SUBJECT: M.Sc in PHYSICS	After completion for the course student will able to
PROGRAMME OUTCOMES	**PO1:Recall** and **describe** fundamental concepts of classical mechanics, electromagnetism, quantum mechanics, and statistical mechanics. **PO2:Explain** the underlying principles and theories of advanced physics topics such as solid-state physics, nuclear physics, and particle physics. **PO3:Apply** mathematical techniques and physical principles to **solve** complex problems in theoretical and experimental physics. **PO4:Analyze** and **interpret** experimental data, identifying patterns and deriving conclusions about physical phenomena. **PO5:Design** and **conduct** experiments, integrating knowledge from different areas of physics to investigate new phenomena. **PO6:Critically evaluate** scientific research papers, **assess** the validity of methodologies, and **judge** the significance of results within the broader context of the field. **PO7:Develop** and **propose** innovative solutions to real-world problems by synthesizing concepts from various domains of physics. **PO8:Lead** and **manage** independent research projects, demonstrating advanced skills in project planning, execution, and communication of results. **PO9:Demonstrate** ethical conduct in scientific research and professional practice, **upholding** integrity and responsibility. **PO10:Recognize** the importance of lifelong learning and **engage** in continuous professional development to stay updated with advancements in the field of physics. **PO11:Utilize** advanced laboratory equipment and computational tools to **conduct** sophisticated experiments and simulations.
PROGRAMME SPECIFIC OUTCOMES	**SO1:Identify** and **recall** advanced concepts in specialized areas of physics, such as condensed matter physics, astrophysics, and quantum field theory. **SO2:Summarize** and **interpret** the latest developments and research findings in various branches of physics. **SO3:Apply** theoretical knowledge to **perform** advanced

	simulations and modeling of physical systems using software tools. **SO4:Analyze** complex physical systems and **break down** their components to understand their functioning and underlying principle. **SO5:Integrate** knowledge from various subfields of physics to **design** innovative experiments and **propose** new theoretical models. **SO6:Evaluate** experimental results and **compare** them with theoretical predictions to **validate** or **refute** existing theories. **SO7:Formulate** new hypotheses based on existing knowledge and **design** experiments to test these hypotheses. **SO8:Collaborate** with interdisciplinary teams to **address** complex scientific problems and **contribute** to multi-disciplinary research projects.
COURSE OUTCOMES	
SEMESTER-1	
PHY- 411: Classical and Relativistic Mechanics	**CO1:Analyze** the principles of small oscillations and **apply** normal coordinates and normal modes to the vibration of linear symmetric molecules. **CO2:Explain** the concept of generalized coordinates for rotation and **describe** rotation as an orthogonal transformation. **CO3:Derive** the equations for the general motion of a rigid body using Euler angles and **calculate** angular momentum and kinetic energy in terms of Euler angles. **CO4:Apply** the inertia tensor and moments of inertia to **solve** problems involving the motion of a heavy symmetrical top. **CO5:Examine** the motion in a non-inertial frame of reference and **calculate** the effects of the Coriolis force. **CO6:Use** Poisson brackets to **formulate** equations of motion and **identify** canonical invariants. **CO7:Apply** Liouville's theorem to **analyze** the conservation properties in phase space. **CO8:Generalize** Newton's force equation to covariant form and

	derive the energy-momentum relation in relativistic mechanics.
PHY- 412 : Quantum Mechanics (I)	**CO1:Explain** the inadequacies of classical mechanics and **describe** the wave-particle duality and wave-packets. **CO2:Apply** the uncertainty principle and **derive** the Schrödinger equation. **CO3:Analyze** commuting observables and the removal of degeneracy, and **evaluate** the evolution of systems with time and constants of motion. **CO4:Apply** quantum mechanics to the rigid rotator and **solve** the radial equation for hydrogen and hydrogen-like atoms. **CO5:Analyze** symmetries under rotation, **determine** the algebra of the generators, and **diagonalize** the matrix representation of generators.
PHY-413: Mathematical Methods for Physics	**CO1:Apply** the residue theorem to **evaluate** integrals by the method of residues. **CO2:Analyze** multi-valued functions, including branch points and branch cuts, and **perform** contour integration involving branch points. **CO3:Define** linear vector spaces, **determine** linear independence, basis, and dimension, and **apply** the Cauchy-Schwarz inequality. **CO4:Construct** orthonormal bases using the Schmidt orthogonalization process and **compute** dual vectors and scalar products.
PHY- 414: Computer Programming	**CO1:Describe** the basics of programming languages and **explain** the components of a computer system. **CO2:Identify** constants, variables, and data types in C programming and **apply** operators and expressions in writing simple C programs. **CO3:Perform** input and output operations in C and **write** programs involving decision-making and branching. **CO4:Implement** decision-making and looping constructs in C programs to solve repetitive tasks. **CO5:Utilize** arrays and strings in C programs to manage collections of data. **CO6:Create** user-defined functions in C to **modularize** code

	and enhance reusability. **CO7:Explain** the concept of pointers and **use** pointers for dynamic memory allocation and manipulation of data. **CO8:Define** structures and unions in C and **demonstrate** their uses in complex data management. **CO9:Implement** file management operations in C to **read** from and **write** to files.
SEMESTER-2	
PHY-421 Electrodynamics	**CO1:Explain** Maxwell's equations and their significance in describing electromagnetic phenomena. **CO2:Analyze** the equation of continuity and conservation of charge, and **apply** the Lorentz force law. **CO3:Derive** Poynting's theorem and **explain** the conservation of energy and momentum using Maxwell's stress tensor. **CO4:Describe** electromagnetic potentials and **perform** gauge transformations, including Lorentz and Coulomb gauges. **CO5:Solve** the inhomogeneous wave equation for potentials using the Green function method and **explain** retarded potentials. **CO6:Analyze** the propagation of plane electromagnetic waves in free space, dielectrics, and conductors, and **describe** reflection, refraction, and polarization. **CO7:Apply** Fresnel's laws and the oscillator model to **understand** dispersion in various media, including dielectrics, conductors, and plasma. **CO8:Explain** the concepts of anomalous dispersion, resonant absorption, and the Kramers-Kronig dispersion relations. **CO9:Derive** retarded potentials and **analyze** fields and radiation due to an arbitrary system of charges and currents using multipole expansion. **CO10:Calculate** the emission of radiation in the electric dipole, magnetic dipole, and electric quadrupole approximations, and **analyze** simple radiating systems such as linear centerfed antennas.
PHY-422: Quantum Mechanics (II)	**CO1:Describe** the experimental evidence for spin angular momentum and **explain** Pauli's theory and spin wave functions. **CO2:Analyze** the properties of Pauli matrices and **apply** them to

	systems of two spin-12\frac{1}{2}21 particles. **CO3:Explain** the symmetry and anti-symmetry of wave functions, and **apply** the spin-statistics relation and Pauli exclusion principle. **CO4:Demonstrate** the implications of the Pauli principle and **calculate** the Fermi level in various systems. **CO5:Apply** time-independent perturbation theory to **calculate** energy levels and eigenfunctions up to the second order, and **analyze** the anharmonic oscillator problem. **CO6:Differentiate** between non-degenerate and degenerate cases in perturbation theory, and **explain** the removal of degeneracy in the Stark effect and helium atom problem. **CO7:Utilize** the W.K.B approximation to **analyze** turning points, bound states, and tunneling phenomena. **CO8:Apply** the Bohr-Sommerfeld quantization formula and **estimate** ground state and excited state energy levels using the variational principle. **CO9:Explain** the optical theorem and **analyze** low-energy scattering cases (l=0), scattering length, and effective range.
PHY-423: Basic Electronics	**CO1:Explain** the concepts of T and Π\PiΠ networks and **convert** between these network forms using appropriate methods. **CO2:Apply** Foster's reactance theorem to analyze and **simplify** network circuits. **CO3:Analyze** transistor parameters and **construct** equivalent circuits for transistors in CE, CB, and CC configurations. **CO4:Evaluate** the small signal low and high frequency transistor circuits, and **analyze** the impact of the Miller effect and gain-bandwidth product. **CO5:Explain** the effect of cascading stages in amplifiers and **apply** feedback principles to **analyze** feedback circuits. **CO6:Evaluate** the advantages of master-slave flip-flop configurations and **apply** them to **design** robust sequential logic circuits.
PHY-424: Statistical Mechanics	**CO1:Describe** the fundamental concepts of kinetic theory, including binary collisions and the Boltzmann transport

	equation. **CO2:Explain** the H-theorem and **derive** the Maxwell-Boltzmann distribution law. **CO3:Calculate** the mean free path of particles in a gas and **analyze** its implications for kinetic theory. **CO4:Explain** the elements of ensemble theory, phase space, and the ergodic hypothesis. **CO5:Apply** Liouville's theorem to **analyze** the behavior of dynamical systems in phase space. **CO6:Differentiate** between micro-canonical, canonical, and grand-canonical ensembles, and **calculate** thermodynamic functions for each ensemble. **CO7:Apply** the equipartition theorem to classical ideal gases and **explain** Gibb's paradox. **CO8:Analyze** energy and density fluctuations in the canonical and grand-canonical ensembles, respectively. **CO9:Describe** the concept of the density matrix and **apply** Quantum Liouville's theorem to quantum systems. **CO10:Explain** the different ensembles in quantum mechanics and **calculate** equilibrium averages of observables.
IDC- 429: IDC or Open Elective Course (PHYSICS)	**CO1:** Describe the historical development of modern physics, from Galileo and Newton to Einstein, and explain their contributions to our understanding of the solar system, galaxies, and astrophysical objects, including the Big Bang cosmology. **CO2:** Analyze the structure and behavior of molecules, atoms, nuclei, and elementary particles, and discuss the methodologies used in their observation and experimentation across various laboratories. **CO3:** Explain the principles of nuclear physics, including binding energy, nuclear fusion, and fission, and evaluate their applications in nuclear reactors, nuclear medicine, X-rays, MRI, and PET/CT scans. **CO4:** Distinguish between the solid, liquid, and gaseous states of matter, and compare the properties and uses of metals, insulators, and semiconductors. Investigate the photoelectric effect, superconductivity, and novel materials, as well as the

	principles of light, lasers, and heat engines. **CO5:** Understand the fundamentals of electronics, including the operation of microphones, speakers, and amplifiers. Analyze the concepts of power generation and transmission, and describe the basics of computer systems and their applications.
SEMESTER-3	
PHY- 511: Solid-State Physics	**CO1:Describe** crystal structures and bonding in solids, and **explain** normal modes of mono- and diatomic lattices. **CO2:Analyze** the salient features of dispersion curves and **calculate** the phonon density of states. **CO3:Apply** quantum theory to **determine** heat capacity of solids and **interpret** the implications for lattice vibrations. **CO4:Explain** the Sommerfeld theory of the free electron gas and **calculate** the density of states and electronic heat capacity. **CO5:Analyze** the temperature dependence of the Fermi-Dirac distribution function and **apply** it to problems involving cyclotron resonance and the Hall effect. **CO6:Describe** the AC conductivity and optical properties of materials, and **apply** concepts of thermionic emission. **CO7:Apply** Bloch's theorem to **analyze** the nearly free electron model (NFEM) and tight-binding models, and **solve** problems using the Kronig-Penney model and effective mass concept. **CO8:Differentiate** between intrinsic and extrinsic semiconductors, **calculate** carrier concentration, and **analyze** electrical conductivity and magnetic field effects. **CO9:Explain** the Clausius-Mossotti relation, and **analyze** sources of polarizability, including dipolar dispersion, piezoelectricity, and ferroelectricity.
PHY- 512: ELECTIVE PAPER – I (Condensed matter Physics-I)	CO1: Lattice Dynamics and Energy Band Theory Analyze Lattice Vibrations: Understand harmonic and anharmonic approximations in lattice dynamics. Apply the Born-Oppenheimer approximation to the Hamiltonian for lattice vibrations, quantization, and phonons. Study Electron Waves: Describe the wave equation for an electron in a periodic potential. Apply the Bloch-Floquet theorem to understand energy bands, Brillouin zones, and effective mass of an electron. Use the tight-binding approximation to model electron behavior in solids.

	CO2: Fermi Surfaces Understand Fermi Surfaces: Characterize and construct Fermi surfaces for metals. Analyze experimental techniques for studying Fermi surfaces, including the De Haas-van Alphen effect and cyclotron resonance. CO3: Beyond the Independent Electron Approximation Explore Advanced Theories: Apply the Hartree and Hartree-Fock equations to describe electron correlation and screening. Use the Thomas-Fermi theory to understand the dielectric function in materials beyond the independent electron approximation. CO4: Wannier Representation Utilize Wannier Functions: Define Wannier functions and their role in describing electronic states. Apply the equation of motion in the Wannier representation to study impurity levels and excitons. Analyze weakly bound and tightly bound excitons and their implications in solid-state physics.
PHY- 513: X-ray and Laser Spectroscopy	**CO1:Describe** Sommerfeld's extension of the Bohr theory and **explain** the vector atom model, including the quantum states of one-electron atoms. **CO2:Analyze** atomic orbitals and the hydrogen spectrum using Pauli's principle, and **explain** the effects of spin-orbit interaction and fine structure in alkali spectra. **CO3:Apply** intensity rules to determine the behavior of equivalent and non-equivalent electrons and **calculate** interaction energy in LS and jj coupling. **CO4:Explain** the Stark effect and **analyze** the spectral characteristics of two-electron systems. **CO5:Analyze** vibrational energy levels of diatomic molecules, treating them as simple harmonic oscillators, and **explain** the effects of anharmonicity and Morse potential on energy levels and spectra. **CO6:Explain** Raman spectroscopy and **analyze** its applications in molecular spectroscopy.
PHY-514: RESEARCH METHODOLOGY	**CO1:Apply** statistical concepts and procedures to analyze data and **create** diagrammatic representations of data. **CO2:Calculate** measures of central tendency, dispersion,

	skewness, and kurtosis, and **interpret** their significance in data analysis. **CO3:Analyze** normal distribution and **apply** simple and multiple correlation techniques as well as regression analysis to data sets. **CO4:Apply** principal component analysis and **design** experiments using Completely Randomized Block Design, Randomized Block Design, and Latin Square Design. **CO5:Apply** non-parametric procedures and **plot** graphs to represent statistical data effectively.
SEMESTER - IV	
PHY- 521: Nuclear Physics	**CO1:Describe** the fundamental properties of nuclei, including composition, mass, charge, density, radii, spin parity, isospin, and statistical properties. **CO2:Apply** methods to measure nuclear size using nuclear and electromagnetic techniques, including electron scattering. **CO3:Analyze** the ground state of the deuteron with central forces and **explain** low-energy neutron-proton scattering, including concepts like scattering length and spin dependence of nuclear forces. **CO4:Evaluate** proton-proton and neutron-neutron scattering with elementary concepts and **interpret** their significance in nuclear interactions. **CO5:Explain** the exchange nature of nuclear forces and **apply** phenomenological nucleon-nucleon potentials to describe nuclear interactions. **CO6:Apply** the Breit-Wigner formula to analyze nuclear reactions and **interpret** its use in describing resonances.
PHY- 522: Particle Physics	**CO1: Identify and classify elementary particles** Demonstrate the ability to categorize particles into leptons, baryons, mesons, and gauge fields and trace the history of particle discovery and understand the evolution of particle physics. **CO2: Analyze symmetries and conservation laws** Apply conservation laws including energy, momentum, angular momentum, electric charge, lepton and baryon number to particle interactions. Interpret the Eight-Fold Way and the Gell-Mann Nishijima

	scheme and their implications for particle classification. **CO3: Explain the quark model and its applications** Illustrate the SU(3) symmetry group and its role in the classification of hadrons.Define and differentiate between color and flavor in the quark model. **CO4: Evaluate methods for particle detection and radiation measurement** Demonstrate understanding of radiation passage through matter and derive stopping power (dE/dx) for heavy charged particles. Compare and contrast various detection methods including G.M. counters, semiconductor detectors, bubble chambers, cloud chambers, spark counters, and Cherenkov detectors. **CO5: Assess and describe particle accelerators and radiation sources** Explain the operation principles of particle accelerators including Van de Graaff generators, cyclotrons, synchrotrons, linear and circular accelerators, and colliders. Discuss the role of these accelerators in particle physics research and their impact on radiation detection and particle studies.
PHY -523: ELECTIVE PAPER-II(Condensed Matter Physics (II))	CO1: Magnetism • Understand Magnetic Properties: Describe diamagnetism, paramagnetism, and the related susceptibility concepts. Explain Langevin’s equation, the Curie law, and quantum theories like Pauli paramagnetism. Discuss Landau levels and different types of magnetism (ferro, anti-ferro, ferrimagnetism). • Analyze Magnetic Phenomena: Explain the Weiss molecular field, exchange interaction, and the temperature dependence of magnetism. Discuss ferromagnetic phase transitions, spin waves, magnons, and the Bloch $T^{3/2}$ law. Understand antiferromagnetic order and the Neel temperature. • Magnetic Resonances: Provide a basic description of magnetic resonances such as Nuclear Magnetic Resonance (NMR) and Electron Spin Resonance (ESR), and discuss their applications. Explain the Bloch equation. CO2: Superconductivity • Characterize Superconductors: Discuss the fundamental

	properties of superconductors, including flux exclusion (Meissner effect), London's equation, and the concept of Cooper pairs. Explain the BCS theory and its ground state, and compare theoretical results with experimental observations. Describe supercurrent and coherence length. CO3: Types of Superconductors • Different Superconductors: Differentiate between Type-I and Type-II superconductors. Provide an overview of high-temperature superconductors, heavy fermion superconductors, and fullerene superconductors. CO4: Nanostructured Materials • Understand Nanostructures: Introduce various types of nanostructured materials and discuss their mechanical, magnetic, and optical properties. Explain the size-dependent effects and derive the energy spectrum and density of states for quantum wells, quantum wires, and quantum dots using quantum mechanical solutions.