitting, SIM number, IMEI number, need for data encryption, architecture (block diagram) of mobile communication network, idea of GSM, CDMA, TDMA and FDMA technologies, simplified block diagram of mobile phone handset, 2G, 3G and 4G concepts (qualitative only). GPS navigation system (qualitative idea only).

Suggestive Readings:

1. *Electronic Communications, D. Roddy and J. Coolen, Pearson Education India.*
2. *Advanced Electronics Communication Systems- Tomasi, 6th edition, Pren- tice Hall.*
3. *Electronic Communication systems, G. Kennedy, 3rd Edn, 1999, Tata McGraw Hill.*
4. *Principles of Electronic communication systems Frenzel, 3rd edition, McGraw Hill.*
5. *Communication Systems, S. Haykin, 2006, Wiley India.*
6. *Electronic Communication system, Blake, Cengage, 5th edition.*
7. *Wireless communications, Andrea Goldsmith, 2015, Cambridge University Press.*

Module 4:

Communication Electronics (Practical) Credit: 1
(Total Lectures: 30)

List of Experiments: (a few experiments may be added in future)

1. To design an Amplitude Modulator
2. To study envelope detector for demodulation of AM signal
3. To study FM - Generator and Detector circuit
4. To study AM Transmitter and Receiver
5. To study FM Transmitter and Receiver
6. To study Time Division Multiplexing (TDM)
7. To study Pulse Amplitude Modulation (PAM)
8. Study of the Global Positioning System (GPS) to determine geographical coordinates and evaluate the accuracy of GPS measurements.

Suggestive Readings:

1. *Electronic Communication systems, G. Kennedy, 1999, Tata McGraw Hill.*
2. *Electronic Communication system, Blake, Cengage, 5th edition.*

Semester – VII
Course Code: PHS-DC-MJ-703
Course Name: Astronomy and Astrophysics

Learning Objectives:

The course aims to provide a clear understanding of the fundamental concepts of astronomy and astrophysics through a project-based approach. It seeks to develop students' interest in the subject, enhance analytical skills, and enable them to apply theoretical knowledge to practical astrophysical problems. The course also promotes independent learning along with the development of scientific writing and effective presentation skills.

Learning Outcomes:

After completion of the course, students will be able to:

- **Understand** fundamental concepts of astronomy and astrophysics
- **Apply** physical laws to astrophysical systems
- **Interpret** observational data and astronomical measurements
- **Explain** stellar, galactic, and cosmological evolution
- **Develop** skills in scientific research, report writing, and presentation

Course Content

Astronomy and Astrophysics (Theory) Credit: 3

Total Lectures: 45

Module 1:
(Total Lectures: 14)

1. Historical Background

(a) Astronomy in ancient civilizations. Contributions of classical astronomers and transition to modern astronomy.

(b) Emergence of astrophysics with the application of physical laws, Development of observational tools such as telescopes.

(c) Understanding the structure and evolution of the universe. Importance of study of Astronomy and Astrophysics.

2. Astronomical Scales and Positional Astronomy

(a) Astronomical units: mass, length, time, and magnitude scales. Astronomical distances: AU, parsec, light-year. Brightness, radiant flux, luminosity, inverse square law. Stellar parameters: radius, mass, temperature (basic methods).

(b) Celestial sphere and coordinate systems: Horizon system, Equatorial system, Geographical system. Spherical trigonometry basics (spherical triangles).

(c) Diurnal motion of stars. Conversion between coordinate systems. Time measurement: sidereal time, solar time, equation of time. Distance measurement: parallax method. Magnitude scale: apparent & absolute magnitude, distance modulus.

3. Astronomical Techniques and Observational Methods
(a) Optical telescopes: Refracting telescopes, Reflecting telescopes (Newtonian). Telescope mountings: alt-azimuth and equatorial. Space telescopes and their importance.
(b) Detectors: Photographic plates, Photomultiplier tubes, CCD detectors. Detection limits and observational constraints.

Module 2:
(Total Lectures: 17)

4. Physical Principles of Astrophysics
(a) Gravitation in astrophysics: Newtonian gravity, Basic idea of general relativity. Virial theorem and applications, Thermodynamic equilibrium.
(b) Blackbody radiation: Planck law, Wien's law, Stefan–Boltzmann law.
(c) Radiative processes: emission and absorption, Radiative transfer equation, Mean free path and optical depth.

5. The Sun and the Solar System
(a) Star and star formation. Solar parameters: mass, radius, luminosity, temperature. Structure of the Sun: Core, Radiative zone, Convective zone, Photosphere, Chromosphere, Corona. Solar activity: sunspots, solar flares, solar cycle. Introduction to solar magnetohydrodynamics.
(b) Solar system: planets, satellites, asteroids, comets. Origin of solar system: nebular hypothesis. Brief introduction to stellar types and compact objects.

6. Stellar Structure and Stellar Evolution
(a) Atomic Spectra revisited. Stellar spectra and classification (OBAFGKM). Spectral types and their Temperature dependence. Black Body approximation. Hertzsprung–Russell diagram and its interpretation. Luminosity Classification. Types of stars: main sequence, giants, dwarfs.
(b) Stellar structure equations: Hydrostatic equilibrium, Energy transport (radiative & convective). Nuclear energy generation in stars.
(c) Stellar evolution: Low-mass stars, High-mass stars. Late stages: white dwarfs, neutron stars, black holes. Supernova explosions. Chandrasekhar limit, degeneracy pressure and possibility of Neutron star. Introduction to polytropic models and Lane–Emden equation.

Module 3:
(Total Lectures: 14)

7. Galaxies
(a) Types of galaxies: spiral, elliptical, irregular**,** Galaxy classification (Hubble classification). Star clusters: open and globular. Quasars and radio galaxies.
(b) Structure of the Milky Way: disk, bulge, halo. Galactic rotation and differential rotation. Oort constants. Rotation curve and dark matter. Spiral arms and star distribution. Galactic nucleus properties.

8. Large Scale Structure of the Universe
(a) Cosmic distance ladder. Distance measurement methods: Cepheids, supernovae. Redshift and Doppler effect. Hubble's law and expanding universe.
(b) Galaxy clusters and Dark Matter. Dark Energy. Olbers' paradox. Big Bang theory. Cosmic microwave background radiation. Cosmological principle (homogeneity & isotropy).

Module 4:

Astronomy and Astrophysics (Project and Presentation) Credit: 1

Total Lectures/Classes: 30

Each student is required to complete a project work based on topics covered in the syllabus. A project paper should have the following components – Title Page, Abstract, Introduction, Theory/Background, Methodology, Result and Discussion (including graphs, tables and Python scripts where necessary), Conclusion, References**.** The project must be presented in the form of a Power Point presentation during the semester-end examination in front of the examiners along with a write up around 1500 words, approximately**.**

Few suggested topics of Project **(Students may choose one or propose their own; data (real or assumed); source: online, books, journals or supplied):**

1. Determination of stellar distances using parallax
2. Coordinate transformation exercises
3. Magnification of a Telescope
4. Light Gathering Power Comparison
5. Resolving Power Demonstration
6. Simple Refracting Telescope Model
7. Reflecting Telescope (Newtonian) Study
8. Observational Limits in Astronomy
9. Plotting blackbody spectra
10. Applications of virial theorem in astrophysical systems
11. Study of radiative transfer in stars
12. Solar structure diagram and analysis
13. Determination of Solar Limb Darkening Coefficient
14. Study of sunspot and differential rotation of the Sun
15. Model of solar system formation
16. Stellar Spectral Classification (OBAFGKM Sequence)
17. Hertzsprung–Russell Diagram Plot and Interpretation
18. Life Cycle of Stars (Low-mass vs High-mass Stars)
19. Types of Stars: Main Sequence, Giants, and White Dwarfs
20. Rotation curve analysis
21. Structure of Milky Way mapping (use scale)
22. Classification of galaxies using images
23. Verification of Hubble's law
24. Study of cosmological models
25. Redshift-distance relation

Suggestive Readings:

1. *An Introduction to Modern Astrophysics – Bradley W. Carroll and Dale A. Ostlie, Pearson Education.*
2. *Fundamental Astronomy – Hannu Karttunen et al., Springer.*
3. *Astronomy: Principles and Practice – A. E. Roy and D. Clarke, Institute of Physics Publishing.*

4. *An Introduction to the Study of Stellar Structure – Subrahmanyan Chandrasekhar, Dover Publications.*
5. *Introductory Astronomy and Astrophysics (4th Edition) – Michael Zeilik and Stephen A. Gregory, Saunders College Publishing.*
6. *The Physical Universe: An Introduction to Astronomy – Frank H. Shu, University Science Books.*
7. *Astrophysics: A Modern Perspective – K. S. Krishnasamy, New Age International (P) Ltd., New Delhi, 2002.*
8. *An Introduction to Astrophysics – Baidyanath Basu, Prentice-Hall of India Pvt. Ltd., New Delhi, 2001.*
9. *Textbook of Astronomy and Astrophysics with Elements of Cosmology – V. B. Bhatia, Narosa Publishing House.*

Semester - VII
Course Code: PHS-DC-MJ-704
Course Name: Research Methodology and Research Ethics

Learning Objectives:

The course introduces students to the basic ideas of scientific research, how to find research problems, collect and analyze data, write scientific reports, and follow ethical practices in research. It also familiarizes students with basic research tools and online platforms such as Overleaf and Google Scholar.

Learning Outcomes:

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

- **Distinguish** between various types of research, such as basic, applied, quantitative, and qualitative, to select the appropriate approach for a given problem.
- **Formulate** clear research problems and hypotheses based on a systematic review of scientific literature from databases like Google Scholar, arXiv, and ResearchGate.
- **Apply** basic statistical methods—including mean, standard deviation, and uncertainty analysis—to interpret and represent experimental data graphically.
- **Utilize** essential ICT and visualization tools, such as Microsoft Excel, Python scripts, and Overleaf/LaTeX, to manage data and draft professional scientific documents.
- **Construct** a well-structured research paper or project report that includes a logical flow from abstract and methodology to results, discussion, and properly formatted references.
- **Demonstrate** effective communication skills by preparing and delivering a professional PowerPoint or poster presentation based on their independent project.
- **Identify** and avoid unethical research practices, specifically plagiarism and submission to predatory journals, by implementing proper citation techniques and academic honesty.
- **Manage** a digital researcher profile using identification systems like ORCID and reference management tools to streamline the scholarly publication process.

Course Content

Research Methodology and Research Ethics (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 20)

1. Introduction to Research, Data Collection and Data Analysis

(a) Meaning and importance of research; Objectives of research; Motivation for doing research; Types of research: Basic (fundamental) research, Applied research, Quantitative and qualitative research; Steps of the research process; Identification of a research problem; Importance of defining the research problem clearly; Introduction to literature review; Sources of scientific information: books, journals, theses and online databases; Basic idea of hypothesis in research.
(b) Sources of data in scientific research; Types of data: quantitative and qualitative; Methods of data collection; Tabulation and graphical representation of data; Basic statistical ideas: mean, standard

deviation and data distribution; Introduction to experimental errors and uncertainty in measurements; Introduction to simple mathematical modelling in science.

Module 2:
(Total Lectures: 17)

2. Use of ICT Tools in Research

(a) Role of Information and Communication Technology in research; Use of internet for scientific information; Searching research articles using: Google Scholar; Research Gate; arXiv; Introduction to researcher identification systems such as ORCID; Basic idea of reference management tools. Introduction to Overleaf/LaTeX for writing scientific documents; Basic use of spreadsheet software such as Microsoft Excel for data handling; Introduction to plotting and visualization tools using Python.

3. Scientific Writing and Presentation

(a) Structure of a scientific research paper: Title, Abstract, Introduction, Theory/Background, Methodology, Result and Discussion (including graphs, tables and Python scripts where necessary), Conclusion, References**.**

(b) Preparing figures, graphs and tables; Writing references and bibliography and different standard styles; Preparation of seminar reports and project reports; Preparing presentation slides using Microsoft PowerPoint or Libre Office Impress; Basic idea of poster presentation.

Module 3:
(Total Lectures: 8)

Meaning and importance of research ethics; Academic honesty and responsible research; Meaning of plagiarism and how to avoid it; Proper citation of sources; Basic idea of predatory journals and unethical publication practices.

Module 4:
Research Methodology and Research Ethics (Project and Presentation) Credit: 1
Total Lectures/Classes: 30

Each student shall select a **topic related to their syllabus** in consultation with the course teacher. The topic may involve **a review of a scientific concept, recent developments, or applications in the chosen area.** The report should follow a **simple scientific format** of around **1500 - 2000 words.** The project must be presented in the form of a PowerPoint presentation during the semester-end examination in front of the examiners**.**

Topics of Project **(Students may choose one or propose their own related to the syllabus).**

Semester – VIII
Course Code: PHS-DC-MJ-801
Course Name: Basics of Spectroscopy and LASER

Learning Objectives:

This course, at the beginning, deals with a brief review of the background of atomic spectroscopy including discussion on the different series of hydrogen. The quantization of hydrogen atom and the concept of electron spin and magnetic moment of electron to explain the fine structure of atomic spectra and phenomena like Zeeman effect followed by spectroscopy of inner electrons leading to X rays will be discussed. Microwave Spectroscopy, Infrared Spectroscopy, Raman spectroscopy, NMR and ESR spectroscopy constitute the molecular spectroscopy part. Finally, basic concepts of working of LASER and its application are included. After successful completion of the course, the students will be able to understand the field of spectroscopy and the influence of using LASER as the source in the experiments on spectroscopy.

Learning Outcomes:

After completion of the course, students will be able to:

- **Elucidate** the features like characteristics of atomic spectra, the electron spin, spin magnetic moments.
- **Explain** space quantization and Zeeman effect.
- **Use** spectral notations for atomic and molecular states and corresponding term symbols.
- **Describe** basic principle of Raman spectroscopy and Franck Condon principle.
- **Acquire** basic knowledge in the areas of astrophysics, nuclear physics, medical physics, geology and other inter-disciplinary fields of Physics, Chemistry and Biology.

<u>Course Content</u>

Basics of Spectroscopy and LASER (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 20)

Atomic spectroscopy:

(a) Predictions of classical theory, characteristics of atomic spectra. Hydrogen spectrum, Ritz combination principle, different spectral series (Lyman, Balmer, Paschen, Brackett and Pfund series) and Rydberg constant. Bohr–Sommerfeld atomic model and quantum conditions, hydrogen spectra, excitation and ionization of atoms. Franck and Hertz experiment.
(b) Atomic emission spectroscopy, atomic absorption spectroscopy and atomic fluorescence spectroscopy. (Basic theory and applications are to be discussed)
(c) Helium and alkali atom spectra. Selection rules. X-rays: continuous and characteristic X-rays; Moseley's law and its explanation from Bohr's theory.

Module 2:
(Total Lectures: 18)

Molecular spectroscopy:

(a) Microwave Spectroscopy: Classification of molecules- Linear molecules, Symmetric tops, Spherical tops, Asymmetric tops. Rotational spectra of rigid diatomic molecules, selection rules, isotope effect. Intensities of rotational spectral lines. Microwave spectrometer. Information derived from rotational spectra.

(b) Infrared Spectroscopy: Vibration-rotation spectra, selection rule. Franck-Condon principle. IR spectrometer, applications of IR spectroscopy.

(c) Raman Spectroscopy: Raman effect, Stokes and anti-Stokes lines. Quantum theory of Raman effect. Applications of Raman spectroscopy.

(d) Nuclear Magnetic Resonance (NMR) Spectroscopy and Electron Spin Resonance (ESR) Spectroscopy: Brief discussion.

Module 3:
(Total Lectures: 7)

Introduction to LASER:

Absorption and emission of radiation, spontaneous and stimulated emission, Einstein's A and B coefficients. Active medium, meta-stable states, different methods of pumping and population inversion, resonant cavity or optical resonator. Three level and four level lasers. Ruby laser and He-Ne laser. Applications of lasers.

Suggestive reading:

1. *Atomic Physics, J. B. Rajam and foreword by Louis De Broglie, 2010, S. Chand and Co.*
2. *Physics of Atoms and Molecules, B. H. Bransden and C. J. Jochain, 2nd edition, Pearson*
3. *Introduction to Atomic Spectra by H.E. White, McGraw Hill Book Company*
4. *Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, 1994, Tata McGraw – Hill*
5. *Introduction to Molecular Spectroscopy by G.M. Barrow, McGraw-Hill International Edition*
6. *Introduction to Spectroscopy, D. L. Pavia, G. M. Lampman, G. A. Kriz and J. R. Vyvyan, 5th edition, 2014, Brookes/Cole*
7. *Physics of the Atom by A.B. Gupta, 2012, Books and Allied (P) Ltd*
8. *Atomic Physics, S. N. Ghoshal, 2019, S. Chand Publication*
9. *Laser Physics and Spectroscopy by P.N. Ghosh, Levant Books, India, 2016*

Module 4:

Basics of Spectroscopy and LASER (Practical) Credit: 1
Total Lectures: 30

List of Experiments:

1. Adjustment of a spectrometer by Schuster's method and to calibrate the spectrometer (D-λ curve) and hence to determine an unknown wavelength.
2. To draw the μ-λ curve for the material of a prism using a spectrometer and to find the dispersive power.
3. Measurement of the slit width and the separation between the slits of a double slit by observing the diffraction and interference fringes using spectrometer and laser source.
4. To find the number of lines per centimeter of a plane transmission grating and hence to measure the wavelength of an unknown spectral line and to determine the resolving power of the grating (laser sources should be used).
5. To study the diffraction pattern of a crossed grating with the help of a laser source.
6. Apply the Beer-Lambert relationship to determine the concentration of an absorbing substance in its aqueous solution by calibrating UV-Vis spectrometer.

6. To determine the Rydberg constant using Balmer lines of Hydrogen Spectrum using Hydrogen discharge tube , Spectrometer and Diffraction grating .

7. Determination of Wavelengths of Mercury Spectral Lines using a diffraction grating, spectrometer, and a Mercury lamp

Suggestive Readings:

1. *Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.*
2. *A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal.*
3. *Advanced level Physics Practicals, Michael Nelson, and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.*
4. *A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.*
5. *Advanced practical physics, B. Ghosh, K. G. Mazumder, 2009. Sreedhar Publishers.*
6. *Advanced practical physics, B. Ghosh, 2009. Sreedhar Publishers.*
7. *Laboratory Manual of physics, M. Jana, 2020. Books & Allied(P) Ltd.*
8. *An advance course in practical physics, D. Chattopadhyay, P. C. Rakshit, 2009, New Central Book Agency (P) Ltd.*

Semester – VIII
Course Code: PHS-DC-MJ-802
Course Name: Nanomaterials and Material Science

Learning Objectives:

The primary objective is to provide students with a theoretical and practical understanding of physical properties at the nanoscale. It aims to develop conceptual mastery of how reduced dimensionality influences electronic structures and size-dependent effects, while introducing precision fabrication pathways and the operational physics of state-of-the-art characterization instrumentation.

Learning Outcomes:

After completion of the course, students will be able to:

- **Determine** energy levels in quantum structures analytically, and select appropriate synthesis and characterization strategies for specific geometries.
- **Describe** complex transport phenomena, such as tunnelling and Coulomb blockade.
- **Evaluate** the role of nanomaterials in advancing modern technologies like solar cells, MEMS and NEMS.

Course Content

Nanomaterials and Material Science (Theory) **Credit: 3**
Total Lectures: 45

Module 1:
(Total Lectures: 15)

Introduction to nanotechnology: Emergence, challenges, Carbon age, New forms of carbon (Graphene sheet to CNT); Nanoscale fundamentals: Influence of nucleation rate on crystal size, surface-to-volume ratio, defects in nanocrystals, surface effects on properties; Types of nanocrystals: One-dimensional (1D), Two-dimensional (2D), and Three-dimensional (3D) nanostructured materials; Quantum confinement Effect: Electronic band structure and density of states (DOS) at the nanoscale, size effects and quantum confinement in quantum dots, quantum wires; Nanomaterials synthesis: Top-down and bottom-up approaches, Mechanical methods(ball milling), Energy based methods (PVD, MBE, laser ablation, ion sputtering, arc discharge), Chemical methods (CVD, sol-gel, electro-deposition, spray pyrolysis, hydrothermal synthesis), Green synthesis (microorganisms, plant extracts, algae-mediated synthesis.)

Module 2:

(Total Lectures: 15)

Characterization techniques: Structural (XRD), optical (UV-Vis, FL spectroscopy, DLS), surface charge (zeta potential), functional groups (FTIR), imaging (SEM, TEM, AFM, STM); Nanomaterials and their properties: Carbon nanotubes (CNTs), noble metals (Au, Ag), metal oxides (TiO_2, Cu_2O, ZnO), semiconductors (Si, Ge, CdS, ZnSe, PbS), ceramics and composites, dilute magnetic semiconductors, size-dependent properties – mechanical, physical, and chemical properties.

Module 3:

(Total Lectures: 15)

Applications of nanomaterials: Integration of nanoparticles and nanowires into photonic devices (LEDs, solar cells); **Environmental & Bio-applications:** Gas sensors, drug delivery systems, environmental remediation. Biomedical applications: hydrogels and nanogels, membrane-based water purification; Nanotoxicology: antibacterial properties, cytotoxicity analysis, wastewater treatment.

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Suggestive Readings:

1. *Introduction to Nano: Basic to Nanoscience and Nanotechnology by Amretashis Sengupta and Chandan Sarkar Springer.*
2. *Introduction to Nanotechnology by Charles P. Poole Jr. and Frank J. Owens.*
3. *Nanostructures and Nanomaterials: Synthesis, Properties, and Applications by Guozhong Cao and Ying Wang.*
4. *The Physics of Low-Dimensional Semiconductors by John H. Davies.*
5. *Characterization of Nanophase Materials edited by Zhong Lin Wang.*
6. *Quantum Heterostructures: Microelectronics and Optoelectronics by Vladimir V. Mitin, Viacheslav A. Kochelap, and Michael A. Stroscio.*
7. *Nanophysics and Nanotechnology by Edward L. Wolf.*

Module 4:

Nanomaterials and Material Science (Project/Practical) Credit: 1
Total Lectures: 30

Each student is required to complete a project work based on topics covered in the syllabus. A project paper should have the following components – Title Page, Abstract, Introduction, Theory/Background, Methodology, Result and Discussion (including graphs, tables and Python scripts where necessary), Conclusion, References**.** The project must be presented in the form of a PowerPoint presentation during the semester-end examination in front of the examiners along with a write up around 1500 words, approximately**.**

Few suggested topics of Project **(Students may choose one or propose their own):**

1. Quantum confinement effect in quantum dots.
2. Effect of particle size on surface area (a surface-to-volume ratio study)
3. Characterization techniques in nanotechnology (a review of XRD, SEM and TEM)
4. silver nanoparticles synthesis and application
5. Synthesis of pure ZnO and Cu doped ZnO nanoparticles
6. Green Synthesis of Silver Nanoparticles Using Plant Extracts
7. Graphene: Structure, Properties, and Applications
8. Carbon Nanotubes and Their Technological Applications
9. Nanomaterials in Solar Cell Technology
10. Electrochemical Nanobiosensors for Medical Diagnostics
11. Gold Nanoparticles in Drug Delivery and Cancer Therapy
12. Nanotechnology-Based Water Purification Systems
13. Nanotoxicology: Environmental and Health Impacts of Nanomaterials
14. Characterization of Nanomaterials Using XRD, SEM, and TEM
15. Nanomaterials for Energy Storage and Lithium-Ion Batteries

Semester – VIII
Course Code: PHS-DC-MJ-803
Course Name: Quantum Mechanics II

Learning Objectives:

The course aims to provide students with a comprehensive understanding of the formalism and applications of quantum mechanics. It introduces the mathematical foundations of quantum theory and develops the ability to solve quantum mechanical problems in one- and three-dimensional systems. The course also aims to familiarize students with operator methods, vector spaces and Hilbert space formalism, quantum observables, uncertainty principles, and angular momentum concepts, enabling them to connect abstract theory with physically significant systems such as the harmonic oscillator and the hydrogen atom. Students will develop analytical skills necessary for advanced studies in modern physics and related fields.

Learning Outcomes (Quantum Mechanics II)

Upon successful completion of the course, students will be able to:

- Explain the fundamental principles and interpretation of quantum mechanics.
- Solve the Schrödinger equation for simple one- and three-dimensional systems.
- Analyze bound states, scattering states, and quantum tunneling phenomena.

- Apply vector space and Hilbert space concepts in quantum mechanics.
- Use Dirac notation and operator formalism to represent quantum states and observables.
- Explain uncertainty principles and operator algebra.
- Apply concepts of angular momentum and spherical harmonics.
- Analyze the hydrogen atom and symmetry-related quantum phenomena.
- Develop analytical and problem-solving skills for advanced studies in quantum

Course Content

Quantum Mechanics II (Theory) Credit: 3

Total Lectures: 45

Module 1:

(Total Lectures: 15)

(a)Reviews of introductory concepts: Basic properties wave function, probabilistic interpretation of quantum mechanics, time independent Schrodinger equation, stationary states, and other relevant topics.

(b) Time-independent Schrodinger equation in one dimension: The infinite square well. The linear harmonic oscillator by operator method. The free particle. Bound states and scattering states of the finite square well. Transmission and reflection coefficients. Rectangular barrier potential.

Module 2:

(Total Lectures: 15)

(a) Introductory concepts of vector spaces: linear independence, bases, dimensionality, inner product. Eigenvalues and eigenvectors, orthonormality. Hilbert space. Kets, bras and operators, Base kets and matrix representation. Eigenkets as base kets.

(b) Formalism of quantum mechanics: The superposition and completeness of eigenstates. Observable and results of its measurement. Hermitian operators. Generalized statistical interpretation. The generalized uncertainty relation. Expectation values of dynamic variables. Commutators and operator algebra. Non-commutating observables. Complete set of commuting observables. Change of basis. Symmetry transformations and their relation to commutators and conservation laws.

Module 3:

(Total Lectures: 15)

(a) Schrodinger equation in three dimensions: The three-dimensional box. The three-dimensional harmonic oscillator. Symmetry and degenracy. Orbital angular momentum. Ladder operators. Spherical harmonics. Schrodinger equation in spherical coordinates. Coulomb potential. The hydrogen atom problem.

(b) Identical particles: Two-particle systems, bosonic and fermionic wave functions, Pauli exclusion principle, Slater determinant.

Module 4

Quantum Mechanics II (Project/Practical) Credit: 1

Total Lectures: 30

Each student is required to complete a project work based on topics covered in the syllabus. A project paper should have the following components - Abstract, Introduction, Theory, Methodology, Result and Discussion (use graph and tables, Python implementation if required), Conclusion, Reference. The project must be presented in the form of a Power Point presentation during the semester-end examination in front of the examiners along with a write up around 1500 words, approximately.

Suggested topic (Students may choose their own topic in consultation with class teacher):

1. Quantum Tunneling Through Potential Barriers
2. Visualization of Hydrogen Atom Orbitals
3. Numerical Solution of Schrödinger Equation for Different Potentials
4. Wave Packet Evolution and Quantum-Classical Correspondence
5. Spherical Harmonics and Atomic Orbitals
6. Quantum Harmonic Oscillator and Coherent States
7. Quantum Mechanics Behind MRI and NMR
8. Introduction to Quantum Computing Through Qubits
9. Quantum Dots: Artificial Atoms
10. Quantum Entanglement and Bell States

Semester – VIII
Course Code: PHS-DC-MJ-804
Course Name: Term Paper / Book Review / Literature Review / Project Report/ Field Report

Learning Objectives:

This course aims to train students in research documentation and academic review enabling them to prepare structured scientific reports and encourages independent study and critical evaluation.

Learning Outcomes:

After completing the course, students will be able to:

- Prepare a well-structured scientific document
- Critically analyze scientific literature and books
- Present scientific findings effectively
- Demonstrate independent research and writing ability

Course Content

Term Paper / Book Review / Literature Review / Project Report/ Field Report

Credit: 4
Total Lectures: 60

1. Term Paper:

(a) Concept and importance of term paper. Selection of topic in physics (Preferably from the syllabus of I-VII semesters)
(b) Structure: Abstract, Introduction, Methodology/Theory, Analysis and Discussion, Conclusion and References.

OR

2. Literature Review

(a) Concept and objectives**.** Collection of research papers (10–15 papers) with the help of class teacher.
(b) Review methods: Thematic, Chronological.
(c) Analysis and synthesis of research findings. Identification of research areas.

(d) Research proposal

OR

3. Field Report

(a) Purpose of field-based study. Visit to: Laboratory / Industry / Observatory.
(b) Structure: Introduction, Description of visit, Observations, Analysis, Conclusion.

OR

4. Book Review

(a) Selection of standard physics book.
(b) Structure: Bibliographic details, Summary, Critical evaluation, Strengths and limitations, Conclusion.

Semester – VIII
Course Code: PHS-DRP-1
Course Name: Dissertation
Credit: 12
(For B.Sc. Physics Honours with Research)

The Dissertation / Research Project is designed to provide undergraduate physics students with research experience through experimental, theoretical, computational, or review-based work. The course develops scientific thinking, problem-solving ability, data analysis skills, scientific writing, and presentation skills in accordance with NEP-2020 research-oriented undergraduate education.

Objectives

The course aims to:

- Develop research aptitude and scientific temper.
- Introduce students to literature survey and research methodology.
- Train students in experimentation, simulation, or theoretical analysis.
- Develop skills in data analysis and scientific report writing.
- Improve presentation and viva-voce skills.
- Prepare students for higher studies and research careers.

Learning Outcomes

This 12-credit Dissertation / Research Project syllabus provides undergraduate physics students with foundational training in scientific research, experimentation, data analysis, academic writing, and presentation. After completion of the course, students will be able to:

- Identify and formulate research problems.
- Perform experiments or computational/theoretical investigations.
- Analyse and interpret scientific data.
- Prepare plagiarism-free scientific reports.
- Present research findings effectively.

Projects Types

Projects may be:

- Experimental Physics
- Theoretical Physics
- Computational Physics
- Interdisciplinary Physics
- Review/Survey-based Research

Credit Distribution

Component	**Credits**
Research Proposal & Literature Review	2
Experimental / Computational / Theoretical Work	5
Dissertation Report Writing	3
Presentation & Viva-Voce	2
Total	**12**

Course Structure

Unit I: Research Proposal and Literature Review (2 Credits)

- Research problem identification
- Literature survey
- Research ethics and plagiarism
- Synopsis preparation
- Research methodology

Unit II: Experimental /Analytical / Computational Work (5 Credits)

- Experimental design and data collection
- Instrumentation/simulation/analytical techniques
- Data analysis / Numerical analysis and graph plotting
- Error analysis and interpretation

- Progress seminar and logbook maintenance

Unit III: Dissertation Report Writing (3 Credits)

- Structure of dissertation
- Data presentation and discussion
- References and formatting
- Preparation of final report

Unit IV: Presentation and Viva-Voce (2 Credits)

- Seminar presentation
- Scientific communication
- Viva-voce examination
- Defense of research findings

Evaluation Procedure

Internal Assessment (30%)

- Proposal and literature review
- Progress seminar
- Laboratory/computational work
- Logbook and attendance

External Assessment (70%)

- Quality of dissertation
- Data analysis and methodology
- Seminar presentation
- Viva-voce

General Guidelines

- Each student shall undertake a Dissertation/Project work under the guidance of a faculty supervisor, who will assist in topic selection, research planning, progress monitoring, and evaluation of the work.
- The project topic should preferably be related to current research areas in Physics or allied interdisciplinary fields. The work may be experimental, theoretical, computational, simulation-based, analytical, or review-oriented depending on the nature of the study.
- The project is intended to provide students with basic training in research methodology, literature survey, scientific analysis, data interpretation, and technical report writing.
- The dissertation shall preferably be carried out individually to encourage independent and original scientific work. Interdisciplinary or collaborative projects may be permitted with prior departmental approval.
- Students must maintain regular interaction with the supervisor and keep proper records of progress, observations, calculations, references, and related activities through a logbook or progress report.
- In special cases, students may undertake a comprehensive review and critical analysis of an advanced topic beyond the standard syllabus, subject to approval by the department.

- At the completion of the project, students shall submit a dissertation/report in both hard and soft copy formats, clearly presenting the objectives, methodology, results, analysis, conclusions, and references of the study.
- The dissertation must be original and plagiarism-free. Proper citation and acknowledgement of all references, software, datasets, and sources used in the work are mandatory.
- At the end of the semester, students shall deliver a seminar presentation and defend their work before an evaluation committee through viva-voce examination.
- Submission of the dissertation, seminar presentation, and successful completion of the viva-voce examination shall be mandatory for the award of credits for the course.