Programme: MSc Physics

Course Outcomes

SEMESTER 1

PH010101: MATHEMATICAL METHODS IN PHYSICS – I : The objective of this course is to make students have an idea of vectors, matrices and tensors, it's physical interpretation and applications.

CO1: To **obtain** a basic idea of curl, divergence, gradient and to **understand** line, surface and volume integral

CO2: To **evaluate** curl, divergence and gradient in orthogonal curvilinear coordinate system

CO3: To **understand** the concept of Linear vector space

CO4: To **understand** probability theory and different distributions.

CO5: To **understand** different types of matrices and transformations.

CO5: To **understand** different types of tensors and tensor algebra

CO7: To **understand** the role of metric tensors in defining the distance measures in curved spaces.

CO8: To **understand** Christoffel symbols and Geodesic equation and **apply** it to different coordinate systems

PH010102: CLASSICAL MECHANICS : After completing the course, the students will (i) understand the fundamental concepts of the Lagrangian and the Hamiltonian methods and will be able to apply them to various problems; (ii) understand the physics of small oscillations and the concepts of canonical transformations and Poisson brackets ; (iii) understand the basic ideas of central forces and rigid body dynamics; (iv) understand the Hamilton-Jacobi method and the concept of action-angle variables. This course aims to give a brief introduction to the Lagrangian formulation of relativistic mechanics.

CO 1: To **Understand** the basic concepts of Langrangian and Hamiltonian Formulation and apply it to physical problems.

CO 2: To **understand** the connection between symmetric and conservation laws.

CO 3: To **distinguish** between different types of equilibrium.

CO 4: To **understand** the physics of small oscillations and the concept of normal modes.

CO 5: To **understand** the concepts of canonical transformations and apply it to solve the harmonic oscillator problems .

CO6: To u**nderstand** the concepts of poisson brackets and to relate them to integrals of motion.

CO7: To **understand** the basics of central forces and **apply** them to orbital motion and rigid dynamics .

CO8: To **understand** the basic concepts of rigid dynamics.

CO9: To **apply** the Hamiltonian Jacobi method and action angle variables to different physical problems.

CO10: To c**onstruct** the Lagrangian formulation of Relativistics mechanics.

PH010103: ELECTRODYNAMICS: This course is intended to develop the basic philosophy of spectroscopy. It's aims to equip the student with the understanding of (1) atomic structure and spectra of typical one- electron and two-electron systems. (2) the theory of microwave and infra-red spectroscopies as well as the electronic spectroscopy of molecules; (3) the basics of Raman spectroscopy and the nonlinear Raman effects; (4) the spin resonance spectroscopies such as NMR and ESR. This course also introduces the student to the ideas of Mossbauer spectroscopy.

CO 1: To **understand** electrostatics and magnetostatics in the presence of dielectrics.

CO 2: To **apply** the method of images to find the potential in different situations.

CO 3: To **understand** Maxwell's equation in free space and matter and to apply them to obtain the conservation laws.

CO 4: To **understand** the propagation of em waves in different types of media.

CO 5: To **understand** the potential formulation of electrodynamics and the concept of retarded potentials and to apply the concept of retarded potential and to apply the concept to dipole radiation problems.

CO6: To **apply** the Lienard Wiechert potentials to obtain the power radiated by point charge.

CO7: To **understand** the basic concept of relativity and relativistic electrodynamics and to construct the em field tensor.

CO8: To **understand** propagation of em waves in different waveguides

PH010104: ELECTRONICS: Electronics is the study of the flow of charge (electron) through various materials and devices such as semiconductors, resistors, inductors, capacitors, nanostructures etc. All applications of electronics involve the transmission of power and possibly information.

CO 1: To **understand** and analyze different parameters of voltage series and voltage shunt feedback amplifiers.

CO 2: To **understand** different types of input offset voltage and current.

CO 3: To **understand** the general linear applications of op amps .

CO 4: To **understand** the CMRR and slew rate of opamp and **to analyse** its frequency response.

CO 5: **To understand** and design different types of active filters and oscillators.

CO6: To **understand** the application of op amps in comparators,converters, peak detectors and sample and hold circuits.

CO7: To **study** the internal structure and applications of IC555.

CO8: To **review** analog modulation and to analyze different types of radio receivers

SEMESTER 2

PH010201: MATHEMATICAL METHODS IN PHYSICS – II Introduce the concepts of Laplace and Fourier transforms. Introduce the Fourier series and it's application to solutions of partial differential equations.

CO 1: To **understand** complex functions and complex integrals

CO 2: To **Understand** and apply Cauchy's Integral Theorem and Cauchy's Integral Formula.

CO 3: **To Understand and apply** the Residue Theorem to calculate residues and use them to evaluate complex integrals.

CO5: To **understan**d fourier series and integral transforms such as the Laplace transform and Fourier transform

CO5: To **Apply** integral transforms to solve different problems in Physics

CO6: To **evaluate** integrals using beta and gamma functions

CO6: **To apply B**essel, Legendre, Lauguerre ,Hermite and associated legendre differential equations to different physical problems

CO7: To **understand** different types of partial differential equations and to **solve** the equations in different coordinate systems.

CO8 : To **apply** Green's function method to solve poisson equation and scattering prob;emds

PH010202 QUANTUM MECHANICS-I This course aims to develop the basic structure of quantum Mechanics. After completing the course, the student will (i) understand the fundamental concepts of the Dirac formalism (ii) understand how quantum systems evolve in time; (iii) understand the basics of the quantum theory of angular momentum. Also, this course enables the student to solve the hydrogen atom problem which is a prelude to more complicated problems in quantum mechanics.

CO1: To **understand** the fundamental concept of the Dirac Formalism

CO2: To **construct** matrix representation of kets, Bras and operators

CO3: To **apply** the uncertainty principle to non compatible observables

CO4: To c**onstruct** the position space and momentum space representation of kets

CO5: To **understand** the time evolution of quantum systems

CO6: To **distinguish** between Schroduinger picture and Heisenberg Picture

CO7: To **analyse** the simple harmonic eigen value problems

CO8: To **understand** the non commutating of rotations about different axes and **to obtain** the angular momentum commutation relations

CO9: To e**valuate** Clebsch-Gordon coefficients.

C10: **To construct** the radial wave function for a particle moving under a central potential and obtain the energy eigenvalues of hydrogen atom

PH010203 STATISTICAL MECHANICS: This paper is structured in such a way that the student gets an idea on how the behaviour of a material can be understood taking into account a statistical analysis of the properties of its molecules. The student will also learn how quantum theory is applied to have an understanding of material behaviour, based on the restrictions applied to the molecules in micro regimes.

CO1. To **understand** the connection between thermodynamics and statistics and to analyse the phase space of a classical system.

CO2. To **distinguish** between canonical and micro canonical ensembles.

CO3. To **analyse** the grand canonical ensemble and to develop quantum statistics.

CO4. To **construct** the density matrix.

CO5. To **analyse** the physics of an ideal gas in different ensembles.

CO6. To **analyse** an ideal Bose gas and to **develop** the thermodynamics of radiation and the physics of sound waves.

CO7. To **analyse** an ideal Fermi gas and to **develop** the theory of electrons in a metal.

CO8. To **understand** the physics of phase transitions and thermodynamic potentials and to **derive** the Clapeyron equation.

PH010204: CONDENSED MATTER PHYSICS: This course envisages that the student will understand the properties of a solid, how to characterize the symmetry and its various aspects. The course also illustrates the major role of electrons in determining the properties of solids. The student will be familiarized with the fundamental theories evolved through decades to understand the properties of electrons and its influence on solid behavior. The student is expected to understand how quantum theory can be applied for an effective explanation of crystal behavior.

CO1: To **understand** the crystal structure using X-Ray Diffraction

CO2: To **illustrate** the concept of Reciprocal Lattice and explain Bragg’s law in terms of it

CO3: To **illustrate** Diffraction intensity in terms of Structure factor and form factor

CO4: To **understand** Crystal symmetry and ordered phases of matter

CO5: To **interpret** free electron theory and apply the same for thermal and electrical properties of metals

CO6: To **understand** Band Theory of electrons and classify solids into conductors, insulators and semiconductors

CO7: To **illustrate** the concept of effective mass, thermos-electric effect

CO8: To **understand** Semi metals, superlattices, Bloch Oscillator and Zener Tunnelling

CO9: To **understand** the concept of Crystal vibrations and Phonons

CO10: To **illustrate** density of states of Phonons, Debye and Einstein Model

CO11: To **explain** quantum theory of magnetism in solids

CO12: To **understand** Quantisation of spin waves and the concept of Magnons

CO13: To **illustrate** Domain theory of ferromagnetism

CO14: to **introduce** the concept of Geomagnetism, Biomagnetism and Superfluidity

SEMESTER 3

PH010301: QUANTUM MECHANICS-II: This course aims to extend the concepts developed in the course ' Quantum Mechanics-I . After completing this course, the student will (i) understand the different stationary state approximation methods and be able to apply them to various quantum systems; (ii) understand the basics of time-dependent perturbation theory and its application to semi-classical theory of atom-radiation interaction; (iii) understand the theory of identical particles and its application to helium; (iv) understand the idea of Born approximation and the method of partial waves. Also, this course will introduce the student to the basic concepts of relativistic quantum mechanics.

CO1.To **apply** the time independent perturbation theory to harmonic oscillator subjected to constant electric field, hydrogen atom in a constant magnetic field and constant electric field.

CO2. To **estimate** the ground state energies of a harmonic oscillator, a particle subjected to delta potential, hydrogen atom and hydrogen molecule ion using a variational method.

CO3. To **understand** the WKB method and to apply the quantization condition to the harmonic oscillator and to the tunnelling phenomenon.

CO4. To **develop** the time-dependent perturbation theory in the interaction picture and apply it to the cases of constant perturbation and harmonic perturbation.

CO5. To **analyse** the interaction of an atom with an electromagnetic field and to explain the phenomena of spontaneous emission, stimulated emission and photoelectric effect.

CO6.To **understand** the physics of identical particles and to **analyse** the helium atom.

CO7. To **understand** the method of Born approximation and to **apply** it to the Yukawa potential and the Coulomb potential.

CO8. To **develop** the method of partial waves and to **apply** the method to hard sphere scattering and to the scattering by a finite potential well.

CO9.To **understand** the basic features of the Klein-Gordon equation and its solutions and to **analyse** the non-relativistic limit of the equation.

CO10. To **obtain** the Dirac equation in the Schrodinger form and its solutions and to **analyse** the single particle interpretation and the non-relativistic approximation of the equation.

PH010302: COMPUTATIONAL PHYSICS To help the students to have the basic idea about the techniques used in physics to solve problems with the help of computers when they cannot be solved analytically with pencil and paper since the underlying physical system is very complex. After the completion of this course students might be able to develop their own Algorithms of every method described in the syllabus.

CO 1: To **understand** least square method of curve fitting and **apply** it to straight line, parabola, power curves and exponential curves.

CO 2: To **understand** and **apply** forward, backward, divided difference and cubic interpolation techniques and the corresponding interpolating polynomials for data interpolation and extrapolation.

CO 3: To **understand** the significance as well as the methods of Numerical Differentiation and Integration.

CO 4: To **apply** Numerical Differentiation to solve a given physical condition.

CO 5: To **estimate** errors in the methods of Numerical Integration and Differentiation.

CO 6: To **design** an algorithm for each of the numerical methods learnt.

CO 7 : To **understand** and apply Runge Kutta methods to solve differential equations.

CO 8 : To **understand** and apply numerical methods to solve system of equations.

CO 9 : To **understand** and apply numerical methods to find the inverse of a matrix.

CO 10 : To **understand** and apply numerical methods to find eigenvalues and eigenvectors.

CO 11: To **understand** and **apply** the Power method to find the largest and smallest eigenvalue.

CO 12 : To **understand** and **apply** methods to find solutions to partial differential equations.

PH010303: ATOMIC AND MOLECULAR PHYSICS This course is intended to develop the basic philosophy of spectroscopy. Its aims to equip the student with the understanding of (1) atomic structure and spectra of typical one- electron and two-electron systems. (2) the theory of microwave and infra-red spectroscopies as well as the electronic spectroscopy of molecules; (3) the basics of Raman spectroscopy and the nonlinear Raman effects; (4) the spin resonance spectroscopies such as NMR and ESR. This course also introduces the student to the ideas of Mossbauer spectroscopy.

CO1. To **estimate** the spin orbit interaction energy in hydrogen like atoms and extend it to sodium atom.

CO2. To **analyse** Zeeman effect, Paschen Effect and Stark effect using the vector atom model.

CO3. To **understand** the LS and jj coupling schemes and to **estimate** the interaction energies in two electron systems.

CO4. To **distinguish** between linear, symmetric top, spherical top and asymmetric top molecules and to **analyse** the rotational spectrum of a diatomic molecule.

CO5. To **analyse** both pure vibrational spectrum and vibrational - rotational spectrum of a molecule and to **distinguish** between fundamental frequencies and overtones.

CO6. To **understand** the physics of linear and non-linear Raman effects and the role of Raman spectroscopy in structure determination.

CO7. To **understand** the basic features of electronic spectroscopy and to **construct** the Fortrat parabola.

CO8. To **understand** the physics of Nuclear Magnetic Resonance, instrumentation and application in imaging.

CO9. To **understand** the physics of Electron Spin Resonance and its instrumentation and to **analyse** the ESR spectrum of the hydrogen atom.

C10. To **understand** the principle and instrumentation of Mossbauer spectroscopy and the role of isomer shift, quadrupole interaction and hyperfine interaction.

Elective Paper – I PH810301: SOLID STATE PHYSICS FOR MATERIALS The first chapter of this course intends to disseminate to the students the deviations of crystal symmetry dealt with in ideal situations from perfection to imperfections, in the form of defects and dislocations and how they can affect the fundamental identities of solids such as mechanical, electrical, and magnetic properties. The second chapter deals with atomic diffusion and crystal binding whereas in the third chapter the student is expected to understand the application of quantum theory to understand the crystal properties.

CO1: To **understand** Crystal Imperfection, vacancy, Frenkel and Schottky imperfections,

CO2:To **explain** different types of dislocations, including edge and screw dislocations and imperfections

CO3 To **investigate** the properties of voids in close-packed structures and **analyze** the size, coordination, and significance of voids in crystal structures.

CO4: To **explain** Pauling's rule and its significance

CO5: To **understand** the fundamental principles of Fick's laws

CO6: To **analyze** the Van der Waals-London interactions and their role in crystal formation.

CO7: To **determine** equilibrium lattice constants in crystals and to **calculate** cohesive energy in crystal structures.

CO8: To **discuss** ionic crystals and their characteristics and to **calculate** Madelung energy and Madelung constant for a given ionic crystal.

CO9: To **understand** the fundamental principles governing phase diagrams and **comprehend** the characteristics and significance of unary and binary phase diagrams

CO10 : To **explain** plasma optics and to **analyze** the behavior of plasmons

CO11: To **discuss** the nature and characteristics of polaritons and to **understand** the concept of the Longitudinal-Transverse-Splitting (LST) relation.

C10: To **understand** excitons and to **distinguish** Frenkel and Wannier excitons.

SEMESTER 4

PH010401: NUCLEAR AND PARTICLE PHYSICS This course aims to provide the student with the fundamentals of nuclear and particle physics. After undergoing this course, the student will have knowledge about (1) the basic properties of the nucleus and the nuclear forces. (2) Major models of the nucleus and the theory behind the nuclear decay process;(3) the physics of nuclear reactions (4) the interaction between elementary particles and the conservation laws in particle physics. This course intends to impart some idea about nuclear astrophysics and the practical applications of nuclear physics.

CO1. To **understand** the basic properties of the nucleus and to analyse the different methods for the determination of the nuclear radius.

CO2. To **analyse** the different properties of the deuteron and different scattering experiments and to **obtain** the properties of nuclear forces.

CO3. To **understand** the liquid drop model and to apply it to the binding energy of the nucleus.

CO4. To **develop** the shell model of the nucleus and to estimate the magnetic dipole moment and the electric quadrupole moment of the nucleus.

CO5.To **analyse** the beta decay using Fermi's theory and to understand the parity violation in beta decay.

CO6. To **understand** the features of gamma decay.

CO7.To **analyse** the nuclear reactions and to distinguish between direct reactions and compound nucleus reactions.

CO8. To **understand** the interaction between the elementary particles and the classification of elementary particles

CO9. To analyse the connection between symmetries and conservation laws and to understand the basic ideas of the quark model and the standard model of particle physics.

CO10. To **understand** the basics of RBS, CAT and PET.

Elective Paper – II PH810402: SCIENCE OF ADVANCED MATERIALS This course is structured with an objective to impart onto the students the properties of a few important materials and their applications, and methods to modify the properties in order to suit them for various technologies and applications.

CO 1: To **understand** the types , properties and applications of ceramics

CO 2: To **understand** the Perovskite structure and its significance in ceramic materials CO 3:To **understand** the the basic principles of polymerization and to study different types of polymers like thermosetting, thermoplastic, and conducting polymers

CO 4:To **provide** knowledge on mechanisms of deformation and strengthening, crystallization, melting and glass transition

CO 5: To **understand** different composite materials and their properties.

CO6: To **understand** different optical properties of materials

CO7: To **understand** the fundamental concepts of Laser principles and to provide knowledge on different types of Lasers.

CO8: To **understand** the principle, structure, materials and characteristics of different Photonic materials

CO9: To **understand** the basic concepts and features of Photonic crystals, Liquid crystals, optics of metamaterials, Amorphous semiconductors. detector arrays and CCDs

CO10: To **understand** the concept of superconductivity and their properties and applications and to **distinguish** Type I and Type II superconductors

CO11: To **understand** the principle behind the tunneling of single particles through potential barriers and Josephson tunneling and its applications in superconducting devices.

CO12: To **understand** the principle and working of thin film deposition techniques and to **apply** the acquired knowledge to design thin films for specific applications, such as antireflection coatings, solar cells, and sensors.

CO13: To **understand** the mechanism of crystal growth

Elective Paper – III PH810402 NANOSTRUCTURES AND MATERIALS CHARACTERISATION This course envisages to make the student familiarize with the tremendous change in the properties of materials when they come to the nanoscale. The student will be familiarized with a few nanomaterials, their properties and applications, methods to synthesize nanomaterials, etc. Apart from synthesis, the student will understand how to characterize the synthesized material in order to understand their properties, using sophisticated tools and instrumentation.

CO 1: To **understand** the applications of the Schrödinger equation in the nanoworld and to **analyze** the behavior of particles in nanostructures.

CO 2: To **understand** the principles behind nanostructures for quantum dots, nanowires, superlattices, and heterostructures and to **acquire** knowledge on the preparation of quantum nanostructures and the size and dimensionality effect, including single electron tunneling.

CO3: To **understand** various types of nanostructures to gain insights into self-assembly and catalysis processes in nanostructure synthesis.

CO4: To **analyze** the synthesis routes for nanostructures, and to **distinguish** bottom-up approaches (PVD, CVD, MBE, PLD, wet chemical) and top-down approaches (mechanical alloying, nanolithography).

CO 5:To **Understand** the structure, fabrication, properties, and applications of carbon clusters, fullerenes and Carbon Nanotubes (CNTs).

CO6: To **understand** the properties and applications of 2-D nanostructure- graphene .

CO7: To **analyze** the properties and applications of superparamagnetic nanoparticles, Giant Magnetoresistance (GMR), ferrofluids, colossal magnetoresistance, and nanostructured thermal devices.

CO8: To **understand** the functioning of nanomachines and nanodevices like Micro-Electro-Mechanical Systems (MEMs), Nano-Electro-Mechanical Systems (NEMs), and nanosensors.

CO9: To **understand** the principles and applications of Fourier transform spectrometry Differential, difference and derivative spectroscopy, photoacoustic and thermal lens spectroscopy

CO10: To **Understand** the theory of fluorescence and phosphorescence spectrophotometry, including PL power and total luminescence spectroscopy.

CO11: To **Understand** the principles of X-Ray Diffraction, X-ray photoelectron spectroscopy (XPS) and X-ray fluorescence spectroscopy

CO12: To **understand** the working principles of Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), and Scanning Tunneling Microscopy (STM).

CO13: To **understand** the working principle of mass spectrometry.

CO14: To **Understand** the working principles of different thermal methods and **apply** principles of pH measurement, potentiometry, voltammetry, and electrogravimetry in analytical techniques.