# DEPARTMENT OF PHYSICS AND MATERIALS SCIENCE

# MSc (Physics)
# Trimester System

# SCHEME AND SYLLABUS

## Academic Year (2026-2027)

**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**Specializations:**

- **(i) Nuclear Physics**
- **(ii) Condensed Matter Physics**

**Program Objectives:**

- To understand the underlying physics in respective specializations and be able to teach and guide successfully.
- To introduce advanced ideas and techniques that are applicable in respective fields.
- To develop human resources with a solid foundation in theoretical and experimental aspects of respective specializations as preparation for careers in academia and industry.

**Program Outcomes:**

Students will understand:

- Fundamentals and advancements in nuclear physics and their applications in nuclear reactors, accelerators, and medicine.
- Fundamentals and advancements in electronics and their applications in electronic devices.
- Fundamental and electromagnetic properties of materials, their characterization techniques, as well as advancements in nanomaterials.

## Course Scheme

| | Course Code | Course Name | L | T | P | Credits | Total Credits |
|---|---|---|---|---|---|---|---|
| **Term I** | PHY101 | Mathematical Methods in Physics | 4 | 1 | 0 | 4.5 | **20.5*** |
| | PHY102 | Classical Mechanics | 4 | 1 | 0 | 4.5 | |
| | PHY103 | Electronics | 4 | 1 | 0 | 4.5 | |
| | PHY104 | AI for Physics | 4 | 0 | 0 | 4.0 | |
| | PHY105 | Lab – I | 0 | 0 | 6 | 3.0 | |
| ***Includes self-effort of 3 h / week.** | | | | | | | |
| **Term II** | PHY201 | Quantum Mechanics | 4 | 1 | 0 | 4.5 | **21*** |
| | PHY202 | Electrodynamics | 4 | 1 | 0 | 4.5 | |
| | PHY203 | Condensed Matter Physics | 4 | 1 | 0 | 4.5 | |
| | PHY204 | Nuclear and Particle Physics | 4 | 1 | 0 | 4.5 | |
| | PHY205 | Lab - II | 0 | 0 | 6 | 3.0 | |
| ***Includes self-effort of 3 h / week.** | | | | | | | |
| **Term III** | PHY301 | Atomic & Molecular Physics | 4 | 1 | 0 | 4.5 | **19** |
| | PHY302 | Statistical Mechanics | 4 | 1 | 0 | 4.5 | |
| | | Elective – I | 3 | 1 | 0 | 3.5 | |
| | | Elective - II | 3 | 1 | 0 | 3.5 | |
| | PHY305 | Lab - III | 0 | 0 | 6 | 3.0 | |
| ***Includes self-effort of 3 h / week.** | | | | | | | |
| **Term IV** | PHY401 | Computational Methods | 3 | 1 | 0 | 3.5 | **17.5** |
| | | Elective – III | 3 | 1 | 0 | 3.5 | |
| | | Elective – IV | 3 | 1 | 0 | 3.5 | |
| | PHY404 | Summer Internship | - | - | - | 2.0 | |
| | PHY405 | Lab - IV | 0 | 0 | 6 | 3.0 | |
| | PHY406 | Seminar (Literature review) | - | - | - | 2.0 | |
| ***Includes self-effort of 3.5 h / week.** | | | | | | | |
| **Term V** | PHY501 | Dissertation Seminar | - | - | - | 4.0 | **04** |
| **Term VI** | PHY601 | Dissertation | - | - | - | 12.0 | **16** |
| **Total** | | | | | | | **94** |

**Student must choose one of the following specialisations:**

| | **Specialisation in Nuclear Physics** | | **Specialisation in Condensed Matter Physics** | |
|---|---|---|---|---|
| **Elective** | **Course Code** | **Course Name** | **Course Code** | **Course Name** |
| I | PHY303 | Particle Physics | PHY306 | Advance Condensed Matter Physics |
| II | PHY304 | Radiation Technology | PHY307 | Characterization Techniques |
| III | PHY402 | Advance Nuclear Physics | PHY406 | Semiconductor Physics |
| IV | PHY403 | Nuclear Reactor Physics | PHY407 | Physics of Nanomaterials |

**Note: Self-effort hours will be evaluated by means of minor project / assignment / literature review / seminar, etc.**

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**MATHEMATICAL PHYSICS**

**PHY101**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives:** To impart knowledge about various mathematical tools employed to study physics problems.

**Syllabus:**

**Course Objectives:** To impart knowledge about various mathematical tools employed to study physics problems.

**Linear Algebra:** Vector Spaces, Bases and linear independence, dimensionality, inner product, similarity transformations, orthogonal matrices, Hermitian matrices, unitary matrices, Eigenvalues and eigenvectors, Matrix diagonalization.

**Complex Variables:** Introduction, Cauchy-Riemann conditions, Cauchy's Integral formula, Laurent expansion, Singularities, Calculus of residues.

**Differential Equations:** Second order homogeneous and non-homogeneous equation with constant coefficients and variable coefficients, Series solutions, Partial differential equations of theoretical physics, Separation of variables.

**Special Function:** Legendre functions: generating function, Recurrence relations and special properties, Orthogonality; Hermite functions, Laguerre functions; Dirac-delta functions, Beta functions, Gamma functions and their basic properties; Bessel functions, Generating function, Orthogonality.

**Fourier and Laplace Transforms:** Fourier series and their applications, Dirichlet conditions, Gibbs phenomenon, Fourier and Laplace transforms, their respective inverse transforms, Application of transforms in solving differential equations.

**Tensors:** Scalar, Vector and tensor quantities, Contravariant and covariant tensors, Addition, multiplication and contraction of tensors, Application of tensors in coordinate transformations.

**Group Theory:** Concept of group, Multiplication table for discrete group, Lie groups, generators, U(1), SU(2), SU(3).

**Course Learning Outcomes:** Students will have developed the ability to:

1. use frequently occurring matrices in physics
2. use complex numbers and variables.
3. solve differential equations of second order especially with variable coefficients to study special functions and their properties.

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4. perform fourier series expansion and obtain Fourier and Laplace transforms.
5. explain tensor and its basic operations.
6. describe the basics of Group Theory.

***Recommended Books:***


1. *Arfken G. and Weber H. J., Mathematical Methods for Physicists, Academic Press, (2005).*
2. *Rajput B. S., Mathematical Physics, Pragati Prakashan, (2002).*
3. *Boas M. L. Mathematical Methods in the Physical Sciences, John Wiley & Sons, New York, (1983).*
4. *Harper C. Analytical Mathematics in Physics, Prentice Hall, (1999).*

**CLASSICAL MECHANICS**

**PHY102**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives**

Develop a comprehensive understanding of Newtonian, Lagrangian, and Hamiltonian mechanics and apply these principles to analyze the motion of particles, rigid bodies, oscillatory systems, central force problems, and wave motion in physical systems.

**Syllabus:**

**Unit 1: Newtonian Mechanics**

One- and many-particle systems, Conservation of linear and angular momentum, Work-energy theorem.

**Unit 2: System of Particles**

Constraints, D'Alembert principle, Principle of virtual work, Degree of freedom, Generalized coordinates and momenta, Lagrange's equation and application of linear harmonic oscillator, Simple pendulum and central force problems, Cyclic coordinate, Symmetries and conservation laws, Hamiltonian, Lagrange's equation from Hamilton's Principle, Principle of least action derivation of equation of motion, variation and end points.

**Unit 3: Central Force**

Reduction of the two-body problem into a single-body problem. Definition and characteristics of central force; Closure and stability of circular orbits. General analysis of orbits: bounded and unbounded orbits, Kepler's law of motion, scattering in the center of mass and laboratory frame of reference, Rutherford scattering.

**Unit 4: Rigid Body Dynamics**

Rigid Body Dynamics: Eulerian angle, Inertia tensor, Principal moment of inertia. Euler's equation of motion of a rigid body, Force-free motion of a symmetrical top.

**Unit 5: Canonical Transformation**

Canonical transformation, Legendre Transformation, Generating functions. Conditions for a transformation to be canonical, Hamilton-Jacobi equation, Hamilton's principle, and characteristic functions, Action and action angle variables

**Unit 6: Wave Motion**

Small oscillations, Normal modes, and normal coordinates. Examples: Two coupled pendulums, Vibration of a linear tri-atomic molecule, Dispersion relation.

**Course Learning Outcomes:**

The students will be able to:

1. apply Newtonian and Lagrangian mechanics to analyze the motion of particles and systems under various force fields.
2. analyze central force motion, orbital dynamics, and scattering phenomena using conservation laws and analytical methods.
3. evaluate rotational dynamics of rigid bodies and apply Hamiltonian mechanics, canonical transformations, and Hamilton–Jacobi theory.
4. analyze small oscillations, normal modes, coupled systems, and wave propagation in mechanical systems.

**Recommended Books:**

1. Goldstein, H., Classical Mechanics, Pearson Education, (2007)
2. Rana, N.C. and Joag, P.S., Classical Mechanics, Tata McGraw-Hill, (2017).
3. Takwale, R. G. and Puranik, P. S., Introduction to Classical Mechanics, Tata McGraw-Hill (2017).

**ELECTRONICS**

**PHY103**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives:**

To provide theoretical knowledge in transistor circuit design, Operational amplifiers and digital system design

**Syllabus:**

**Semiconductor Devices and their applications**: Introduction to transistors like MOSFET, BJT etc., Applications of transistors as a switch, clipper and power amplifier.

**Operational Amplifiers:** Operational Amplifier, Differential Amplifier, Transfer and frequency characteristics, Compensation in Operational Amplifiers, Application of OP-AMP as adder, Multiplier, Differentiator, Integrator, Log and Antilog Amplifier.

**Logic circuits:** Standard gate assemblies, Parallel and Serial operations, Combinational logic circuits- Seven segment display circuits, Decoder, Multiplexer, Encoder, Sequential logic circuits- Flip-flops, Registers, Counters, Synchronous and Asynchronous circuit.

**Memory systems:** Read Only Memory, Random Access Memory, Applications of ROM and RAM, Memory Storage cell, Read, Write and Address operations.

**DAC/ ADC circuits:** Digital to Analog Converters- Weighted resistor and 2R Ladder type, analog to digital Converters- ramp and flash ADC.

**Course Learning Outcomes:**

The students will be able to:

1. design and analyse transistor-based circuits for applications such as switching, clipping, and power amplification in electronic systems.
2. design operational amplifier-based circuits.
3. design digital circuits based on flip-flops, encoders, decoders, multiplexers, registers, and counters.
4. describe the architecture and operation of ROM, RAM, and memory storage cells, including read and write operations.
5. analyse the working principles and design of analog-to-digital (A/D) and digital-to-analog (D/A) converters.

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**Recommended Books**


1. *Millman, J. and Taub, H., Pulse Digital and Switching Wave forms, Tata McGraw Hill, (1991).*
2. *Boylestad, R.L. and Nashelsky, L., Electronic Devices and Circuit Theory, Prentice Hall of India, (2007).*
3. Mano M., Digital Logic and computer Design, PHI (2004).
4. Tocci R. J., Digital Systems-Principles and Applications, Prentice Hall of India (2002).

**AI FOR PHYSICS**

**PHY104**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 0 | 0 | 4 |

**Course Objectives:**

1. To develop a conceptual understanding of Artificial Intelligence, Machine Learning, Deep Learning, and Neural Networks without requiring any programming background.

2. To introduce ethical frameworks, data privacy regulations, and governance standards for responsible AI use in scientific research.

3. To familiarise real-world applications of AI in Physics, including particle physics, condensed matter, and materials science.

**Syllabus:**

**UNIT I**: **Understanding AI: From Basics to Modern Tools**: Define "intelligence" in machines. Brief history: Turing Test, chess-playing computers, AI winters. Narrow AI vs General AI. Everyday AI: search engines, voice assistants; Key vocabulary: algorithm, data, model, prediction; **Neural Networks, Deep Learning, and Modern AI**: artificial neurons and connected layers; neural network (NN) - the "black box" intuition. What is "deep" in Artificial Learning?; Different types of NN: CNN, RNN, GAN, Autoencoder, Transformers and RBM and thier application (definition only). **AI Tools, Chatbots, and Prompt Engineering:** Large Language Models (LLMs), Overview of popular AI tools: ChatGPT, Gemini, Claude, Copilot; Hallucinations, reasoning failures, and knowledge limits of current AI; Prompt engineering.

**UNIT II**: **Introduction to AI Ethics**: Principles of fairness, accountability, transparency, privacy and explainability; AI Governance, Societal Impact, and Scientific Ethics; Data Privacy, Governance and and Standards: DPDP Act (India), GDPR (EU), EU AI Act, National Strategy for AI (India) and NIST AI RMF (USA); Explainable AI (XAI); Safety-by-Design in AI; AI Policy and Case Resolution.

**UNIT III**: **AI Applications in Physics**: Physics-Informed Neural Networks (PINNs); AI in Particle Physics and Astrophysics; AI in Condensed Matter, Materials Science, and Quantum Computing.

**Course Learning Outcomes:**

After completing this course students will be able to:

**1.** Explain the fundamental concepts and taxonomy of AI.

**2.** Critically analyse the ethical, legal, and governance dimensions of AI technologies.

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**3.** Identify and describe applications of AI techniques in physical sciences

**Recommended Books:**

**1.** Stuart Russell & Peter Norvig, Artificial Intelligence: A Modern Approach (4th Edition, Pearson, 2021).

**2.** Patrick Henry Winston, Artificial Intelligence (3rd Edition, Addison-Wesley, 1992).

**3.** Rajendra Akerkar, Introduction to Artificial Intelligence (2$^{nd}$ Edition, PHI Learning, 2022).

**4.** Mehta, P. et al., *A High-Bias, Low-Variance Introduction to Machine Learning for Physicists*, Physics Reports, 810, 1–124 (2019).

**5.** Carleo, G. et al., *Machine Learning and the Physical Sciences*, Reviews of Modern Physics, 91(4), 045002 (2019).

**Approved by Academic Council in its 4$^{th}$ meeting held on 5$^{th}$ June 2026.**

**LAB-I**

**PHY105**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 6 | 3 |

**Course Objectives:**

To experimentally realize analog and digital electronics circuits**.**

**Syllabus**

**List of Experiments:**

1. To study the switching characteristics of a transistor (NPN & PNP).
2. Study the static drain and transfer characteristics (dynamic resistance of drain, mutual conductance and amplification factor) of a JFET at a given operating point.
3. Study the forward and reverse characteristics of given p-n junctions (at least 2) and determine materials constants, bandgap, variation of junction capacitance and the nature of the junction (abrupt/linearly graded).
4. Gain and frequency characteristics of a double stage RC coupled BJT amplifier.
5. To study MOSFET as output power amplifier and plot the static drain characteristics.
6. Study the mathematical operations and frequency response of the given operational amplifier.
7. Study the input and output characteristics of a differential amplifier.
8. To construct logic gates AND, NOT, EX-NOR and EX-OR using NANAD gates and verify their truth tables.
9. To design and construct multiplexer and demultiplexer and verify their truth tables.
10. To study the fundamentals of basic memory units and to become familiar with various types of flip-flops and verifying the Truth tables of Flip- Flops.
11. To study BCD to binary decoder and encoder
12. To study binary to seven segment decoder.
13. To design various flip-flops (R-S, D-, T-, J-K, J_K master slave) using gates and verify their truth tables.
14. To design and construct Half/Full adder and subtractor circuits.
15. To study the working of a 4-bit comparator and adder/subtractor chips.
16. To construct and study various ripple counters using J-K flip-flops.
17. To construct and study various synchronous counters using J-K flip-flops.
18. To construct and study various registers using J-K flip-flops.
19. To study 4-bit and 8-bit DAC for various $V_{ref}$.
20. To study and understand the working of the given 4-bit ADC.

**Course learning outcomes:** Students will have achieved the ability to:

1. design and evaluate different transistor-based applications.
2. design and evaluate various Op-Amp circuits for mathematical operations.
3. analyze the fundamental components of the digital circuits like flip-flops, adder, encoders *etc.*
4. design and analyze various counters and registers.
5. evaluate given ADC and DAC circuits.

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**QUANTUM MECHANICS**

**PPH201**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives:** To understand the basic subtleties of quantum mechanics and use Schrodinger equation to understand the complex behavior of various quantum mechanical systems

**Syllabus:**

**Schrödinger wave equation:** Introduction to Quantum Mechanics, Schrödinger's time independent and time dependent wave equation, Interpretation and normalization of wave function, Wave packet, Probability density, Expectation value and Ehrenfest theorem, Generalized uncertainty principle.

**Solution of Schrödinger equation:** Constant potential in one dimension: Potential Step, Rectangular Potential Barrier and tunneling, Linear Harmonic Oscillator, Rigid Rotator and Hydrogen atom.

**Angular momentum in Quantum mechanics:** General solution of the angular momentum Eigen value problems and the angular momentum matrices, Eigenvectors for spin ½ particles, Addition of two angular momenta, Clebsch-Gordan coefficient, System of identical particles, Indistinguishability principle, Symmetry of wave functions, Connection of symmetry with spin and statistics.

**Perturbation theory:** *Time independent perturbation theory:* Nondegenerate case: First order perturbation, second order perturbation, Perturbation of harmonic oscillator. Degenerate case*:* Removal of degeneracy in second order, Zeeman Effect without electron spin, first order Stark effect in Hydrogen. *Time dependent perturbation theory:* The equation of motion in interaction picture, Transition probability and Fermi-Golden Rule, Selection Rules of transitions.

**Theory of Scattering:** Scattering cross sections of microscopic objects using Partial wave method and Phase shift, Born approximation, Concept of WKB approximation.

**Course Learning Outcomes:** The students will have achieved the ability to:

1. explain the probabilistic yet deterministic nature of quantum world.
2. calculate the physical properties (position/momenta/energies) of quantum systems.
3. apply different approximation methods to complex quantum phenomena.
4. Explore the scattering phenomena of quantum entities.

***Recommended Books:***


1. *Schiff, L.I., Quantum Mechanics, McGraw Hill (2008)*
2. *Thankapan, V.K., Quantum Mechanics, New Age International (2004).*
3. *Ghatak, A. and Loknathan, S., Quantum Mechanics, MacMillan (2004).*


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4. *Sakurai, J.J., Advanced Quantum Mechanics, Pearson Education (2007)*

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**ELECTRODYNAMICS**

**PHY202**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives:** To apprise the students regarding the concepts of electrodynamics and Maxwell equations and use them in various situations.

**Syllabus**

**Boundary Value Problems**: Uniqueness Theorem, Dirichlet or Neumann Boundary conditions, solution of Electrostatic & Magnetostatic Boundary value problems.

**Maxwell Equations, Energy flow and Potentials**: Maxwell equations, Poynting's Theorem, scalar and vector potentials, Gauge transformation, Lorentz and Coulomb gauges, Hertz potential.

**Electromagnetic Waves:** Electromagnetic waves in free space and isotropic dielectrics, Polarization, Energy transmitted by a plane wave, Waves in conducting media, Skin depth. Reflection and Refraction of electromagnetic waves at plane interface, Fresnel's amplitude relations. Reflection and transmission coefficients, Polarization by reflection. Brewster's angle, Total internal reflection, EM waveguides, TE, TM and TEM waves, Energy flow and attenuation in Rectangular wave guides, Cavity resonators (conceptual).

**Radiation and Charged Particle Motion:** Radiation from localized oscillating sources; electric dipole and quadrupole radiation; centre-fed linear antenna; non-relativistic and relativistic motion of charged particles in electric and magnetic fields; adiabatic invariance.

**Course learning outcomes:** Students will have achieved the ability to:

1. solve boundary value problems in electrostatics and magnetostatics.
2. use Maxwell equations in analyzing the electromagnetic field due to time varying charge and current distribution.
3. describe the nature of electromagnetic wave and its propagation through different media and interfaces.
4. explain charged particle dynamics and radiation from localized time varying electromagnetic sources.

***Recommended Books:***


1. *Griffiths, D. J., Introduction to Electrodynamics, Dorling Kingsley, (1998).*
2. *Jackson, J.D., Classical Electrodynamics, Wiley Eastern, (1999).*


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3. *Puri, S.P., Classical Electrodynamics, Tata McGrawHill, (1999).*
4. *Jordan, E.C. and Balmain, K.G., Electromagnetic Wave and radiating systems, Prentice Hall of India, (2007).*

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**CONDENSED MATTER PHYSICS**

**PHY203**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives:** To study some of the basic properties of the condensed phase of matter especially solids.

**Syllabus:**

**Electrical Conductivity and Free Electron Fermi gas:** Drude theory, DC conductivity, Hall effect and magneto-resistance, AC conductivity, thermal conductivity, Fermi-Dirac distribution, Free electron gas in three dimension, thermal properties of an electron gas, Wiedemann-Franz law.

**Thermal Properties:** Quantization of elastic waves: Phonon, Classical theory of Specific heat. Average energy of harmonic oscillator, Phonon Density of states. Einstein and Debye models of specific heat. Electronic contribution to specific heat. Anharmonic effect: thermal expansion, Phonon collision process, Thermal conductivity.

**Concept of Energy Band:** Nearly free electron model and origin of energy gap, magnitude of gap, Bloch function, Kronig-Penny model, Wave equation of electron in periodic potential, Bloch theorem and crystal momentum, Classification of metal, insulator and semiconductors.

**Dielectrics:** Dielectric properties of insulators, Types of polarizations, Local field, Claussius-Mossotti equation, Dielectric constant and loss.

**Magnetism:** Types of magnetism, Susceptibility, Permeability and their relation. Diamagnetism: Langevin Quantum theory of Diamagnetism. Paramagnetism: Quantum Theory, Paramagnetism of rare earth and iron group ions, Crystal field Splitting and quenching of orbital angular momentum. Paramagnetism of conduction electrons**.** Ferromagnetism, Ferrimagnetism and Antiferromagnetism: Curie point and exchange integral, saturation magnetization. Ferromagnetic Domains and their origin.

**Superconductivity:** Superconductivity, critical temperature, Meissner effect, Destruction of superconductivity by magnetic field, Type I and type II superconductors, Isotope effect, energy gap, London equation, London penetration depth, BCS theory of superconductivity, Coherence length.

**Course learning outcomes:** Students will have achieved the ability to:

1. contrast the electrical properties of solids using classical and quantum free electron theories.
2. evaluate and predict the thermal properties of solids.
3. explain the concept of energy bands and analyze their influence on the electrical properties of solids.

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4. predict the dielectric properties of insulators.
5. describe and interpret different magnetic phenomena, their underlying physics, characteristics, and technological applications.
6. explain the phenomenon of superconductivity, including its properties, key parameters related to potential applications.

***Recommended Books***


1. *Kittel, C., Introduction to Solid State Physics, John Willey, (2007).*
2. *Omar, M.A., Elementary Solid State Physics, Pearson Education, (1999).*
3. *Srivastava, J.P., Elements of Solid State Physics, Prentice Hall of India, (2008).*
4. *Ashcroft, N.W. and Mermin, N.D., Solid State Physics, Cengage Learning, (2008).*
5. *Dekker, A.J., Solid State Physics, Macmillan, (2003).*

**NUCLEAR AND PARTICLE PHYSICS**

**PHY204**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives**: To impart knowledge about concepts, properties and interactions related to nuclear and particle physics.

**Syllabus:**

**Nuclear Size and Shape:** Scattering and electromagnetic methods for determining the nuclear radius, Wave mechanical properties of nucleus and statistics, Nuclear angular momentum and Parity, Electric and magnetic moments, nuclear deformations and shapes, Nuclear excited states.

**Nuclear Forces:** Types of nuclear potentials, Ground and excited states of deuteron, Exchange forces and mass formula, n-p scattering at low energies, Scattering length, Spin dependence of n-p scattering, effective range theory in n-p scattering, Meson theory of nuclear forces.

**Nuclear Models:** Liquid drop model, coupling of angular momenta, Extreme single particle model and analysis of its predictions, Spin-orbit coupling, Magnetic moment, Electric quadrupole moment, Collective model (qualitative).

**Nuclear Reactions:** Type of reactions, reaction cross section, conservation laws, Q-values and its significance, Coulomb excitation, compound nucleus, energy of excitation.

**Particle Physics**

Particle Classification: Fermions and bosons, Particles and antiparticles, Quarks and leptons, HEP Natural Units, Bound states of quarks, Mesons and Baryons. Fundamental interaction of quarks, Forces and conservations laws: Isospin, Parity, strangeness, hypercharge, Charge conjugation, Time reversal invariance. Quark Model: CP violation, CPT invariance, QCD and Gellman Nishijima Formula, Relativistic Quantum Mechanics (Qualitative).

**Course learning outcomes:** Students will be able to:

1. explain the ground state properties of the nucleus for study of the nuclear structure behavior.
2. explain the deuteron behavior at ground and excited states. Nucleon-Nucleon scattering.
3. demonstration of the shell model and collective model descriptions.
4. understand various aspects of nuclear reactions.
5. understand the basics of particle physics and interactions.

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**Recommended Books**


1. *Roy, R.R. and Nigam, B.P., Nuclear Physics, New Age International Ltd., (2001).*
2. *Tayal, D. C., Nuclear Physics, Himalaya Publication home, (2007).*
3. *Kaplan Irving, Nuclear Physics, Narosa Publishing House, (2000).*
4. *Krane, K.S. Nuclear Physics, Wiley India Pvt. Ltd., (2008).*
5. *Griffith, D. , Introduction to Elementary Particle Physics.*

**LAB-II**

**PHY205**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 6 | 3 |

**Course Objectives:** Apply standard characterization and analysis methods to investigate the electrical, magnetic, dielectric, thermal, mechanical, and superconducting properties of materials.

**List of Experiments:**

1. Investigation of Hall Voltage as a function of current and magnetic field and determination of Hall Coefficient and carrier concentration of the given sample of semiconductor.
2. Study of magneto resistance behavior of semiconductors/manganites.
3. Investigation of Four probe and two probe resistance measurement and determination of contact resistance.
4. Investigation of B-H curve: (i) to determine the value of permeability and coercivity of ferrite sample. (ii) to distinguish between soft and hard ferrites.
5. Investigation of ferroelectric behavior of $BaTiO_3$.
6. To determine the Curie temperature of given ferrite sample.
7. To determine the dielectric constant of PCB laminate.
8. To determine the Young's modulus of brass using ultrasonic interferometer.
9. Studies on the thermoluminescence of KCl/KBr single crystal sample and determination of activation energy and color centers.
10. Determination of Tc for the given superconductivity material.
11. Determination of Stefan-Boltzmann constant.
12. To determine the first excitation potential of gas (Argon) by Frank-Hertz experiment.
13. Determine the resistivity of the given metal thin film sample and determine its temperature coefficient of resistance using four probe method.
14. Investigate thermoelectric properties of materials.

**Course learning outcomes:** Students will have achieved the ability to:

1. measure Hall coefficient, resistance and magnetoresistance of a given sample.
2. determine the Curie temperatures of ferroelectric and ferrite samples.
3. investigate the B-H curves of ferro/ferri magnetic materials
4. measure the dielectric constant of a dielectric material.
5. determine the Young's modulus of a given metal/metal alloy using ultrasonic interferometer.

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**ATOMIC AND MOLECULAR PHYSICS**

**PHY301**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives:** To learn atomic spectroscopy of one and two valance electrons atoms, molecular spectroscopy of diatomic molecules and resonance spectroscopy.

**Syllabus:**

**One Electron Atom**: Vector model of a one electron atom, Quantum states of an electron in an atom, Hydrogen atom spectrum, Spin-orbit coupling, Relativistic correction, Hydrogen fine structure, Spectroscopic terms, Hyperfine structure.

**Two valance Electrons Atom**: Vector model for two valance electrons atom, LS coupling, Pauli exclusion principle, Interaction energy for LS coupling, Lande interval rule, jj coupling, interaction energy for jj coupling.

**Atom in Magnetic Field**: Zeeman effect, Magnetic moment of a bound electron, Magnetic interaction energy in weak field. Paschen-Back effect, Magnetic interaction energy in strong field.

**Molecular Spectroscopy**: Rotational and vibrational spectra of diatomic molecule, Raman Spectra, Electronic spectra, Born-Oppenheimer approximation, Vibrational coarse structure, Franck-Condon principle, Rotational fine structure of electronic-vibration transitions, ESR, NMR.

**Course Learning Outcomes:** Students will be able to

1. Explain the atomic spectroscopy of one- and two-valence electron atoms.
2. Interpret the changes in atomic behavior under the influence of externally applied magnetic fields.
3. Differentiate the rotational, vibrational, electronic, and Raman spectra of molecules.
4. Describe the principles of electron spin resonance (ESR) and nuclear magnetic resonance (NMR) spectroscopy.

**Recommended Books:**

**1.** H. E. *White, Introduction to Atomic Spectra, McGraw Hill, (1934).*

**2**. C. N. *Banwell and E. M. McCash, Fundamentals of molecular spectroscopy, Tata McGraw Hill,* (1995).

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**STATISTICAL MECHANICS**

**PHY302**

| L | T | P | Credit |
|---|---|---|---|
| 4 | 1 | 0 | 4.5 |

**Course Objectives:**

1. To introduce the statistical basis of thermodynamics and the macro-micro connection.

2. To develop understanding of microcanonical, canonical, and grand canonical ensemble theories.

3. To familiarize students with quantum statistics (Bose-Einstein and Fermi-Dirac distributions).

**Syllabus:**

**The Statistical Basis of Thermodynamics**: The macroscopic and microscopic states, contact between statistics and thermodynamics, classical ideal gas, Gibbs paradox and its solution.

**Ensemble Theory:** Phase space and Liouville's Theorem, The microcanonical ensemble theory and its application to ideal gas of monatomic particles, Partition function, Classical ideal gas in canonical ensemble theory, Energy fluctuations, Equipartition and virial theorems, A system of harmonic oscillators as canonical ensemble, Thermodynamics of magnetic systems and negative temperatures, The grand canonical ensemble and significance of statistical quantities. Classical ideal gas in grand canonical ensemble theory. Density and energy fluctuations.

**Ideal Bose Systems:** Basic concepts and thermodynamic behaviour of an ideal Bose gas, Bose- Einstein condensation, Discussion of gas of photons (the radiation fields) and phonons (The Debye field), Liquid helium and super fluidity.

**Ideal Fermi Systems**: Thermodynamic behaviour of an ideal Fermi gas, Discussion of heat capacity of a free-electron gas at low temperatures, Pauli paramagnetism.

**Course Learning Outcomes:**

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

1. Describe the statistical basis of thermodynamics

2. Compare microcanonical, canonical, and grand canonical ensembles and apply them to derive thermodynamic properties.

3. Distinguish between classical, Bose-Einstein, and Fermi-Dirac statistics.

4. Analyze ideal Bose and Fermi gas behavior and apply it to explain BEC, and Pauli paramagnetism.

**Recommended Books:**

1. Pathria, R.K., Statistical Mechanics, Butterworth-Heinemann, (1996)

2. Reif, F., Fundamentals of Statistical and Thermal Physics, Waveland, (2008).

**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**PHYSICS LAB-III**

**PHY305**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 6 | 3 |

**Course Objectives:** To expose the students to various detectors in nuclear and particle physics so that they can investigate various relevant aspects and be confident to handle sophisticated instruments and analyze the data.

**List of Experiments:**

1. Dead time of a Geiger Muller (GM) Counter (Two source method).
2. Dead time of a Geiger Muller (GM) Counter (Absorber method).
3. To determine the operating voltage of a PMT and to find the photo peak efficiency of a NaI (Tl) crystal of given dimension for ϒ rays of different energies.
4. To calibrate a ϒ ray spectrometer and to determine the energy of a given gamma ray source.
5. Pulse height ϒ ray spectrum with multi-channel analyzer.
6. Energy resolution of a NaI (Tl) detector.
7. To verify the inverse square law with $^{137}$Cs source.
8. To study Compton scattering using ϒ rays of suitable energy.
9. To study the time resolution of a coincidence setup.
10. To determine ϒ ray attenuation coefficient for different metals.
11. To study the relationship between thickness of absorber and backscattering using GM counter.
12. To study the shielding effect of radiation penetrability.
13. To study anisotropy of ϒ ray cascade emission in $^{60}$Co source.
14. To determine the half-life of a radioactive sample.
15. Simple simulations in FOARTRAN90 for nuclear physics.
16. Studies on the Electric Spin Resonance spectrum of the given DPPH sample and determination of Lande *g* factor.
17. Studies on the NMR spectrum of ethyl benzene in $CDCl_3$ and obtain the $^1$H NMR spectrum and obtain the chemical shift and multiplicity.

**Course learning outcomes:** Students will have achieved the ability to:

1. operate a GM counter and Scintillation counter with MCA.
2. determination of mass absorption coefficient for the given material, variation of resolution with energy and activity of the given gamma source.
3. determine $1/r^2$ law and the decay statistics for the given beta and gamma sources.
4. design and run simulations for nuclear physics problems in FORTRAN90.
5. handle nuclear materials and nuclear safely management.
6. analyse and interpret experimental data using graphs.

**COMPUTATIONAL METHODS**

**PHY401**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objectives:** To learn computer programming using FORTRAN 90, solve physics problems through different numerical techniques and use computer programming for simulation and data analysis

**Syllabus:**

**Introduction:** Flow charts; Fortran 90: Integer and Floating point arithmetic**,** Operators and Expressions, While, Do-While, For loops, Arrays and Strings, Functions, I/O with files**.**

**Root Finding Methods**: Non-linear and transcendental equations: Secant Method, False Position, Newton-Raphson Method; Convergence of solutions; Solution of simultaneous linear equations, Gauss Elimination, pivoting, iterative method

**Interpolation and Approximation**: Introduction to interpolation, Lagrange approximation, Newton polynomials, Curve fitting by least squares, Polynomial least squares and cubic splines fitting.

**Numerical Differentiation and Integration**: Numerical differentiation, Quadrature, Simpson's rule, Gauss's quadrature formula, Newton-Cotes formula.

**Differential Equations**: Euler's method, Runge-Kutta methods.

**Random Variables and Monte Carlo Methods**: Random numbers, Pseudo-random numbers, Monte Carlo integration, Monte Carlo Simulations: Buffen's needle experiment, Importance of sampling

**Course Outcomes**: Students will be able to

1. Solve simple computational problems in physics using FORTRAN 90 programming.
2. Use numerical techniques for solving non-linear and transcendental equations; interpolation, numerical integration, and solve differential equation.
3. Generate pseduo-random numbers and implement Monte Carlo methods.

***Recommended Books:***


1. *Mathews, J.H., Numerical Methods for Mathematics, Science and Engineering, Prentice-Hall, (2000).*
2. *Rajaraman, V., Computer programming in Fortran 90 and 95, Prentice-Hall of India, (2008).*
3. *Salaria, R.S., Programming in Fortran, Khanna Publishing, (2008).*
4. *William H. Press, Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery, Numerical Recipes: The Art of Scientific Computing, Cambridge University Press, (2007).*


**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**LAB-IV**

**PHY405**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 6 | 3 |

**Course Objective:** The student is able to use computer programming for simulation and data analysis.

**Laboratory Assignments:**

1. To find mean, standard deviation and frequency distribution of an actual data set from any physics experiment.
2. To determine Wien's constant using bisection method and false position method.
3. To solve Kepler's equation by Newton-Raphson method.
4. To solve van der Waals gas equation for volume of a real gas by the method of successive approximation.
5. To interpolate a real data set from an experiment using the Lagrange's method, and Newton's method of forward differences and cubic splines.
6. To fit Einstein's photoelectric equation to a realistic data set and hence calculate Planck's constant.
7. To find the area of a unit circle by Monte Carlo integration.
8. To simulate nuclear radio activity using Monte Carlo Method.
9. To study the motion of an artificial satellite by solving Newton's equation for its orbit using Euler method.
10. To study the growth and decay of current in RL circuit containing (a) DC source and (b) AC using Runge Kutta method.

**Course Outcomes**: Students will be able to

1. write computer programs using FORTRAN 90.
2. use different numerical methods to solve problems using computer programs.
3. simulate physical systems using Monte Carlo Method.

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**PARTICLE PHYSICS**

**PHY303**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objectives:** To develop an advanced understanding of elementary particles, fundamental interactions and their governing principles, including the concepts of fields, symmetries and conservation laws in particle physics.

**Syllabus:**

**Introduction:** Introduction to elementary particles and their classification, fermions and bosons, quarks and leptons, hadrons, mesons and baryons, fundamental interactions, HEP units, symmetries and conservation laws, parity, charge conjugation, time reversal invariance, CP violation and CPT theorem.

**Relativistic Quantum Mechanics:** Klein-Gordon equation, Dirac equation and its plane wave solutions, solution of Klein Gordan equation for a particle with Coulomb potential, significance of negative energy solutions, spin angular momentum of the Dirac particle

**Strong Interactions:** Interactions and fields in particle physics, Classical and quantum pictures, Invariance in classical mechanics and in quantum mechanics. Types of symmetries and their breaking, Quantum chromodynamics QCD, Global and gauge invariance Feynman diagrams, Feynman rules, Path integration method: Wick's Theorem. Scattering matrix.

**Hadron-Hadron Interactions:** Cross section and decay rates, Pion spin, Isospin, Two-nucleon system, Pion-nucleon system, Strangeness and Isospin, and Hypercharge.

**Static Quark model of Hadrons:** The Eightfold way, Meson nonet, Baryon octet, Baryon Decuplet, hypothesis of quarks, SU (3) symmetry, Quark spin and color, Quark-antiquark combinations.

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**Weak Interactions:** Classification of weak interactions, Fermi theory, Parity non-conservation in β-decay, Helicity of neutrino, Experimental verification of parity violation.

**Course learning outcomes:** Students will be able to:

1. explain elementary particles, fundamental interactions, symmetries, and conservation laws.
2. apply Klein–Gordon and Dirac equations in relativistic quantum mechanics.
3. analyse strong interactions using QCD, gauge invariance, and Feynman diagrams.
4. describe hadron interactions using isospin, strangeness, and decay processes.
5. classify hadrons using quark model and SU(3) symmetry.
6. explain weak interactions, β-decay, and parity violation.

***Recommended Books***


1. *Perkins, D.H., Introduction to High Energy Physics, Cambridge University Press, (2000).*
2. *Hughes, I.S., Elementary Particles, Cambridge University Press, (1991).*
3. *Close, F.E., Introduction to Quarks and Partons, Academic Press, (1979).*
4. *Segre, E., Nuclei and Particles, Benjamin-Cummings, (1977).*
5. *Khanna, M.P., Introduction to Particle Physics, Prentice-Hall of India, (2004).*


**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**RADIATION TECHNOLOGY**

**PHY304**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objectives:** To impart knowledge in depth about nuclear radiation, its detection, nuclear spectrometry and related safety aspects

**Syllabus:**

**Interactions of Nuclear Radiations:** Origin and energy spectra, Brief discussion of interactions of gamma rays, Electron and heavy charged particles with matter.

**Nuclear Radiation Detector:** Gas filled detectors; Ionization chamber, Proportional counter and GM counter, Scintillation detector, semiconductor detector, neutron detector.

**Nuclear Spectrometry and Applications:** Measurement of nuclear energy levels, spins, parities, moments, internal conversion coefficients, Angular correlation, perturbed angular correlation, measurement of g-factor and hyperfine fields, Mossbauer Effect, Positron annihilation, particle and photon induced x-ray emission, Elemental concentration analysis by charged particles and neutron activation analysis.

**Safety Aspects**: Radiation exposure & monitoring, Radiation dose unit, Safety limits, Dose calculations, Design consideration of simple shields. Diagnostic nuclear medicine, Therapeutic nuclear medicine.

**Course learning outcomes:** Students will be able to:

1. describe nuclear radiation interactions.
2. explain the working of various radiation detectors.
3. explain various aspects of nuclear spectrometry.
4. identify the concepts of radiation doses and related safety measures.

**Recommended Books:**


1. *Knoll G. F., Radiation Detection and Measurement, John Wiley & Sons, (2010).*


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2. *Singuru R. M., Introduction to experimental nuclear physics, Wiley Eastern Publications, (1987).*
3. *Muraleedhara V. Nuclear radiation Detection, measurement and Analysis, Narosa Publishing House, (2009).*

**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**ADVANCED NUCLEAR PHYSICS**

**PHY402**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objectives**: To impart knowledge about nuclear deformations, and advance nuclear models for understanding of related reaction dynamics. Besides this, students will be exposed to heavy ion physics and nuclear astrophysics.

**Syllabus:**

**Exotic Nuclear Systems:** Weakly bound Nuclei and their interactions, Importance of Exotic nuclear systems, halo shapes and Radioactive ion beams, bubble nuclei, Nuclear Molecule.

**Collective Model of Nucleus:** Effect of quadrupole deformations and higher multipole deformations, Limitation of Shell model, Collective model, Identification of rotational and vibrational nuclei and their properties. Multi Phonon coupling, Nilsson model, Cranking shell model.

**Heavy-Ion Physics:** Fusion fission dynamics, tightly and loosely bound interactions, nuclear isomers, Nuclear Dynamics at low, Intermediate and high energies, Relativistic heavy ion collisions. Super heavy nuclei.

**Nuclear Astrophysics:** Hot big bang cosmology, Stellar nucleosynthesis, energy production in stars, pp chain, CNO cycle.

**Course learning outcomes:** Students will be able to:

1. understand exotic nucleus system.
2. explain collective description of nuclear behavior.
3. examine dynamics of heavy-ion reactions.
4. understand basic aspects of astrophysics.

***Recommended Books:***


1. *Pal, M.K., Theory of Nuclear Structure, East-West Press Delhi, (1983).*
2. *Preston M. A. and Bhaduri R. K., Structure of Nucleus Addison-Wesley, (2000).*


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3. *Lilley J.S.,Nuclear physics principles and applications John Wiley & sons Ltd., (2007).*
4. *Krane K.S. Nuclear Physics, Wiley India Pvt. Ltd., (2008).*

## NUCLEAR REACTOR PHYSICS

## PHY403

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objectives:** To impart knowledge on core fundamentals about nuclear reactors and related topics.

**Syllabus:**

**Neutron moderation:** Elastic and Inelastic scattering, moderating ratio, slowing down Density, Resonance escape, Moderators.

**Fission Process and diffusion theory:** Prompt neutrons, Fast fission, Fission energy, Thermal utilization, Fission products, Chain reaction, Multiplication factor, Leakage of neutrons, Critical size, Diffusion and slowing down theory, Homogenous and heterogeneous reactors.

**Materials for Nuclear Reactors:** Fuel materials, Moderator and Reflectors, Cladding materials, Coolants and control Rods. Fertile, fissionable and fissile materials.

**Type of Power reactors:** Boiling water reactors, Pressurized water reactors, pressurized heavy water reactors, Light water cooled graphite moderated reactors, Gas cooled reactors, Advanced gas cooled reactors, High temperature gas cooled reactors and liquid metal cooled reactors and Fast breeder reactors, Plasma production and its diagnosis, Present status of fusion reactors and their impact on energy production.

**Fuel and waste management:** Fuel management schemes, Fuel composition, Fuel cycle cost and waste management.

**Course Outcomes:** Students will be able to:

1. study the neutron moderation process.
2. apply diffusion theory for fusion-fission dynamics.
3. select materials relevant for reactor design and energy production.
4. categorize different nuclear reactors.
5. analyze fuel and waste management.

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***Recommended Books:***

1. *Glasstons, Sammuel and Sesonske, Alexander, Nuclear reactor Engineer, CBS Publishers & Distributors, (2004).*
2. *Lamarshs, J.R., Introduction to Nuclear Reactor Theory, Addison-Wesley Publishing Co., (1966).*

## ADVANCED CONDENSED MATTER PHYSICS

## PHY306

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objectives:** To study some of the advanced properties of the condensed phase of matter especially solids.

**Syllabus:**

**Energy Band and Fermi Surface:** Construction of Fermi Surface. Experimental methods of Fermi surface determination: Quantization of Orbits, Landau Levels, De Haas-van Alphen effect and its application for determination of Fermi surface of copper, Cyclotron resonance method for semiconductors and metals, Magnetoresistance method.

**Lattice Vibrations:** Vibration of lattice with monoatomic and diatomic basis: Dispersion relation, optical and acoustical branches.

**Magnetism:** Types of magnetism, Susceptibility, Permeability and their relation. Diamagnetism: Langevin Quantum theory of Diamagnetism. Paramagnetism: Quantum Theory, Paramagnetism of rare earth and iron group ions, Crystal field Splitting and quenching of orbital angular momentum. Paramagnetism of conduction electrons**.** Ferromagnetism, Ferrimagnetism and Antiferromagnetism: Curie point and exchange integral, saturation magnetization. Ferromagnetic Domains and their origin.

**Ferroelectrics:** Introduction to Piezo, Pyro and Ferroelectric materials. Ferroelectric crystals and their classification. Theory of ferroelectric displacive transitions; polarization catastrophe and frozen-in soft optical phonons. Applications of ferroelectric materials

**Superconductivity:** Gaiver and Josephson tunneling, AC and DC Josephson effect, SQUID and its application. Failure of BCS theory of superconductivity, Ginzburg-Landau theory: magnetic flux quantization and coherence length.

**Course learning outcomes:** Students will be able to:

1. explain the fundamentals of crystal structures and bonding in metallic, ionic, and covalent solids.
2. evaluate the influence of defects on the properties of solids.

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3. derive and interpret dispersion relations for lattice vibrations in monoatomic and diatomic crystals.
4. apply the concept of energy bands to construct and interpret the Fermi surface.
5. classify piezoelectric, pyroelectric, and ferroelectric materials.
6. examine Josephson junctions and limitations of BCS theory for superconductors.

***Recommended Books:***


1. *Kittel, C., Introduction to Solid State Physics, John Willey (2007) 7th ed.*
2. *Ashcroft, N.W., and Mermin, N.D. Solid State Physics, Cengage Learning (1976).*
3. *Dekker, A.J., Solid State Physics, Macmillan (1965).*
4. *Datta, S., Ahmad, H. and Pepper, M., Electronic Transport in Mesoscopic Systems, Cambridge University Press (1997).*

**CHARACTERIZATION TECHNIQUES**

**PHY307**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objective(s):** To introduce the students to the principles of electron microscopy, X-ray diffraction and various spectroscopic and thermal techniques.

**Syllabus:**

**Introduction:** Importance and need of materials characterization techniques.

**Electron Microscopy:** Comparison among optical and electron microscopy, Interaction of electron with solids, Scanning electron microscopy, Transmission electron microscopy and specimen preparation techniques, Scanning transmission electron microscopy, Energy dispersive spectroscopy, Wavelength dispersive spectroscopy.

**Diffraction Methods:** Fundamental crystallography, Generation and detection of X-rays, Diffraction of X-rays, X-ray diffraction techniques, Electron diffraction.

**Surface Analysis:** Atomic force microscopy, scanning tunnelling microscopy, X-ray photoelectron spectroscopy.

**Spectroscopy:** Fourier transform infrared spectroscopy, Raman spectroscopy, UV/Visible spectroscopy, PL spectroscopy.

**Thermal Analysis:** Thermo-gravimetric analysis, Differential thermal analysis, Differential scanning calorimetry and dilatometry.

**Course learning outcomes:** Students will be able to:

1. identify appropriate techniques for analysing structure, composition, and properties of materials.
2. analyse crystal structures and determine phase information using X-ray diffraction and electron diffraction techniques.
3. measure the vibrational/electronic transitions to estimate the parameters like energy band gap by spectroscopic techniques.

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4. assess thermal behaviour and phase transitions of materials using TGA, DTA, DSC, and dilatometry.

***Recommended books:***


1. *Li, Lin, Ashok Kumar Materials Characterization Techniques Sam Zhang; CRC Press, (2008).*
2. *Cullity, B.D., and Stock, R.S., "Elements of X-Ray Diffraction", Prentice-Hall, (2001).*

# SEMICONDUCTOR PHYSICS

## PHY406

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objective:** This course introduces relevant quantum mechanical principles and statistical mechanics required to model energy band structures, carrier statistics, and non-equilibrium transport phenomena in crystalline solids. Students will evaluate the physics of p-n junctions, and heterostructures, providing the theoretical rigor necessary to design and optimize nanoscale electronic and optoelectronic devices.

**Syllabus:**

**Unit 1: Energy Bands and Charge Carriers in Semiconductors**

Bonding Forces in Solids; Energy Bands; Kronig-Penney model; Direct and Indirect Semiconductors; Electrons and Holes; Effective Mass; Intrinsic and Extrinsic semiconductors; The Fermi Level; Electron and Hole Concentrations at Equilibrium; Temperature Dependence of carrier concentrations; Compensation and Space Charge Neutrality; Density of states in 3D, 2D, and 1D; Fermi-Dirac statistics; Calculation of intrinsic and extrinsic carrier concentrations.

**Unit 2: Drift of Carriers**

Conductivity and Mobility; Drift and Resistance; Effects of Temperature and Doping on Mobility; The Hall Effect; Invariance of the Fermi Level at Equilibrium, Temperature dependence of mobility and carrier concentration.

**Unit 3: Excess Carriers in Semiconductors**

Optical Excitation in Semiconductor: Optical absorption, carrier generation, Carrier life time, diffusion length and photo conductivity, Direct and indirect recombination and trapping, Photoconductive devices. Diffusion of carriers, Einstein relation, Continuity equation, Carrier injection, Diffusion length. Haynes-Shockley experiment.

**Unit 4: p-n junction**

p-n junction and contact potential, Fermi levels, Space charge, Reverse and Forward bias, Zener and Avalanche breakdown. Capacitance of p-n junction, Schottky barriers; Schottky barrier height, C-V characteristics, current flow across Schottky barrier: thermionic emission, Rectifying contact and Ohmic contact.

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**Unit 5: Semiconductor Devices**

Device Fabrication: Crystal growth by Czochralski and Float zone method. Oxidation, lithography, etching, deposition and doping.

Field Effect Transistors: Working principle of JEFT, Amplifying and switching; Pinch off and saturation, Qualitative description of I-V characteristics.

Bipolar Junction Transistors (BJT): Working principle of BJT operation; Minority carrier distribution; Qualitative description of I-V characteristics

Solar Cell: Ideal conversion efficiency, Fill factor, Equivalent circuit, Voc, Isc and Load resistance, Spectral response.

**Course learning outcome:**

Students will be able to:

1. explain the formation of energy bands and differentiate between direct and indirect bandgap semiconductors.
2. model transport phenomena in semiconductors using the concepts of mobility, drift and Diffusion.
3. sketch and interpret energy band diagrams for p-n junctions and Schottky barriers under equilibrium, forward, and reverse bias.
4. describe the underlying physics of the Hall and Haynes-Shockley experiments and their role in determination of carried concentration.
5. explain the working, design considerations and applications of various semiconducting devices such as BJT, FETs, solar cells, *etc.*

**Recommended Books:**


1. Streetman, B. and Banerjee, S., Solid State Electronics, Pearson, (2016).
2. Neamen, DA, Semiconductor Physics and Devices, McGrawHill, 4$^{th}$ Edition (2012).
3. Sze, S.M., Physics of Semiconductor Devices, John Wiley, (1981).
4. Tyagi, M.S., Introduction to semiconductor materials and devices, John Wiley, (2000).
5. Mishra, U. K. and Singh, Jaspreet, Semiconductor Device Physics and Design, Springer, (2008).
6. Pierret, R.F., Semiconductor Device Fundamentals, Pearson Education Inc., (2006).


**Approved by Academic Council in its 4$^{th}$ meeting held on 5$^{th}$ June 2026.**

**PHYSICS OF NANOMATERIALS**

**PHY407**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 1 | 0 | 3.5 |

**Course Objectives: Course Objectives:**

The course aims to enable students to understand:

1. the role of reduced dimensionality and quantum confinement in determining the physical properties of nanomaterials;
2. various synthesis and characterization techniques for nanoscale materials and structures;
3. the relationship between structure, size, morphology and properties of nanomaterials;
4. applications of nanomaterials in modern technology.

**Syllabus:**

**Introduction to Nanomaterials**

Classification of nanomaterials, Characteristic length scales and dimensionality, Surface-to-volume ratio and surface effects, Density of states in 0-D, 1-D, 2-D and 3-D systems, Variation of band gap and electronic properties with particle size.

**Quantum Confinement and Low-Dimensional Systems**

Quantum confinement effect, Electron confinement in infinite potential well, Quantum wells, quantum wires and quantum dots, Excitons in nanostructures, Tunneling phenomena, Quantum dot and wire, overview of nanoscale electronic structures.

**Synthesis and Characterization Techniques**

Top-down and bottom-up approaches, Mechanical milling, Lithography techniques, Chemical vapour deposition, Chemical bath deposition, Hydrothermal and solvothermal methods, chemical coprecipitation, Sol-gel Self-assembly techniques. Basic characterization methods: X-ray diffraction (XRD), Electron microscopy (SEM/TEM), particle size and zeta potential analysis.

**Physical Properties of Nanomaterials**

Size and shape dependence of optical, electrical, thermal and magnetic properties, Surface plasmon resonance, Transport properties in nanostructures.

**Approved by Academic Council in its 4$^{th}$ meeting held on 5$^{th}$ June 2026.**

**Nanomaterials and Emerging Applications**

Nanoparticles, Nanocoatings and Nanocomposites, Nanotubes, Fullerenes, Thin film chemical sensors, Carbon fullerenes and Carbon nanotubes, Solar cells, Drug deliveries systems and hyperthermia and optoelectronic devices.

**Course Learning Outcomes:**

The students will be able to:

1. explain the fundamental concepts of nanomaterials including classification, dimensionality, surface effects, density of states, and quantum confinement in low-dimensional systems.
2. describe and compare various synthesis and characterization techniques used for the preparation and analysis of nanomaterials.
3. analyze the size- and shape-dependent optical, electrical, thermal, and magnetic properties of nanomaterials and their underlying nanoscale phenomena.
4. evaluate the applications of nanomaterials in sensors, nanocomposites, carbon nanostructures, solar cells, drug delivery, and optoelectronic devices.

**Recommended Books:**


1. *Poole,C.P., Owens,F.J., Introduction to NanotechnologyJohn Wiley &Sons (2003)*
2. *Bimerg, D., Grundmann, M., and Ledentsov, N.N., Quantum Dot Heterostructures, John Wiley (1999).*
3. *Jain, K.P., Physics of Semiconductor Nanostructures, Narosa (1997).*
4. *Fendler, J.H., Nano particles and Nano-structured Films, John Wiley &Sons (1998).*
5. *Timp, G., Nanotechnology, Springer-Verlag (1999).*


**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**SUMMER INTERNSHIP**

**PHY404**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 0 | 2 |

**Course Objective:**

The objectives of this Summer Internship course are to:

1. Provide students with exposure to research environments in in-house laboratories, industries, or external research institutes.
2. Enhance students' abilities in technical communication, report writing, and oral presentation of research outcomes.
3. Foster professional ethics, teamwork, independent learning, and research aptitude through hands-on training.

**Course Learning Outcomes (CLOs)**

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

1. **Apply** theoretical concepts and laboratory techniques to carry out research-oriented tasks during the internship.
2. **Analyze and interpret** experimental observations, research data, and scientific findings obtained during the training period.
3. **Demonstrate** professional skills, research ethics, teamwork, and effective interaction within a research or industrial environment.
4. **Prepare and present** a technical report and seminar summarizing the objectives, methodology, results, and outcomes of the internship work.
5. **Evaluate** the significance and applications of the research work undertaken during the internship.

**Evaluation Scheme:**

1. Presentation: A presentation in front of the departmental committee about the work done during the summer internship.

   **Max. Marks: 40**

2. Report Writing: A technical report that will highlight the work done during the summer internship.

   **Max. Marks: 60**

**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**SEMINAR (LITERATURE REVIEW)**

**PHY406**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 0 | 2 |

**Course Objective:** This course is focused on facilitating student to gain skills of collecting, interpreting and presenting information of interest through seminar and report presentation.

**Course Learning Outcomes (CLOs):**

The student will be able to

- Identify and understand assumptions and arguments that exist in the national and international literature in the identified area of work/topic
- evaluate and synthesize evidence in order to draw conclusions based on research gaps
- ask meaningful questions and originate plausible research and technical gaps and the implications of the expected outcomes

**Evaluation Scheme:**

3. Oral Presentation: A PowerPoint presentation and discussion therein that will highlight the strength of the presenter in the concept, background, literature and gap/lacunae related to identified area/topic

   **Max. Marks: 40**

4. Report Writing: A technical report that will highlight the students' strengths in concept and literature base on the identified area/topic; and capability to present the information in appropriate scientific formats.

   **Max. Marks: 60**

**Approved by Academic Council in its 4th meeting held on 5th June 2026.**

**DISSERTATION (SEMINAR)**

**PHY501**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 0 | 4 |

**Course Objective:** This course is focused on preparing students for their Final Dissertation by providing a platform to explore, critically evaluate and refine research ideas. Students will learn how to identify research problems and gaps in current knowledge, review and synthesize relevant literature, formulate research questions and objectives, and propose appropriate methodologies. The course emphasizes research planning, academic writing, ethical considerations, and effective communication of research ideas. Through seminars, presentations, and constructive feedback, students will develop the skills and confidence required to undertake extensive and independent research for their Final Dissertation.

**Course Learning Outcomes (CLOs):**

The student will be able to

1. identify and critically evaluate research problems and gaps in the field of Physics through comprehensive literature review and analysis.
2. formulate clear research questions, objectives and a feasible research plan for the Final Dissertation.
3. design and justify appropriate research methodology and approaches suitable for addressing the identified problem.
4. critically analyze and synthesize existing research to develop novel ideas and research perspectives.
5. communicate and present research ideas effectively through seminar presentations and academic discussions.
6. demonstrate ethical awareness and academic integrity in research planning and reporting.
7. incorporate feedback and refine research proposals to prepare a strong foundation for the Final Dissertation.

**Evaluation Scheme:**

1. **Oral Presentation:** A seminar presentation through PowerPoint and interactive discussion that will evaluate the student's understanding of the selected research area/topic, including conceptual background, review of literature,

identification of research gaps, proposed objectives, and methodology for the Final Dissertation. The presentation will also assess the student's communication skills, critical thinking, and ability to respond to academic queries.

**Max. Marks: 40**

2. **Report Writing:** A technical seminar report based on the identified research area/topic that will evaluate the student's ability to conduct literature survey, critically analyze existing research work, identify research gaps, and present the proposed research plan in an appropriate scientific and academic format. The report will also assess clarity of writing, organization of content, referencing style, and academic integrity. The preliminary results of the work done can also be presented in the report.

**Max. Marks: 60**

**DISSERTATION**

**PHY601**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 0 | 12 |

**Course Objective:**

This course is focused on facilitating student to carry out extensive research and development project or technical project at place of work through problem and gap identification, development of methodology for problem solving, interpretation of findings, presentation of results and discussion of findings in context of national and international research. The overall goal of the dissertation is for the student to display the knowledge and capability required for independent work.

**Course Learning Outcomes (CLOs):**

The student will be able to

1. gain in-depth knowledge and use adequate methods in the major subject/field of study.
2. create, analyze and critically evaluate different technical/research solutions
3. clearly present and discuss the conclusions as well as the knowledge and arguments that form the basis for these findings
4. identify the issues that must be addressed within the framework of the specific dissertation in order to take into consideration.