MADHABDEV UNIVERSITY

DEPARTMENT OF PHYSICS

SYLLABUS: FOUR-YEAR UNDERGRADUATE PROGRAMME (FYUGP) IN PHYSICS (HONOURS/RESEARCH)

Under National Education Policy - NEP 2020

Approved in the meeting of the Board of Studies of the Department of Physics on: July 11, 2026

FYUGP SYLLABUS (UNDER NEP-2020) OF THE DEPARTMENT OF PHYSICS MADHABDEV UNIVERSITY

Approved in the meeting of the Board of Studies of the Department of Physics held on July 11, 2026

<u>Members Present</u>

Sl. no.	Name of the members
1.	**Dr. Limpon Bora** Academic Registrar, Madhabdev University
2.	**Dr. Arindam Phukan** (HoD i/c) Chairperson Dept. of Physics, Madhabdev University
3.	**Dr. Lakhinath Borah** Member, Dept. of Physics, Madhabdev University
4.	**Dr. Sudipta Hazarika** Member, Dept. of Physics, Madhabdev University
5.	**Dr. Dhruba Jyoti Gogoi** Member, Dept. of Physics, Madhabdev University
6.	**Prof. Mrinal Kumar Das** External member HoD, Dept. of Physics, Tezpur University
7.	**Prof. Upamanyu Das** External member Dept. of Physics, Bhattadev University

Comprehensive Program Learning Outcomes and Academic Framework

Four-Year Undergraduate Programme (FYUGP) in Physics (Honours/Research)

Madhabdev University | Department of Physics

1. Preamble and Institutional Context

The Department of Physics at Madhabdev University, functioning under the transformative directives of the National Education Policy (NEP-2020), has structurally redefined undergraduate physics education. This meticulously designed Four-Year Undergraduate Programme (FYUGP) in Physics (Honours/Research) constitutes a paradigm shift from traditional, passive learning models toward a dynamic, interdisciplinary, and research-intensive educational framework.

This curriculum is engineered to cultivate a new generation of physicists who are not only theoretically profound and mathematically rigorous but also experimentally autonomous and ethically grounded. By synthesizing classical mechanics, advanced quantum mechanics, computational physics, and robust research methodologies, the program guarantees that graduates are equipped to address both fundamental scientific inquiries and applied technological challenges. The framework intentionally integrates Indian Knowledge Systems (IKS) to provide cultural and historical context, ensuring graduates possess a decolonized perspective on the evolution of global science.

2. Academic Framework and Pedagogical Philosophy

The FYUGP curriculum operationalizes the core philosophies of the NEP-2020 through specific, verifiable structural implementations designed to foster holistic development, vocational preparedness, and academic excellence.

2.1 The Multiple Entry and Exit Architecture

Reflecting the flexible ethos of the NEP-2020, the FYUGP is structured to provide functional, employable skills at every distinct exit point, ensuring no academic year is without tangible value.

- **Year 1 (Undergraduate Certificate - 40 Credits):** Students exiting after the first year possess foundational knowledge in Newtonian mechanics, properties of matter, vector calculus, and electromagnetism. They acquire basic laboratory skills and digital literacy, rendering them capable of entry-level technical roles or laboratory assistance.
- **Year 2 (Undergraduate Diploma - 84 Credits):** Completion of the second year guarantees proficiency in wave optics, thermal physics, and analog/digital electronics. Students are equipped with intermediate experimental skills and cyber security knowledge, suitable for technical vocations in electronics and optical instrumentation.
- **Year 3 (Bachelor of Science - 128 Credits):** The three-year degree provides a rigorous foundation in Quantum Mechanics, Statistical Mechanics, Solid State Physics, and Computational Physics (Python/Numerical Methods). Graduates are fully prepared for standard postgraduate studies or roles in data analysis and scientific computing.
- **Year 4 (B.Sc. Honours / Honours with Research - 174 Credits):** The culmination of the FYUGP mirrors the rigor of the first year of a traditional Master’s degree. Students master advanced classical mechanics, quantum field theory, plasma physics, and electromagnetic theory. Those in the Research track execute continuous Research Projects (RP-I to RP-III), mastering advanced statistical inference, LaTeX, and instrument calibration, rendering them ideal candidates for premier doctoral programs globally.

2.2 Multidisciplinary Synthesis and Holistic Education

The program mandates the synthesis of knowledge across scientific domains. Through Multidisciplinary Courses (MDC), Value Addition Courses (VAC), and Skill Enhancement Courses (SEC), students integrate environmental science, cyber security, and life skills into their physics education. This holistic approach trains students to view physical phenomena not as isolated academic problems, but as interconnected components of a broader natural and technological ecosystem.

2.3 Integration of Indian Knowledge Systems (IKS)

A defining feature of this academic framework is the formal integration of Indian Knowledge Systems. The curriculum bridges ancient epistemologies with modern discoveries. Students critically evaluate Maharishi Kanada's atomistic theory (Vaisheshika Sutra), Aryabhatta's relative motion, and the mathematical innovations of the Kerala School. Furthermore, they trace this lineage to the monumental 20th-century contributions of S.N. Bose, C.V. Raman, Meghnad Saha, and S. Chandrasekhar, fostering a sense of intellectual heritage and historical continuity in the pursuit of scientific truth.

2.4 Deep Research Exposure and Methodological Rigor

The FYUGP framework mandates a transition from knowledge consumption to independent knowledge creation. The 7th and 8th semesters are heavily weighted toward Research Methodology and Computational Modeling. Students are trained in advanced statistical error analysis (Maximum Likelihood Estimation, Monte Carlo), the FAIR data principles, research ethics (avoiding FFP), and professional scientific authorship using LaTeX. The continuous research projects ensure graduates can independently formulate hypotheses, design experiments, analyze complex datasets, and defend their conclusions.

3. Graduate Attributes (GAs)

Graduate Attributes constitute the core competencies, intrinsic qualities, and defining characteristics that a Madhabdev University Physics graduate will internalize by the completion of the four-year FYUGP.

- **GA 1: Disciplinary Knowledge and Theoretical Rigor:** Deep, systematic comprehension of fundamental and advanced physical laws—spanning classical dynamics, quantum mechanics, electrodynamics, and statistical thermodynamics. Graduates possess the ability to theoretically model and mathematically describe complex natural phenomena.
- **GA 2: Analytical Reasoning and Mathematical Fluency:** Exceptional cognitive ability to deconstruct physical systems using advanced mathematics, including vector calculus, differential equations, complex analysis, tensor calculus, and group theory.
- **GA 3: Experimental Autonomy and Methodological Precision:** Independent proficiency in designing experiments, operating high-end analytical instrumentation (vacuum systems, spectrometers, sensors), and executing precise physical measurements with rigorous statistical error analysis.
- **GA 4: Computational and Technological Dexterity:** Adept handling of modern computational tools and hardware. Graduates are proficient in Python programming, numerical ODE solvers, digital/analog circuit design, and microprocessor (8085) architecture, enabling them to simulate physical systems and design instrumentation.
- **GA 5: Scientific Authorship and Communication:** The ability to articulate complex scientific findings with absolute clarity to both expert and lay audiences. Graduates are proficient in professional typesetting (LaTeX) to produce publication-ready manuscripts and deliver rigorous academic defenses.
- **GA 6: Professional Ethics and Research Integrity:** Unyielding adherence to scientific ethics, understanding the gravity of research misconduct (Fabrication, Falsification, Plagiarism), intellectual property rights, and the ethical utilization of AI in academic research.
- **GA 7: Cultural Contextualization (IKS):** An appreciation for the historical continuity of science, specifically recognizing the epistemological contributions of Indian Knowledge Systems (IKS), fostering a decolonized and globally aware perspective on scientific discovery.
- **GA 8: Environmental Stewardship and Societal Awareness:** A critical understanding of thermodynamics and wave phenomena applied to environmental contexts, equipping the graduate to engage with global sustainability challenges and apply physical principles to societal problems.
- **GA 9: Lifelong Learning and Adaptability:** The cognitive flexibility and self-directed motivation required to continuously assimilate emerging physical paradigms, adapt to evolving technologies, and thrive in a rapidly changing global scientific landscape.

4. Programme Educational Objectives (PEOs)

Programme Educational Objectives define the professional and career accomplishments that graduates of the FYUGP in Physics (Honours/Research) are expected to achieve within three to five years post-graduation.

- **PEO 1 (Academic Excellence and Frontier Research):** Secure placements in premier doctoral programs, integrated Ph.D. programs, or high-level research fellowships by leveraging robust foundational knowledge and success in national-level competitive examinations (e.g., IIT-JAM, CSIR-NET, GATE, JEST).
- **PEO 2 (Technological and Industrial Leadership):** Apply advanced principles of electronics, solid-state physics, and computational modeling to solve complex engineering and data problems in high-technology sectors, including semiconductor manufacturing, telecommunications, IT/Data Science, and industrial instrumentation.
- **PEO 3 (Professional Integrity and Ethical Stewardship):** Exhibit leadership, collaborative teamwork, and unyielding ethical integrity in diverse professional environments, championing transparent data practices and rigorous analytical standards.
- **PEO 4 (Societal Impact and Educational Contribution):** Utilize analytical expertise to contribute meaningfully to science education, public science policy, environmental monitoring, or science communication, bridging the gap between advanced physical research and societal development.
- **PEO 5 (Continuous Professional Evolution):** Demonstrate sustained professional growth by mastering new theoretical frameworks, computational languages, and interdisciplinary methodologies, drawing continuous inspiration from global advancements and indigenous scientific heritage.

5. Programme Learning Outcomes (PLOs)

Upon successful completion of the FYUGP in Physics (Honours/Research), graduates will demonstrate mastery across cognitive, psychomotor, and affective domains, encapsulated in the following specific Programme Learning Outcomes:

- **PLO 1 (Core Physical Principles):** Formulate, explain, and apply the foundational laws of classical mechanics, electromagnetism, optics, and thermodynamics to accurately predict the behavior of macroscopic physical systems.
- **PLO 2 (Advanced Quantum and Statistical Systems):** Analyze complex subatomic and multi-particle systems utilizing the advanced postulates of quantum mechanics, time-dependent/independent perturbation theories, and the formalisms of classical and quantum statistical mechanics (Bose-Einstein, Fermi-Dirac).
- **PLO 3 (Mathematical and Analytical Modeling):** Apply advanced mathematical techniques—including complex analysis, Fourier/Laplace transforms, special functions, and tensor algebra—to derive analytical solutions for complex boundary-value problems and field equations.
- **PLO 4 (Computational Physics and Simulation):** Translate physical problems into algorithmic logic; utilize Python and numerical methods (Runge-Kutta, Monte Carlo, root-finding, matrix diagonalization) to simulate quantum, statistical, and classical dynamic systems.
- **PLO 5 (Applied Electronics and Instrumentation):** Design, construct, and analyze both analog (BJT, Op-Amp, oscillators) and digital (flip-flops, registers, microprocessors) electronic circuits, applying these principles to practical data acquisition and sensor technologies.
- **PLO 6 (Experimental Execution and Data Inference):** Autonomously execute complex laboratory experiments in modern physics, solid-state physics, and optics. Perform rigorous statistical inference, uncertainty propagation, and curve-fitting to extract highly reliable physical constants.
- **PLO 7 (Advanced Subatomic and Plasma Physics):** Evaluate the structural properties of nuclei, the symmetries of elementary particles (Standard Model), and the fluid/kinetic dynamics of plasmas in both laboratory and astrophysical contexts.
- **PLO 8 (Research Methodology and Scientific Authorship):** Identify literature gaps, formulate testable hypotheses, and execute independent research projects. Communicate findings ethically and professionally utilizing LaTeX, adhering to international peer-review and FAIR data standards.
- **PLO 9 (Interdisciplinary Synthesis and IKS):** Integrate physical principles with allied disciplines (chemistry, computer science) and critically evaluate the historical evolution of physical concepts through the lens of Indian Knowledge Systems (IKS).

6. Course Learning Outcomes (CLOs)

The curriculum is driven by specific, measurable Course Learning Outcomes for each core paper (PHYM series) across the eight semesters.

Semester I

PHYM 101: Physics I

- **CLO 1:** Apply Newton's laws, Galilean invariance, and Kepler's laws to solve two-body problems and central force motions.
- **CLO 2:** Evaluate the macroscopic properties of matter, including rigid body dynamics, elasticity, surface tension, and fluid viscosity.
- **CLO 3:** Utilize vector calculus (gradient, divergence, curl, integral theorems) to formulate physical laws in multiple coordinate systems.
- **CLO 4:** Describe ancient Indian Knowledge Systems (atomism, relative motion) and recognize the foundational contributions of 20th-century Indian physicists.

Semester II

PHYM 201: Physics II

- **CLO 1:** Apply Gauss's Law, Laplace/Poisson equations, and the method of images to solve complex electrostatic potential problems.
- **CLO 2:** Analyze the dielectric properties of matter, polarization vectors, and boundary conditions for displacement vectors.
- **CLO 3:** Formulate magnetic fields using Biot-Savart and Ampere’s laws, and evaluate the ferromagnetic properties of matter (B-H curves).
- **CLO 4:** Analyze AC circuits (series/parallel LCR) and apply network theorems (Thevenin, Norton, Superposition) to complex electrical systems.

Semester III

PHYM 301: Mathematical Physics-I

- **CLO 1:** Solve first and second-order ordinary differential equations using integrating factors and the Wronskian.
- **CLO 2:** Apply the method of separation of variables to solve partial differential equations (Laplace, Wave, Diffusion) in various symmetries.
- **CLO 3:** Utilize the Frobenius method to derive solutions using special functions (Legendre, Bessel, Hermite) and apply their recurrence relations.
- **CLO 4:** Apply Beta, Gamma, and Dirac-Delta functions to evaluate physical integrals and model point sources.

PHYM 302: Laboratory-I

- **CLO 1:** Measure the acceleration due to gravity and moments of inertia using advanced pendulums and flywheels.
- **CLO 2:** Determine elastic moduli (Young's, Rigidity) and fluid viscosity using precise optical lever and capillary flow methods.
- **CLO 3:** Verify electrical network theorems and analyze the frequency response of LCR resonant circuits.
- **CLO 4:** Calibrate and operate Ballistic Galvanometers to measure unknown capacitances and high resistances.

Semester IV

PHYM 401: Wave and Optics

- **CLO 1:** Formulate the differential wave equation and analyze the superposition of collinear and perpendicular harmonic oscillations (Lissajous figures).
- **CLO 2:** Evaluate interference phenomena using wavefront and amplitude division (Young's, Fresnel Biprism, Newton's Rings).
- **CLO 3:** Analyze Fraunhofer and Fresnel diffraction patterns, and calculate the resolving power of optical instruments.
- **CLO 4:** Explain the principles of spatial/temporal coherence, lasing action (Einstein coefficients), and holography.

PHYM 402: Thermal Physics

- **CLO 1:** Apply the First and Second Laws of thermodynamics to calculate work, internal energy, and the efficiency of heat engines (Carnot cycle).
- **CLO 2:** Calculate entropy changes in reversible and irreversible processes, and apply thermodynamic potentials to phase transitions.
- **CLO 3:** Derive and apply Maxwell's thermodynamic relations to physical systems (e.g., Joule-Kelvin effect, Clausius-Clapeyron equation).
- **CLO 4:** Formulate the kinetic theory of gases to evaluate Maxwell-Boltzmann velocity distributions and transport phenomena (viscosity, thermal conductivity).

PHYM 403: Electronics-I

- **CLO 1:** Simplify logic circuits using Boolean algebra, De Morgan's laws, and Karnaugh maps.
- **CLO 2:** Design digital combinational circuits (adders, multiplexers) and analyze sequential circuits (flip-flops, shift registers).
- **CLO 3:** Explain the physics of PN junctions, drift/diffusion currents, and apply diodes in rectification and voltage regulation.
- **CLO 4:** Analyze Bipolar Junction Transistors (BJT) in various configurations, design biasing circuits, and evaluate single-stage CE amplifiers using hybrid models.

PHYM 404: Laboratory-II

- **CLO 1:** Investigate wave optics experimentally, determining refractive indices, dispersive powers, and laser wavelengths using prisms, gratings, and interferometry.
- **CLO 2:** Determine the Mechanical Equivalent of Heat (J) and thermal conductivities of various materials.
- **CLO 3:** Construct and verify digital logic circuits, including universal gates, adders, and subtractors.
- **CLO 4:** Characterize semiconductor devices (diodes, Zener, BJT) and design functional transistor amplifiers.

Semester V

PHYM 501: Mathematical Physics-II

- **CLO 1:** Apply Cauchy-Riemann conditions, Cauchy's Integral formula, and Residue theorem to evaluate complex contour integrals.
- **CLO 2:** Expand periodic and non-periodic functions using Fourier series and analyze their orthogonality.
- **CLO 3:** Apply Fourier transforms to solve one-dimensional wave and heat flow equations.
- **CLO 4:** Utilize Laplace transforms and convolution theorems to solve coupled differential equations and damped harmonic oscillator problems.

PHYM 502: Quantum Mechanics-I

- **CLO 1:** Explain the historical origins of quantum theory and articulate the formal postulates of wave mechanics and operators.
- **CLO 2:** Formulate and solve the time-independent Schrödinger equation for 1D potentials (infinite/finite wells, tunneling, harmonic oscillator).
- **CLO 3:** Analyze 3D central potential problems, separating variables to derive the radial and angular wavefunctions of the Hydrogen atom.
- **CLO 4:** Interpret electron spin via the Stern-Gerlach experiment and evaluate atomic spectra under external magnetic fields (Zeeman effect).

PHYM 503: Classical Dynamics

- **CLO 1:** Apply Lagrangian and Hamiltonian formalisms to derive equations of motion for complex dynamical systems and central force fields.
- **CLO 2:** Analyze small amplitude oscillations, determining the normal modes and eigenfrequencies of coupled systems.
- **CLO 3:** Apply Lorentz transformations, four-vector formalism, and relativistic kinematics to high-energy decay processes and electrodynamics.
- **CLO 4:** Formulate the continuity equation and Navier-Stokes equation to describe fluid dynamics, streamline motion, and turbulence.

PHYM 504: Lab III (Computational Physics)

- **CLO 1:** Write robust Python scripts utilizing NumPy and Matplotlib to perform data visualization and file I/O operations.
- **CLO 2:** Execute advanced error analysis, performing linear/non-linear least-squares curve fitting and Chi-square goodness-of-fit tests on physical data.
- **CLO 3:** Program numerical algorithms to find roots (Newton-Raphson) and solve linear algebra matrices for physical systems (coupled oscillators, Kirchhoff's laws).
- **CLO 4:** Computationally simulate statistical mechanics distributions (MB, FD, BE), specific heat models (Debye, Einstein), and blackbody radiation spectra.

Semester VI

PHYM 601: Statistical Mechanics

- **CLO 1:** Formulate the macrostates, microstates, and partition functions of an ideal gas using Maxwell-Boltzmann statistics and the Sackur-Tetrode equation.
- **CLO 2:** Derive Wien’s, Rayleigh-Jeans, and Stefan-Boltzmann laws from the classical and quantum theories of blackbody radiation.
- **CLO 3:** Apply Bose-Einstein statistics to analyze photon gases, liquid Helium, and Bose-Einstein condensation.
- **CLO 4:** Apply Fermi-Dirac statistics to evaluate the specific heat of metals, electron gases, and the Chandrasekhar mass limit for white dwarfs.

PHYM 602: Solid State Physics

- **CLO 1:** Characterize crystal structures using reciprocal lattice theory and interpret X-ray diffraction patterns (Bragg's Law).
- **CLO 2:** Analyze lattice dynamics, acoustic/optical phonons, and their contribution to the specific heat of solids (Einstein/Debye models).
- **CLO 3:** Evaluate the dielectric, ferroelectric, and magnetic (dia-, para-, ferromagnetic) properties of materials using classical and quantum mechanical models.
- **CLO 4:** Apply the Kronig-Penney band theory to classify conductors/semiconductors and explain the qualitative tenets of BCS superconductivity.

PHYM 603: Nuclear and Particle Physics

- **CLO 1:** Analyze the general properties of nuclei, binding energy curves, and model nuclear structure using the Liquid Drop and Shell models.
- **CLO 2:** Formulate the kinematics and transition probabilities of alpha, beta, and gamma radioactive decays.
- **CLO 3:** Calculate reaction cross-sections, Q-values, and model the interaction of nuclear radiation with matter (Compton scattering, pair production).
- **CLO 4:** Classify elementary particles using conservation laws, the quark model, and fundamental symmetries (parity, isospin, strangeness).

PHYM 604: Lab IV (Solid State and Modern Physics)

- **CLO 1:** Determine Planck's constant, the electron charge (Millikan oil drop), and e/m ratio using foundational modern physics apparatus.
- **CLO 2:** Analyze atomic spectra (Hydrogen, Iodine) and demonstrate quantum tunneling via tunnel diode I-V

characteristics.

- **CLO 3:** Measure the magnetic susceptibility, dielectric constants, and PE hysteresis loops of solid-state materials.
- **CLO 4:** Determine semiconductor properties including resistivity variations with temperature (four-probe), Hall coefficients, and band gaps.

Semester VII (Honours/Research Year)

PHYM 701: Mathematical Physics-III

- **CLO 1:** Analyze linear vector spaces, diagonalize complex matrices, and apply the Cayley-Hamilton theorem to operator mechanics.
- **CLO 2:** Construct solutions for inhomogeneous partial differential equations using Green's functions.
- **CLO 3:** Classify physical symmetries using discrete group representations, character tables, and continuous Lie groups ($SU(2)$, $SO(3)$).
- **CLO 4:** Formulate the geometric laws of physics using tensor calculus, covariant derivatives, and curvature tensors.

PHYM 702: Electronics-II

- **CLO 1:** Design timing circuits (IC 555) and sequential counters, and program 8085/8051 microprocessors using Assembly Language.
- **CLO 2:** Analyze feedback effects on amplifiers and evaluate sinusoidal oscillator circuits using the Barkhausen criterion.
- **CLO 3:** Design linear and non-linear computational circuits (integrators, differentiators, zero-crossing detectors) using Operational Amplifiers.
- **CLO 4:** Evaluate analog-to-digital conversion techniques and the physics of Field Effect Transistors (JFET, MOSFET) in switching applications.

PHYM 703: Classical Mechanics (Advanced)

- **CLO 1:** Apply variational principles to formulate Euler-Lagrange and Hamilton's equations for constrained systems.
- **CLO 2:** Analyze complex dynamical systems including precessing orbits, classical scattering cross-sections, and coupled normal modes.
- **CLO 3:** Evaluate phase space dynamics utilizing canonical transformations, Poisson brackets, and Hamilton-Jacobi theory.
- **CLO 4:** Formulate the dynamics of rotating rigid bodies (Euler angles) and assess deterministic chaos and non-linear stability in phase space.

PHYM 704: Research Methodology in Physics

- **CLO 1:** Execute Maximum Likelihood Estimation, Monte Carlo simulations, and Chi-square testing for rigorous uncertainty quantification.
- **CLO 2:** Deconstruct the operational physics of transducers, high-vacuum systems, and premier analytical instruments (XRD, SEM, FTIR).
- **CLO 3:** Analyze signal-to-noise ratios, transient responses, and numerical ODE solvers (Runge-Kutta).
- **CLO 4:** Produce professional scientific manuscripts using LaTeX and critically navigate the ethical frameworks of academic publishing and data FAIRness.

Semester VIII (Honours/Research Year)

PHYM 801: Quantum Mechanics-II

- **CLO 1:** Utilize Dirac bra-ket notation, projection operators, and Heisenberg/Interaction pictures to analyze abstract quantum states.
- **CLO 2:** Calculate angular momentum additions via Clebsch-Gordan coefficients and construct wavefunctions for identical particles (Pauli exclusion).

- **CLO 3:** Compute fine structure corrections and Stark/Zeeman energy shifts using time-independent perturbation theory and WKB approximations.
- **CLO 4:** Evaluate transition probabilities under time-dependent perturbations utilizing Fermi's Golden Rule and semi-classical radiation theory.

PHYM 802: Electromagnetic Theory

- **CLO 1:** Apply Maxwell's equations to formulate electromagnetic energy density, Poynting vectors, and radiation from accelerated charges.
- **CLO 2:** Describe the propagation of EM waves in unbounded media, conducting media, and dilute plasmas (ionosphere).
- **CLO 3:** Solve boundary value problems to derive reflection/transmission coefficients and Fresnel's formulae for bounded media.
- **CLO 4:** Analyze the polarization state of light in anisotropic media, double refraction, and EM wave propagation in optical waveguides.

PHYM 803: Plasma Physics

- **CLO 1:** Explain fundamental plasma parameters, Debye shielding, and the criteria defining the plasma state.
- **CLO 2:** Analyze the guiding center drifts and magnetic mirror confinement of charged particles in non-uniform electromagnetic fields.
- **CLO 3:** Apply fluid equations and Magnetohydrodynamics (MHD) to describe macroscopic plasma behavior and wave dispersion relations.
- **CLO 4:** Formulate the kinetic theory of plasmas using the Vlasov equation to evaluate collisionless Landau damping.

PHYM 804: Laboratory V

- **CLO 1:** Verify electromagnetic principles through experiments on microwave reflection, polarization (Malus' law), and ultrasonic wave diffraction.
- **CLO 2:** Construct and characterize advanced electronic circuits, including flip-flops, op-amp integrators, phase-shift oscillators, and ADC/DAC converters.
- **CLO 3:** Execute 8085 microprocessor programming for arithmetic and data handling tasks.
- **CLO 4:** (For Computational track) Numerically solve the radial Schrödinger equation and simulate molecular dynamics (Lennard-Jones gas) using Python.

7. PLO - CLO Mapping Matrix

The following matrix dictates the primary alignment between the Course Learning Outcomes (CLOs) of each core paper and the overarching Programme Learning Outcomes (PLOs). A checkmark (✓) indicates a strong, intentional pedagogical alignment where the course significantly drives the respective PLO.

Semester	**Course Code & Title**	**PLO 1(Core Physics)**	**PLO 2(QM & Stat)**	**PLO 3(Math Model)**	**PLO 4(Comp Sim)**	**PLO 5(Electronics)**	**PLO 6(Exp Data)**	**PLO 7(Adv Fields)**	**PLO 8(Research)**	**PLO 9(IKS/ Inter)**
I	**PHYM 101:** Physics I	✓		✓						✓
II	**PHYM**	✓				✓				

	201: Physics II									
III	**PHYM 301:** Math Physics I			✓						
III	**PHYM 302:** Lab I	✓					✓			
IV	**PHYM 401:** Wave & Optics	✓								
IV	**PHYM 402:** Thermal Physics	✓	✓							
IV	**PHYM 403:** Electronics I					✓				
IV	**PHYM 404:** Lab II	✓				✓	✓			
V	**PHYM 501:**			✓						

	Math Physics II									
V	**PHYM 502:** Quantum Mech I		✓							
V	**PHYM 503:** Classical Dynamics	✓		✓						
V	**PHYM 504:** Lab III (Comp)		✓	✓	✓		✓			
VI	**PHYM 601:** Statistical Mech		✓							
VI	**PHYM 602:** Solid State Physics		✓			✓				
VI	**PHYM 603:** Nucle							✓		

	ar & Particle									
VI	**PHYM 604:** Lab IV		✓			✓	✓	✓		
VII	**PHYM 701:** Math Physics III			✓				✓		
VII	**PHYM 702:** Electronics II					✓				
VII	**PHYM 703:** Classical Mech (Adv)	✓		✓						
VII	**PHYM 704:** Research Method				✓		✓		✓	✓
VIII	**PHYM 801:** Quantum Mech II		✓	✓						

VIII	**PHYM 802:** Electromagnetic	✓		✓				✓		
VIII	**PHYM 803:** Plasma Physics							✓		
VIII	**PHYM 804:** Lab V				✓	✓	✓	✓		

(Note: Minor courses, Multidisciplinary Courses, and Skill Enhancement Courses map extensively to PLO 9, ensuring interdisciplinary synthesis and holistic development across the FYUGP timeline.)

FYUG Program Structure
Department of Physics
Madhabdev University

Year	Semester	Course	Course Code and Title of the Course	Total Credits
Year 01	1st Semester	**C-1**	**PHYM 101:** Physics I	4
		Minor1	**PHYN 101:** Physics I (for disciplines other than Physics)	4
		MDC-1	Natural Science (Physics for All)	3
		AEC- 1	Life skills	4
		VAC-1	Yoga/ NSS/sports and Physical Education	2
		SEC-1	Lib & Info sources/Computer Operating system/Introduction to communication	3
	Total of Semester1			**20**
	2nd Semester	**C-2**	**PHYM 201:** Physics II	4
		Minor2	**PHYN 201:** Physics II (for disciplines other than Physics)	4
		MDC-2		3
		AEC- 2	MIL/ALT.E/Madhabdev Studies	4
		VAC-2	Basic Yoga/ NSS/ Rover & Ranger	2
		SEC-2	Library /Digital Literacy	3
	Total of Semester2			**20**
	Grand Total (Semester 1 and 2)			**40**
Students on exit shall be awarded Undergraduate Certificate (in the field of study/discipline) after securing the requisite 40 credits in Sem 1 and 2 provided they secure 4 credits in work based vocational courses offered during summer term or internship/ apprenticeship in addition to 6 credits from skill based courses earned during 1st and 2nd Semester.				
		C-3	**PHYM 301:** Mathematical Physics-I	4

Year 02	**3rd Semester**	**C-4**	**PHYM 302:** Lab-I	4
		Minor3	**PHYN 301:** Thermal Physics and Statistical Mechanics(for disciplines other than Physics)	4
		MDC-3		3
		VAC-3	Environmental Studies	3
		SEC-3	Cyber Security	4
	Total of Semester 3			**22**
	4th Semester	**C-5**	**PHYM 401:** Wave and Optics	4
		C-6	**PHYM 402:** Thermal Physics	4
		C-7	**PHYM 403:** Electronics-I	4
		C-8	**PHYM 404:** Lab-II	4
		Minor4	**PHYN 401:** Lab-I (for disciplines other than Physics)	4
			Internship	2
	Total of Semester 4			**22**
	Grand Total (Semester1 to4)			**84**
Students on exit shall be awarded Undergraduate Diploma (in the field of study/ discipline) after securing the requisite 84 credits on completion of Sem 4 provided they secure additional 4 credits in skill based vocational course offered during 1st year or 2nd year summer term				
	5th Semester	**C-9**	**PHYM 501:** Mathematical Physics-II	4
		C-10	**PHYM 502:** Quantum Mechanics-I	4
		C-11	**PHYM 503:** Classical Dynamics	4
		C-12	**PHYM 504:** Lab III	4
		Minor 5	**PHYN 501:** Wave and Optics	4
			Internship	2
	Total of Semester 5			**22**

Year 03	**6th Semester**	**C-13**	**PHYM 601:** Statistical Mechanics I	4
		C-14	**PHYM 602:** Solid State Physics-I	4
		C-15	**PHYM 603:** Nuclear and Particle Physics	4
		C-16	**PHYM 604:** Lab IV	4
		Minor-6	**PHYN 601:** Elements of Modern Physics	4
			Project / Seminar	2
	Total of Semester 6			**22**
	Grand Total (Semester1 to 6)			**128**
Students on exit shall be awarded Bachelor of (in the field of study/discipline) Honours (3years) after securing the requisite128 credits on completion of Semester 6				
Year4	**Semester 7**	**C-17**	**PHYM 701:** Mathematical Physics III	4
		C-18	**PHYM 702:** Electronics-II	4
		C-19	**PHYM 703:** Classical Mechanics	4
		C-20	**PHYM 704:** Research Methodology in Physics	4
		Research Project (RP-I)	**PHYM RP-I:** Research Project-I/Field Work	2
		Minor-7	**PHYN 701:** Electronics and Solid-State Physics	4
	Total of Semester 7			**22**
	Semester 8	**C-21**	**PHYM 801:** Quantum Mechanics II	4
		C-22	**PHYM 802:** Electromagnetic Theory	4
		C-23	**PHYM 803:** Plasma Physics	4
		C-24	**PHYM 804:** Laboratory V (for B.Sc. honours degree) / **Research project-III** (for B.Sc. with research degree)	4
		Research Project (RP II)	**PHYM RP-II:** Research Project-II	4

		Minor	**PHYN 801:** Laboratory-II	4
	Total of Semester 8			**24**
	Grand Total (Semester 1 to 8)			**174**

A 4 year Under Graduate Degree (Honours) in Major discipline will be awarded who completes 174 credits. 4 year Under Graduate Degree (Honours with Research) will be awarded to those who secure 75% marks and above in the first six Semesters and who wish to undertake research at Under Graduate level. Those students who progress in 4 years Under Graduate Degree (Honours) in Major discipline have to complete one major paper in lieu of a project.

Syllabus for FYUGP:
Semester: I
(Core-1)

Course Type: Core Course
Paper Name: Physics I
Paper code: PHYM 101
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives

To establish a strong foundation in classical mechanics, the macroscopic properties of matter, vector calculus, and to introduce both the historical roots of Indian Knowledge Systems (IKS) and the monumental contributions of Indian scientists to modern physics.

Course Outcomes (COs)

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

1. Apply Newton's laws, conservation principles, and Kepler's laws to solve two-body problems and analyze central force motions.
2. Evaluate the macroscopic properties of matter, including the dynamics of rigid rotating bodies, elasticity, surface tension, and fluid viscosity.
3. Utilize vector calculus, differential operators, and integral theorems to formulate and solve physics problems in multiple coordinate systems.
4. Describe the evolution of physical concepts through ancient Indian Knowledge Systems and recognize the foundational contributions of Indian physicists to modern quantum and astrophysics.

Course Content (End-Semester Marks: 70)

Unit I: Newtonian Mechanics, Gravitation, and Relativity (26 Lectures | 33 Marks)

Newtonian Mechanics: Concept of frame of references (Inertial and non-inertial). Review of Newton's laws of motion. Galilean Transformation and Galilean invariance. Two-body problem, reduction of two-body problem to one-body problem. Centre of mass, angular momentum and torque, angular momentum of a system of particles about their Centre-of mass, principle of conservation of angular momentum, Impulse.

Force, Work and Energy: Conservative and Non-conservative force, Work-Energy Theorem, Work done in conservative field, conservative force as potential gradient. Elastic and Inelastic collisions. Laboratory and Centre-of-mass reference frames.

Gravitation: Central force, Motion of a particle under central force field. Gravitational field and potential, calculation of gravitational field and potential due to spherical shell and solid sphere. Kepler's laws, satellites in a circular orbit and applications. Geosynchronous orbits, Weightlessness. Basic idea of Global Positioning System (GPS).

Special Theory of Relativity: Michelson-Morley experiment and its outcomes. Postulates of special theory of relativity, Lorentz Transformation, Length contraction, Time dilation, variation of mass with velocity, Mass-Energy Equivalence, Relativistic addition of velocities.

Unit II: Properties of Matter (14 Lectures | 16 Marks)

Rigid Body Dynamics: Equation of motion of rotating rigid bodies, moment of inertia, theorems of Moment of Inertia. Calculation of M.I of a circular lamina, a solid cylinder, a hollow sphere and a solid sphere. Kinetic Energy of Rotation, Motion involving both translation and rotation. Theory of compound pendulum and determination of ‘g’.

Elasticity: Hooke’s law, Stress-Strain diagram. Young modulus, Bulk modulus and Modulus of Rigidity, Poisson’s ratio, relation between elastic constants. Bending of beam, the cantilever. Work done in stretching and work done in twisting a wire. Twisting a couple on a cylinder.

Fluid Mechanics: Surface Tension and Surface Energy, angle of contact, rise of liquid in a capillary tube. Viscosity: Streamline flow, turbulent flow, equation of continuity, determination of coefficient of viscosity by Poiseuille’s method, Stoke’s method.

Unit III: Mathematical Physics (14 Lectures | 17 Marks)

Vector Calculus: Elements of vector calculus, Properties of vector under rotation, Scalar and Vector fields.

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

Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. 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).

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

Unit IV: Indian Knowledge Systems (IKS) and Contributions to Modern Physics (6 Lectures | 4 Marks)

Ancient Foundations: Maharishi Kanada’s *Vaisheshika Sutra*: concepts of *Anu* and *Paramanu* (atomism), and the categorization of motion (*Karma*). Relative motion in the *Aryabhatiya*. Early formulations of gravitation: Brahmagupta's concept of *Gurutvakarshana* and Bhaskaracharya's description of Earth's attractive force. Brief overview of the Kerala School (Madhava of Sangamagrama) and infinite series.

Contributions to Modern Physics: Foundational impact of Indian scientists in the 20th century: Satyendra Nath Bose (Bose-Einstein statistics and Bosons), C.V. Raman (Raman scattering/effect), Meghnad Saha (Thermal ionization equation in astrophysics), Homi J. Bhabha (Cosmic rays and Bhabha scattering), and Subrahmanyan Chandrasekhar (Chandrasekhar limit for white dwarfs).

Reference books:

- Mechanics D.S. Mathur, S. Chand & Co
- Elements of Properties of Matter, D.S.Mathur, S. Chand & Co
- Properties of Matter, Brijlal and Subramaniam.

- Mechanics (In SI Units): Berkeley Physics Course Vol 1 Charles Kittel, Walter Knight, et al Tata McGrawHill 2007
- Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons
- Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
- Mathematical Physics, Dass and Verma.S. Chand & Co

Expected learner outcome: This course will

1. Introduce the students to the basic concepts of mechanics.
2. Enable students to get a vast idea of conservation laws and its correlation with nature and symmetry.
3. Enable the students to understand different properties of matter with realization.
4. Develop analytical skills to solve vector algebra with application to physics.
5. Develop knowledge of special relativity to understand relativistic formulation of modern theories.

Semester: II

Core-2

Course Type: Core Course
Paper Title: Physics II
Paper code: PHYM 201
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: The course will enable the student to

1. To have a detailed knowledge about electric and magnetic fields.
2. To have an idea about formulation and application of dielectric properties of matter.
3. To acquire a clear understanding of magnetic properties of matter.
4. To understand the origin of the Maxwell equations.
5. Apply various network theorems such as Superposition, Thevenin, Norton, Reciprocity, Maximum Power Transfer, etc. and their applications in electronics, electrical circuit analysis, and electrical machines.

Unit-I: Electric Field and Electric Potential: (22 marks)

Electric field: Electric field lines. Electric flux.Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry.

Conservative nature of Electrostatic Field.Electrostatic Potential.Laplace's and Poisson equations.The Uniqueness Theorem.Potential and Electric Field of a dipole. Force and Torque on a dipole.

Electrostatic energy of system of charges.Electrostatic energy of a charged sphere.Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors.Parallel-plate capacitor.Capacitance of an isolated conductor.Method of Images and its application to (1) Plane Infinite Sheet and (2) Sphere. **(20 L)**

Unit-II: Dielectric Properties of Matter: (12 marks)

Electric Field in matter.Polarization, Polarization Charges.Electrical Susceptibility and DielectricConstant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vectorD. Relations between E,P and D. Gauss' Law in dielectrics. **(10 L)**

Unit-III: Magnetic Field and Magnetic Properties of Matter: (16 marks)

Magnetic force between current elements and definition of Magnetic Field B.Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and itsDipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to (1)Solenoid and (2) Toroid. Properties of **B:** curl and divergence. Vector Potential. Magnetic Force on(1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field. Magnetization vector **(M).** Magnetic Intensity**(H).** Magnetic Susceptibility and permeability.Relationbetween **B, H, M**. Ferromagnetism**.B-H** curve and hysteresis. **(15 L)**

Unit-IV: Electromagnetic Induction: (5 marks)

Faraday's Law.Lenz's Law.Self-Inductance and Mutual Inductance.Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction to Maxwell's Equations. Charge Conservation and Displacement current. **(5 L)**

Unit-V: Electrical Circuits: (15 marks)

AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit.

Network theorems:

Ideal Constant-voltage and Constant-current Sources.Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits. Ballistic Galvanometer: Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping. CDR. **(10 L)**

Recommended readings:

- Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012,Tata McGraw
- Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
- Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
- Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, 2008, Pearson Education
- Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.
- Electricity and Magnetism, J.H.Fewkes&J.Yarwood. Vol. I, 1991, Oxford Univ. Press

Expected learner outcome: This course will

1. Students will have a theoretical as well as practical knowledge about different electrical and magnetic properties of matter.
2. Develop the basic theoretical knowledge as well as experimental skills of the students on electrical networking.
3. Train the students to handle and repair instruments based on electric and magnetic field effects.

Semester III
Core-3

Course Type: Core Course
Paper Title: Mathematical Physics-I
Paper code: PHYM 301
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: The course will enable the student to

1. To understand the importance of differential equations in physical science.
2. To learn different methods to solve ordinary and partial differential equations.
3. To acquire a clear understanding of linear differential equations and solutions using special functions.
4. To understand the theory of errors and special integrals.

Unit I: Ordinary Differential Equations: (22 marks)

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.

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

(20 L)

Unit II: Partial Differential Equation: (12 marks)

Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical andspherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes. Diffusion Equation.

(10 L)

Unit III: Frobenius Method and Special Functions: (23 marks)

Singular Points of Second Order Linear Differential Equations and their importance.Frobenius method and its applications to differential equations.Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations.Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions (Jo(x) and J1(x)) and Orthogonality.

(20 L)

Unit IV: Some Special Integrals &Theory of Errors (13 marks)

Beta and Gamma Functions and Relation between them.Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).

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.

(10 L)

Recommended readings:

- Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.
- Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.
- Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
- Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
- Partial Differential Equations for Scientists & Engineers, S.J. Farlow, 1993, Dover Pub.
- Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
- Mathematical methods for Scientists & Engineers, D.A. McQuarrie, 2003, Viva Books

Expected learner outcome: The students will

1. gain complete analytical knowledge regarding differential equations.
2. develop the basic theoretical knowledge to solve any kind of differential equation applied in physical situations.
3. be trained to use special integrals and error functions.

Core-4

Course Type: Core Course
Paper Title: Laboratory-I
Paper code: PHYM 302
Credits: 4 (Laboratory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: The course will enable the student to

1. Explore various experimental methods to analyze mechanical phenomena and material properties.
2. Utilize instruments and methodologies to measure physical quantities and verify scientific principles.
3. Study the characteristics of various electrical circuits to understand their behavior under different conditions.
4. Utilize measurement techniques to compare and analyze different electrical quantities such as electromotive forces and capacitances
5. Investigate the frequency response of electrical circuits to analyze their impedance characteristics and performance at different frequencies.
6. Verify theoretical principles such as Thevenin's theorem, Norton's theorem, and other fundamental laws of electrical circuits to understand their practical implications.

Group-A (Mechanics and properties of Matter)

1. Determination of g using bar pendulum.
2. Determination of g using Keter's pendulum.
3. To study the Motion of Spring and calculate (a) Spring constant, (b) g and (c) Modulus of rigidity.
4. To determine the Moment of Inertia of a Flywheel
5. To determine g and velocity for a freely falling body using Digital Timing Technique
6. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
7. To determine the Young's Modulus of a Wire by Optical Lever Method.
8. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
9. To determine the elastic constants of a wire by Searle's method.
10. To determine the height of a building using a Sextant
11. To verify Jurin's law using the Traveling Microscope.
12. Determine the Young's Modulus of a bar by uniform bending method.

Group-B (Electricity and Magnetism)

1. To study the characteristics of a series RC Circuit.
2. To compare two EMFs using the potentiometer.

3. Frequency response of a series LCR circuit.
4. Frequency response of a parallel LCR circuit.
5. Measurement of field strength B and its variation in a solenoid (determine dB/dx)
6. To verify the Thevenin and Norton theorems.
7. To determine self-inductance of a coil by Anderson's bridge.
8. Determine a high resistance by leakage method using Ballistic Galvanometer (BG)
9. Determination of a Condenser using B.G
10. To determine an unknown Low Resistance using Carey Foster's Bridge.
11. To compare capacitances using De'Sauty's bridge.

Recommended Readings:

- Practical Physics. K.G Mazumdar & B.Ghosh, Shreedhar Publisher,Kolkata
- B.Sc Practical Physics C.L.Arora, S.Chand & Co.
- Practical Physics: Bhaskar Jyoti Hazarika, Ashoka Book Stall,Guwahati
- A textbook of Advanced Practical Physics Samir Kr Ghosh, Central Publisher

Expected Learner outcomes: The student will be skilled in

1. Explore experimental methods to determine g using different type of pendulums, the student shall perform experiments related to mechanics: Rotational dynamics (Flywheel), elastic properties (Young Modulus and Modulus of Rigidity) and fluid dynamics (Poiseulle's method, Searle method, Jurin's law) etc, investigate spring motion, and utilize instruments like a sextant and a traveling microscope to measure building height and smaller distances etc.
2. Build up confidence in handling different types of electric circuits like RC,LCR etc, using DC/AC power sources, frequency generator, perform experiments using Anderson's bridge, De'Sauti's bridge, Carey-Foster's bridge, BG etc and also hand on learning on Network Theorems of electricity.

Semester IV
Core 5

Course Type: Core Course
Paper Title: Wave and Optics
Paper code: PHYM 401
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: The course will enable the student to:
1. Aware themselves about different phenomena of waves and optics.
2. Apply basic knowledge of principles and theories about the behaviour of light and the physical environment to conduct experiments.
3. Explain several phenomena we can observe in everyday life that can be explained as wave phenomena.
4. Understand the principle of superposition of waves, so thus describe the formation of standing waves and also have an analytical knowledge about different types of wave motion.
5.To understand phenomena like interference, diffraction, polarization etc in both theoretical and practical aspects.
6. Understand the working of selected optical instruments like biprism, interferometer, diffraction grating, Lasers and holograms.

Unit I: Wave Motion: (marks 12)

Plane and Spherical Waves.Longitudinal and Transverse Waves.Plane Progressive (Travelling) 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. Velocity of Waves: Velocity of Transverse Vibrations of Stretched Strings. Velocity of Longitudinal Waves in a Fluid in a Pipe.Newton's Formula for Velocity of Sound.Laplace's Correction.**(10 L)**

Unit II: Superposition of Collinear Harmonic oscillations: (marks 17)

Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences.
Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequency and their use.
Superposition of Two Harmonic Waves:

Standing (Stationary) Waves in a String: Fixed and Free Ends.Analytical Treatment.Phase and Group Velocities.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. **(15 L)**

Unit III: Wave optics & Interference: (marks 16)

Electromagnetic nature of light, definition and properties of wave front.Huygens principle. Temporal and Spatial coherence.

Interference: Division of amplitude and wavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's 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.

Interferometer: Michelson Interferometer-(1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4)Refractive Index, and (5)Visibility of Fringes. Fabry Perot interferometer. **(15 L)**

Unit IV: Diffraction: (marks 25)

Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula. (Qualitative discussion only)

Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope.Double slit. Multiple slits. Diffraction grating.Resolving power of grating.

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. Fresnel's Integral, Fresnel diffraction pattern of a straight edge, a slit and a wire.

Laser & Holography: Lasing action, Einstein co-efficients, Population Inversion,spontaneous and stimulated emission, metastable states, examples of Lasers

Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves. Point source holograms. **(20 L)**

Recommended readings:

- Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
- Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill.
- Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
- Optics, AjoyGhatak, 2008, Tata McGraw Hill
- The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
- The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
- Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.

Expected Learner outcomes: The student will be able to

1. Develop an understanding of various aspects of harmonic oscillations and waves specially.
(i) Superposition of collinear and perpendicular harmonic oscillations
(ii) Various types of mechanical waves and their superposition.
2. This course in basics of optics will enable the student to understand various optical phenomena, principles, workings and applications of optical instruments.

Core 6

Paper Title: Thermal Physics

Course Type: Core Course
Paper Title: Thermal Physics
Paper code: PHYM 402
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: This course will enable a student to

1. Comprehend the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations.

2. Learn about Maxwell’s thermodynamic relations.
3. Learn the basic aspects of kinetic theory of gases, Maxwell-Boltzman distribution law, equitation of energies, mean free path of molecular collisions, viscosity, thermal conductivity, diffusion and Brownian motion.
4. Learn about the real gas equations, Van der Waal equation of state, the Joule Thomson effect.

Unit I:Zeroth and First Law of Thermodynamics: (**marks 10)**

Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Coefficient. **(8 L)**

Unit II:Second Law of Thermodynamics: (marks 12)

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, 2 nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot’s Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale. **(10 L)**

Unit III: Entropy: (marks 10)

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.Entropy Changes in Reversible and Irreversible Processes.Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot’s Cycle. Third Law of Thermodynamics.Unattainability of Absolute Zero. **(7 L)**

Unit IV:Thermodynamic Potentials: (marks 8)

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, ClausiusClapeyron Equation and Ehrenfest equations **(7 L)**

Unit V: Maxwell’s Thermodynamic Relations: (marks 8)

Derivations and applications of Maxwell’s Relations, Maxwell’s Relations:(1) ClausiusClapeyron equation, (2) Values of Cp-Cv, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process **(8 L)**

Unit VI: Kinetic Theory of Gases : (marks 12)

Distribution of Velocities: Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern’s Experiment.Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases.

Molecular Collisions: Mean Free Path. Collision Probability.Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance **(10 L)**

Unit VII: Real Gases: (marks 10)

Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants.Continuity of Liquid and Gaseous State.Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants.Law of Corresponding States.Comparison with Experimental Curves.P-V Diagrams.Joule's Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment.Joule- Thomson Effect for Real and Van der Waal Gases.Temperature of Inversion.Joule- Thomson Cooling. **(10 L)**

Recommended readings:

- Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
- A Treatise on Heat, MeghnadSaha, and B.N.Srivastava, 1958, Indian Press
- Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
- Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
- Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press
- Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.

Expected Learner outcomes: A student will be expected to gain some insights of basic thermal physics.

1. This basic course in thermodynamics will enable the student to understand various thermo dynamical concepts, principles.
2. Sound understanding of Kinetic theory of gases and transport phenomena based on this theory.
2. Basic understanding of how real gases behave after studying Andrew's and Joule-Thomson experiment etc.

Core 7

Course Type: Core Course
Paper Title: Electronics-I
Paper code: PHYM 403
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: At the completion of this course, a student will be able

1. Describe number systems and Boolean algebra.
2. Know about the basic laboratory equipment of electronics.
3. Understand basic digital electronics concepts and digital circuits.
4. Explain the properties of intrinsic and extrinsic semiconductors.
5. Know about the basics of semiconductor PN junction, its various types and its application to different electronic circuits.
6. Understand bipolar junction transistor and its applications as amplifiers.

Section A: Introduction to Digital Electronics
Unit I: Boolean algebra: (marks 8)

De Morgan's Theorems.Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products.Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map. **(7 L)**

Unit II: Data processing circuits: (marks 8)

Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders. Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders.Half & Full Subtractors, 4-bit binary Adder/Subtractor. **(7L)**

Unit III: Sequential Circuits (marks 8)

SR, D, and JK 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.Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits). **(8L)**

Section B: Introduction to Analog Electronics

Unit IV Semiconductor Diodes: (marks 12)

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity.PN Junction Fabrication (Simple Idea).Barrier Formation in PN Junction Diode.Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diodes. Drift Velocity. Derivation for Barrier Potential, Barrier Width and Current for Step Junction. Current Flow Mechanism in Forward and Reverse Biased Diodes. **(10L)**

Unit V:Two-terminal Devices and their Applications: (marks 6)

Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter Zener Diode and Voltage Regulation. Principle and structure of (1) LEDs, (2) Photodiode and (3) Solar Cell. **(6 L)**

Unit VI:Bipolar Junction transistors: (marks 16)

n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations.Current gains α and β Relations between α and β. Load Line analysis of Transistors.DC Load line and Q-point.Physical Mechanism of Current Flow.Active, Cutoff and Saturation Regions.Transistor Biasing and Stabilization Circuits.Fixed Bias and Voltage Divider Bias. **(14 L)**

Unit VII: Amplifiers: (marks 12)

Transistor as 2- port Network.h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains.Classification of Class A, B & C Amplifiers. **(10 L)**

Recommended readings:

- Digital Principles and Applications, A.P. Malvino, D.P.Leach and Saha, 7th Ed., 2011, Tata McGraw Hill.
- Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
- Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
- Digital Electronics G K Kharate ,2010, Oxford University Press
- Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
- Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
- Solid State Electronic Devices, B.G.Streetman&S.K.Banerjee, 6th Edn.,2009, PHI Learning
- Electronic Devices & circuits, S.Salivahanan&N.S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill

Expected Learner outcomes: This course will enable a student to

1. Identify and understand digital electronic principles and systems.
2. Apply the knowledge to analyze and apply digital circuits in solving circuit level problems.
3. Build real life applications using digital systems.
4. Learn the foundation knowledge of analog electronic systems.
5. Learn the working and applications of PN junction and bipolar junction transistors (BJT).

6. Learn to analyze circuits containing PN junction and BJT along with the application of BJT as amplifiers.

Core 8

Course Type: Core Course
Paper Title: Laboratory-II
Paper code: PHYM 404
Credits: 4 (Practical/Laboratory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: A student will be able to

1. Engage in experimental exploration of wave phenomena and optics.
2. Investigate various phenomena using hands-on experiments with different sources and setups.
3. Develop understanding of theoretical concepts and practical skills in analyzing optical properties and wave behavior.
4. Conduct experiments to explore heat transfer and thermal conductivity.
5. Gain practical insights into heat transfer mechanisms and material properties.
6. Explore electronic components and circuits through hands-on experiments and study their characteristics.
7. Study Bipolar Junction Transistors in different configurations and design amplifiers. Analyze frequency response of transistor amplifiers. Gain practical insights into electronic circuit design and behavior.

Group A: Wave and Optics

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2–T law.
2. To study Lissajous Figures.
3. To determine the refractive index of the Material of a prism using sodium source.
4. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
5. To determine wavelength of sodium light using Fresnel Biprism.
6. To determine wavelength of sodium light using Newton's Rings.
7. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
8. To determine dispersive power and resolving power of a plane diffraction grating.

Group B: Thermal Physics

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 Cu by Searle's Apparatus.
3. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.

Group C: Electronics-I

- To test a Diode and Transistor using a Multimeter.
- To design a switch (NOT gate) using a transistor.
- To verify and design AND, OR, NOT and XOR gates using NAND gates.
- To design a combinational logic system for a specified Truth Table.
- Half Adder, Full Adder and 4-bit binary Adder.
- Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C.
- To study V-I characteristics of PN junction diodes, and Light emitting diodes.
- To study the V-I characteristics of a Zener diode and its use as voltage regulator.
- Study of V-I & power curves of solar cells, and find maximum power point & efficiency.
- To study the characteristics of a Bipolar Junction Transistor in CE configuration.

- To study the various biasing configurations of BJT for normal class A operation.
- To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
- To study the frequency response of voltage gain of a RC-coupled transistor amplifier.

Recommended readings:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, KitabMahal
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani
- Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, McGraw Hill.
- Electronic Principle, Albert Malvino, 2008, Tata Mc-Graw Hill.
- Electronic Devices & circuit Theory, R.L. Boylestad& L.D. Nashelsky, 2009, Pearson
- Fundamentals of Digital Circuits — A. Anand Kumar, 4th Edn., PHI Learning

Expected Learner outcomes:

1. Experiment with wave phenomena and optics. Investigate using hands-on experiments with diverse sources and setups. Develop understanding of theoretical concepts and practical skills in optical analysis.
2. Explore heat transfer and conductivity through experiments. Determine heat equivalence and investigate thermal conductivity using various methods. Gain insights into material properties and heat transfer.
3. Conduct experiments to explore electronic components and circuits. Test diodes and transistors, design logic gates and amplifiers, and analyze characteristics such as voltage-current curves and frequency response. Gain practical insights into electronic circuit design.

Semester V
Core 9

Course Type: Core Course
Paper Title: Mathematical Physics-II
Paper code: PHYM 501
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: A student will be able

1. To have an introduction to the theories of functions of complex variables, analytic function, contour integration and its application.
2. To calculate Fourier series and transformation of a function
3. To have understanding regarding different kind of integral transforms
4. To have deep understanding of Laplace transformation and its real life application

Unit I: Complex Analysis: (26 marks)

Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy Riemann Conditions. Examples of analytic functions. 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. Simply and multiply connected region.Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals. **(24 L)**

Unit II: Fourier Series: (15 marks)

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.Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity. **(12 L)**

Unit III: Integrals Transforms: (14 marks)

Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train & other functions. The representation of Dirac delta functions as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations. **(12 L)**

Unit IV: Laplace Transforms: (15 marks)

Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2nd order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1st order. Solution of heat flow along infinite bar using Laplace transform.**(12 L)**

Recommended readings:

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Mathematics for Physicists, P. Dennery and A.Krzywicki, 1967, Dover Publications
- Complex Variables, A.S.Fokas&M.J.Ablowitz, 8th Ed., 2011, Cambridge Univ. Press
- Complex Variables, A.K. Kapoor, 2014, Cambridge Univ. Press

- Complex Variables and Applications, J.W. Brown & R.V. Churchill, 7th Ed. 2003, Tata McGraw-Hill
- First course in complex analysis with applications, D.G. Zill and P.D. Shanahan, 1940, Jones & Bartlett

Expected Learner outcomes: This course will enable a student to

1. Enable analytical skill to solve different complex integration
2. Acquire different techniques for solving integral transformations
3. Application of Fourier and Laplace transformation in Physics

Core 10

Course Type: Core Course
Paper Title: Quantum Mechanics-I
Paper code: PHYM 502
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives

To introduce the foundational origins of quantum theory, the formal postulates of wave mechanics, and the mathematical formulation of the Schrödinger equation applied to basic one-dimensional and three-dimensional physical systems.

Course Outcomes (COs)

Upon successful completion, students will be able to:

1. Explain the historical origins of quantum mechanics, wave-particle duality, and the fundamental postulates governing quantum states and observables.
2. Formulate and solve the time-independent Schrödinger equation for 1D potentials, including tunneling and the harmonic oscillator.
3. Analyze the transition from 1D to 3D systems, understanding degeneracy and the radial/angular solutions of the Hydrogen atom.
4. Interpret the concept of electron spin through the Stern-Gerlach experiment and describe the behavior of atoms in magnetic fields.

Course Content (End-Semester Marks: 70)

Unit I: Origins and Postulates of Quantum Mechanics (15 Lectures | 17 Marks)

Inadequacies of classical physics (blackbody radiation, photoelectric effect, Compton scattering). Wave-particle duality, de-Broglie hypothesis, phase and group velocity. The Heisenberg uncertainty principle and commutators. Ehrenfest's theorem and constants of motion (Heisenberg equation of motion), The formal Postulates of Quantum Mechanics: state vectors, observables, measurement, and time evolution. Wave-function in coordinate and momentum representations. Physical interpretation (Born rule) and normalization. Operators in quantum mechanics: linear, Hermitian, and Parity operators.

Unit II: One-Dimensional Eigenvalue Problems (15 Lectures | 17 Marks)

The Schrödinger equation (time-dependent and time-independent). Probability current density. Bound states: Particle in a 1D infinitely deep box and the finite potential well. Unbound states: Step potential and Tunneling through a rectangular barrier (transmission and reflection coefficients). The Linear Harmonic Oscillator (solved via the differential/power series method); zero-point energy, Hermite polynomials, and parity of oscillator states.

Unit III: Three-Dimensional Systems and the Hydrogen Atom (15 Lectures | 18 Marks)

Extension to three dimensions: Particle in a 3D box and the mathematical emergence of degeneracy. Motion in a central potential: separation of variables into radial and angular parts. Orbital angular momentum and spherical harmonics (qualitative discussion). The Hydrogen atom: derivation of radial wavefunctions, principal, orbital, and magnetic quantum numbers. Energy eigenvalues and shapes of probability densities for s and p orbitals.

Unit IV: Spin and Magnetic Interactions (15 Lectures | 18 Marks)

The discovery of electron spin: The Stern-Gerlach experiment and spatial quantization. Spin angular momentum and magnetic dipole moments. Gyromagnetic ratio and the Bohr magneton. Larmor precession. Introduction to atomic spectra: Qualitative discussion of spin-orbit coupling. Behavior of atoms in external magnetic fields: Normal and anomalous Zeeman effect (qualitative framework).

Suggested Readings:

1. Introduction to Quantum Mechanics, D. J. Griffith, Pearson Education.
2. Concepts of Modern Physics, A. Beiser, Tata McGraw-Hill.
3. A Text book of Quantum Mechanics, P. M. Mathews and K. Venkatesan, McGraw Hill.
4. Quantum Mechanics, R. Eisberg and R. Resnick, Wiley.
5. Quantum Mechanics, L. I. Schiff, Tata McGraw Hill.
6. Quantum Mechanics, G. Aruldhas, 2nd Edition, PHI Learning of India.
7. Quantum Mechanics, B. C. Reed, Jones and Bartlett Learning.
8. Quantum Mechanics: Foundations & Applications, A. Bohm, Springer.
9. Quantum Mechanics for Scientists & Engineers, D. A. B. Miller, Cambridge University Press.
10. Quantum Mechanics, E. Merzbacher, John Wiley and Sons.

Core 11

Course Type: Core Course
Paper Title: Classical Dynamics
Paper code: PHYM 503
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: At the completion of this course, a student will be able

1. To understand the mechanics of point particles with revision of Newtonian mechanics.
2. To understand Lagrangian and Hamiltonian formulation.
3. To know about small oscillations.
4. To appreciate the special theory of relativity and its importance.
5. Study on Fluid dynamics.

Unit I: Classical Mechanics of Point Particles: (24 marks)

Review of Newtonian Mechanics; Application to the motion of a charge particle in external electric and magnetic fields- motion in uniform electric field, magnetic field- gyroradius and gyrofrequency, motion in crossed electric and magnetic fields. Generalized coordinates and velocities, virtual work, D'Alembert's principle, Hamilton's principle, Lagrangian and the Euler-Lagrange equations, one-dimensional examples of the Euler-Lagrange equations- one-dimensional Simple Harmonic Oscillations and falling body in uniform gravity; applications to simple systems such as coupled oscillators Canonical momenta & Hamiltonian. Hamilton's equations of motion.

Applications: Hamiltonian for a harmonic oscillator, solution of Hamilton's equation for Simple Harmonic Oscillations; particle in a central force field- conservation of angular momentum and energy.

(20 L)

Unit II: Small Amplitude Oscillations: (12 marks)

Minima of potential energy and points of stable equilibrium, expansion of the potential energy around a minimum, small amplitude oscillations about the minimum, normal modes of oscillations example of N identical masses connected in a linear fashion to (N -1) - identical springs. **(10 L)**

Unit III: Special Relativity and Relativistic Electrodynamics: (24 marks)

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. Four-vectors: space-like, time-like and light-like. Four-velocity and acceleration. Metric and alternating tensors.Four-momentum and energy-momentum relation. Doppler effect from a four vector perspective. Concept of four-force. Conservation of four-momentum. Relativistic kinematics. Application to two-body decay of an unstable particle.

Magnetism as relativistic phenomena, Potential formulation of relativistic electrodynamics Electromagnetic field tensor, Dual tensor, Covariant formulation of electrodynamics. **(20 L)**

Unit IV: Fluid Dynamics: (10 marks)

Density and pressure in a fluid, an element of fluid and its velocity, continuity equation and mass conservation, stream-lined motion, laminar flow, Poiseuille's equation for flow of a liquid through a pipe, Navier-Stokes equation, qualitative description of turbulence, Reynolds number. **(10 L)**

Recommended readings:

- Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rd Edn. 2002,Pearson Education.
- Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
- Classical Electrodynamics, J.D. Jackson, 3rd Edn., 1998, Wiley.
- The Classical Theory of Fields, L.D Landau, E.M Lifshitz, 4th Edn., 2003, Elsevier.
- Introduction to Electrodynamics, D.J. Griffiths, 2012, Pearson Education.
- Classical Mechanics, P.S. Joag, N.C. Rana, 1st Edn., McGraw Hall.
- Classical Mechanics, R. Douglas Gregory, 2015, Cambridge University Press.
- Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.
- Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press

Expected Learner outcomes: This course will enable a student to

1. Have a theoretical understanding of the basics of classical mechanics.
2. Know about Lagrangian and Hamiltonian dynamics of a system.
3. Detailed knowledge about special theory of relativity and relativistic electrodynamics.

Core 12

Paper Name: Lab-III

Paper Code PHYM 504 **Credit: 4**

Lab: Computational Physics

Course Objectives: At the completion of this course, a student will be able

- Get an insight to computer hardware and computer applications.
- Learn programming language from basic level such as C/Python
- Familiarize with use of computers to solve Physics problems.
- Familiarize with numerical computation software such as SCILAB/ MATLAB to solve complex problems related to Physics.
- Perform error and uncertainty analysis appropriate to experimental lab work, applied to real physics data
- Reproduce key results of statistical mechanics computationally through distribution plotting and thermodynamic calculations

This course will consist of lectures (both theory and practical) in the Lab. Evaluation is to be done not on the programming but on the basis of formulating the problems.

Unit I: Python Programming

Environment setup: Anaconda distribution, Jupyter Notebook, Google Colab; Core Python: Data types, • Arithmetic, relational, and logical operators; operator precedence, Control flow: if-elif-else; while and for loops; break, continue, pass, Functions: defining and calling; default arguments; returning multiple values; lambda, Lists and tuples: creation, indexing, slicing, append, pop; dicts and sets, File I/O: reading and writing plain-text and CSV files using open() and the csv module. NumPy, Matplotlib.

Practical exercises

- Plot sin(x), cos(x), and their sum on one figure with labels
- Read a CSV of measured values; compute mean and SD; plot histogram
- Solve a 3×3 resistor-network equation using numpy.linalg.solve and verify by hand

Unit II: Error Analysis

Error analysis concepts

Significant figures and rounding in experimental reporting, Types of errors: gross, systematic, random — with real lab examples, Mean, deviation from mean, average deviation, standard deviation, variance, Standard error of the mean; when to report SD vs SE, Propagation of uncertainties: addition/subtraction; multiplication/division; general formula, The Gaussian (Normal) distribution: shape, 68-95-99.7 rule, physical reason for its appearance, Chi-square (χ^2) statistic: definition, reduced χ^2, goodness-of-fit interpretation, Linear least-squares regression: slope, intercept, and their uncertainties — numpy.polyfit and scipy.optimize.curve_fit, Non-linear curve fitting: fitting exponential decay and power-law models, Residual plots: diagnosing systematic error vs random scatter

Physics-based problems

- Radioactive decay counting data: fit $N(t) = N_0 \exp(-\lambda t)$; extract half-life with uncertainty
- Pendulum: measure T vs L; fit $T = 2\pi\sqrt{(L/g)}$; extract g with propagated uncertainty; compare with accepted value
- Ohm's law: V-I data for a resistor; linear fit; extract R with uncertainty; identify non-ohmic behaviour
- Specific heat measurement: cooling curve fit; extract heat capacity and its uncertainty
- Hydrogen spectrum: Balmer series wavelengths; fit to $1/\lambda = R(1/4 - 1/n^2)$; extract Rydberg constant

Unit III: Root Finding, Linear Algebra & Solving Physical Systems

Root finding: Bisection method, Newton-Raphson method, Secant method

Applications of root finding

- Energy levels of a finite square well: transcendental equation; locate roots graphically then refine numerically
- Kepler's equation $M = E - e \sin E$: solve for eccentric anomaly E given mean anomaly M and eccentricity e
- Critical angle in total internal reflection; resonance frequency of an LCR circuit

Linear systems — conceptual background: What it means to solve Ax = b; geometric interpretation,

- numpy.linalg.solve for small systems: Kirchhoff's voltage and current laws
- numpy.linalg.inv and det: when to use and when to avoid inverse (efficiency)
- numpy.linalg.eig: eigenvalues and eigenvectors; physical meaning as normal modes

Physics applications of linear algebra

- Kirchhoff's laws: set up and solve a multi-loop circuit network as a matrix equation
- Coupled oscillators: mass-spring chain; write equation of motion matrix; find eigenfrequencies and normal modes
- Least-squares fitting recast as a linear system: connection to Unit II curve fitting
- Rotation of axes, principal moments of inertia: diagonalise the inertia tensor (2D case)

Unit IV: Statistical Mechanics - Distributions & Thermodynamic Quantitites

Classical and quantum distribution functions

- Maxwell-Boltzmann distribution: derivation of occupancy formula; plot f(E) vs E at several temperatures
- Fermi-Dirac distribution: Fermi energy, temperature dependence; plot and compare with MB at high and low T
- Bose-Einstein distribution: chemical potential, condensation threshold; plot and compare
- High-T and low-T limiting behaviour; crossover between quantum and classical statistics

Partition function and thermodynamic quantities

- Partition function $Z(\beta)$ for discrete energy levels: 2-level and 3-level systems
- MB, FD, BE statistics applied to same system: plot and compare occupation numbers
- Average energy $\langle E\rangle = -\partial(\ln Z)/\partial\beta$; energy fluctuation ΔE; specific heat $C_v = \partial\langle E\rangle/\partial T$
- Plot $\langle E\rangle$, ΔE, and C_v vs T for each statistic; identify physical regimes

Blackbody radiation

- Planck's radiation law: derive occupancy using BE statistics; plot $B(\nu,T)$ at several T
- Overlay Rayleigh-Jeans law: demonstrate ultraviolet catastrophe at high frequency
- Wien's displacement law: locate peak numerically using root finding from Unit III
- Stefan-Boltzmann law: verify by numerically integrating Planck spectrum (preview of Unit, 8th sem)

Specific heat of solids

- Dulong-Petit law: classical equipartition; $C_v = 3Nk_B$; plot as horizontal line
- Einstein model: quantised oscillators; Einstein function; low-T exponential drop-off
- Debye model: phonon density of states; Debye integral; T^3 law at low T
- Plot all three models on same axes; high-T convergence; low-T comparison with experiment

Recommended readings:

- Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
- Numerical Recipes in C: The Art of Scientific Computing, W.H. Pressetal., 3rd Edn., 2007, Cambridge University Press.
- Numerical methods: E. Balaguruswamy, Std. Edition, 2017, McGraw Hill
- An introduction to computational Physics, T.Pang, 2nd Edn.,2006, Cambridge Univ. Press
- Introduction to Modern Statistical Mechanics, D. Chandler, Oxford University Press, 1987
- Numerical Recipes in Python — W. H. Press et al., Cambridge University Press
- An Introduction to Computational Physics — T. Pang, 2nd Edn., Cambridge University Press, 2006
- Computational Physics — M. Newman, CreateSpace, 2013
- Python for Scientists — J. M. Stewart, Cambridge University Press
- Elementary Numerical Analysis — K. E. Atkinson, 3rd Edn., Wiley India, 2007

Expected Learning Outcomes: This course will enable a student to

1. Use computer programme for solving Physics problems.
2. Prepare algorithms and flowcharts for Physics problem solving.
3. Learn computer coding to solve differential equations for physics problem solving.

Semester VI

Core 13

Course Type: Core Course
Paper Title: Statistical Mechanics
Paper code: PHYM 601
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: At the completion of this course, a student will be able

1. To understand different terms used in classical statistics with proper relation with thermodynamics.
2. To know about the theory of classical and quantum description of radiation.
3. To analyze different classical and quantum statistics.

Unit I: Classical Statistics: (20 marks)

Macrostate& Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations, Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature. **(18 L)**

Unit II: Classical Theory of Radiation: (11 marks)

Properties of Thermal Radiation.Blackbody Radiation.Pure temperature dependence.Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure.Wien's Displacement law. Wien's Distribution Law. Saha's Ionization Formula. Rayleigh-Jean's Law.Ultraviolet Catastrophe.**(9 L)**

Unit III: Quantum Theory of Radiation: (7 marks)

Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.**(5 L)**

Unit IV: Bose-Einstein Statistics: (15 marks)

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 and Thermodynamic functions of photon gas. Bose derivation of Planck's law. **(13 L)**

Unit V: Fermi-Dirac Statistics: (17 marks)

Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit. **(15 L)**

Recommended readings:

- Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
- Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
- Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall
- Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
- An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford

Univ. Press

Expected Learning Outcomes: This course will enable a student to

1. Have an idea about classical statistics and its applications.
2. Get a clear understanding of classical and quantum radiation.
3. Analyze quantum statistics and its applications in different fields.

Core 14

Course Type: Core Course
Paper Title: Solid State Physics
Paper code: PHYM 602
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: At the completion of this course, a student will be able

1. To understand different crystal structure and basic lattice dynamics.
2. To have an idea about magnetic properties of matter.
3. To know about dielectric and ferroelectric properties of matter.
4. Understanding of band theory to distinguish among conductors, semiconductors and insulators.
5. To have a clear concept of superconductivity.

Unit I: Crystal Structure: (14 marks)

Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis – Central and Non-Central Elements.Unit Cell.Miller Indices.Reciprocal Lattice.Types of Lattices.Brillouin Zones.Diffraction of X-rays by Crystals.Bragg's Law.Atomic and Geometrical Factor. **(12 L)**

Unit II: Elementary Lattice Dynamics: (12 marks)

Lattice Vibrations and Phonons: Linear Monoatomic 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 **(10 L)**

Unit III: Magnetic Properties of Matter: (10 marks)

Dia-, Para-, Ferri- and Ferromagnetic Materials.Classical Langevin Theory of dia– and Paramagnetic Domains.Quantum Mechanical Treatment of Paramagnetism.Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains.Discussion of B-H Curve.Hysteresis and Energy Loss. **(8 L)**

Unit IV: Dielectric Properties of Materials: (12 marks)

Polarization.Local Electric Field at an Atom. Depolarization Field.Electric Susceptibility.Polarizability.ClausiusMosotti Equation.Classical Theory of Electric Polarizability.Normal and Anomalous Dispersion.Cauchy and Sellmeir relations.Langevin-Debye equation.Complex Dielectric Constant.Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, TO modes. **(8 L)**

Unit V: Ferroelectric Properties of Materials: (6 marks)

Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop. **(6 L)**

Unit VI: Elementary band theory: (10 marks)

Kronig Penny model.Band Gap.Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (four probe method) & Hall coefficient. **(10 L)**

Unit VII: Superconductivity: (6 marks)

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth.Isotope effect. Idea of BCS theory (No derivation) **(6 L)**

Recommended readings:

- Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
- Elements of Solid State Physics, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
- Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
- Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning
- Solid-state Physics, H. Ibach and H. Luth, 2009, Springer
- Solid State Physics, Rita John, 2014, McGraw Hill
- Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
- Solid State Physics, M.A. Wahab, 2011, Narosa Publications

Expected Learning Outcomes: This course will enable a student to

1. Equip a student with basic concepts of solid state physics so that the knowledge can be applied for further development of the subject.
2. Get an overview of different crystal structures and the dynamics of crystal lattice
3. Get an idea of magnetic and dielectric properties of solids
4. Get basic knowledge on the band theory of solid and superconductivity in metals and alloys

Core 15

Course Type: Core Course
Paper Title: Nuclear and Particle Physics
Paper code: PHYM 603
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: At the completion of this course, a student will be able

1. Get basic concepts of Nuclear Physics.
2. Understand the radioactive decay and nuclear reactions.
3. Get the idea and working principles of nuclear detectors
4. Emphasize on the existing connections with other domains of Physics, in particular Quantum, mathematical and particle physics

Unit I: General Properties of Nuclei: (12 marks)

Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity.**(10 L)**

Unit II: Nuclear Models: (12 marks)

Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of nuclear force. **(10 L)**

Unit III: Radioactivity decay: (12 marks)

(a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics. **(10 L)**

Unit IV: **Nuclear Reactions and Interaction of Nuclear Radiation with matter: (12 marks)**

Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross Section. Energy loss due to ionization (Bethe-Block formula), Cerenkov radiation. photoelectric effect, Compton scattering. Gama ray interaction with matter, pair production **(10 L)**

Unit V:Nuclear Radiations detector and particle accelerator: (12 marks)

Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT).Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons. **(10 L)**

Unit VI: Particle Physics: (10 marks)

Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons. **(10 L)**

Recommended readings:

- Introductory nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
- Concepts of nuclear Physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
- Introduction to the Physics of nuclei & particles, R.A. Dunlap. (Thomson Asia, 2004).
- Introduction to High Energy Physics, D.H. Perkins, Cambridge Univ. Press
- Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
- Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
- Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde (IOPInstitute of Physics Publishing, 2004).
- Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
- Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (Academic Press, Elsevier, 2007).
- Theoretical Nuclear Physics, J.M. Blatt &V.F.Weisskopf (Dover Pub.Inc., 1991)

Expected Learning Outcomes: This course will enable a student to

1. Acquire knowledge of elementary and nuclear particles, as well as the characteristics and events that surround them.
2. Implement the same understanding to solve nuclear and particle physics problems.

Core 16

Paper Name: Lab IV

Paper Code PHYM 604 **Credit: 4**

Course Objectives: At the completion of this course, a student will be able

1. Gain a comprehensive understanding of fundamental concepts in modern physics, through hands-on experimentation and theoretical analysis.
2. Gain expertise in experimental techniques to investigate diverse phenomena in modern physics, enabling the application of these skills to advance scientific understanding and address real-world challenges.
3. Gain a deep understanding of condensed matter physics principles through hands-on experiments.
4. Develop expertise in experimental techniques for characterizing material properties, advancing knowledge and technological applications in materials science.

Group A: Modern Physics

1. Measurement of Planck's constant using black body radiation and photo-detector
2. Photo-electric effect: photo current versus intensity and wavelength 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 absorption lines in the rotational spectrum of Iodine vapour.
8. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
9. To setup the Millikan oil drop apparatus and determine the charge of an electron.
10. To show the tunneling effect in tunnel diode using I-V characteristics.
11. To determine the wavelength of laser source using diffraction of single slit.
12. To determine the wavelength of laser source using diffraction of double slits.
13. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating.

Group B: Solid State Physics

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 determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)
6. To determine the refractive index of a dielectric layer using SPR
7. To study the PE Hysteresis loop of a Ferroelectric Crystal.
8. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
9. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 ^{o}C) and to determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.
11. To determine the band gap of semiconductor by P-N junction method.

Recommended readings:

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

Expected Learning Outcomes: This course will enable a student to

1. Proficiency in applying fundamental principles of modern physics to experimental investigations.

2. Competence in utilizing a variety of experimental techniques and instrumentation for data acquisition and analysis.
3. Ability to interpret experimental results critically and draw meaningful conclusions based on theoretical frameworks.
4. Effective communication of experimental findings through written reports and oral presentations, demonstrating understanding and relevance to real-world applications.

Semester VII
Core 17

Course Type: Core Course
Paper Title: Mathematical Physics - III
Paper code: PHYM 701
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60 (39 Lectures + 21 Tutorials)

Course Objectives
To equip students with the advanced mathematical foundations required for postgraduate theoretical physics, focusing on abstract linear vector spaces, boundary value problems, symmetry through group theory, and the differential geometry of tensors.

Course Outcomes (COs) & Bloom's Taxonomy Mapping
Upon successful completion of this course, students will be able to:

1. Analyze linear vector spaces, diagonalize complex matrices, and apply the Cayley-Hamilton theorem to operator mechanics.
2. Construct solutions for inhomogeneous partial differential equations using Green's functions and evaluate linear integral equations.
3. Classify physical symmetries using discrete group representations, character tables, and continuous Lie groups ($SU(2)$, $SO(3)$).
4. Formulate the geometric laws of physics using tensor calculus, covariant derivatives, and curvature tensors.

Course Content (End-Semester Marks: 70)

Unit I: Linear Vector Spaces and Matrices (22 Hours: 14L + 8T | 25 Marks)
Linear vector spaces: definition and examples, linear independence, basis and dimension, inner product, norm of a vector, orthonormal basis, Gram-Schmidt orthogonalization method, Schwarz's and Bessel's inequalities. Linear operators, matrix representation of linear operators. Special types of matrices: symmetric and antisymmetric, orthogonal, Hermitian and anti-Hermitian, unitary, normal. Eigenvalues and eigenvectors. Change of basis, similarity transformation, orthogonal and unitary transformations, diagonalization of matrices. **Cayley-Hamilton Theorem and its applications**. Infinite-dimensional vector spaces, Hilbert space.

Unit II: Partial Differential Equations and Integral Equations (14 Hours: 9L + 5T | 17 Marks)
Partial differential equations: method of separation of variables in Cartesian, spherical, and cylindrical coordinate systems. Laplace’s equation, Poisson’s equation, diffusion equation. Examples of boundary value problems in physics. Inhomogeneous differential equations and Green’s functions. Introduction to integral equations: linear integral equations of the first and second kind (Fredholm and Volterra equations).

Unit III: Group Theory (12 Hours: 8L + 4T | 14 Marks)
Groups: definition and examples. Groups of symmetry transformation: cyclic group, dihedral group, permutation group. Subgroups, Lagrange’s theorem, cosets, conjugacy classes. Group representation: reducible and irreducible representations, Schur’s lemmas, and character tables. Continuous or Lie groups, generators of continuous groups. Special orthogonal groups: $SO(2)$, $SO(3)$. Unitary groups: $U(1)$, $SU(2)$.

Unit IV: Tensor Analysis (12 Hours: 8L + 4T | 14 Marks)
Basics of tensor algebra, contravariant and covariant tensors. Line element and metric tensor, associated tensors. Christoffel's symbols, geodesics, covariant derivatives. Riemannian Christoffel's tensor (curvature tensor), Bianchi identities. The Ricci tensor, Ricci scalar, and the Einstein tensor. Parallel transport.

Suggested Readings

1. **George B. Arfken and Hans J. Weber**, *Mathematical Methods for Physicists* (Academic Press).
2. **A.W. Joshi**, *Matrices and Tensors in Physics* (New Age International).
3. **A.W. Joshi**, *Elements of Group Theory for Physicists* (New Age International).
4. **Mary L. Boas**, *Mathematical Methods in the Physical Sciences* (Wiley).
5. A.K. Ghatak, I.C. Goyal, and S.J. Chua, *Mathematical Physics: Differential Equations and Transform Theory* (Macmillan).

Core 18

Course Type: Core Course
Paper Title: Electronics-II
Paper code: PHYM 702
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives

This course equips students with the analog and digital electronics foundations required for experimental and instrumentation physics, focusing on sequential and timing circuits, microprocessor/microcontroller architecture and programming, feedback and oscillator theory in analog amplifiers, operational amplifier design, and analog-to-digital conversion techniques.

Course Outcomes (COs) & Bloom's Taxonomy Mapping

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

- **CO1 [Understand & Apply]:** Design timing/counting circuits and explain 8085/8051 architecture and programming.
- **CO2 [Analyze & Evaluate]:** Analyze feedback effects on amplifiers and evaluate oscillator circuits using the Barkhausen criterion.
- **CO3 [Understand & Apply]:** Explain op-amp characteristics and apply them to design linear and non-linear op-amp circuits.
- **CO4 [Apply & Create]:** Design D/A and A/D converters and apply FET devices in amplification and switching.

Course Content (End-Semester Marks: 70)

<u>**Section A: Digital Electronics**</u>
Unit I: Sequential Circuits (10 marks| 8L)
Flipflops and its types, IC 555: block diagram and applications: Astable multivibrator and Monostable multivibrator. Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counter.
Unit II:Computer Architecture, Microprocessors, and Microcontrollers (18 marks|16L)

Data storage (idea of RAM and ROM).Computer memory.Memory organization & addressing. Memory Interfacing. Memory Map.

Main features of 8085. Block diagram. Components. Pin-out diagram. Buses.Registers.ALU.Memory. Stack memory. Timing & Control circuitry.Timing states.Instruction cycle, Timing diagram of MOV and MVI.Introduction to Assembly Language: 1 byte, 2 byte & 3 byte instruction

Introduction to 8051 microcontroller and embedded systems, instruction set, addressing mode, programming, time delay generation, look up table implementation etc.

Section B: Analog Electronics

Unit III: Feedback in Amplifiers: (8 marks|7L)

Effect of positive and negative feedback on Input impedence, Output impedence, Gain , Stability, Distortion and noise. . Two stage RC coupled Amplifier and its frequency response.

Unit IV: Sinusoidal Oscillators: (7 marks|7 L)

Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley &Colpitts oscillators.

Unit V: Operational Amplifiers: (13 marks|10L)

Characteristics of an Ideal and Practical Op-Amp. (IC 741) Open-loop and Closed-loop Gain .Frequency Response. CMRR. Slew Rate and concept of Virtual ground.

Applications of Op-Amps:

(1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator,

(6) Log amplifier, (7) Zero crossing detector (8) Wein bridge oscillator.

Unit VI: Conversion: (3 marks|3 L)

Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution. A/D Conversion (successive approximation)

Unit VII: Integrated Circuits: **(3 marks|3L)**

Active & Passive components. Discrete components. Wafer.Chip.Advantages and drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification of ICs.Examples of Linear and Digital ICs.

Unit VIII: Modern Semiconductor Devices : (8 marks|6L)

JFET, and MOSFET, structure, working, derivation of the equations of IV characteristics under different conditions, D- MOSFET, E- MOSFET, Digital switching, active load, introduction to CMOS, MESFET and FINFET technology. Silicon Controlled Rectifier (SCR): structure, working principle, V–I characteristics and applications.

Recommended readings:

- Digital Principles and Applications, A.P. Malvino, D.P.Leach and Saha, 7th Ed., 2011, Tata McGraw Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
- Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
- Digital Electronics G K Kharate ,2010, Oxford University Press
- Digital Systems: Principles & Applications, R.J.Tocci, N.S.Widmer, 2001, PHI Learning
- Logic circuit design, Shimon P. Vingron, 2012, Springer.
- Digital Electronics, SubrataGhoshal, 2012, Cengage Learning.
- Digital Electronics, S.K. Mandal, 2010, 1st edition, McGraw Hill
- Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
- OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
- Electronic circuits: Handbook of design & applications, U.Tietze, C.Schenk,2008, Springer
- Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.

Expected Learning Outcomes: This course will enable a student to

- Learn to analyze circuits containing BJT along with the application of BJT oscillators.
- Develop basic knowledge of operational amplifier and its applications.
- Study timer and counter circuits
- Design and study analog to digital conversion techniques
- Develop basic codes for 8085 microprocessor.

Core-19

Course Type: Core Course
Paper Title: Classical Mechanics
Paper code: PHYM 703
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives
To provide students with a rigorous foundation in the advanced analytical formulations of classical mechanics, bridging the gap between Newtonian mechanics, continuous field theories, and modern non-linear dynamics/chaos.
Course Outcomes (COs) & Bloom's Taxonomy Mapping
Upon successful completion of this course, students will be able to:

- **CO1 [Understand & Apply]:** Apply variational calculus to formulate Lagrangian and Hamiltonian equations, and utilize Noether's theorem to link symmetries with conserved quantities.
- **CO2 [Apply & Analyze]:** Analyze complex dynamical systems, including classical scattering, precessing orbits in central fields, and coupled small oscillations.
- **CO3 [Analyze & Evaluate]:** Evaluate phase space dynamics using canonical transformations, Poisson brackets, and the Hamilton-Jacobi formalism.
- **CO4 [Evaluate & Create]:** Assess the stability of non-linear systems, interpret chaotic behavior, phase space attractors, and formulate the mechanics of continuous classical fields.

Course Content (End-Semester Marks: 70)
Unit I: Analytical Foundations and Symmetries (12 Lectures | 14 Marks)
Lagrangian Formulation: Generalized coordinates, constraints, D'Alembert's principle. Variational calculus, Action, and Hamilton's principle. Euler-Lagrange equations.
Hamiltonian Formulation: Legendre transformations, Hamilton's equations. Phase space trajectories. Liouville's theorem. Scaling laws and potential reconstruction.
Symmetries: Cyclic coordinates, conservation theorems. Continuous symmetries and an introduction to Noether's theorem for discrete particles.

Unit II: Central Force, Scattering, and Coupled Oscillations (12 Lectures | 14 Marks)
Central Force & Scattering: The Kepler problem, hidden symmetry (Runge-Lenz vector), perturbations, and precessing orbits. The classical scattering problem, differential cross-sections, and impact parameters.
Small Oscillations: Systems with many degrees of freedom. Expansion of kinetic and potential energies (non-diagonal terms). Eigenvalue equations, normal modes, and normal coordinates.

Unit III: Canonical Transformations and H-J Theory (12 Lectures | 14 Marks)
Canonical Framework: Canonical variables and Poisson brackets. Fundamental properties and equations of motion in Poisson bracket form.
Transformations: Canonical transformations, generators of infinitesimal transformations.
Hamilton-Jacobi Theory: The Hamilton-Jacobi equation, integrable canonical flows. Action and angle variables. Adiabatic invariants.

Unit IV: Rigid Body Dynamics and Classical Fields (12 Lectures | 14 Marks)
Rigid Body Dynamics: Linear transformations, rotations, and rotating frames. Definition of a rigid body, Eulerian angles, Euler's theorem. Angular momentum, kinetic energy, and the moment of inertia tensor. Euler's equations of motion, the heavy symmetrical top.
Continuous Systems: Systems with infinite degrees of freedom. Classical fields: Lagrangian and Hamiltonian formulations. Equations of motion for continuous fields.

Unit V: Non-Linear Dynamics and Deterministic Chaos (12 Lectures | 14 Marks)
Stability and Bifurcations: Flows in phase space, integrable vs. non-integrable systems. Equilibria and linear stability theory. Bifurcations in Hamiltonian systems.
Chaos Theory: Maps, winding numbers, return maps, and area-preserving maps. Deterministic chaos, strange attractors, period doubling, and Lyapunov exponents. Geometry and integrability in phase space.

Suggested Readings

1. **H. Goldstein, C. Poole, and J. Safko**, *Classical Mechanics* (Pearson)
2. **L.D. Landau and E.M. Lifshitz**, *Mechanics (Course of Theoretical Physics)* (Butterworth-Heinemann)
3. **Steven H. Strogatz**, *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering* (CRC Press)
4. **S.N. Biswas**, *Classical Mechanics* (Books & Allied)
5. **N.C. Rana and P.S. Joag**, *Classical Mechanics* (McGraw Hill)

Core-20

Course Type: Core Course
Paper Title: Research Methodology in Physics

Paper code: PHYM 704
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives

- Expand error analysis protocols to include Maximum Likelihood Estimation (MLE), Monte Carlo uncertainty modeling, and rigorous hypothesis testing paradigms.
- Elucidate the operational principles and hardware architectures of critical analytical instrumentation.
- Develop research-level proficiency in signal processing, noise mitigation, transducer physics, and vacuum technology.
- Derive and analyze formal numerical algorithms for differentiation, integration, interpolation, and the Runge-Kutta 4th order (RK4) method.
- Analytically apply probability distributions, specifically Binomial, Poisson, and Normal models, to physical measurement challenges.
- Attain fluency in professional scientific authorship using the LaTeX typesetting system.

- Internalize the ethical frameworks of modern research, focusing on authorship integrity, data FAIRness, peer-review standards, and the role of Artificial Intelligence.

Course Outcomes (COs)

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

- **CO1 [Apply & Analyze]:** Execute Maximum Likelihood Estimation and Monte Carlo simulations for rigorous uncertainty quantification and validate experimental datasets through formal hypothesis testing.
- **CO2 [Understand]:** Deconstruct the operational block-diagrams and physical tenets of premier analytical instruments utilized in contemporary physics research.
- **CO3 [Understand & Apply]:** Model the behavior of signal, noise, and transducers within research environments, optimizing instrumentation selection for high-vacuum and low-noise applications.
- **CO4 [Analyze & Evaluate]:** Derivate and evaluate the convergence and stability of numerical differentiation, integration, interpolation, and ODE solvers (RK4).
- **CO5 [Apply]:** Synthesize Binomial, Poisson, and Normal probability distributions to characterize physical measurements and counting statistics.
- **CO6 [Create]:** Produce high-impact, professional scientific manuscripts and technical reports utilizing the LaTeX typesetting ecosystem.
- **CO7 [Understand & Evaluate]:** Critically assess ethical scientific conduct, navigating the nuances of data integrity, authorship taxonomies, peer-review, and AI utilization.

Unit I: Statistical Inference and Advanced Error Analysis (7 Lectures | 7 Marks)

Metrological concepts: Accuracy, precision, resolution, sensitivity, and calibration. Classification of errors: gross, systematic, and random errors. Propagation of uncertainties in single- and multivariable functions. Gaussian (Normal) distribution and standard deviation. Weighted mean and least-squares fitting. Chi-square (χ^2) test for goodness of fit. Introduction to Maximum Likelihood Estimation (concept only). Analysis and interpretation of experimental data using statistical methods.

Unit II: Signals, Noise, and Systems Theory (7 Lectures | 7 Marks)

Analytical study of periodic and aperiodic signals. Transfer functions and frequency response of higher-order systems. Transient response dynamics: rise time, overshoot, and settling time. Theoretical analysis of noise: Johnson (thermal), shot, and 1/f spectral densities. Signal-to-noise ratio (SNR) optimization, noise figure.

Unit III: Transducer Physics and Vacuum Technology (12 Lectures | 15 Marks)

Generalized performance of zero-, first-, and second-order measurement systems. Transducer signal conditioning and calibration. Physics of temperature sensors (RTDs/ thermistors/ thermocouples/ semiconductor sensors (AD590/LM35)). Position and force transducers: strain gauges, piezoelectric crystals, and LVDTs.

Radiation detection principles: ionization chambers and scintillation counters. Kinetic theory of gases applied to high-vacuum systems: pumping speeds of mechanical, diffusion, and turbomolecular pumps. Pressure monitoring via Pirani, Penning, and ionization gauges.

Unit IV: Analytical Spectroscopy and Chromatography (10 Lectures | 10 Marks)

UV-Visible Spectrophotometry: Electronic transitions, Beer–Lambert law, and block diagram of a spectrophotometer. **Infrared Spectroscopy and FTIR:** Molecular vibrations, basic principle, and Michelson interferometer. **Atomic Absorption Spectroscopy (AAS):** Principle, instrumentation, and applications. **Chromatography:** Principles and classification (paper, TLC, GC, HPLC). **Introduction to advanced characterization techniques:** Basic principles and applications of X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), and Transmission Electron Microscopy (TEM).

Unit V: Numerical Methods and Differential Solvers (16 Lectures | 20 Marks)

Numerical differentiation via Taylor series expansions. Integration techniques: composite Trapezoidal and Simpson’s rules. Interpolation theory: Lagrange polynomials, Newton’s difference formulas. ODE solvers:

analytical derivation of Euler and Runge-Kutta methods. Matrix algebra: iterative convergence (Jacobi/Gauss-Seidel).

Unit VI: Probability Theory and LaTeX Typesetting (5 Lectures | 6 Marks)

Probabilistic frameworks: conditional probability and Bayes' theorem. Discrete and continuous distributions: Binomial, Poisson (counting statistics), and Normal (Central Limit Theorem). Professional LaTeX typesetting: document structuring, mathematical environments (inline/display), figure/table embedding, and BibTeX citation management.

Unit VII: Research Ethics and Scientific Conduct (3 Lectures | 5 Marks)

Analysis of research misconduct: Fabrication, Falsification, and Plagiarism (FFP). Professional standards in authorship (CRediT taxonomy) and peer-review responsibilities. Data stewardship: FAIR principles and reproducibility. Intellectual property, predatory publishing mitigation (Beall's criteria), and ethical AI disclosure policies.

Core Scholarly References

- Numerical Methods for Engineers — S. C. Chapra & R. P. Canale, McGraw Hill.
- An Introduction to Error Analysis — J. R. Taylor, University Science Books.
- Principles of Instrumental Analysis — D. A. Skoog, F. J. Holler, S. R. Crouch, Cengage.
- Introduction to Measurements and Instrumentation — A. K. Ghosh, PHI Learning.
- Statistical Methods in Experimental Physics — W. T. Eadie et al., North-Holland.
- The Not So Short Introduction to LaTeX — T. Oetiker et al.
- On Being a Scientist: A Guide to Responsible Conduct in Research — National Academies Press.
- The Vacuum Experimenter's Handbook — A. Chambers, Springer.

Semester VIII
Core-21

Course Type: Core Course
Paper Title: Quantum Mechanics-II
Paper code: PHYM 801
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives
To equip students with the abstract formalism of vector spaces, advanced approximation techniques for complex quantum systems, and the semiclassical treatment of radiation.

Course Outcomes (COs)
Upon successful completion, students will be able to:
- CO1 [Apply & Analyze]: Utilize Dirac notation, projection operators, and the algebraic method to analyze abstract quantum states and the harmonic oscillator.
- CO2 [Apply]: Calculate angular momentum additions and construct wavefunctions for systems of identical particles using the Pauli exclusion principle.
- CO3 [Analyze & Evaluate]: Apply time-independent approximation methods to compute fine structure corrections and energy shifts in atomic systems.
- CO4 [Evaluate]: Evaluate transition probabilities under time-dependent perturbations using Fermi's Golden Rule and analyze selection rules.

Course Content (End-Semester Marks: 70)
Unit I: Abstract Formalism, Operators, and Symmetries (15 Lectures | 17 Marks)
The Schrödinger, Heisenberg, and Interaction pictures, Dirac notation for state vectors (bra-ket formalism). Linear vector spaces and Hilbert space. Different types of Operators, Projection operators, generalized uncertainty relations, and change of basis. Symmetries and conservation laws in quantum mechanics. The Linear Harmonic Oscillator (LHO) by operator method (creation and annihilation operators).

Unit II: Angular Momentum (15 Lectures | 18 Marks)
Angular momentum algebra, commutation relations. Eigenvalues of J^2 and J_z. Stern-Gerlach experiment, Spin angular momentum and Pauli matrices, Addition of angular momenta and Clebsch-Gordan coefficients.

Unit III: Time-Independent Approximation Methods (15 Lectures | 18 Marks)
Time-independent perturbation theory (including degeneracy and non-degenerate cases) and applications. Spin-orbit coupling and fine structure of Hydrogen. The Variational method and its application to the Helium atom. The WKB approximation (connection formulas and bound states). The Stark effect and the Zeeman effect.

Unit IV: Time-Dependent Methods and Radiation (15 Lectures | 17 Marks)
Time-dependent perturbation theory. Fermi's golden rule and transition probabilities. Harmonic perturbations. Semi-classical theory of radiation: interaction of atoms with an electromagnetic field, emission and absorption of radiation, dipole approximation, and selection rules.

Suggested readings:

1. Modern Quantum Mechanics, J. J. Sakurai, Addison Wesley.
2. Quantum Mechanics, L. I. Schiff, McGraw Hill.
3. Quantum Mechanics, Bransden and Joachain, Pearson Education.
4. Quantum Mechanics, Powell and Craseman, Narosa Publishing House.
5. Quantum Mechanics, R. Shankar, Kluwer Academic.

6. Quantum Mechanics, D. J. Griffiths, Pearson Education.
7. Quantum Mechanics, Mathews and Venkatesan, McGraw Hill.
8. Quantum Mechanics, R. L. Liboff, Pearson Education.

Expected Learning Outcomes:

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

- Utilize the abstract formalism of Dirac notation, Hilbert space, and operator mechanics to perform rigorous analyses of quantum systems, such as the linear harmonic oscillator.
- Apply the algebraic laws of angular momentum and spin to construct wavefunctions for many-body systems of identical particles adhering to the Pauli exclusion principle.
- Evaluate energy shifts and fine structure corrections in atomic systems by applying advanced approximation methods, specifically time-independent perturbation theory, variational principles, and the WKB approximation.
- Formulate the semi-classical theory of radiation using Fermi's Golden Rule to determine transition probabilities and selection rules for systems undergoing time-dependent perturbations.

Core 22

Course Type: Core Course
Paper Title: Electro-Magnetic Theory
Paper code: PHYM 802
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Description: Electromagnetic Theory forms one of the fundamental pillars of modern physics, providing a unified framework for understanding electric and magnetic fields and their interactions. This course equips students with advanced mathematical and physical concepts necessary to analyze electromagnetic phenomena, wave propagation, radiation, and the behavior of charged particles. It serves as the foundation for specialized areas such as optics, plasma physics, microwave engineering, antenna theory, condensed matter physics, and quantum electrodynamics.

Course Objectives (CO)

1. Understand basic knowledge of Maxwell equations and their applications in various media.

2. Understand basic knowledge of polarization of EM wave.

3. Understand the basic knowledge of wave guide and its applications in optical fibers.

Learning Outcomes (LO)

1.Solve problems relevant to interfaces between media with defined boundary conditions.

2. Use Maxwell's equations to describe the behavior of electromagnetic waves in vacuum as well as medium.

3. Describe states and methods of polarization and analyze the polarization state of a light source.

Course Contents:

Unit I: Maxwell Equations: (L 13 M 15)

Review of Maxwell's equations, Displacement Current, Vector and Scalar Potentials, Gauge Transformations: Lorentz and Coulomb Gauge, Boundary Conditions at Interface between Different Media, Wave Equations.Plane Waves in Dielectric Media, Poynting Theorem and Poynting Vector, Electromagnetic (EM) Energy Density, Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density, Radiation from accelerated charge, radiation from electric dipole.

Unit II: EM Wave Propagation in Unbounded Media: (L 10 M 12)

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. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth, application to propagation through ionosphere.

Unit III: EM Wave in Bounded Media: (L 10 M 12)

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 reflection (normal Incidence)

Unit IV: Polarization of Electromagnetic Waves: (L 10 M 13)

Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light

Unit V: Rotatory Polarization: (L 4 M 5)

Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade polarimeter.

Unit VI: Wave Guides: (L 10 M 10)

Planar optical wave guides. Planar dielectric wave guide.Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves , Field energy and power transmission.

Unit VII: Optical Fibers: (L 3 M 3)

Numerical aperture , Step and Graded Indices (Definitions only), Single and Multimode fibres

References:

- Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
- Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
- Introduction to Electromagnetic Theory, T.L. Chow, 2006, Jones & Bartlett Learning
- Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
- Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning
- Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.

Core-23

Course Type: Core Course
Paper Title: Plasma Physics
Paper code: PHYM 803
Credits: 4 (Theory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Description:

With the recent increase in interest towards controlled fusion and widespread use of plasma in different industrial, agricultural and health sectors, in space research etc, there is a demand for the study of plasma physics. To fulfill this demand, the course on plasma physics is designed for the students to develop theoretical knowledge about plasma (both in nature and Laboratory) its applications and diagnostics.

Course Objectives (CO)

1.To Understand the fundamental concepts of plasma, its characteristics, classifications, and applications.

2.Analyze the motion of charged particles in electric and magnetic fields and understand particle confinement mechanisms.

3.Develop the fluid description of plasmas and relate plasma behavior to electromagnetic theory.

4.Explain the propagation of waves in plasmas and their significance in laboratory and space plasmas.

5.Understand the kinetic description of plasmas, including the Vlasov equation, MHD approximation, and Landau damping.

6.To Acquire introductory knowledge of laboratory plasma generation techniques and commonly used plasma diagnostic methods

Course Contents:

Unit I: Basics of Plasmas: Concepts of Plasmas: Definition, Plasma parameters, criterion of plasmas, concepts of plasma temperature, Debye shielding, classification of Plasmas, Application of plasmas. (**L= 6. M=8**)

Unit II: Charged Particles in Electro-magnetic fields: Motion of charged particles in electromagnetic fields: uniform E & B fields, guiding centre, non-uniform fields, grad-B and curvature drift, diffusion across magnetic fields, adiabatic invariants, magnetic mirror. (**L=14, M=18**)

Unit III: Plasma as Fluids: Introduction, Navier-Stoke's equation, Relation of plasma physics to ordinary electromagnetics, fluid equation of motion, fluid drifts perpendicular and parallel to B, plasma approximation. (**L=12, M=12**)

Unit IV: Waves in Plasmas: Plasma oscillations, electron plasma waves, ion acoustic waves, propagation of waves in presence of magnetic fields, dispersion relations, cut offs and Resonance, propagation through ionosphere, Van Allen Belts.(**L=16, M=18**)

Unit V: Kinetic theory of Plasmas:

Need for kinetic theory, Vlasov equation, MHD as approximation to kinetic theory, Landau Damping

(**L=8, M=8**)

Unit VI: Introduction to Laboratory Plasmas and Diagnostics:

Types of Laboratory Plasmas and production mechanism, Electrical Probes and Optical Diagnostics (OES and Laser based)in plasmas. (**L=4, M=6**)

References:

1. Introduction to plasma physics and Controlled Fusion, F. F. Chen, Plenum Press
2. Fundamentals of plasma physics, R. A. Bittencourt, Springer.
3. Introduction to Plasma Physics, R. J. Goldston and P. H. Rutherford, IoP Publishing
4. Principles of Plasma Discharges and Materials Processing, M.A.Lieberman and A.J.Lichtenberg, Wiley Interscience

5. Principles of plasma diagnostics, I. H. Hutchinson, Cambridge University Press.

Learning Outcomes (LO)

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

1. Explain the basic properties of plasmas, plasma parameters and criterion, Debye shielding and sheath formation, plasma temperature,
2. Solve problems involving charged particle motion in uniform and non-uniform electromagnetic fields, including particle drifts and magnetic mirror effects.
3. Apply fluid equations to describe plasma behavior and distinguish between fluid and kinetic approaches to plasma physics.
4. Analyze plasma oscillations, wave propagation, dispersion relations, cut-offs, resonances, and ionospheric plasma phenomena.
5. Describe the kinetic theory of plasmas using the Vlasov equation and explain the concepts of MHD approximation and Landau damping.
6. Identify different laboratory plasma sources and explain the principles of basic plasma diagnostic techniques such as electrical probes, optical emission spectroscopy (OES), and laser-based diagnostics.
7. Appreciate the applications of plasma physics in fusion research, space science, materials processing, and industrial technologies.

Core 24

Course Type: Core Course
Paper Title: Laboratory V
Paper code: PHYM 804
Credits: 4 (Practical/Laboratory)
Marks Distribution: 70 (End-Semester) + 30 (In-Semester) = 100 (Total)
Total Contact Hours: 60

Course Objectives: At the end of this course the students will be able to

1. Experimentally verify fundamental laws and principles of electromagnetism.
2. Investigate the behavior of electromagnetic waves in different mediums.
3. Construct and analyze flip-flop circuits for sequential logic operations.
4. Develop skills in programming the 8085 microprocessor for arithmetic and control tasks.
5. Design and characterize analog circuits using operational amplifiers, transistors, and timers.
6. Study frequency response, oscillation, and amplification properties of electronic circuits.
7. Design and study sensor based systems for measurement of various physical parameters

Supports: Electronics II (7th-sem theory) · EMT & Non-linear Optics · Plasma Physics · Total experiments: 48

Group A — Electronics II Practicum (22 experiments)

Carried forward as-is from 7th-semester Electronics II theory paper (no 7th-semester lab)

1. Flip-Flop (RS, Clocked RS, D-type, JK) circuits using NAND gates
2. JK Master-slave flip-flop using Flip-Flop ICs
3. 4-bit Counter using D-type/JK Flip-Flop ICs; study of timing diagram
4. 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs
5. Astable multivibrator of given specifications using a 555 Timer
6. Monostable multivibrator of given specifications using a 555 Timer
7. 8085 Microprocessor programs: addition/subtraction (direct and indirect addressing), multiplication by repeated addition, division by repeated subtraction, 16-bit number handling, CALL/RETURN, block data handling, and one further program (e.g. parity check or interrupt handling)
8. Frequency response of voltage gain of an RC-coupled transistor amplifier

9. Wien bridge oscillator for a given frequency using an op-amp
10. Phase-shift oscillator of given specifications using a BJT
11. Colpitts oscillator
12. Digital-to-analog converter (DAC) of given specifications
13. Analog-to-digital converter (ADC) IC
14. Inverting amplifier using an op-amp (741/351) for a DC voltage of given gain
15. Inverting amplifier using an op-amp — frequency response
16. Non-inverting amplifier using an op-amp — frequency response
17. Zero-crossing detector and comparator
18. Adding two DC voltages using an op-amp in inverting and non-inverting mode
19. Precision differential amplifier of given I/O specification using an op-amp
20. Op-amp as an integrator
21. Op-amp as a differentiator
22. Circuit to simulate the solution of a 1st/2nd order differential equation

Group B — EMT, Non-linear Optics & Plasma Physics (21 experiments)

Plasma Physics experiments merged into this group

1. Verification of the law of Malus for plane-polarized light
2. Specific rotation of sugar solution using a polarimeter
3. Analysis of elliptically polarized light using a Babinet's compensator
4. Radiation pattern of a simple dipole antenna vs angle
5. Wavelength and velocity of ultrasonic waves in a liquid (kerosene, xylene) via diffraction through an ultrasonic grating
6. Reflection and refraction of microwaves
7. Polarization and double-slit interference in microwaves
8. Refractive index of a liquid by total internal reflection using Wollaston's air-film
9. Refractive index of glass and a liquid by total internal reflection using a Gaussian eyepiece
10. Polarization of light by reflection; determination of the polarizing (Brewster) angle for an air-glass interface
11. Verification of Stefan's law of radiation; determination of Stefan's constant
12. V-I characteristics of a PN junction diode: determination of the Boltzmann constant and the semiconductor energy band gap
13. Calibration curve of a Jamin's interferometer; refractive index of air
14. Wavelength of a monochromatic source using Michelson's interferometer; Sodium D-line splitting
15. Wavelength of a monochromatic source using a Fabry-Perot interferometer; Sodium D-line splitting
16. Wavelength of He-Ne laser light
17. Wavelength of laser light via single-slit diffraction, double-slit diffraction, and a plane diffraction grating (with angular spread)
18. Velocity of sound using a CRO
19. Thermal conductivity of a bad conductor by Lee and Charlton's disc method
20. Ionization potential of mercury (electron-impact ionization in a vapour)
21. Complex dielectric constant and plasma frequency of a metal using Surface Plasmon Resonance (SPR)

Group C — Computational Physics (Python) (5 experiments)

Builds on PHYM 504 (5th-semester Computational Physics Laboratory): Python, NumPy, root-finding, and statistical-distribution methods are assumed prior knowledge and are not repeated here

1. Numerical solution of the s-wave radial Schrödinger equation for the hydrogen atom (ground and first excited state) by the shooting method; plot of energy eigenvalues and wavefunctions
2. Numerical solution of the s-wave radial Schrödinger equation for a screened Coulomb potential; ground-state energy for varying screening length
3. Molecular-dynamics simulation of a Lennard-Jones gas: equilibrium density fluctuations, approach to equilibrium, velocity distribution vs Maxwell distribution
4. Numerical solution of the radioactive decay equation ($dN/dt = -\lambda N$) by the Runge-Kutta method; comparison with the analytic exponential solution
5. Preparation of a scientific report with numerical results, tables, and graphs using LaTeX

Recommended readings:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing
- House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted
- 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, I.Prakash& Ramakrishna, 11th Ed., 2011, KitabMahal
- Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer
- Modern Digital Electronics, R.P. Jain, 4th Edition, 2010, Tata McGraw Hill.
- Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill.
- Microprocessor Architecture Programming and applications with 8085, R.S. Goankar, 2002, Prentice Hall.
- Microprocessor 8085:Architecture, Programming and interfacing, A. Wadhwa, 2010, PHI Learning.

Expected Learner Outcomes: This course will enable students to

1. Experimentally verify fundamental laws and principles of electromagnetism.
2. Experimentally verify different sequential circuits and familiarize with 8085 microprocessor programming
3. Design and study instrumentation systems and measure physical parameters for scientific purposes.