University of Kalyani
কল্যাণী বিশ্ববিদ্যালয়

M.Sc. in Physics Curriculum

(2026 – 2028)

As per NEP-2020 Framework

Approved by the

Post-Graduate Board of Studies

Department of Physics, Faculty of Science

in its

18th PGBOS Meeting held on 14th July, 2026

2026

About the Department: The Department of Physics at the University of Kalyani, one of its oldest departments, completed more than 60 years in 2021. A systematic history was compiled to preserve its legacy and guide future development despite gaps in early records. The University of Kalyani was founded in 1960 by the Government of West Bengal as a unitary university focused on Agriculture and Rural Development under its first Vice-Chancellor, Prof. Sachindra Nath Dasgupta. It initially had Faculties of Arts, Science, Agriculture, and Education; the Agriculture Faculty became the independent Bidhan Chandra Krishi Viswavidyalaya in 1973. The university became affiliating in 1998, incorporating colleges from Nadia and Murshidabad, and discontinued undergraduate teaching in Science and Arts & Commerce from 2003. It now operates with five faculties: Science, Arts & Commerce, Education, Engineering Technology & Management, and Fine Arts & Music.

Established in 1961 with only two teachers, the Department of Physics began with Pass-level courses and admitted its first B.Sc. Honours students in 1962. The first Honours batch graduated in 1965, M.Sc. admissions started the same year, and the first M.Sc. batch passed out in 1967. Research began in the early 1970s, with the first Ph.D. awarded in 1976. The department operated from temporary sites until moving into its permanent building in 1969, which was later expanded. Undergraduate programmes ran until 2000 (last batch graduated 2003). It now offers postgraduate M.Sc. and Ph.D. programmes under the semester and credit systems (implemented from 2008 and 2014-15 respectively). The syllabus has been periodically upgraded, including major revisions in 2012, 2017 and 2021, and further updated on 2026 according to NEP-2020, incorporating advanced and contemporary topics with continuous evaluation. The M.Sc. intake has been increased to 80 students, and a Pre-Ph.D. coursework was introduced in 2010.

The department has a dedicated faculty of 6 Professors and 2 Assistant Professors, supported by 3 technical staff. Over 110 scholars have successfully completed Ph.D. programmes, with approximately 25 currently pursuing research. Its teaching and research activities have received UGC and DST support through FIST (Level 0: 2001-04), SAP-I (2002-2007), and FIST Level-1 (2013-2018) programmes.

Preamble (about the course): From the quantum to the cosmic, physics is the language in which nature reveals its deepest secrets. The M.Sc. in Physics programme of the University of Kalyani is designed to take students on this journey — from the elegant symmetries of classical mechanics to the strange certainties of quantum theory, from the ordered lattices of solids to the extreme physics of stars, and from the mathematics that describes it all to the instruments that let us measure it.

Structured under the NEP-2020 framework, this curriculum is built for a generation of physicists who must be equally at home in the laboratory, at the computer, and at the frontier of ideas. It blends rigorous core training in mechanics, quantum theory, electrodynamics, and condensed matter physics with the tools of the present era — computation, data analysis, and artificial intelligence — while making room for interdisciplinary exploration, entrepreneurial thinking, and an engagement with the Indian

Knowledge System that reminds us physics has always been a conversation across cultures and centuries.

Through its Major, Minor, Skill-Enhancement, and research components — culminating in a guided dissertation — the programme aims to produce graduates who do not merely learn physics, but think like physicists: curious, rigorous, and unafraid of complexity. Whether a student's path leads to a doctorate, a laboratory, a classroom, or a start-up, this curriculum is meant to be the launching point.

Program Learning Outcomes: (aligned to NHEQF Level 6.5)

PLO1 (Knowledge & Understanding — disciplinary depth): Demonstrate advanced, specialized knowledge of the core sub-fields of physics — classical and statistical mechanics, quantum mechanics, electrodynamics, solid state physics, and nuclear/particle physics/electronics — with a critical understanding of current developments in each area.

PLO2 (Knowledge & Understanding — research methods): Demonstrate advanced understanding of the research principles, methods, and instrumentation techniques used in experimental and theoretical physics.

PLO3 (Technical/Professional Skills): Apply advanced cognitive and technical skills — mathematical formalism, laboratory technique, and computational tools — to perform complex, specialized physics tasks.

PLO4 (Skills — Research Design & Evaluation): Evaluate existing research findings and independently design, conduct, and report an original investigation that contributes new knowledge in a chosen area of physics.

PLO5 (Application of Knowledge & Skills): Apply advanced theoretical and technical knowledge to identify, analyze, and solve complex and unfamiliar problems — including applied contexts such as materials, devices, and renewable energy systems.

PLO6 (Generic Outcomes — Communication & Research Skills): Communicate complex technical findings clearly to specialist and non-specialist audiences in written, oral, and presentation form; formulate research questions, collect and analyze data, and draw evidence-based conclusions.

PLO7 (Constitutional, Humanistic & Ethical Values): Practice research integrity — avoiding fabrication, falsification, and plagiarism — and situate physics within India's constitutional, ethical, and indigenous knowledge traditions.

PLO8 (Employability, Entrepreneurship & Lifelong Learning): Demonstrate the adaptability, entrepreneurial mindset, and self-directed learning skills needed to pursue careers in research, industry, or teaching, or to launch physics-based ventures.

Semester-wise Programme Structure

Semester	Course Code	Course Title	Course Type	Credit Pattern			Credit Value	Marks Distribution		
				Lecture (L)	Self-Study/ Tutorial (SS/T)	Practical (P)		Summative Assessment	Continuous Assessment	Total Marks
SEM I #	PHY-MJR-401	Classical and Statistical Mechanics	Major (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-MJR-402	Quantum Mechanics	Major (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-MJR-403	Solid State Physics	Major (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-MJR-404	General Practical-I	Major (PR)	1	0	3	4	75 (Th + Exp)	25 (Lab Performance Viva)	100
	PHY-SEC-405	Adv. Mathematical Tools	SEC	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-VAC-449	Instrumentations & Techniques in Physics	Value added course	Faculty guided VLE				Gradation based evaluation		
		NCrF Level 6: UGC Course Level 400-449		13	4	3	20	355	145	500
		VLE: Virtual Learning Environment								
		W – Written; P – Practical; PPT – Power Point Presentation; A – Assignment submission								
SEM II #	PHY-IDS-451*	Physics in the daily use instruments*	Inter-disciplinary	2	2	0	4	60 (W)	40 (W)	100
	PHY-MJR-452	Electronics	Major (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-MJR-453	General Practical-II	Major (PR)	1	0	3	4	75 (Th + Exp)	25 (Lab Performance Viva)	100
	PHY-MNR-454	Electrodynamics & Plasma	Minor (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-MNR-455	Nuclear and Particle Physics	Minor (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-SEC-456	Concept of Renewable Energy: Generation and Storage	SEC	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-VAC-499	Entrepreneurship and Start-up in Physics	VAC	Faculty guided VLE				Gradation based evaluation		
		NCrF Level 6: UGC Course Level 450-499		15	6	3	24	415	185	600

* Meant for an interdisciplinary course for students from departments of KU including Physics. Physics students will opt for an interdisciplinary course from Physics/other PG departments of KU (mandatory).

After the 1st and 2nd semesters, students may opt for the exit option. Students who exit at the end of 1st year (1st and 2nd semesters) shall be awarded a Postgraduate Diploma in physics (as per UGC nomenclature – NHEQF Level 6).

SEM III	PHY-IKS-501	Indian Knowledge System in Physics	IKS (Th)	2	2	0	4	60 (W)	40 (W)	100
	PHY-MJR-502	Atomic Molecular and Spectroscopy	Major (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-MJR-503	Adv Practical-I	Major (PR)	1	0	3	4	75 (Th + Exp)	25 (Lab Performance Viva)	100
	PHY-MNR-504 (Any One)	1. Adv. Solid State Physics 2. Adv. Nuclear physics 3. Adv. Electronics 4. Adv. Particle Physics	Minor (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
	PHY-MNR-505 (Any One)	1. Material Science 2. Applied Nuclear Physics 3. Applied Electronics 4. Gravitation and Cosmology	Minor (Th)	3	1	0	4	70 (W)	30 (W/PPT+A)	100
		NCrF Level 6.5: UGC Course Level 500-549		12	5	3	20	345	155	500
SEM IV	PHY-MJR-551	Research Methodology	Major (Th)	2	2	0	4	60 (W)	40 (W)	100
	PHY-MJR-552	Adv Practical-II	Major (PR)	1	0	3	4	75 (Th + Exp)	25 (Lab Performance Viva)	100
	PHY-SEC-553	Computation Technique, Data Analysis and AI Application in Physics	SEC	1	1	2	4	25 (W) 50 (P)	25 (W/PPT+A)	100
	PHY-GRP-599*	Guided Research Project*	Dissertation	--	2	6	8	120 (Thesis Evolution)	80 (PPT+ Viva)	200
		NCrF Level 6.5: UGC Course Level 550-599		4	5	10	20	330	190	500
		* If students carry out their research project in other departments of same or different institutes, faculty member of Physics Department will act as internal supervisor, as well as internal examiner. Evaluation: Thesis Write-up: 120; Seminar presentation: 40; Viva-Voce: 40 (evaluated by both external & internal examiners)								
		Grand total					**84**	**1420**	**700**	**2100**

<table>
<tr><th colspan="3">Credit Distribution – 84 Credits</th></tr>
<tr><td>Major (MJR) courses: 40 credits</td><td colspan="2">Minor [MNR] + SEC courses: 16 + 12 = 28 credits</td></tr>
<tr><td rowspan="2">Theory + Practical</td><td>MNR
(Mandatory)</td><td rowspan="2">SEC – 4 credits</td></tr>
<tr><td>Theory</td></tr>
<tr><td>Courses: 10
Theory Credits: 21
Self-Study/ Tutorial: 07
Practical Credits: 12</td><td>Courses: 04
Theory Credits: 12
Self-Study/ Tutorial: 04</td><td>Courses: 03
Theory Credits: 07
Self-Study/ Tutorial: 03
Practical Credits: 02</td></tr>
<tr><td>Total: 10 courses and 40 credits</td><td>Total: 4 courses and 16 credits</td><td>Total: 3 courses and 12 credits</td></tr>
<tr><td>Interdisciplinary (IDS) – 4 credits</td><td>Indian Knowledge System (IKS) – 4 credits</td><td>Dissertation – 08 credits</td></tr>
<tr><td>Course: 01
Credits: 04</td><td>Course: 01
Credits: 04</td><td>Course: 01 (GRP)
Credits: 08</td></tr>
<tr><td>Total: 1 course and 4 credits</td><td>Total: 1 course and 4 credits</td><td>Total: 1 course and 8 credits</td></tr>
</table>

Semester-I

PHY-MJR-401

Classical and Statistical Mechanics

(Major)

Credit: 4	Full Marks: 100
No of Lectures: 60	Continuous Assessment: 30
	Term end examination: 70

Course overview: This comprehensive theoretical physics course bridges analytical mechanics with macroscopic thermodynamics. Students will master the mathematical frameworks governing both single particles and continuous systems, then transition into quantum and statistical systems to analyze phase changes, quantum gases, and astrophysical phenomena.

Course Learning Outcome (CLOs): Upon successful completion of this comprehensive course, students will be able to:

CLO1: Formulate and transform equations of motion across Newtonian, Lagrangian, and Hamiltonian mechanics using the Principle of Least Action and Legendre transformations.

CLO2: Apply Noether's theorem and canonical tools (Poisson brackets, generating functions, Hamilton-Jacobi theory) to link symmetries to conservation laws and solve complex trajectories.

CLO3: Model 3D rigid body rotations and continuous media using Euler angles, inertia tensors, gyroscopic precession dynamics, and Lagrangian/Hamiltonian field densities.

CLO4: Construct classical and quantum ensembles (microcanonical, canonical, grand canonical) and density matrices to extract thermodynamic variables and track spin-state averages.

CLO5: Analyze ideal quantum gases (Fermi-Dirac/Bose-Einstein) to model astrophysical phenomena like white dwarfs, neutron stars, and Bose-Einstein condensation thresholds.

CLO6: Evaluate non-ideal systems and phase changes using virial coefficients, Joule-Thomson expansion curves, Ehrenfest criteria, and Landau's Mean Field Theory.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓		✓					
CLO2	✓		✓					
CLO3	✓		✓					
CLO4	✓		✓					
CLO5	✓				✓			
CLO6	✓				✓			

Course content:

(Classical Mechanics)

Module-I

Revision of classical mechanics

Derive Euler-Lagrange from Principle of Least Action. Show equivalence between Lagrangian and Newtonian mechanics. Understand how to go from Lagrangian to Hamiltonian via Legendre transformation. Explain Noether's theorem with at least one example (energy or momentum). Solve simple problems using generalized coordinates (e.g., pendulum, Atwood machine, particle in electromagnetic field). Know when to use Lagrangian vs Hamiltonian. (4 Lectures)

Canonical Transformation

Equations of canonical transformation; generating functions; examples of canonical transformations; integral invariants of Poincare; Lagrange and Poisson brackets as canonical invariants; infinitesimal contact transformations; constants of motion and symmetry principles; generators of infinitesimal symmetry transformations. (4 Lectures)

Hamilton-Jacobi theory

Hamilton's principal and characteristic functions; Hamilton Jacobi equations for these two functions; separation of variables in the Hamilton-Jacobi method (e.g. simple harmonic motion, Kepler problem etc) (6 Lectures)

Module-II

Rigid body dynamics:

Lagrange's equations of motion for a rigid body; Euler's theorem on the motion of a rigid body; infinitesimal rotations. Euler's equations of motion. Force free motion of a rigid body; heavy symmetrical top with one point fixed; precession and nutation; Larmor precession; gyroscope and asymmetrical top, condition for Fast and sleeping top. (8 Lectures)

Mechanics of Continuous Media:

Transition from discrete to continuous systems; the Lagrangian formulation; stress energy tensor and conservation theorems; Hamiltonian formulation; Poisson brackets and momentum representation; examples. (8 Lectures)

(Statistical Mechanics)

Module-III

Revision of statistical mechanics:

Random Walk, phase space, phase points, Phase trajectory, Ensemble, Liouville's equation, Gibbs paradox; Free energy, entropy. Micro canonical, canonical and grand canonical ensembles. energy and density fluctuations, partition function and statistical definition of thermodynamic quantities, examples of some standard systems- ideal gas, Harmonic oscillators, rigid rotators, para magnetism; spin ½ system and negative temperature concept. (8 Lectures)

Density Matrix:

Quantum mechanical and statistical averaging, quantum Liouville equation, Density matrix for stationary ensembles. Construction of density matrix, Polarization vector, Pure and Mixed states, Application to a free particle in a box, an electron in a magnetic field, beam of spin ½ particles. (6 Lectures)

Module-IV

Quantum Statistics: Fermi and Bose distributions:

Quantum gas in equilibrium; quantum gases of elementary particles; number density and chemical potential; energy density, equation of state and different thermodynamic quantities; relativistic quantum gas; black body radiation and Planck's law; degenerate Bose gas; lattice specific heat and phonons; Bose condensation and super fluidity; degenerate Fermi gas; degeneracy pressure; specific heat of degenerate Fermi gas; Riemann's ξ and integrals of quantum statistics : relativistic degenerate electron gas; high temperature dense matter; white dwarfs and neutron stars. (8 Lectures)

Real Gas:

Free energy; virial equation of state; second virial coefficient and Joule Thomson expansion; inversion temperature, model calculation and van der Waals equation of state. (3 Lectures)

Phase Transitions:

Liquid-gas, order-disorder, ferroelectric and ferromagnetic transitions; critical points; Ehrenfest's classification; order parameter; continuous and discontinuous transactions; Landau's theory of continuous transitions; continuity of entropy; discontinuity of specific heat; singularities of order parameter and partition function; generalized susceptibility; mean field theory; critical exponents; scaling and fluctuations of order parameter. (5 Lectures)

Reference Books:

1. Goldstein, Poole and Safko: Classical Mechanics – Addison Wesley / Narosa.
2. Landau and Lifshitz : Mechanics – Pergamon.
3. Rana and Joag: Classical Mechanics – Tata-McGraw Hill.
4. Whittaker : Analytical Dynamics of Particles and Rigid Bodies – Cambridge.
5. Fetter and Walecka : Theoretical Mechanics of Particles and Continua – McGraw Hill.
6. RaychaudhuriA.K: Classical Mechanics – Oxford.
7. Simmons: Differential Equations – Tata-McGraw Hill.
8. Bhatia: Classical Mechanics – Narosa.
9. Landau and Lifshitz: Statistical Mechanics – Pergamon
10. Toda, Kubo and Saito: Statistical Physics – Springer Verlag.
11. Reif: Fundamentals of Statistical and Thermal Physics – McGraw Hill.
12. Pathria: Statistical Mechanics – Pergamon.
13. Ma: Statistical Mechanics – World Scientific.
14. Huang: Statistical Mechanics – John Wiley

PHY-MJR-402

Quantum Mechanics

(Major)

Credit: 4	Full Marks: 100
No of Lectures: 60	Continuous Assessment: 30
	Term end examination: 70

Course overview: This course develops quantum mechanics from its formal mathematical structure through to relativistic wave equations. It begins with the linear vector space (Dirac bra-ket) formalism that underlies all of quantum theory, then builds two of the theory's most important solved systems — the harmonic oscillator and angular momentum — using operator methods. The second half of the course turns to approximation techniques needed for realistic, non-exactly-solvable problems (variational, perturbative, and WKB methods), scattering theory, and the role of symmetry in quantum systems, before closing with an introduction to relativistic quantum mechanics through the Klein–Gordon and Dirac equations. An optional module introduces the basics of quantum computation for students who wish to see a modern application of the formalism. Throughout, the course emphasizes operator algebra and representation-independent reasoning as the unifying method connecting every topic.

Course Learning Outcomes (CLOs): On successful completion of this course, students will be able to:

CLO1: Represent quantum states and observables using the Dirac bra-ket formalism, and move fluently between abstract operator notation and position/momentum representations.

CLO2: Solve the quantum harmonic oscillator using creation and annihilation operators, and construct and interpret coherent states.

CLO3: Apply the general theory of angular momentum — including spin and the addition of angular momenta — to compute eigenvalues, eigenfunctions, and Clebsch–Gordan coefficients.

CLO4: Select and apply an appropriate approximation method (variational, perturbative, or WKB) to a quantum system that has no exact solution, and justify the choice.

CLO5: Analyze scattering processes using partial-wave analysis and the Born approximation to compute cross-sections.

CLO6: Use symmetry principles and conservation laws to constrain the behavior of quantum systems, and identify the consequences of discrete symmetries such as parity and time reversal.

CLO7: Derive the Klein–Gordon and Dirac equations, and interpret their free-particle and negative-energy solutions, including the physical basis of hole theory.

CLO8: (Optional module) Describe qubits, quantum gates, and quantum teleportation as an application of the course's formalism to quantum information.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓		✓					
CLO2	✓		✓					
CLO3	✓		✓					
CLO4	✓				✓	✓		
CLO5	✓				✓			
CLO6	✓							
CLO7	✓							
CLO8	✓							✓

Course content:

Module I

Linear Vector Space formulation:

Vector Space Formalism: Linear vector space, dimension and basis; state vectors and the principle of superposition; ket and bra vectors; inner product and dual space; orthonormality, completeness and closure; the Hilbert space. (6 Lectures)

Operators: Linear operators, Hermitian adjoint and Hermitian operators; projection and parity operators; matrix representation of kets, bras and operators; eigenvalues and eigenvectors; expectation values. (5 Lectures)

Position and Momentum Representations: Discrete and continuous bases; position representation; momentum representation; connecting the two representations. (3 Lectures)

Pictures of Time Evolution: Schrödinger, Heisenberg and Interaction pictures; equations of motion; time evolution of expectation values. (3 Lectures)

Module II

Harmonic Oscillator and Angular Momentum:

Harmonic Oscillator (Operator Method): Creation and annihilation operators; oscillator algebra; Hamiltonian and number operator; energy eigenvalues and eigenfunctions; coherent states and minimum uncertainty. (4 Lectures)

Angular Momentum: General Formalism: Angular momentum as generator of rotation; commutation rules; eigenvalues and eigenfunctions; matrix representation; rotation matrices and spherical harmonics. (4 Lectures)

Spin and Composite Angular Momentum: Spin angular momentum; algebra of Pauli spin matrices and spinors; spin-1/2 particle in a magnetic field; addition of two angular momenta and Clebsch–Gordan coefficients. (4 Lectures)

Module III

Approximation Methods and Scattering:

Time-Independent and Variational Methods: Variational method for stationary states; time-independent perturbation theory, non-degenerate and degenerate cases. (3 Lectures)

Time-Dependent Perturbation Theory: Transition amplitude; constant and harmonic perturbations; Fermi's golden rule. (3 Lectures)

WKB and Special Approximations: WKB approximation; adiabatic and sudden approximations, with representative applications. (3 Lectures)

Scattering theory: Scattering amplitude; differential and total cross-sections; partial-wave analysis and phase shifts; Born approximation; hard-sphere scattering. (4 Lectures)

Quantum Computation: Bits and qubits; Bloch sphere representation; quantum gates and circuits; quantum teleportation; an outline of physical realizations. (3 Lectures)

Module IV

Symmetries and Relativistic Quantum Mechanics:

Symmetries: Symmetry operations as unitary and anti-unitary transformations; conservation laws from invariance; discrete symmetries — parity and time reversal. (3 Lectures)

Klein–Gordon Equation: Continuity equation and indefinite norm; free-particle solutions; negative-energy solutions and their interpretation; the charged Klein-Gordon field and coupling to an electromagnetic field. (4 Lectures)

Dirac Equation: Motivation and derivation; continuity equation; non-relativistic correspondence; spin and magnetic moment; Lorentz covariance and gamma matrices. (5 Lectures).

Hole Theory: Free-particle solutions of Dirac Equation, Negative-energy solutions revisited; hole theory and the positron. (3 Lectures).

Reference Books:

1. Introduction to Quantum Mechanics, David J. Griffiths, Third edition, Cambridge University Press.
2. Introductory Quantum Mechanics, Fourth edition, Richard L. Liboff, Pearson.
3. Quantum Mechanics, Amit Goswami, Waveland Press.
4. Quantum Mechanics: Concepts and Applications. Nouredine Zettili (John Wiley and sons).
5. Quantum Theory" D. Bohm (Prentice-Hall).
6. Lectures on Quantum Mechanics 2nd Edition, Ashok Das, World Scientific
7. J. J. Sakurai: Modern Quantum Mechanics -Addison Wesley.
8. Schwabl: Quantum Mechanics -Narosa.
9. Bransden and Joachain: Introduction to Quantum Mechanics -Longmans

10. Landau and Lifshitz: Quantum Mechanics -Pergamon

11. Davydov: Quantum Mechanics –Pergamon

12. Gasiorowicz: Quantum Physics -John Wiley

13. Byam: Lecture Notes on Quantum Mechanics -Benjamin

14. Schweber: Relativistic Quantum Field Theory -Harper and Row

15. Bjorken and Drell : Relativistic Quantum Mechanics -McGraw Hill

16. Greiner: Relativistic Quantum Mechanics -Springer.

17. Quantum Computation and Quantum Information, M. A. Nielsen & I. Chuang, Cambridge University Press (2000)

18. G. Greenstein and A. G. Zajonc the Quantum Challenge Modern Research on the

19. Foundations of Quantum Mechanics-Narosa Publishing House

20. Mikio Nakahara and Tetsuo Ohmi,"Quantum Computing", CRC Press (2008)

21. Ashok Das, Lectures on Quantum Field Theory, World Scientific Publishing Company.

PHY-MJR-403

Solid State Physics

(Major)

Credit: 4 | Full Marks: 100

No of Lectures: 60 | Continuous Assessment: 30

Term end examination: 70

Course overview: This paper is a general, non-specialist introduction to the physics of the solid state, intended for all M.Sc. Physics students regardless of eventual specialization. It develops the subject in the order in which its ideas actually build on one another: the structural and bonding basis of crystals; the lattice vibrations and electronic band structure that follow from that structure; the transport and magnetic behaviour that follow from band structure; and finally, the collective phenomena — superconductivity and dielectric/optical response — that require the full picture. The paper does not presuppose second quantization, many-body theory, or group-theoretic methods; those are left to advanced condensed matter electives.

Course Learning Outcomes (CLOs): On successful completion of this course, students will be able to:

CLO1: Describe crystal structures and bonding mechanisms, and interpret diffraction data to determine structural parameters.

CLO2: Explain lattice vibrations (phonons) and their contribution to the specific heat of solids.

CLO3: Derive and apply free-electron and band theory to distinguish metals, semiconductors, and insulators.

CLO4: Analyze transport phenomena in metals and semiconductors, including conductivity and the Hall effect.

CLO5: Account for the magnetic behaviour of solids in terms of atomic and exchange interactions.

CLO6: Explain the phenomenology and microscopic basis of superconductivity, and the dielectric and optical response of solids.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓		✓					
CLO2	✓							
CLO3	✓							
CLO4	✓				✓			
CLO5	✓							
CLO6	✓							

Course content:

Module I

Crystal Structure, Bonding, and Diffraction:

Crystal lattices: Bravais lattices, unit cell, symmetry elements, Miller indices; simple crystal structures (fcc, bcc, hcp, diamond, NaCl, CsCl, zinc blende). (4 lecture)

Crystal binding: ionic, covalent, metallic, van der Waals, and hydrogen bonding; cohesive energy and criteria of structural stability. (3 lecture)

Diffraction methods: reciprocal lattice; Brillouin zones; Bragg's law; crystal and atomic structure factors; Laue, rotating-crystal, and powder (Debye–Scherrer) methods. (7 lecture)

Imperfections in solids: point defects (vacancies, interstitials), line defects (dislocations); defect concentration and its temperature dependence. (3 lecture)

Module II

Lattice Dynamics and Electronic Band Theory:

Lattice vibrations: harmonic approximation; vibrations of monatomic and diatomic linear chains; dispersion relations; phonons and their quantization; Einstein and Debye models of specific heat. (6 lecture)

Free electron theory: Sommerfeld model, density of states, Fermi energy and Fermi surface. (4 lecture)

Band theory: electrons in a periodic potential; Bloch theorem; Kronig–Penney model; formation of energy bands; nearly-free-electron and tight-binding approximations; effective mass and the concept of holes; classification of solids as metals, semiconductors, and insulators by band structure. (5 lecture)

Module III

Transport Properties, Semiconductors, and Magnetism:

Transport properties: elementary Boltzmann transport picture; electrical and thermal conductivity of metals; Wiedemann–Franz law; the Hall effect. (4 lecture)

Semiconductors: intrinsic and extrinsic semiconductors; carrier concentration and mobility; temperature dependence of conductivity, Hall Effect. Measurement of conductivity (4 probe method) & Hall coefficient. (4 lecture)

Magnetism in solids: diamagnetism and paramagnetism; Hund's rule; ferromagnetism, antiferromagnetism, and ferrimagnetism; exchange interaction (qualitative); domains and hysteresis; an outline of spin waves. (7 lecture)

Module IV

Superconductivity and Dielectric/Optical Properties:

Superconductivity: experimental facts; the Meissner effect; London equations and penetration depth; Type I and Type II superconductors; flux quantization; the Josephson effect; an outline of BCS theory and high-Tc superconductors. (7 lecture)

Dielectric properties: polarization mechanisms; local field; dielectric loss and relaxation; ferroelectricity. (4 lecture)

Optical properties: absorption, luminescence, and excitons in solids; an outline of colour centres. (4 lecture)

Reference Books:

1. C. Kittel — Introduction to Solid State Physics, John Wiley.
2. N. W. Ashcroft and N. D. Mermin — Solid State Physics, Cengage/Saunders.
3. S. O. Pillai — Solid State Physics, New Age International.
4. Ali Omar — Elementary Solid-State Physics: Principles and Applications, Addison-Wesley.
5. A. J. Dekker — Solid State Physics, Macmillan.
6. C. P. Poole Jr. — Superconductivity, Academic Press.
7. D. L. Bhattacharyya — Solid State Physics, Calcutta Book House.
8. J. P. Srivastava — Elements of Solid-State Physics, PHI

PHY-MJR-404

General Practical-I

(Major)

Credit: 4

Full Marks: 100

Continuous Assessment: 25

Term end examination: 75

Course overview: This course provides hands-on mastery over radiation detection principles, optical interferometry, and atomic spectroscopy. Students explore the transition from classical wave theory to quantum mechanical behaviors. Also, it delivers foundational skills in analog circuit design, semiconductor performance analysis, and the thermodynamic profiling of nanostructured systems.

Course Learning Outcomes (CLOs): Upon successful completion of this practical course, students will be able to:

CLO1: Calibrate radiation detectors and quantify nuclear decay mechanics by isolating the Geiger-Müller plateau voltage and computing the half-life of long-lived isotopes (^{40}K) through Poisson and Gaussian statistical data tracking.

CLO2: Model radiation attenuation profiles across metallic barriers to determine material-specific mass absorption coefficients and deduce the maximum kinetic energy and range of beta/gamma emissions.

CLO3: Apply precise optical interferometry using a Michelson interferometer and Fabry-Perot etalon to measure sub-nanometer doublet separations ($\Delta\lambda$), determine thin-film refractive indices, and isolate magnetic field atomic orbital shifts (Zeeman Splitting).

CLO4: Map quantum states and atomic configurations using spectrometers to construct energy level diagrams, identify Rydberg series parameters, and isolate molecular dissociation energy boundaries.

CLO5: Synthesize and optimize power and signal conditioning circuits by building Zener/emitter-follower regulated DC power supplies and common-emitter AC amplifiers to extract line/load regulation rules and gain-bandwidth boundaries.

CLO6: Characterize multi-junction and industrial power semiconductor hardware including Diacs, Triacs, SCRs, UJTs, and FETs/MOSFETs configured as source-follower switches or relaxation multi-vibrators.

CLO7: Evaluate acoustic and thermal profiles of advanced fluids by computing sound velocities via ultrasonic interferometry alongside tracking the concentration-dependent thermal conductivity and viscosity scales of nanostructured fluids.

CLO8: Trace solid-state thermodynamic phase transitions by diagnosing tracking variables across metallic matrices to determine the precise ferromagnetic Curie temperature boundary of elemental Nickel.

CLO9: Examine data modeling and structural laboratory constraints by applying meticulous experimental error tracking, building data tables, and presenting physical systems clearly for advanced viva-voce and practical evaluation panels.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1		✓	✓					
CLO2			✓		✓			
CLO3		✓	✓					
CLO4		✓	✓					
CLO5			✓		✓			
CLO6			✓		✓			
CLO7			✓		✓			
CLO8			✓					
CLO9						✓	✓	

Course contents:

Nuclear Physics and Advanced Optics (Group A students only)

List of Experiments:

1. a) Determination of the Plateau region of a GM tube. (b) Analysis of statistical fluctuations at low and high count rates.
2. Determination of the half-life of a long lived radioactive sample (40K).
3. Study of gamma absorption in Aluminium and Lead using a GM tube and determination of the mass absorption coefficient.
4. Study of beta absorption in Aluminium using a GM tube and determination of range and energy of beta particles.
5. a) Calibration of a Michelson interferometer using Na-D lines as standard.
   b) Measurement of d between Na-D lines.
   c) Determination of refractive index/thickness of a thin sheet of a transparent material.
6. Study of spectra of Hydrogen atom using a constant deviation spectrograph/spectrometer, to identify the Rydberg series and to construct its energy level diagram.
7. Study of the molecular spectra of I2 in absorption and determination of the dissociation energy.
8. Study of emission spectra of Cu and to determine the energy diagram with possible transition.
9. Study of the Zeeman splitting of Na-D lines using a constant deviation spectroscope and Fabry-Perot etalon.

Electronics and Solid State Physics (Group B students only)

List of Experiments:

1. Construction of a power supply with semiconductor devices, zener diodes and using an emitter follower and to study its performance ripple factor, line and load regulations.
2. Construction of a single stage common emitter voltage amplifier, measurement of its gain, input and output impedances and the determination of the gain-bandwidth product using R-C coupling.
3. Experiments on Diac, Triac, SCR and UJT
4. Design and construction of astable multivibrator and the study of its characteristics and performance.
5. Experiments on Modulation and demodulation.
6. Study the characteristics of FET and MOSFET and use of these as source followers.
7. OP-AMP based experiments
8. Study of velocity of sound by ultrasonic interferometer
9. Study of thermal conductivity of nanofluid.
10. Study of viscosity of nanofluid.
11. Study of ferromagnetic Curie temperature of nickel.

References:

1. Laboratory manual

PHY-SEC-405

Adv. Mathematical Tools

(SEC)

Credit: 4 | Full Marks: 100

No of Lectures: 60 | Continuous Assessment: 30

Term end examination: 70

Course overview: This advanced course establishes the core mathematical architecture required to formulate and solve high-level physical theories. Students will transition from complex function landscapes and differential operator mechanics to functional spaces, continuous symmetry group algebras, and coordinate-invariant tensor calculus. These tools serve as the foundational language for general relativity, quantum mechanics, and field theories.

Course Learning Outcomes (CLOs): Upon successful completion of this advanced mathematical methods course, students will be able to:

CLO1: Resolve complex boundary integrations and geometric spaces using Cauchy's residue theorem, branch cut tracking, analytic continuation, and conformal transformations.

CLO2: Formulate and solve physical field equations by applying Sturm–Liouville operator theory, Fourier/Laplace integral transforms, and inhomogeneous Green's functions.

CLO3: Deconstruct finite and continuous symmetries using subgroups, character orthogonality theorems, Young tableaux representations, and the generator algebras of Lie groups (SO(3), SU(2), SU(3)).

CLO4: Analyze curved geometries and non-Euclidean spaces by calculating covariant/contravariant tensor fields, metric tensors, and Christoffel symbols.

CLO5: Formulate coordinate-invariant physical laws on curved manifolds using parallel transport vectors, geodesics, and tensor-based differential operators (gradient, divergence, curl, Laplacian).

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓		✓					
CLO2	✓		✓					
CLO3	✓		✓					
CLO4	✓		✓					
CLO5	✓				✓			

Course content:

Module-1

Complex Variables: Complex limit, Complex differentiation, Analytic Function, complex integration, integral theorems, Taylor and Laurent Series, Residue theorem and evaluation of residue; Cauchys residue theorem; evaluation of definite integrals by the method of contour integration (including integration around branch cuts); evaluation of principal values of improper integrals; summation and inversion of series. Analytic Continuation: Definition and some elementary theorems; Schwarz reflection principle; power series method of analytic continuation. Complex Mapping. Conformal Transformation. (8 lectures)

Eigenfunction methods for differential equations: Sets of functions. Some useful inequalities Adjoint, self-adjoint and Hermitian operators Properties of Hermitian operator. Reality of the eigenvalues; orthogonality of the eigenfunctions; construction of real eigenfunctions, Sturm–Liouville equations Valid boundary conditions; putting an equation into Sturm–Liouville form. (7 lectures)

Module -II

Integral Transforms: Fourier transform, Laplace transforms; Parsevals theorem and convolution theorem; partial differential equation and its classification; Solution of partial and ordinary differential equation by above transformations. (7 lectures)

Green's Functions: Inhomogeneous differential equation (Poisson equations, wave equation, etc.); Green's Functions, definition and properties (for self adjoint differential operators only) computation of Green's function, direct computation, eigenfunction expansion, integral transform method. (8 lectures)

Module-III

Finite Group Theory: Introduction, subgroups, conjugacy classes, cosets, factor groups, normal subgroups, and direct products; permutation groups with cyclic notation and Young tableaux representations; homomorphisms and isomorphisms; and group representations encompassing reducible/irreducible types, unitary representations, Schur's lemma, orthogonality theorems, characters, and direct products of representations. (8 lectures)

Continuous groups introduce Lie groups along with orthogonal and unitary groups such as O(2), SO(2), SO(3), SU(2), SU(3), their representations, and generator algebras. (6 lectures)

Module-IV

Tensors: Coordinate transformation, Jacobian determinant, definition of tensors; contravariant, covariant and mixed tensors; tensor algebra, Riemannian Geometry, signature requirement, metric tensor, invariant volume, associated tensors. (10 lectures)

Tensor calculus: Parallel transport, covariant differentiation, Christoffel symbols; Geodesics equation.

Gradient, divergence, curl and Laplacian in terms of tensors. (6 lectures)

Reference Books:

1. Sokolnikoff : Tensor Analysis-Wiley Toppan

2. Lass : Vector and Tensors-McGraw Hill Kogakusha

3. Joshi :Matrices and Tensors-New Age International.

4. A.W. Joshi : Group theory.

5. Riley, Hobson and Bence Mathematical Methods for Physics and Engineering: A Comprehensive Guide.

6. Mathews and Walker: Mathematical Methods of Physics

7. Arfken and Weber: Mathematical methods for Physicists

8. Morse and Feshbach: Methods of Theoretical Physics

9. Pipes and Harvil: Applied Mathematics for Physicists and Engineers

10. Harper: Introduction to Mathematical Physics

11. Courant and Hilbert: Methods of Mathematical Physics –John Wiley.

12. Smirnov: Course on Higher Mathematics

13. Complex Analysis: A First Course with Applications" by Dennis G. Zill

PHY-VAC-449

Instrumentations & Techniques in Physics

(Value added course (VAC))

Gradation based evaluation

Course overview: Module-I of this course focuses on creating extreme environments required for clean, precise physics experiments. Module-II focuses on tools used to "see" and map material structures at the atomic and nanoscale, on probing the electronic. Module-III focuses on vibrational, and Module-IV focuses on chemical states of matter and high-energy physics, nuclear physics instrumentation, and large-scale facilities.

Course Learning Outcomes (CLOs): Upon successful completion of this course, students will be able to

CLO1: Design & Measure Vacuums: Engineer multi-stage systems to reach ultra-high vacuum conditions and select optimal gauges to monitor low-pressure gas behaviors.

CLO2: Resolve Material Structures: Determine crystal sizes, atomic arrangements, and surface topologies using advanced XRD, electron microscopes (SEM/TEM), and scanning probes (AFM/STM).

CLO3: Decode Molecular Spectroscopies: Identify chemical bonds, oxidation states, and spin environments by analyzing optical, vibrational (FTIR/Raman), surface (XPS), and magnetic resonance (NMR/ESR) data.

CLO4: Manipulate Beams & Detect Radiation: Model relativistic particle trajectories inside linear and circular accelerators, and select optimal detector arrays for high-resolution radiation spectroscopy.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1		✓	✓					
CLO2		✓	✓		✓			
CLO3		✓	✓					
CLO4		✓	✓		✓			

Course content:

Module – I

Vacuum Technology & Cryogenics:

Vacuum Science: Behaviour of gases at low pressures, mean free path, and pump throughput. (3 lectures)

Vacuum Pumps: Principles and operational ranges of Roughing pumps (Rotary, Sorption) and High/Ultra-High Vacuum (UHV) pumps (Diffusion, Turbo-molecular, Ion, and Cryo-pumps). (6 lectures)

Vacuum Measurement: Pirani, Penning, and Thermocouple gauges. (3 lectures)

Module – II

Structural & Morphological Characterization:

X-ray Techniques: X-ray diffraction (XRD) physics, Bragg's law, Laue method. Structure factor determination and estimation of crystallite size using the Scherrer formula. (5 lectures)

Electron Microscopy: Electron-matter interactions. Working principles: Scanning Electron Microscopy (SEM) & Energy Dispersive X-ray Spectroscopy (EDS), Transmission Electron Microscopy (TEM) & High-Resolution TEM (HRTEM) (6 lectures)

Scanning Probe Microscopy (SPM): Principles of Atomic Force Microscopy (AFM; Scanning Tunnelling Microscopy (STM) based on quantum tunnelling. (4 lectures)

Module – III

Analytical & Spectroscopic Techniques:

Optical Spectroscopy: UV-Visible-NIR Absorption spectroscopy (Beer-Lambert law), Photoluminescence (PL) spectroscopy (radiative transitions and excitons). (4 lectures)

Vibrational Spectroscopy: Fourier Transform Infrared (FTIR) spectroscopy and Raman Spectroscopy (Classical and Quantum theories, selection rules, and fingerprinting structures). (4 lectures)

Surface Analysis: X-ray Photoelectron Spectroscopy (XPS) for chemical state and composition analysis; Auger Electron Spectroscopy (AES). (4 lectures)

Magnetic Resonance: Principles of Nuclear Magnetic Resonance (NMR) and Electron Spin Resonance (ESR) spectroscopy. (3 lectures)

Module – IV

Types of Accelerators and Radiation Detection Techniques:

Fundamental Acceleration Mechanics: Lorentz Force in Accelerators, Electric fields for energy gain (E), magnetic fields for bending and focusing (B). (3 lectures)

Electrostatic Accelerators: Cockcroft-Walton Voltage Multiplier, Van de Graaff & Tandem Accelerators. (3 lectures)

Li**near Accelerators (Linacs):** Drift tube structures and RF voltage timing. Linacs (DTL): Resonant cavities, standing waves, and relativistic velocity matching. (3 lectures)

Cyclotron: Two hollow "Dees," constant magnetic field and constant RF frequency, Relativistic Limit: Mass increase causing loss of resonance. (3 lectures)

Storage Rings & Synchrotron Light Sources: Constant Radius Orbit; Synchronizing magnetic field strength and RF frequency with particle momentum, Insertion devices (Wigglers and Undulators) for producing bright X-ray beams. (3 lectures)

Radiation Detectors: Gas-filled detectors (Ionization chambers, Geiger-Müller counters), Scintillation detectors (NaI(Tl), plastic scintillators) coupled with PMTs, and Semiconductor detectors (HPGe, Si-Li) for high-resolution gamma and X-ray spectroscopy. (3 lectures)

Note: A Field visit may be conducted for either of the two modules to gain a comprehensive knowledge in the domain of the instruments.

Reference Books:

1. A. Roth — Vacuum Technology, North-Holland.
2. J. F. O'Hanlon — A User's Guide to Vacuum Technology, Wiley.
3. N. S. Harris — Modern Vacuum Practice, McGraw-Hill.
4. B. D. Cullity and S. R. Stock — Elements of X-Ray Diffraction, Pearson/Prentice Hall.
5. D. B. Williams and C. B. Carter — Transmission Electron Microscopy: A Textbook for Materials Science, Springer.
6. J. Goldstein et al. — Scanning Electron Microscopy and X-Ray Microanalysis, Springer.
7. C. Julian Chen — Introduction to Scanning Tunneling Microscopy, Oxford University Press.
8. C. N. Banwell and E. M. McCash — Fundamentals of Molecular Spectroscopy, McGraw-Hill.
9. N. B. Colthup, L. H. Daly, and S. E. Wiberley — Introduction to Infrared and Raman Spectroscopy, Academic Press.
10. D. Briggs and M. P. Seah (eds.) — Practical Surface Analysis: Auger and X-ray Photoelectron Spectroscopy, Wiley.
11. J. A. Weil and J. R. Bolton — Electron Paramagnetic Resonance: Elementary Theory and Practical Applications, Wiley.
12. Atta-ur-Rahman — Nuclear Magnetic Resonance, Springer.
13. Glenn F. Knoll — Radiation Detection and Measurement, Wiley. (the standard reference for detector physics)
14. S. Y. Lee — Accelerator Physics, World Scientific.
15. Klaus Wille — The Physics of Particle Accelerators: An Introduction, Oxford University Press.

Semester-II

PHY-IDS-451

Physics in the daily use instruments

(IDS: Inter-disciplinary)

Credit: 4 | Full Marks: 100

No of Lectures: 60 | Continuous Assessment: 40

Term end examination: 60

Course overview: This interdisciplinary course explores the physics underlying everyday household, medical, and personal-use instruments, bridging classical and modern physics with practical technology. Spanning four modules, it covers thermodynamics and electromagnetism in appliances like refrigerators, induction cooktops, microwave ovens, and motors; wave physics and optics in audio devices, cameras, and displays; the physics of home medical and safety instruments such as thermometers, pulse oximeters, and smoke detectors; and power storage, generation, and semiconductor technologies including batteries, solar panels, LEDs, and solid-state drives. By connecting core physics principles—thermodynamics, electromagnetism, optics, acoustics, nuclear physics, and quantum/semiconductor physics—to devices used in daily life, the course fosters applied, interdisciplinary scientific reasoning and equips students to understand the technology that surrounds them.

Course Learning Outcomes (CLOs): On successful completion of this course, students will be able to:

CLO1: Explain the physical principles (phase-change cooling, induction heating, electromagnetic induction, Lorentz force) governing the operation of refrigerators, air conditioners, induction cooktops, microwave ovens, motors, and transformers used in daily life.

CLO2: Describe the working principles of audio devices (microphones, speakers, piezoelectric buzzers, ultrasonic cleaners) and optical/display technologies (digital cameras, CMOS sensors, LCD/OLED/e-paper displays) based on wave physics and optics.

CLO3: Analyze the physical principles (thermistor response, blackbody radiation, Beer-Lambert law, oscillometry, radioactive decay, Tyndall scattering) underlying common home medical and safety instruments such as thermometers, pulse oximeters, blood pressure monitors, and smoke detectors.

CLO4: Explain the electrochemical, photovoltaic, and semiconductor principles behind batteries, solar panels, UPS systems, LEDs, and solid-state drives (SSDs), including quantum tunneling effects in flash memory.

CLO5: Correlate fundamental physics concepts (thermodynamics, electromagnetism, optics, nuclear physics, quantum mechanics, and semiconductor physics) with their practical, real-world implementation in everyday household and personal-use instruments.

CLO6: Develop the ability to critically evaluate and explain the working of unfamiliar household gadgets using foundational physics principles, fostering interdisciplinary and applied scientific thinking.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓				✓			
CLO2	✓				✓			
CLO3	✓				✓			
CLO4	✓				✓			
CLO5	✓				✓	✓		
CLO6					✓	✓		✓

Course content:

Module – I

Household Thermodynamics & Heat Transfer:

Refrigerators & Air Conditioners: Phase-change cooling, latent heat of vaporization, compressor cycles, and the Second Law of Thermodynamics. (4 lectures)

Induction Cooktops: Faraday's law of induction, high-frequency magnetic fields, and eddy currents generating localized heat directly in cookware. (4 lectures)

Electromagnetism in Household Appliances:

Microwave Ovens: Cavity magnetrons, dielectric heating, dipole rotation of water molecules, and standing wave nodes (why turntable plates rotate). (3 lectures)

Electric Motors & Transformers: Lorentz force; back-EMF in blenders, washing machines, and step-down transformers in wall chargers. (4lectures)

Module -II

Waves, Acoustics & Audio Electronics:

Microphones & Speakers: Electrodynamic transducers, piezoelectricity in buzzer alarms, and acoustic resonance. (4 lectures)

Ultrasonic Cleaners: High-frequency sound waves, fluid pressure differentials, and acoustic cavitation bubbles. (3 lectures)

Optics & Light Measurement:

Digital Camera: Convex lens systems, focal lengths, aperture stops, and the photoelectric effect in CMOS image sensors. (4 lectures)

Displays (LCD, OLED, e-Paper): Polarized light, liquid crystal birefringence, organic light-emitting diodes, and electrophoretic ink particle movement. (4 lectures)

Module – III

Medical & Diagnostic Instruments at Home:

Digital Thermometers: Thermistors (NTC/PTC temperature coefficients) vs. Infrared pyrometers (Blackbody radiation and Wien's displacement law). (3 lectures)

Pulse Oximeters: Beer-Lambert law—differential absorption of red (660 nm) and infrared (940 nm) light by oxygenated vs. deoxygenated haemoglobin. (3 lectures)

Blood Pressure Monitors: Oscillometric method—detecting arterial wall vibrations via pressure transducers. (3 lectures)

Nuclear Physics & Radiation in Safety Devices:

Ionization Smoke Detectors: Americium-241 (α - decay), air molecule ionization, steady current generation, and smoke particle interference. (3 lectures)

Optical Smoke Detectors: Tyndall scattering—smoke particles scattering infrared light beams into photodiode sensors. (3 lectures)

Module – IV

Power Storage, Generation & Smart Energy:

Batteries (Lithium-ion & Alkaline): Electrochemistry, redox reactions, ion diffusion across separators, and internal resistance. (3 lectures)

Rooftop Solar Panels: Photovoltaic effect, p-n junction energy band gaps, and DC-to-AC power inverters. (3 lectures)

Uninterruptible Power Supplies (UPS): Energy storage, relay switching speeds, and AC-DC-AC conversion. (3 lectures)

Modern Quantum & Semiconductor Gadgets:

LED Light: Electroluminescence, energy band gaps, and blue LEDs coated with yellow phosphor for white light output. (3 lectures)

Solid State Drives (SSDs): Quantum tunneling, floating-gate MOSFETs, and charge trapping in non-volatile flash memory. (3 lectures)

Reference Books:

1. Louis A. Bloomfield — How Things Work: The Physics of Everyday Life, Wiley
2. David Halliday, Robert Resnick, Jearl Walker — Fundamentals of Physics, Wiley
3. Richard Wolfson — Essential University Physics, Pearson
4. Yunus A. Çengel and Michael A. Boles — Thermodynamics: An Engineering Approach, McGraw Hill
5. P. K. Nag — Engineering Thermodynamics, McGraw Hill Education
6. David J. Griffiths — Introduction to Electrodynamics, Cambridge University Press
7. Millman and Halkias — Electronic Devices and Circuits, McGraw Hill
8. Irving L. Kosow — Electric Machinery and Transformers, Prentice Hall
9. Eugene Hecht — Optics, Pearson
10. Lawrence Kinsler et al. — Fundamentals of Acoustics, Wiley
11. S. M. Sze and Kwok K. Ng — Physics of Semiconductor Devices, Wiley
12. Ben G. Streetman and Sanjay Banerjee — Solid State Electronic Devices, Prentice Hall

13. Charles Kittel — Introduction to Solid State Physics, Wiley
14. Irving Kaplan — Nuclear Physics, Narosa Publishing House
15. Glenn F. Knoll — Radiation Detection and Measurement, Wiley
16. John G. Webster (Ed.) — Medical Instrumentation: Application and Design, Wiley
17. R. S. Khandpur — Handbook of Biomedical Instrumentation, McGraw Hill Education
18. B. H. Khan — Non-Conventional Energy Resources, McGraw Hill Education
19. Ned Mohan, Tore M. Undeland, William P. Robbins — Power Electronics: Converters, Applications, and Design, Wiley

PHY-MJR-452

Electronics

(Major)

Credit: 4 | Full Marks: 100

No of Lectures: 60 | Continuous Assessment: 30

Term end examination: 70

Course overview: This course covers analog and digital electronics across four modules, including power semiconductor devices and power circuits, operational amplifiers and IC fabrication, network analysis and analog modulation techniques (AM/FM), digital circuits and 8085 microprocessor fundamentals, and transmission lines with waveguides and microwave oscillators — providing students with a strong theoretical and practical foundation in circuit design, communication systems, and microwave engineering.

Course Learning Outcomes (CLOs): On completion of this course, students will be able to:

CLO1: Power Devices & Circuits: Explain the construction, characteristics, and operation of power semiconductor devices (MOSFET, CMOS, UJT, SCR, DIAC, TRIAC, IGBT) and analyze regulated power supplies, DC-DC converters, and SCR-based power control circuits.

CLO2: Operational Amplifiers & IC Fabrication: Design and analyze op-amp-based circuits (instrumentation amplifiers, integrators, differentiators, log/antilog amplifiers, active filters) and describe the monolithic IC fabrication process for BJTs, MOSFETs, and passive components.

CLO3: Network Analysis & Noise: Analyze passive filter networks (constant-k and m-derived filters) in terms of propagation constant and characteristic impedance, and evaluate noise sources and noise figure in electronic systems.

CLO4: Analog Modulation Techniques: Explain and compare amplitude and angle (FM/PM) modulation techniques, including generation and detection circuits, and evaluate their application in communication systems such as TV broadcasting.

CLO5: Digital Circuits & Data Conversion: Analyze D/A and A/D converter architectures (weighted resistor, R-2R ladder, successive approximation, dual-slope) and digital building blocks such as encoders, decoders, and tri-state devices.

CLO6: Microprocessor Fundamentals: Describe the architecture of the 8085 microprocessor (ALU, registers, flags, timing/machine cycles) and write basic assembly language programs, along with understanding memory addressing and interfacing concepts.

CLO7: Transmission Lines & Waveguides: Analyze transmission line parameters (characteristic impedance, propagation constant, VSWR, reflection coefficient) and explain wave propagation in rectangular/circular waveguides and microwave oscillator devices (klystron, magnetron).

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓				✓			
CLO2	✓				✓			
CLO3	✓				✓			
CLO4	✓				✓			
CLO5	✓		✓		✓			
CLO6	✓		✓		✓			
CLO7	✓				✓			

Course Content:

Module-I

Power semiconductor devices: MOSFET, CMOS, Power MOS, UJT, SCR, diac, triac, IGBT. (6 lectures)

Power circuits: Regulated power supply; basic concepts; series regulator using BJT and op-amp regulator; DC to DC converter; buck, boost and buck-boost converter, SMPS; Power control by SCR. (6 lectures)

Operational Amplifiers: Instrumentation amplifiers, Practical integrator and differentiator, Log and anti-log amplifier, Multiplier and Divider, RC active filters-first and second order low pass and high pass filter, band pass and band elimination filter. (5 lectures)

Integrated Circuit Fabrication: Monolithic Integrated-circuit technology, Planner process, fabrication of BJT, MOSFET, diodes, Integrated-circuit resistors, capacitors. (3 lectures)

Module-II

Network Analysis: Constant k low pass, high pass; band pass and band elimination filters, m derived filters, propagation constants, characteristic impedance for T and Π sections, neper and decibel. (3 lectures)

Noise: Different sources of noise; signal to noise ratio; definition and calculation of noise figure. (2 lectures)

Analog Modulation: Basic concepts of modulation, Different modulation techniques, Amplitude Modulation- sidebands; double sideband, single sideband and carrier suppressed mode of transmission; power relation; modulation index, typical circuits for generation and detection of amplitude modulated waves; envelope and average detection, generation and detection of suppressed carrier type AM signals. VSB AM and QAM technique in TV broadcasting. Angle Modulation- Concepts of frequency and phase modulation, Frequency spectrum; bandwidth; reactance tube and p-n junction methods of generation of FM waves; Armstrong system; demodulation by staggered tuned and Foster Seeley discriminator circuits, equivalence between PM and FM. (8 lectures)

Module-III

Digital circuits: D/A converters- Weighted Resistor, R-2R Ladder; A/D converters-parallel comparator, Successive Approximation, Dual-slope; Encoders, Decoders, tri-state devices. (3 lectures)

Elements of Microprocessors: Basic concepts, block diagram of 8085 µP, functions of ALU, Flags, ALE and different registers, instruction set, Assembly language programming, machine cycle- op-code fetch, memory read, memory write and timing diagram; Memory: FF or Latch as storage elements; array of memory elements; addressing of registers; memory map and address lines, absolute and partial decoding and multiple address ranges. (10 lectures)

Module-IV

Transmission Lines: Parallel wire and coaxial lines; transmission line equation; characteristic impedance; propagation constant; high frequency transmission lines; travelling wave interpretation; VSWR; Coefficient of reflection; principle of stub line matching; directional coupler. (6 lectures)

Waveguides and Microwaves oscillators: Fundamentals of waveguides- wave equations & Maxwell's equations, wave propagation modes; Rectangular and Circular waveguide- field analysis, cutoff frequency and dominant mode, power & attenuation; resonant cavities; reflex klystron; magnetron. (8 lectures)

Reference Books:

1. Malvino and Leach: Digital Principles and Applications – Tata McGraw Hill
2. Streetman: Solid State Electronic Devices – Prentice Hall India
3. Gaekwad: Op –Amps and Linear Integrated Circuits – Prentice Hall India
4. Taub and Schilling: Digital Integrated Electronics – McGraw Hill Kogakusha
5. Kennedy: Electronic Communication Systems – Tata McGraw Hill
6. D. Roy Chowdhuri and Jain, Linear Integrated Circuits, New Age International (P) Ltd.
7. Milman and Grable, Microelectronics. Tata McGraw-Hill
8. R P Jain, Modern Digital Electronics, Tata McGraw-Hill
9. J D Ryder, Electronic Fundamentals and applications, PHI
10. J D Ryder, Networks, Lines and Fields, PHI
11. Gaonkar: Microprocessor Architecture, Programming and Applications with 8085, PRI
12. Roddy and Coolen, Electronic Communications, Pearson
13. Samuel Y. Liao, Microwave Devices and Circuits, Pearson
14. B. C. Sarkar and S. Sarkar, Analog Electronics, Damodar Prakashani
15. B. C. Sarkar and S. Sarkar, Digital Electronics
16. Ram: Fundamentals of Microprocessors and Microcomputers – D. Rai and Sons
17. Sarkar: Microwave Propagation and Technique – S. Chand
18. Robert W. Erickson, D. Maksimovic, Fundamentals of power electronics, Kluwer Academic Publishers

PHY-MJR-453

General Practical-II

(Major)

Credit: 4

Full Marks: 100

Continuous Assessment: 25

Term end examination: 75

Course overview: This course provides hands-on mastery over radiation detection principles, optical interferometry, and atomic spectroscopy. Students explore the transition from classical wave theory to quantum mechanical behaviors. Also, it delivers foundational skills in analog circuit design, semiconductor performance analysis, and the thermodynamic profiling of nanostructured systems.

Course Learning Outcomes (CLOs): Upon successful completion of this practical course, students will be able to:

CLO1: Calibrate radiation detectors and quantify nuclear decay mechanics by isolating the Geiger-Müller plateau voltage and computing the half-life of long-lived isotopes (^{40}K) through Poisson and Gaussian statistical data tracking.

CLO2: Model radiation attenuation profiles across metallic barriers to determine material-specific mass absorption coefficients and deduce the maximum kinetic energy and range of beta/gamma emissions.

CLO3: Apply precise optical interferometry using a Michelson interferometer and Fabry-Perot etalon to measure sub-nanometer doublet separations ($\Delta\lambda$), determine thin-film refractive indices, and isolate magnetic field atomic orbital shifts (Zeeman Splitting).

CLO4: Map quantum states and atomic configurations using spectrometers to construct energy level diagrams, identify Rydberg series parameters, and isolate molecular dissociation energy boundaries.

CLO5: Synthesize and optimize power and signal conditioning circuits by building Zener/emitter-follower regulated DC power supplies and common-emitter AC amplifiers to extract line/load regulation rules and gain-bandwidth boundaries.

CLO6: Characterize multi-junction and industrial power semiconductor hardware including Diacs, Triacs, SCRs, UJTs, and FETs/MOSFETs configured as source-follower switches or relaxation multi-vibrators.

CLO7: Evaluate acoustic and thermal profiles of advanced fluids by computing sound velocities via ultrasonic interferometry alongside tracking the concentration-dependent thermal conductivity and viscosity scales of nanostructured fluids.

CLO8: Trace solid-state thermodynamic phase transitions by diagnosing tracking variables across metallic matrices to determine the precise ferromagnetic Curie temperature boundary of elemental Nickel.

CLO9: Examine data modeling and structural laboratory constraints by applying meticulous experimental error tracking, building data tables, and presenting physical systems clearly for advanced viva-voce and practical evaluation panels.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1		✓	✓					
CLO2			✓		✓			
CLO3		✓	✓					
CLO4		✓	✓					
CLO5			✓		✓			
CLO6			✓		✓			
CLO7			✓		✓			
CLO8			✓					
CLO9						✓	✓	

Course contents:

Nuclear Physics and Advanced Optics (Group A students only)

List of Experiments:

1. a) Determination of the Plateau region of a GM tube. (b) Analysis of statistical fluctuations at low and high count rates.
2. Determination of the half-life of a long lived radioactive sample (40K).
3. Study of gamma absorption in Aluminium and Lead using a GM tube and determination of the mass absorption coefficient.
4. Study of beta absorption in Aluminium using a GM tube and determination of range and energy of beta particles.
5. a) Calibration of a Michelson interferometer using Na-D lines as standard.
   b) Measurement of d between Na-D lines.
   c) Determination of refractive index/thickness of a thin sheet of a transparent material.
6. Study of spectra of Hydrogen atom using a constant deviation spectrograph/spectrometer, to identify the Rydberg series and to construct its energy level diagram.
7. Study of the molecular spectra of I2 in absorption and determination of the dissociation energy.
8. Study of emission spectra of Cu and to determine the energy diagram with possible transition.
9. Study of the Zeeman splitting of Na-D lines using a constant deviation spectroscope and Fabry-Perot etalon.

Electronics and Solid State Physics (Group B students only)

List of Experiments:

1. Construction of a power supply with semiconductor devices, zener diodes and using an emitter follower and to study its performance ripple factor, line and load regulations.
2. Construction of a single stage common emitter voltage amplifier, measurement of its gain, input and

output impedances and the determination of the gain-bandwidth product using R-C coupling.

3. Experiments on Diac, Triac, SCR and UJT
4. Design and construction of astable multivibrator and the study of its characteristics and performance.
5. Experiments on Modulation and demodulation.
6. Study the characteristics of FET and MOSFET and use of these as source followers.
7. OP-AMP based experiments
8. Study of velocity of sound by ultrasonic interferometer
9. Study of thermal conductivity of nanofluid.
10. Study of viscosity of nanofluid.
11. Study of ferromagnetic Curie temperature of nickel.

References:

1. Laboratory manual

PHY-MNR-454

Electrodynamics & Plasma

(Minor)

Credit: 4	Full Marks: 100
No of Lectures: 60	Continuous Assessment: 30
	Term end examination: 70

Course overview: This course offers an advanced treatment of classical electrodynamics and plasma physics, beginning with Maxwell's equations, conservation laws, gauge transformations, and the solution of inhomogeneous wave equations, before progressing through multipole radiation, the fields and radiation of moving and accelerated charges (including Larmor's formula, Bremsstrahlung, and Cerenkov radiation), and radiation scattering phenomena, and concluding with an introduction to magnetohydrodynamics and plasma physics — covering Alfvén waves, plasma oscillations, and Debye screening — to build a rigorous foundation in the theory of electromagnetic fields and their application to charged-particle and plasma systems.

Course Learning Outcomes (CLOs): By the end of this course, students will be able to:

CLO1: Derive and apply Maxwell's equations and Poynting's theorem, and use conservation of linear and angular momentum via Maxwell's stress tensor to analyze electromagnetic field systems.

CLO2: Apply scalar and vector potentials with gauge transformations (Lorentz and Coulomb gauge) to solve inhomogeneous wave equations using Green's function methods, and interpret retarded/advanced solutions and multipole expansions of localized charge distributions.

CLO3: Analyze electric and magnetic dipole and quadrupole radiation from localized oscillating sources using the Hertz potential and multipole expansion of the electromagnetic field.

CLO4: Apply Liénard-Wiechert potentials to determine the fields of uniformly moving and accelerated charges, and use Larmor's formula (and its relativistic generalization) to analyze radiation from parallel and circular accelerations, including Bremsstrahlung and Cerenkov radiation.

CLO5: Explain the concept of radiation reaction and electromagnetic mass in the context of accelerated charges.

CLO6: Analyze radiation damping and scattering of electromagnetic waves by free and harmonically bound electrons, and evaluate coherent and incoherent scattering from systems of charges, including Bragg diffraction.

CLO7: Apply MHD equations to conducting fluids in magnetic fields, and explain concepts such as flux freezing, magnetic pressure, magnetic viscosity, and the pinch effect.

CLO8: Analyze plasma phenomena including Alfvén waves, plasma oscillations, and Debye screening to characterize the collective behavior of charged particles in a plasma.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓				✓			
CLO2	✓				✓			
CLO3	✓				✓			
CLO4	✓				✓			
CLO5	✓							
CLO6	✓				✓			
CLO7	✓				✓			
CLO8	✓				✓			

Course content:

Module-I

Electromagnetic Fields: Maxwell's equations & Poynting's theorem (mention only), Conservation of linear and angular momentum - Maxwell's stress tensor, scalar and vector potentials, gauge transformations- Lorentz gauge and Coulomb gauge, the inhomogeneous wave equations - solution of inhomogeneous wave equations by Green's function; retarded and advanced solutions; Multipole expansion of localized charge distributions, Magnetic monopole. (15 Lectures)

Module-II

Multipole Radiations: Electric and magnetic dipole field and radiation of a localized oscillating source; Hertz potential and corresponding field equations; Multipole expansion of the electromagnetic field; Electric quadrupole radiations; Sources of multipole radiation-multipole moment. (6 Lectures)

Moving Charge: Lienard-Wiechert potentials, the field of a uniformly moving point charge; convection potential and virtual photons. (3 Lectures)

Radiation from an Accelerated Charge: Fields of an accelerated charge; angular and frequency distributions of the emitted radiation; special cases of acceleration-parallel and perpendicular (circular orbit) to velocity; Larmor's formula and its relativistic generalization; Bremsstrahlung; Cerenkov radiation; radiation reaction; electromagnetic mass. (8 Lectures)

Module-III

Scattering: Radiation damping; scattering by a free electron; scattering and absorption of radiation by a harmonically bound electron; scattering of electromagnetic waves from a system of charges, coherent and incoherent Bragg diffraction. (14 lectures)

Module-IV

Magneto-hydrodynamics and Plasma Physics: Conducting fluid in a magnetic field; freezing in of lines of force; MHD equations; magnetic pressure; magnetic viscosity; pinch effect; Alfven waves; plasma oscillations; screened potential and Debye length. (14 Lectures)

Reference Books:

1. Classical Electrodynamics – J. D. Jackson – John Wiley & Sons
2. Introduction to Electrodynamics – David J. Griffiths – Pearson Education / Addison-Wesley

3. The Classical Theory of Fields (Vol. 2) – L. D. Landau & E. M. Lifshitz – Pergamon Press / Butterworth-Heinemann
4. Electrodynamics of Particles and Plasmas – P. C. Clemmow & J. P. Dougherty – Addison-Wesley / Cambridge University Press (reprints)
5. Introduction to Plasma Physics – R. J. Goldston & P. H. Rutherford – Institute of Physics Publishing (IOP)
6. Principles of Plasma Electrodynamics – A. F. Alexandrov, L. S. Bogdankevich, A. A. Rukhadze – Springer-Verlag
7. Electrodynamics and Plasma Physics – Dr. Subhasish Chatterjee – Laxmi Publications

PHY-MNR-455

Nuclear and Particle Physics

(Minor)

Credit: 4 | Full Marks: 100
No of Lectures: 60 | Continuous Assessment: 30
Term end examination: 70

Course overview: This course provides a comprehensive post graduate-level study of nuclear and particle physics, progressing from foundational nuclear properties, models, and decay processes to the structure of complex nuclei, nuclear reactions, and fission/fusion phenomena, before culminating in an introduction to particle physics, including relativistic kinematics, discrete symmetries, and the quark model — equipping students with the theoretical tools and conceptual framework needed to understand and analyze nuclear stability, nuclear transformations, and the fundamental constituents of matter.

Course Learning Outcomes (CLOs): On successful completion of this course, students will be able to:

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

CLO1: Explain basic nuclear properties (mass, charge, parity, isospin, binding energy) and apply the Liquid Drop Model, semi-empirical mass formula, and Fermi Gas Model to predict nuclear stability and structure.

CLO2: Analyze α, β, and γ decay using barrier penetration theory (Gamow's theory), Fermi's theory of beta decay, and selection rules; interpret Kurie plots and log ft values.

CLO3: Describe how charged particles interact with matter and evaluate detector principles used for energy measurement and particle identification.

CLO4: Analyze the deuteron and nucleon-nucleon (n-p, p-p, n-n) scattering systems using square-well potentials, effective range theory, and concepts of charge symmetry/independence.

CLO5: Compare the Shell Model and Collective Model of the nucleus, and use them to explain magic numbers, ground-state spins/parities, magnetic moments, and vibrational/rotational spectra.

CLO6: Classify nuclear reactions, apply conservation laws and Q-value kinematics, and distinguish compound-nucleus versus direct reaction mechanisms using cross-section formalism (including the Breit-Wigner formula).

CLO7: Explain the mechanisms of nuclear fission (Bohr-Wheeler theory) and fusion, and relate these processes to energy generation and nucleosynthesis in stars.

CLO8: Apply relativistic kinematics and Mandelstam variables, and explain discrete symmetries (parity, charge conjugation, time reversal, CPT) and their role in particle interactions.

CLO9: Use the Gell-Mann–Nishijima formula, quark model, and quantum number conservation to classify baryons, mesons, and their resonances, including charm/beauty/truth quarks.

CLO10: Explain the role of neutrinos in parity non-conservation (Wu's experiment), muon decay and time dilation, and distinguish between different neutrino types.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓							
CLO2	✓				✓			
CLO3	✓	✓	✓					
CLO4	✓				✓			
CLO5	✓							
CLO6	✓				✓			
CLO7	✓				✓			
CLO8	✓							
CLO9	✓							
CLO10	✓					✓		

Course content:

Module-I

Basic nuclear properties: mass; Change; parity; isospin; binding energy; separation energy. **Nuclear size:** Rutherford scattering, electron scattering and form factors, charge density radius and potential radius, Wood-Saxon potential, experimental methods of determination.

Static Electric and Magnetic Moments of a Nucleus; magnetic dipole and electric quadrupole moments. experimental determination. (5 lectures)

Liquid Drop Model: properties of the model; the semi-empirical mass formula and its application to considerations of nuclear stability, Degenerate Fermi Gas Model applications. **Nuclear Disintegrations:** Nuclear Emission: Penetration of potential barrier; nature of barrier for neutrons, protons and alpha particles; Gamow's theory of alpha disintegration and calculation of reduced widths and decay half-lives. Beta Decay- Fermi theory; Kurie plot; log fτ values, classification and selection rules; Gamma disintegration and selection rule. (8 lectures)

Interaction of charged particles with matter: ionization formula, range-energy relationship, charged particle detectors, energy measurement and identification of charged particles. (2 lectures)

Module-II

Deuteron: Properties of the deuteron; ground and excited states of deuteron with square-well potential; deuteron radius and probability. (2 lectures)

Scattering Problem: **n-p** scattering at low energies; effective range formula and scattering length, shape-independent approximation; modification of effective range for deuteron bound state; scattering by hard sphere and finite square-well potential. **p-p scattering** at low energies; identity of particles, antisymmetrization of wavefunction; comparison with n-p scattering; interference between nuclear and Coulomb forces; effective range. **n-n scattering**; charge-independence and charge symmetry, mirror nuclei, exchange forces and saturation, repulsive core; Relative stability of the *n-n*, *n-p*, and *p-p* systems. (7 lectures)

Structure of Complex Nuclei: **Shell Model**: Evidence of shell structure; magic numbers; effective single particle potentials (square-well and harmonic oscillator); extreme single-particle model- its successes and failures in predicting ground state spin, parity and magnetic moments; Nordheim's rules; Schmidt limits, anomalous magnetic moments of nucleons and qualitative discussions about their origin. **Collective Model**: Evidence of collective motion; nature of vibrational and rotational spectra; qualitative discussion in terms of phonons and rigid rotators; quadrupole moments of deformed even-even nucleus. (7 lectures)

Module-III

Nuclear Reactions: Classification; conservation principles; kinematics and Q-values; exoergic and endorgic reactions; threshold energy, Experimental setup; cross sections – elastic, inelastic, reaction, total; principle of detailed balance; Partial wave method of calculating cross sections. **Compound Nuclear Reactions:** characteristics; resonance and compound nucleus formation; one level Breit Wigner formula; **Direct Reactions:** characteristics; types of direct reactions with examples elastic, inelastic, transfer, stripping, pick-up, knock on and break-up reactions (qualitative discussion with example). (9 lectures)

Nuclear Fission: Spontaneous and induced fissions; elementary discussion of Bohr-Wheeler theory; barrier penetration and decay rates in fission; mass distribution of decay products; fission isomers. (4 lectures)

Nuclear Fusion and thermo nuclear reaction: Source of energy in stars, Nucleo-synthesis. (2 lectures)

Module-IV

Brief history of particle discovery, Relativistic Kinematics and Mandelstam variables. parity; charge conjugation and charge parity; G-parity, time reversal invariance and the principle of detailed balance; CPT theorem (statement only) and its consequences; strangeness; Gell-Mann Nishijima formula; hypercharge; Properties of Charged Pions and Muons decay modes: measurement of charge, spin, parity, lifetime of pions and muons. (8 lectures)

Methods of determination of mass, spin, parity and other quantum numbers of other particles (Principles only). quark structure of baryons and mesons; charm, beauty and truth prediction of Ω; mass formula; baryon and meson resonances, quarkonium; Pauli principle and the colour of quarks. Gluons as mediators in quark quark interaction. Role of Neutrino in parity non-conservation in beta decay; Wu's experiment, Muon Decay and time dilation, Different types of neutrinos. (7 lectures)

Reference Books:

1. M. K. Pal: Theory of Nuclear structure (EWA press)
2. Cohen: Concepts of Nuclear Physics (Tata McGraw Hill)
3. Wong: Introductory Nuclear Physics (Prentice Hall)
4. Blatt and Weiskopff : Theoretical Nuclear Physics (Dover)
5. Evans: The Atomic Nucleus (McGraw Hill)

6. Roy and Nigam: Nuclear Physics (New Age International)
7. S. N. Ghoshal: Nuclear Physics (S Chand Publication)
8. Preston and Bhaduri: Structure of the Nucleus (Levant Books)
9. Y.M. Jana: An Introduction to Nuclear Physics (Narosa, New Delhi)
10. Krane: Introductory Nuclear Physics (Wiley India, New Delhi).
11. D. Griffiths: Introduction to Elementary Particles (Wiley-VCH) — widely regarded as the most accessible entry point; excellent for Mandelstam variables, quark model, and conservation laws.
12. D. H. Perkins: Introduction to High Energy Physics (Cambridge University Press) — strong on experimental methods, symmetries, and neutrino physics.
13. Arthur Beiser, Concepts of Modern Physics, McGraw Hill.

PHY-SEC-456

Concept of Renewable Energy: Generation and Storage

(SEC)

Credit: 4 | Full Marks: 100

No of Lectures: 60 | Continuous Assessment: 30

Term end examination: 70

Course overview: This Skill Enhancement Course introduces M.Sc. Physics students to the fundamental principles, technologies, and practical aspects of renewable energy generation and storage. The course covers solar, wind, biomass, and other renewable energy sources, along with modern energy storage systems such as batteries, fuel cells, and supercapacitors, equipping students with applied, employability-oriented knowledge relevant to the growing clean-energy sector.

Course Learning Outcomes (CLOs): On successful completion of this course, students will be able to:

CLO1: Explain the physical principles underlying solar photovoltaic and solar thermal energy conversion and evaluate the performance of solar cell/module systems.

CLO2: Describe the working principles and resource assessment methods for wind, biomass, geothermal, tidal, and hydrogen-based renewable energy systems.

CLO3: Analyze and compare various energy storage technologies (batteries, fuel cells, supercapacitors, mechanical and thermal storage) based on their working principles and performance parameters.

CLO4: Assess the challenges and strategies for integrating renewable energy sources into conventional and smart grid systems.

CLO5: Evaluate the environmental, economic, and policy dimensions of renewable energy deployment, including national/international initiatives.

CLO6: Apply conceptual and analytical skills developed in the course to identify suitable renewable energy and storage solutions for real-world applications, supporting skill-based employability in the clean energy sector.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	✓				✓			
CLO2	✓				✓			
CLO3	✓		✓		✓			
CLO4					✓	✓		
CLO5						✓	✓	
CLO6					✓			✓

Course Content:

Module I

Solar Energy-Principles and Technologies:

Solar radiation: spectrum, insolation, solar constant; Photovoltaic effect; Solar cell materials- silicon, thin film, perovskite; I-V characteristics, fill factor and efficiency of solar cells; Solar photovoltaic

(SPV) system components- panel, charge controller, inverter, battery; Grid-connected and stand-alone SPV systems; Solar thermal energy- flat plate and concentrating collectors; Solar water heating and solar cookers; Applications and challenges in solar energy adoption. (15 lectures)

Module II

Wind, Biomass and Other Renewable Sources:

Wind energy: origin, wind resource assessment, wind turbine types (horizontal and vertical axis); Power in wind, Betz limit, tip speed ratio; Wind farm siting and grid integration; Biomass energy: sources, biochemical and thermochemical conversion (biogas, biodiesel, gasification, pyrolysis); Geothermal energy: sources and utilization; Tidal, wave and ocean thermal energy conversion (OTEC); Small hydro power; Hydrogen as a renewable energy carrier- production methods (electrolysis, steam reforming). (15 lectures)

Module III

Energy Storage Technologies:

Need and classification of energy storage systems; Electrochemical storage- lead-acid, lithium-ion, sodium-ion, and solid-state batteries- working principles, construction, and performance parameters; Fuel cells- types (PEMFC, SOFC), working principle and applications; Supercapacitors- principle, electrode materials and applications; Mechanical storage- pumped hydro, compressed air energy storage (CAES), flywheel storage; Thermal energy storage- sensible, latent, and thermochemical storage. (15 lectures)

Module IV

Grid Integration, Policy and Sustainability:

Smart grids and microgrids; Integration of renewable energy with conventional grid- challenges of intermittency and grid stability; Energy management systems; Net metering and feed-in tariffs; Government policies and schemes on renewable energy (national and international overview); Environmental and economic impact of renewable energy; Life cycle assessment of renewable energy systems; Emerging trends- green hydrogen economy, floating solar, offshore wind. (15 lectures)

Reference Books:

1. G. N. Tiwari and M. K. Ghosal, Renewable Energy Resources: Basic Principles and Applications, Narosa Publishing House

2. B. H. Khan, Non-Conventional Energy Resources, McGraw Hill Education

3. Godfrey Boyle, Renewable Energy: Power for a Sustainable Future, Oxford University Press

4. C. S. Solanki, Renewable Energy Technologies: A Practical Guide for Beginners, PHI Learning

5. J. Twidell and T. Weir, Renewable Energy Resources, Routledge

6. D. Linden and T. B. Reddy, Handbook of Batteries, McGraw Hill

7. Ryan O'Hayre et al., Fuel Cell Fundamentals, Wiley

PHY-VAC-499

Entrepreneurship and Start-up in Physics

(Value added course (VAC))

Gradation based evaluation

Course overview: This course is aimed to guide students from physics research to a funded startup. It covers entrepreneurial fundamentals and India's innovation ecosystem (Module I), commercializing physics technologies like semiconductors, quantum tech, and photonics (Module II), intellectual property and regulatory frameworks (Module III), business model development and startup formation (Module IV), and venture funding and scaling strategies (Module V). By the end, students can identify commercialization opportunities in physics research, build business models, navigate IP and financing, and prepare startup proposals.

Course Learning Outcomes (CLOs): Upon completion of the course, students will be able to:

CLO1: Understand the fundamentals of entrepreneurship and innovation in science and technology sectors.

CLO2: Identify commercialization opportunities arising from physics research.

CLO3: Develop business models for physics-based products and services.

CLO4: Understand intellectual property rights, technology transfer, and startup financing.

CLO5: Prepare startup proposals and business plans based on scientific innovations.

CLO6: Explore national and international innovation ecosystems supporting deep-tech ventures.

PLO and CLO mapping:

CLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1								✓
CLO2					✓			✓
CLO3					✓			✓
CLO4							✓	✓
CLO5						✓		✓
CLO6								✓

Course content:

Module I

Introduction to Entrepreneurship and Innovation Ecosystem:

Entrepreneurship Fundamentals: Concepts and significance, Entrepreneurial mindset and leadership, Types of entrepreneurship -Technology entrepreneurship, Social entrepreneurship, Academic entrepreneurship, Deep-tech entrepreneurship **Innovation Ecosystem:** Innovation and economic development, Startup ecosystem in India, Innovation-driven entrepreneurship, Role of universities and research institutions **Government Initiatives:** Startup India, Make in India , Atal Innovation Mission , National Deep Tech Startup Policy, Technology Development Board (TDB), BIRAC, DST, SERB, NRF initiatives (7 lectures)

Physics Innovations and Technology Commercialization:

Research to Innovation: Translational research, Technology Readiness Levels (TRL), Innovation lifecycle **Physics-Based Technologies:** Semiconductor technologies, Nanotechnology, Quantum technologies, Photonics and lasers, Sensors and instrumentation, Renewable energy technologies, Advanced materials, Scientific computing and AI applications. **Technology Transfer:** Laboratory to market, University-industry collaboration, Licensing and commercialization pathways. **Product Development:** Problem identification, Customer discovery, Value proposition design (8 lectures)

Module II

Intellectual Property Rights and Regulatory Framework:

Intellectual Property Rights (IPR): Patents, Copyrights, Trademarks, Trade secrets, Industrial designs. **Patent System:** Patentability criteria, Patent search, Patent drafting basics, Filing procedures. **Technology Protection:** Freedom-to-operate analysis, Licensing agreements, Technology transfer agreements. **Regulatory Aspects:** Standards and certification, Regulatory approvals, Ethics in technology entrepreneurship (15 lectures)

Module III

Startup Creation and Business Development:

Business Models: Business Model Canvas, Lean Startup Methodology, Design Thinking, Customer validation. **Market Analysis:** Market research techniques, Competitive analysis, Technology market assessment. **Startup Formation:** Company registration, Legal structures, Team building, Co-founder agreements. **Financial Planning:** Revenue models, Cost estimation, Pricing strategies, Break-even analysis. **Risk Assessment:** Technical risks, Market risks, Financial risks (15 lectures)

Module IV

Funding, Venture Capital and Startup Scaling:

Startup Financing: Bootstrapping, Angel investment, Venture capital, Corporate funding. **Government Funding Opportunities:** NIDHI Program, DST Seed Support, Technology Incubation Schemes, Innovation Grants. **Investor Relations:** Investor expectations, Due diligence, Pitch deck preparation. **Startup Growth:** Scaling strategies, Product diversification, Internationalization, Exit strategies (15 lectures)

Reference Books:

1. Dr. Kalpana Sankar, The Scientist Entrepreneur: Empowering Millions of Women

2. Nistha Tripathi and Varun Aggarwal, Futurepreneurs: 10 Deeptech & AI Startups Redefining Tech in India

3. B.V.R. Mohan Reddy, Engineered in India: From Dreams to Billion-Dollar Cyient

4. Davide Iannuzzi, Entrepreneurship for Physicists: A Practical Guide to Move Inventions from University to Market, IOP Concise Physics

5. Lita Nelsen and Maureen Stancik Boyce, Launching from the Lab: Building a Deep-Tech Startup, MIT Press
6. Michael Szycher, Commercialization Secrets for Scientists and Engineers
7. Bill Aulet, Disciplined Entrepreneurship: 24 Steps to a Successful Startup
8. Eric Ries, The Lean Startup, Crown Business (Crown Publishing Group / Random House)
9. Rajeev Roy, Entrepreneurship (3rd Edition), Oxford University Press (OUP India)
10. Kashyap Deorah, The Golden Tap: The Inside Story of Hyper-Funded Indian Startups, Roli Books
11. S.S. Khanka, Entrepreneurial Development, S. Chand Publishing
12. Poornima M. Charantimath, Entrepreneurship Development and Small Business Enterprises, Pearson Education
13. Rupinder Tewari & Mamta Bhardwaj, Intellectual Property: A Primer for Academia, Publication Bureau, Panjab University (DST-supported)