Academic Council Approval Date: May 30, 2024

SUBJECT: PHYSICS(UG PROGRAMMES-NEP)

Year	Semester	Course Code	PaperTitle	Theory(T)/Practical(P) (Marks)	Credit
4th Year	VII	PHY-400	Research Methodology & Proposal Writing	T(100)	4
		PHY-401	Mathematical Physics III & Classical Mechanics II	T(100)	4
		PHY-402	Quantum Mechanics II	T(100)	4
		PHY-403	Experimental Physics VII	P(100)	4
		PHY-404 (Minor)	Applied Physics I	T(100)	4
	VIII	PHY-450	Theoretical Physics	T(100)	4
		PHY-451 (Minor)	Applied Physics II	T(100)	4
		PHY-452	Research Project/Dissertation	T/P(300)	12
		PHY-453*	Nanophysics	T(100)	4
		PHY-454*	(a) Solid State Physics-II/(b) Nuclear Physics/ (c) High Energy Physics/ (d) Laser Physics	T(100)	4
		PHY-455*	(a) Experimental Techniques in Physics/ (b) Computational Lab.	T/P(100)	4

Note: Students securing 75% or more in aggregate till the 6th semester are eligible to opt for Hons with research and are allowed to take PHY-452. All other students must opt for UG Hons with three advanced courses: PHY-453*, PHY-454*, and PHY-455*.

SEMESTER- VII
Course Code: PHY-400 (Major)
Course Title: Research Methodology and Proposal Writing
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning Objective

This course offers students to learn the different aspects of research methodology like study design, data collection & analysis, scientific conduct and misconduct, and preparation of research report.

Course outcomes

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

- Familiarize with the different aspects of research methodology such as problem identification and study design.
- Learn about various methods of data collection and analysis.
- Learn about various aspects of research and publication ethics.
- Learn about various softwares for writing research proposals and reports.

Unit I

Fundamentals of Research: Purpose, Classification and methods, Problem Identification: Review of literature, Broadening knowledge base in the specific research area, Bringing clarity and focus to the research problem, Study design: quantitative and qualitative study, Identifying concepts and converting them into variables, Types of variables and measurement scales. (15)

Unit II

Data Collection: Methods of data collection, Data collection in quantitative and qualitative research, Major approaches to information gathering, Measurement of attributes in quantitative and qualitative research.

Data analysis: Precision and accuracy, Error analysis, Propagation of errors, General property of distributions, Multivariate Gaussian distributions, Fitting of experimental data using least squares principle. (15)

Unit III

Scientific Conduct: Ethics with respect to science and research, Intellectual honesty and research integrity.

Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP), Redundant publications: duplicate and overlapping publications, Salami slicing, Selective reporting and misrepresentation of data. Violation of publication ethics, Authorship and contributorship; Identification of publication misconduct, complaints and appeals; Predatory publishers and journals. (15)

Unit IV

Proposal writing: Identification of the research problem, Literature survey, Proposal layout. Softwares (such as Latex, Mendeley, Zotero) for writing Paper, Report, Bibliography, Use of AI tools. (15)

Suggested readings (All latest editions)

1. Research in Education, J. W. Best and J. V. Kahn, Pearson/ Allyn and Bacon.
2. Research Methodology – Methods and Techniques, C. K. Kothari, New Age International.
3. Design and Analysis of Experiments, D. C. Montgomery, Wiley.
4. Applied Statistics & Probability for Engineers, D. C. Montgomery and G. C. Runger, Wiley.
5. Management Research Methodology: Integration of Principles, Methods and Techniques, K. N. Krishnaswamy, A. I. Sivakumar and M. Mathiranjan, Pearson Education.
6. Ethics in Science Education, Research and Governance, Indian National Science Academy (INSA), ISBN:978-81-939482-l-7. http://www.insaindia.res.in/pdf, Ethics Book.pdf.

SEMESTER- VII
Course Code: PHY-401 (Major)
Course Title: Mathematical Physics III and Classical Mechanics II
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning Objective

This course offers students to learn various mathematical tools for solving a variety of problems in different branches of physics as well as to understand the two-body & rigid body problems in classical mechanics.

Course Outcomes

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

- Learn and apply the residue theorem, tensor and group theory to solve a variety of problems.
- Learn about a variety of special functions to understand various physical phenomena.
- Learn and apply the techniques of Fourier and Laplace transforms to analyse and solve a variety of problems.
- Understand the various aspects of two-body problem and rigid body motion in classical mechanics.

UNIT I

Application of residue theorem: Evaluation of integrals of higher order poles and multi-valued functions

Tensor Analysis: Coordinate transformations, Tensors up to rank 2 (covariant, contravariant and mixed tensors), Algebra of tensors: Outer and inner products, Contraction, Symmetric and anti-symmetric tensors, Metric tensors.

Introductory Group Theory: Definition, Types of groups: Orthogonal group O(3) and special unitary group SU(2). (15)

UNIT II

Special functions: Associated Legendre differential equation and functions, Generating function, Orthogonality, Spherical harmonics, Bessel differential equations, Bessel and spherical Bessel functions, Neumann and Henkel functions, Plane wave expansion in terms of partial waves, Laguerre and associated Laguerre differential equations and functions, Generating functions, Hypergeometric and confluent hypergeometric functions. (15)

UNIT III

Fourier series & transforms: Complex representation of a Fourier's series, Dirichlets' conditions, The Fourier Transforms, Properties and Representation of Dirac Delta Function, Transforms of derivatives, Parseval's theorem, Convolution theorem, Momentum representation, Application of Fourier Transform in solving 1D heat equation and wave equation.

Laplace transforms: Definition, Properties, Inverse Transform, Convolution theorem, Application of Laplace transform in solving damped harmonic oscillator. (15)

UNIT IV

Two-body problem: Classification of orbits, Differential equation for orbits, Kepler's problems, Scattering in laboratory and center-of-mass frames, Transformation of cross-section and energies from one frame to another, Coulomb scattering.

Rigid body motion: Fixed and moving coordinate systems, Orthogonal transformation, Euler angles, Angular momentum & Inertia Tensor, Rotational kinetic energy, Principal axes transformations, Force-free motion of a rigid symmetric top. (15)

Suggested readings (All latest editions)

1. Mathematical Methods for Physicists, G. B. Arfken and H. J. Weber, Academic Press.
2. Mathematical Methods for Physicists, J. Mathew and R. L. Walker, Pearson.
3. Group Theory and its Applications to Physical Problems: M. Hamermesh, Dover Publications Inc.
4. Fourier and Laplace Transforms: R. J. Beerends, H. G. ter Morsche, J. C. van den Berg, and E.M. van de Vrie, Cambridge University Press.
5. Matrices and Tensors in Physics, A.W. Joshi, New Age International Publishers.
6. Elements of group theory for physicists, A. W Joshi, New Age International Publishers.
7. Mathematical Methods in the Physical Sciences, Mary L. Boas, Wiley.
8. Classical Mechanics, H. Goldstein, C. Poole and J. Safko, Pearson Education Asia.
9. Classical Mechanics, N.C. Rana and P. S. Joag, Tata McGraw Hill.

SEMESTER - VII
Course Code: PHY-402 (M)
Course Title: Quantum Mechanics II
Total contact hours: 60
Full Marks: 100

Learning Objective

This course provides knowledge of various advanced topics in Quantum mechanics and its applications to understand various intrinsic features and physical phenomena at microscopic level.

Course Outcomes

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

- Solve the problems related to Hydrogen atom, Harmonic oscillator and Angular momenta as well as learn the different representations of quantum dynamics.
- Learn about various approximation methods for solving problems related to stationary states.
- Learn the stationary perturbation theories and apply them to obtain corrections to energy eigen kets and eigen values.
- Learn and apply the perturbation theories to deal with the cases of time-dependent perturbation.
- Learn and apply the scattering theory to infer the details about quantum system involving projectile and target.
- Learn about various types of symmetries and conservation laws in quantum mechanics.
- Learn how the special theory of relativity in quantum theory leads to intrinsic spin angular momentum as well as anti-particles.

UNIT I

Hydrogen atom in spherical coordinate, Harmonic oscillator using operator method, Equation of motion: Schrödinger, Heisenberg, and Dirac (Interaction) representations, Theory of angular momenta, Clebsch-Gordon Coefficients. (9)

UNIT II

Approximation methods for stationary states: WKB approximation and its validity, Connection formulae; application to bound states such as tunnelling, Variational method and its applications to various systems including one-dimensional harmonic oscillator and hydrogen atom.

Stationary perturbation theory: Non-degenerate case: first order and second orders corrections, application to various systems including harmonic oscillator with perturbation of types ax, bx^2, cx^3; Degenerate case: first order correction, application to various systems including explanation of Stark effect and Zeeman effect (without spin) in hydrogen atom. (16)

UNIT III

Time dependent perturbation theory: First order transition probabilities, Constant perturbation, Transition to continuum, Harmonic perturbation, Fermi's golden rule, Sudden and adiabatic approximations. (8)

UNIT IV

Scattering Theory: Asymptotic behaviour of scattering wave function, Relation to cross sections, Green's function for scattering problem: Scattering integral equations, Born approximation and its validity criteria, Scattering by screened Coulomb potential, Partial wave analysis: phase shifts, scattering amplitude, optical theorem. (11)

UNIT V

Symmetries and conservation laws in Quantum Mechanics: Infinitesimal and finite unitary transformations, Translation in space and time, Rotational symmetry, Space reflection, Time-reversal invariance. (5)

UNIT VI

Relativistic wave equations: Klein-Gordon equation, Difficulty with probability interpretation, Dirac equation, Four component solutions for free particle, Negative energy solutions and antiparticles, Covariant form of Dirac equation, 4-current density, Properties of γ-matrices, Dirac equation in the presence of electromagnetic field, Non-relativistic reduction, spin and magnetic moments of electrons. (11)

Suggested readings (All latest editions)

1. Quantum Mechanics, E. Merzbacher, John Wiley.
2. Quantum Mechanics, G. Aruldhas, Prentice Hall.
3. Quantum Mechanics, L. I. Schiff, Tata McGraw Hill.
4. Quantum Mechanics, A. Messiah, Dover.
5. Quantum Mechanics, S. Gasiorowitz, Wiley.
6. Quantum Mechanics, V. Devenathan, Narosa Publishing House.
7. Quantum Mechanics, B. H. Bransden and C. J. Joachain.
8. Quantum Mechanics: Concepts and Applications, N. Zettili, Wiley India Pvt. Ltd.
9. Modern Quantum Mechanics, J. J. Sakurai, Addison-Wesley.
10. Advanced Quantum Mechanics, F. Schwabl, Springer.
11. Relativistic Quantum Mechanics, J. D. Bjorken and S. D. Drell, McGraw Hill.

SEMESTER- VII
Course Code: PHY-403 (Major)
Course Title: Experimental Physics-VII
Total contact hours: 120
Total Credit: 04
Full Marks: 100

Learning **Objective**

This course aims the students to learn the experimental determination of physical quantities in various areas of physics.

Course **Outcomes**

Upon successful completion of this course the students will be able to measure some of the important physical quantities related to solid-state, optics and nuclear physics.

List of the experiments:

1. To determine Curie temperature of a ferroelectric material.
2. To determine Curie temperature of a ferromagnetic material.
3. To determine the dielectric constant of the given materials.
4. To determine Boltzmann constant using a semiconductor diode.
5. To determine Stefan's constant by electrical method.
6. To determine the wavelength of He – Ne laser using a Ruler.
7. To measure reflectivity curves of a glass sheet for parallel & perpendicular polarized and un-polarized light.
8. To study Phonon dispersion of a mono-atomic chain of atoms using electronic analogue of the chain.
9. To determine Lande g - factor by E. S. R. method.
10. Determination of difference in wavelength ($\Delta\lambda$) of Na D - lines using Fabry-Perot interferometer.
11. To study the Energy level jumps in Na.
12. To study the magnetic field dependence of transverse magneto-resistance of given semiconductor sample.
13. To determine half-life of neutron irradiated source from the decay curve.

Suggested Readings (All latest editions)

1. Statistical Methods in Experimental Physics, W. T. Eadie et al., North-Holland PublishingCompany.
2. Advanced Level Practical Physics, M. Nelkon and J. M. Ogborn, ELBS.
3. Nuffield Physics Through Experiments, Vols. III & V,Western Printing Services.
4. A Laboratory Manual of Experiments in Physics, L. R. Ingersoll et al., McGraw HillBook Company.
5. An Introduction to Error Analysis, J. R. Taylor, Oxford University Press.
6. Measurement, Instrumentation and Experimental Design in Physics and Engineering, M. Sayer and A. Mansingh,Prentice Hall of India.
7. An advance course in practical Physics, D. Chattopadhyay, P. C. Rakshit and B. Saha, New Central Book Agency.
8. Nuclear Radiation Detectors,S. S. Kapoor and V. S. Ramamurthy, New Age International.

SEMESTER- VII
Course Code: PHY-404 (Minor)
Course Title: Applied Physics-I
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning **Objective**

This course offers students to learn various topics in different branches of applied physics which include Electrodynamics, Space Physics, Spectroscopy, and Nanophysics.

Course **Outcomes**

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

- Understand the propagation of electromagnetic waves in different media.
- Learn about the physical laws related to satellites and their applications in various fields.
- Learn about the theories of atomic and molecular spectroscopies and their applications.
- Learn about nanomaterials, their synthesis and applications.

UNIT I

Electrodynamics

Electromagnetic waves, Spectrum production, Maxwell's equations, Propagation of EM waves in vacuum and different media, Modulation (Amplitude, Frequency & Phase) and Demodulation, Transmitter, Receiver, Transmission lines, Wave guides, Antenna, Principle of radio communication, Radar system. (15)

UNIT II

Space Physics

Principles of satellites in motion, Kepler's laws, Orbital elements, Satellite attitude and its control, Types of orbits: polar and geostationary, earth and sun-synchronous, Orbit optimization, Viewing geometry, Launch vehicles and spacecraft, Rocket propulsion, Satellite data acquisition, Satellite communication, Data collection platforms, Earth station, Remote sensing and its applications in earth resources and management: agriculture, forestry, water resources, military and disaster mitigation, Highlights of India's space mission. (15)

UNIT III

Spectroscopy

General aspects of spectroscopy, Applications of molecular symmetry in spectroscopy, Electronic absorption and emission spectroscopy of atoms and molecules, Spectroscopic techniques: UV-Vis, IR, Raman spectroscopy, NMR spectroscopy, X-ray photoelectron spectroscopy (XPS) and Angle resolved photo emission spectroscopy (ARPES). Applications of Spectroscopy: Structural determination of molecules, Identification of organic and inorganic compounds, Quantitative analysis. (15)

UNIT IV

Nanophysics

Introduction to nanomaterials, Size dependent properties, Nanomaterials with examples: 0D, 1D, 2D and 3D, Bottom-up & Top-down techniques, Methods of Synthesis: RF plasma, Chemical methods, Pulsed laser methods, Sol gel method, Types of carbon nanotubes, synthesis and properties of carbon nanotubes and their applications, Health & environmental impact of nanomaterials. (15)

Suggested Readings (All latest editions)

1. Introduction to Electrodynamics, D. J. Griffiths, Pearson.
2. Theory of satellite orbits in an Atmosphere, Desmond King-Hele, Butterworths, London.
3. Fundamentals of Remote Sensing, George Joseph, University Press.
4. Solar System Astrophysics, J. C. Brandt and P. W. Hodge, McGraw-Hill.
5. Experiments in Modern Physics, A. C. Melissinos and J. Napolitano, Academic Press.
6. Experimental Physics: Modern Methods, R. A. Dunlap, Oxford University Press.
7. Introduction to Nanotechnology, Jr C. P. Poole and F. J. Ownes, Wiley.
8. Carbon Nanotubes, S. Reich, C. Thomsen,and J. Maultzsch, Wiley-VCH.
9. Carbon Nanotubes, Silvania Fiorito, Pan Stanford Publishing Pte. Ltd.

SEMESTER-VIII
Course Code: PHY-450(Major)
Course Title: Theoretical Physics
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning Objective

This course offers students to learn various topics in different branches of theoretical physics which include Electrodynamics, Solid State, Statistical, Atomic & Molecular, and Nuclear & Particle Physics.

Course Outcomes

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

- Understand the origin and propagation of electromagnetic radiation due to oscillating localized sources and moving point charge.
- Understand bondings and defects in crystals as well as the concept of liquid crystals.
- Learn about the concept of random walk, phase transitions, and idea of non-equilibrium systems.
- Learn about the energy shifts of the fine structure of atomic spectral lines, quantum theory of molecular bond formation, and molecular symmetries.
- Learn about the nature of nuclear forces and the origin of the anti-particles.

Unit I

Electrodynamics

Concepts of retarded potential, Fields and radiation of localized oscillating sources, Electric and magnetic dipoles, Electric quadrupole fields, Center fed linear antenna, Multipole expansion of electromagnetic fields, Lienard-Wiechert potentials and fields for a moving point charge, Total power radiated by accelerated charge, Larmor's formula. (12)

Unit II

Solid State Physics

Crystal binding and elastic properties: Cohesive energy, Ionic crystals, Madelung constant, Covalent crystals, Metals, Molecular crystals, Hydrogen bonded solids, Elastic constants; Crystal defects: Point defects, Schottky and Frankel defects, Color centers, Dislocations, Staking faults, Grainboundaries.

Liquid Crystals: Introduction, Different phases of liquid crystals, Concept of order parameter, Radial distribution function and structure factor, Applications. (12)

Unit III

Statistical Physics

1D Random walk problem: Mean, Dispersion, Relative width in the light of binomial distribution.

Phase transitions: First order and Second order, Landau theory, Ising model and its solution in 1D, Idea of nonequilibrium systems, Brownian motion, Langevin equation, Diffusion equation. (12)

Unit IV

Atomic and Molecular Physics

Fine structure of hydrogenic atoms: Relativistic correction to the kinetic energy, Spin-orbit term, Darwin term, Fine structure of spectral lines and their intensities; The Lamb shift, Hyperfine structure and isotope effects; Quantum theory of molecular bond formation: Molecular orbital (MO) method of Hydrogen molecule ion, Valence bond (or Heitler-London) method of hydrogen molecule; Molecular symmetry: Symmetry operation and elements of a point group, Multiplication table for H_2O and NH_3 molecules, Representations of a group, Matrix representation of symmetry elements of a point group, Reducible and irreducible representations, The great orthogonality theorem, Character tables for C_{2v} and C_{3v} point groups. (12)

Unit V

Nuclear and Particle Physics

Nature of the Nuclear force, Form of Nucleon-Nucleon potential, Charge independence and charge symmetry of nuclear forces, Deuteron problem.

Dirac hole theory: Negative energy solutions, Charge conjugation, Parity and Time reversal and other symmetries. (12)

Suggested Readings (All latest editions)

1. Classical Electrodynamics, J. D. Jackson, John Wiley & Sons.
2. Classical Electrodynamics, S. P. Puri, Narosa.
3. Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons.
4. Fundamentals of Statistical and Thermal Physics, F. Reif, Mc-Graw Hill.
5. Statistical Physics, R. K. Pathria, Elsevier.
6. Physics of Atoms and Molecules, B. H. Bransden & C. J. Joachain, Pearson Education.
7. Molecular Structure and Spectroscopy, G. Aruldhas, PHI Learning Private Limited.
8. Chemical Applications of Group Theory, F. A. Cotton, Wiley.
9. Introductory Nuclear Physics, K. S. Krane, John Wiley & Sons.
10. Nuclear Physics, S. N. Ghoshal, S. Chand & Company.
11. Introductory Nuclear Physics, S. S. M. Wong, Wiley-Vch.
12. Introduction to Elementary Particles, D. Griffiths, John Wiley & Sons.
13. Relativistic Quantum Mechanics, J. D. Bjorken and S.D. Drell, McGraw Hill.

SEMESTER- VIII
Course Code: PHY-451 (Minor)
Course Title: Applied Physics-II
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning Objective

This course offers students to learn various topics in different branches of applied physics which include Astronomy & Astrophysics, Plasma Physics, Materials Science and Vacuum Technology.

Course Outcomes

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

- Get basic ideas about astronomical objects as well as formation and decay of stars.
- Learn about the basic properties and applications of Plasma.
- Understand the bondings & defects in crystals, various physical properties of materials, as well as the basic of liquid crystals.
- Learn about basic concepts and applications of vacuum technology.

UNIT I

Astronomy and Astrophysics

History of astronomy, Overview of the night sky, Diurnal and yearly motions of the sun, Size, Mass, Density and Temperature of astronomical objects, Basic concepts of celestial sphere.

Role of gravity in different astrophysical systems, Radiative Process: Radiation theory and Larmor formula, Different radiative processes, Star formation, Stellar evolution, Stellar Structure, Stellar Energy sources, Chandrasekhar's limit, Compact Stars: Brown Dwarf, Neutron Star, Black Holes and their properties, Spiral and elliptical galaxies, Milky Way galaxy, Active galaxy, Quasars. (15)

UNIT II

Plasma Physics

Definition and Properties of Plasma, Plasma production in laboratories, Microscopic description, Motion of a charged particle in electric and magnetic fields curvature, Gradient and External force drifts, Kinetic pressure in a partially ionized gas, Mean free path and collision cross section, Mobility of charged particles, Effect of magnetic field on the mobility of ions, electrons and thermal conductivity, Dielectric constant of plasma, Optical properties of plasma, Applications: Magneto hydrodynamic generator, Generation of microwaves utilizing high density plasma, Plasma diode. (15)

UNIT III

Material Science

Crystal defects: Point defects and their types, Dislocations, Staking faults, Grain boundaries,
Crystal binding: Ionic crystals, Covalent crystals, Metals, Molecular crystals, Hydrogen bonded crystals, Cohesive energy.
Mechanical properties: Stress, Strain, Deformation, Elastic constants, Elastic waves.
Dielectric properties: Dielectric constant, Polarization, Macroscopic and local electric field, Ferroelectric, Piezoelectric and Pyroelectric materials and their applications.
Optical properties: Interaction of light with matter, Reflection, Refraction, Absorption, Transmission, Luminescence.

Liquid Crystals: Introduction, different phases of liquid crystals, applications. (15)

UNIT IV

Vacuum Technology

Introduction, Basic concepts & Applications, Production of Medium, High & Ultra High Vacuum, Pumps, Measurement of Vacuum, Gauges, Vacuum Materials, Valves, Components, Couplings & Chambers, Fluid Flow (Viscous/Molecular) in Vacuum Systems, conductance and pump down calculations. (15)

Suggested Readings (All latest editions)

1. Introduction to Modern Astrophysics, W. Carrol and D.A. Ostlie, Addition Wesley.
2. The Physics of Astrophysics Vol. I & II, Frank H. Shu, University Science Books, USA.
3. Textbook of Astronomy & Astrophysics, V. B. Bhatia, Narosa.
4. Introduction to Plasma Physics, F. F. Chen, Plenum Press.
5. Principles of Plasma Physics, N. A. Krall and A. W. Trivelpiece, San Francisco Press.
6. Introduction to Plasma Physics, R. J. Goldstein and P. H. Rutherford, IOP.
7. Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons Inc.
8. Solid State Physics, N.W. Ashcroft and N. D. Mermin, Horcourt Asia Pvt. Ltd.
9. Introduction to Vacuum Technology, David M. Hata, Elena V. Brewer and Nancy J. Louwagie, Milne Open Textbooks.
10. A User's Guide to Vacuum Technology, John F. O'Hanlen, Wiley.
11. Vacuum Science & Technology- V. V. Rao, K. L. Chopra and T. B. Ghosh, Allied Publishers Pvt Ltd.
12. Modern Vacuum Physics, Austin Chambers, Chapman & Hall/CRC.

SEMESTER-VIII
Course Code: PHY-452 (Major)
Course Title: Research Project/Dissertation
Total contact hours: 360
Total Credit: 12
Full Marks: 300

Distribution of marks

I. Sessional Examination: 3 credits; Marks: 75
   (a) Presentation of work/Lit. Review: 2 credits; Marks: 50
   (b) Presentation/Viva voce: 1 credit; Marks: 25

II. End-Semester Examination : 9 credits; Marks: 225
   (a) Synopsis submission and presentation: 3 credits; Marks: 75
   (b) Laboratory work/Dissertation: 4 credits; Marks: 100
   (c) Final Project presentation/Viva voce: 2 credits; Marks: 50

SEMESTER- VIII
Course Code: PHY-453 (Major*)
Course Title: Nanophysics
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning Objective

This course offers students to learn the various synthesis & characterization techniques of different nanostructured materials and fundamental concepts behind size reduction in various physical properties.

Course Outcomes

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

- Understand the classification of nanomaterials and size effects.
- Familiarize various synthesis techniques of Nanomaterials.
- Understand the basic principles of various characterization techniques.
- Understand the different nano fabrication tools in VLSI field.

Unit I

Basics of Nanomaterials

Characteristics of Nanomaterials, Nucleation and growth of nano systems, Preparation of quantum nanostructures, Size and dimensionality effects, Fermi Gas, Density of States, Properties dependent in DOS, Origin of charge on colloidal sols, Zeta potential, Thermodynamics and kinetics of nanoparticles, Carbon Nanostructures: Nature of Carbon Bonds, New Carbon Structures, Classifications: 0D, 1D, 2D & 3D nanomaterials. (15)

Unit II

Synthesis

Top- down and bottom-up approaches, Nano synthesis techniques based on liquid and vapor phase as the starting material, Wet chemical methods: sol-gel method, hydrothermal, micro emulsion technique, chemical reduction/decomposition of organo-metallic precursors; Film fabrication: Physical vapor deposition, Chemical vapor deposition, Metallo-organic chemical vapor deposition, Sputtering, Electro and electroless depositions; Cryochemical synthesis: Study of rapid solidification, quenching. (20)

Unit III

Characterization techniques

Determination of size of nanoparticles using X-ray diffraction, Brunauer-Emmett-Teller method and laser diffraction, Spectroscopic techniques: Optical spectroscopy, UV-visible and Infrared spectroscopy, Raman spectroscopy, X-ray photoelectron spectroscopy, X-ray Fluorescence, Small Angle X-ray Scattering, Microscopic techniques: Atomic Force Microscopy, Scanning Electron Microscopy and Transmission Electron Microscopy. (15)

Unit IV

Applications in Precision Engineering in VLSI technology

Electron beam lithography (EBL), UV imprint lithography, Nanoimprint lithography, Focused Ion Beam (FIB), Pulsed Laser Ablation, Multilayer structures for device applications, Ion beam nano structuring. (10)

Suggested Readings (All latest editions)

1. Nanocrystals: Synthesis, Properties and Applications, C. N. R. Rao, P. J. Thomos, and G. U. Kulkarni, Springer-Verlag.
2. Introduction to Nanotechnology, Jr. C.P. Poole, and F.J. Owens, Wiley.
3. Kinetics of Heterogeneous Solid State Processes, P. Deb, Springer.
4. Manipulation of Nanoscale materials: An introduction to Nanoarchitectonics, K. Ariga, Royal Society of Chemistry.
5. Quantum Dots: L. Jacak, P. Hawrylak and A.Wojs, Springer.
6. Handbook of Nanostructured Materials and Nanotechnology: H. S. Nalwa (editor), Elsevier.
7. Nanotechnology for dummies: Richard Booker and Earl Boysen, Wiley.
8. Nanostructures-Theory & Modelling, C. Deleure and M. Lannoo, Springer.
9. Nanostructures, V. A. Schukin, N. N. Ledentsov and D. Bimniberg, Springer.

SEMESTER- VIII
Course Code: PHY-454(a) (Major*)
Course Title: Solid State Physics-II
Total Contact hours: 60
Total Credit: 04
Full Marks: 100

Learning **Objectives**:

This course aims to explain the quantum mechanical origin of various crystalline features such as energy bands, Fermi surfaces, as well as properties such as magnetic orderings, superconductivity, and dielectric behaviours.

Course **Outcomes:**

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

- Understand the origin of energy bands due to periodic motion of electrons.
- Understand the concept of Fermi surfaces in metals and their experimental observation.
- Understand the origin of various magnetic orderings and their temperature dependence.
- Learn the various properties of superconductors and their explanations using BCS theory and Ginzburg-Landau theory.
- Learn the properties and classifications of dielectric materials.

UNIT I

Energy Bands in Crystals: Electron motion in a periodic potential, Bloch Theorem (with proof), Born-von-Karman boundary condition, Kronig-Penney model, Nearly free electron gas model, Approximate solution near zone boundary, Illustration of extended, reduced and repeated zone schemes in one dimension, Tight-binding method for energy bands, Calculation of tight-binding bands for linear chain, square lattice and simple cubic lattice with s-valence orbitals, Classifications of crystals into metals, semiconductors and insulators based on band structures. (15)

UNIT II

Fermi Surfaces of Metals: Shape of Fermi surfaces in the free electron and nearly free electron models, Electron orbits, hole orbits and open orbits, Quantization of orbits in a magnetic field, de Haas–Van Alphen effect and its role in experimental determination of Fermi surfaces. (10)

UNIT III

Magnetic Ordering: Different types of magnetic structures (ferromagnetic, antiferromagnetic, ferrimagnetic), Ferromagnetism: Heisenberg model, temperature dependence of saturation magnetization and susceptibility, spin waves (magnons) and low-temperature properties, Antiferromagnetism: Heisenberg model, temperature dependence of susceptibility, spin waves (magnons) and low temperature properties, Ferromagnetic domains: Anisotropy energy, Hysteresis. (14)

UNIT IV

Superconductivity: Thermal conductivity, Specific heat, Energy gap, Isotope effect, London equation, Coherence length, BCS theory and its predictions, Ginzburg-Landau theory, Introduction to high-temperature superconductors. (10)

UNIT V

Dielectric Properties of Insulators: Polarization, Macroscopic electric field, Local electric field, Clausius-Mossotti relation, Theory of polarizability, Ferroelectric crystals: classification, displacive transitions, Landau theory of phase transition (first and second orders), Piezoelectricity. (11)

Suggested Readings (All latest editions):

1. Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons Inc.
2. Solid State Physics, N.W. Ashcroft and N.D. Mermin, Horcourt Asia Pvt. Ltd.
3. Concepts in Solids, P.W. Anderson, World Scientific Publishing Co.
4. Principles of Condensed Matter Physics, P.M. Chaikin and T.C. Lubensky, Cambridge University Press
5. Quantum Theory of Solids, Charles Kittel, John Wiley & Sons Inc., New York
6. Solid State Physics, H. Ibach and H. Luth, Springer, New Delhi.
7. Principles of the Theory of Solids, J.M. Ziman, Cambridge University Press

SEMESTER- VIII
Course Code: PHY-454 (b) (Major*)
Course Title: Nuclear Physics
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning Objective

This course offers students to learn nuclear reactions, nuclear decay, two nucleon systems and statistical analysis of nuclear data.

Course Outcomes

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

- Understand cross sections of nuclear reactions and applications of Breit-Wigner formula.
- Learn the principles of beta & gamma decays and their selection rules.
- Understand two nucleon systems, charge independence and charge symmetry of nuclear forces.
- Analyze nuclear data and find the statistical errors of measurements.

UNIT I

Nuclear Reactions

Derivation of cross section of direct and compound nuclear reactions, Expressions for scattering and reaction cross sections in terms of partial wave amplitude, Resonances, Derivation and applications of Breit-Wigner single level formula for compound nucleus theory. (15)

UNIT II

Nuclear Decay

Fermi's theory of beta-decay, Kurie plots, Fermi and Gamow-Teller transitions, Parity violation in beta-decay, V-A theory (basic idea only), Gamma-decay: Electric and magnetic multipole transitions in nuclei, Parity and angular momentum selection rules, Internal conversion and Applications. (15)

UNIT III

Two-nucleon Systems

Dipole and quadrupole moments of the deuteron, Central and tensor forces, S and D states, Low energy neutron-proton scattering, Effective range theory, Spin dependence of nuclear forces, Charge independence and charge symmetry of nuclear forces, Proton-proton scattering (qualitative idea only), Isospin formalism. (15)

UNIT IV

Statistical Analysis of Nuclear Data

Multichannel analyser and its characteristics, Spectrum analysis, Characterization of nuclear data, Statistical models, Hauser-Feshbach formula and Breit-Wigner Theory for more than one level, Error

Analysis: The statistical error of radiation measurements, the standard error counting rates, Methods of error reduction. (15)

Suggested Readings (All latest editions)

1. Introductory Nuclear Physics, K. S. Krane, John Wiley & Sons.
2. Nuclear Physics, Experimental and Theoretical, H.S. Hans, New Age International (P) Ltd Publisher.
3. Concept of Nuclear Physics, B. L. Cohen, Tata McGraw Hill.
4. Nuclear Physics, S. N. Ghoshal, S. Chand & Company.
5. Introductory Nuclear Physics, L. R. B. Elton, Sir Isaac Pitman & Sons Ltd.
6. Introductory Nuclear Physics, S. S. M. Wong, Wiley-Vch.
7. Radiation Detection and Measurement, G. F. Knoll, John Wiley and Sons.
8. Physics and Engineering of Radiation Detection, S. N. Ahmed, Academic Press.

SEMESTER- VIII
Course Code: PHY-454 (c) (Major*)
Course Title: High Energy Physics
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning Objective

This course offers students to learn Propagator theory, Feynman rules, Gauge symmetries, and Electro-weak interactions.

Course Outcomes

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

- Understand the Propagator theory and its applications.
- Learn the Feynman rules and applications in various scattering involving electrons.
- Understand gauge theories that explain all elementary particle interactions.
- Learn the Higgs mechanism that provides insights into the origin of particle masses and the spontaneous breaking of symmetries.
- Understand the basics of weak interaction & electroweak theory.

UNIT I

Propagator theory and its applications

The nonrelativistic propagator, Definition and properties of the Green's functions, Propagator in positron theory, Coulomb scattering of electrons and positrons, Spin-averaged cross sections, Electron scattering from a Dirac proton, Trace theorem. (17)

UNIT II

Feynman rules and applications

Higher order correction to electron-proton scattering and Feynman rules, Bremsstrahlung and infrared catastrophe, Compton scattering and Klein-Nishima formula, Crossing symmetry, Pair annihilation into gamma rays, electron-electron and electron-positron scattering, Bhabha cross section, Polarization in electron scattering. (17)

UNIT III

Gauge Symmetries

The Lagrangian and single particle wave equations, Noether's theorem: Symmetries and conservation laws; U (1) local gauge invariance and quantum electrodynamics (QED), Non-abelian gauge invariance and quantum chromodynamics (QCD), Spontaneous symmetry breaking, Goldstone's theorem, The Higgs mechanism. (18)

UNIT IV

Weak Interaction & Electroweak Theory

Weak Interaction, Intermediate vector bosons, Glashow-Weinberg-Salam model. (8)

Suggested Readings (All latest editions)

1. Relativistic Quantum Mechanics, J. D. Bjorken and S. D. Drell, McGraw Hill.
2. Quantum Field Theory, F. Mandle and G. Shaw, John Wiley and Sons.
3. Quarks and Leptons, F. Halzen and A. D. Martin, Wiley India.
4. Gauge Theories of the Strong, Weak and Electromagnetic Interactions, C. Quigg, Benjamin Cummings.
5. Introduction to High Energy Physics, D. H. Perkins, Addison-Wesley.
6. Introduction to Elementary Particles, D. Griffiths, John Wiley & Sons.
7. Gauge Theories of the Strong, Weak and Electromagnetic Interactions, C. Quigg, Benjamin Cummings.
8. Gauge Theory of Elementary Particle Physics: Problems and Solutions, T. P. Cheng and Ling-Fong Li, Oxford.

SEMESTER- VIII
Course Code: PHY-454(d) (Major*)
Course Title: Laser Physics
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning Objective

This course offers students to learn the types, pumping mechanisms and application of lasers in various fields.

Course Outcomes

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

- Understand the fundamentals of various resonators and pumping process.
- Learn the working principles of various types of laser.
- Explain non-linear optical phenomena, harmonic generation and optical parametric oscillation.
- Apply knowledge of laser physics to real-world problems in material science, biomedical engineering and optical communication.

UNIT I

Pumping Processes

Optical resonator, Types of optical resonator, Optical pumping, Pumping efficiency, Different arrangements for optical pumping, Electrical pumping and pumping efficiency, Electrical pumping (longitudinal and transverse arrangement), Longitudinal and transverse modes of optical resonator, Three-level laser and four-level laser and their rate equations, Threshold pump power for three-level and four-level laser, Q-factor, Methods of q-switching: rotating mirror, mechanical shutter, electro-optic shutter, acousto-optic shutter, Mode locking (active and passive). (20)

UNIT II

Types of Lasers

Working principle, construction, advantages and disadvantages of different types of laser systems: solid state (Ruby laser, Nd:YAG laser), liquid state (Dye laser), gaseous state (N_2 laser, CO_2 laser), ion laser (Argon ion laser) and semiconductor laser (homogeneous and heterogeneous), Excimer laser. (15)

UNIT III

Fourier and Non-Linear Optics

Fourier optics, Thin lens as phase transformation, Thickness function, Fourier transforming properties of lenses, Object placed in front of the lens, Object placed behind the lens. Non-Linear Optics, Two photon and multi photon processes. Harmonic generation, Second harmonic generation, Phase matching condition, Optical mixing, Parametric generation of light, Self-focusing of light. (15)

UNIT IV

Application of Lasers

Holography, Thermonuclear fusion, Raman scattering, Cooling and Trapping of Atoms, Application of laser in medicine (surgery, ophthalmology, laser angioplasty, dentistry), optical communication, biology, chemistry, astronomy, industries, computers. (10)

Suggested Readings (All latest editions):

1. Principles of Lasers, O. Svelto, Plenum Press.
2. Lasers and Non-Linear optics, B.B. Laud, Wiley Eastern Ltd.
3. Laser fundamentals, W.T. Silfvast, Cambridge University Press.
4. Optical Electronics, A. K. Ghatak and K. Thyagarajan, Cambridge University Press.
5. Introduction to Fourier optics, J. W. Goodman, Robots & Company.
6. Optoelectronics An Introduction, J. Wilson & J. Hawkes, Prentice Hall.

SEMESTER- VIII
Course Code: PHY-455(a) (Major*)
Course Title: Experimental Techniques in Physics
Total contact hours: 60
Total Credit: 04
Full Marks: 100

Learning **Objective**

This course offers students to learn the various experimental techniques using X-ray, Nuclear radiation and light.

Course **Outcomes**

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

- Understand the fundamentals of various X-ray based characterization techniques.
- Learn the working principles of various nuclear radiation based techniques.
- Learn the optical spectroscopy involved in different wavelengths of light.
- Understand the various resonance techniques and magnetometer.

Unit I

X-ray techniques: Electron and X-ray diffraction (from Crystals and Liquids), X-ray Fluorescence (XRF), X-ray absorption spectroscopy. (12)

Unit II

Nuclear Particle/Radiation: Neutron diffraction (from Crystals and Liquids), Neutron Activation Analysis (NAA), Tracer Technique of Gamma Ray Spectroscopy, Rutherford Back Scattering (RBS), Mössbauer Spectroscopy, Positron Annihilation Spectroscopy. (18)

Unit III

Long Wavelength Radiations: Production Techniques of UV/Visible, Microwave, IR radiations, Spectroscopic Techniques: IR, FTIR, UV-Vis, Raman, Photo-luminescence. (15)

Unit IV

Resonance / Magnetometric techniques: Nuclear Magnetic Resonance (NMR), Electron Spin Resonance (ESR), Ferromagnetic Resonance, Vibrating Sample Magnetometer. (15)

Suggested Readings (All latest editions)

1. Experiments in Modern Physics, A. C. Milissinos and J. Napolitano, Academic Press.
2. Radiation Detection and Measurement, G. F. Knoll, John Wiley and Sons.
3. Experimental Physics: Modern Methods, R.A. Dunlap, Oxford University Press.
4. Experimental Techniques in Physics and Materials Sciences, R. Srinivasan, T. G. Ramesh, G. Umesh, and C. S. Sundar, World Scientific.
5. Methods of Experimental Physics, M. I. Pergament, CRC Press.
6. Experimental Methods in the Physical Sciences (All Volumes), Academic Press.
7. Materials Characterization, Yang Leng, John Wiley and Sons.
8. Ferromagnetic Resonance: The Phenomenon of Resonant Absorption of a High-Frequency Magnetic Field in Ferromagnetic Substances, S. V. Vonsovskii (Eds.), Elsevier.

SEMESTER- VIII
Course Code: PHY-455 (b) (Major*)
Course Title: Computational Lab
Total contact hours: 120
Total Credit: 04
Full Marks: 100

Learning **Objective**

This course offers students to learn the application of various computational techniques to solve various problems in different branches of physics.

Course **Outcomes**

Upon successful completion of this course, the students will be able to write the algorithm and execute the programs for:

- Finding the Inverse, Eigen values, Eigen vectors, as well as Diagonalizing the matrices up to order 3.
- Finding solutions of numerical, algebraic and transcendental equations using Bisection and Newton-Raphson methods.
- Solving the first and second order differential equations using Runge-Kutta method.
- Radioactive decay using Monte Carlo simulation.
- Integration of a variety of functions using the methods of Simpson's Rule, Trapezoidal Rule, and Gaussian quadrature formula.
- Iteration to study the logistic map.

List of experiments

1. Matrices (up to order 3): Inverse, Eigen values, Eigen vectors, Diagonalization.
2. Roots of one-variable functions by bisection and Newton-Raphson methods.
3. Roots of simultaneous equations using Newton-Raphson method.
4. Solution of differential equations using Runge-Kutta method: application to RC, LR and LCR circuits.
5. Simulation of radioactive decay using Monte Carlo method.
6. First and second differentiation of a given function.
7. Integrations using Simpson's Rule, Trapezoidal Rule, Gaussian quadrature formula.
8. Exploration of the regions of (i) stable fixed points, (ii) periodic, and (iii) chaotic solutions of a logistic map.

Note: Programming must be done using FORTRAN/ C.

Suggested Readings (All latest editions)

1. Computational Physics an Introduction, R. C. Verma, P. K. Ahluwalia, and K. C. Sharma, New Age International.
2. Computer Programming in FORTRAN 90 and 95, V. Rajaraman, Prentice-Hall.
3. Theoretical Physics on the personal Computer, E. W. Schmid, G. Spitz and W. Losch, Springer-Verlag.
4. Numerical Recipes in FORTRAN, W. H. Press, S. S. Teukolsky, W. T. Vetterling, and B. P. Flannery, Cambridge University Press.
5. Numerical Methods for Scientific and Engineering Computation, New Age International.
6. Numerical Methods, E. Balagurusamy, Tata McGraw-Hill.