SYLLABUS FOR PHYSICS

PART – 1

I Mathematical Methods of Physics:

Dimensional analysis, vector algebra and vector calculus. Matrices – Orthogonal, Hermitian, unitary matrices, eigenvectors and eigenvalues; Caley-Hamilton theorem, diagonalization of matrices. Tensors – definition, types and algebra of tensors. Linear ordinary differential equations of first and second order; Special functions: Helmhotz equation, series solutions-Frobenius method, Bessel, Legendre, Hermite and Laguerre functions – generating functions, recursion relations and orthogonal properties. Partial differential equations - Laplace, wave and heat equations in two- and three-dimensions. Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions, Taylor and Laurent series; poles, residues and evaluation of integrals. Greens functions – definition and properties. Group theory: groups, subgroups and classes, homomorphism and isomorphism, group representation, rotation groups – SO(2), SO(3).

Elements of computational techniques: roots of functions, interpolation, extrapolation; integration by trapezoidal and Simpson's rule; solution of first order differential equations using Runge-Kutta method; finite difference methods.

II Classical Mechanics:

Newton's laws, dynamical systems, fluid dynamics, surface tension, viscosity; simple harmonic motion.

Lagrangian mechanics – generalized coordinates, D'Alembert's principle, Lagrangian equation of motion, Hamilton principle, conservation laws and cyclic coordinates. Central force motions: equivalent one-body problem, equations of motion for orbits, classification of orbits; scattering in central force field, Rutherford scattering, centre of mass frames and laboratory coordinate systems. Rigid body dynamics, Euler theorem, moment of inertia tensor, Euler equations of motion, non-inertial frames and pseudo forces; Periodic motion; small oscillations, normal modes. Hamiltonian mechanics: Legendre transformation and Hamiltonian equations of motion. Variation principle, Poisson brackets and canonical transformations – Hamilton-Jacobi theorem.

Special theory of relativity – Lorentz transformations, relativistic kinematics and mass-energy equivalence.

III Electromagnetic theory:

Electrostatics: Gauss' law and applications, Laplace and Poission equations, boundary value problems. Magnetostatics: Biot-Savart's law, Ampere's theorem. Electromagnetic induction; Maxwell's equations in free space and linear isotropic media, boundary conditions on the fields on the fields at interfaces. Scalar and vector potentials, gauge invariance. Electromagnetic waves in free space. Dielectrics and conductors. Reflection and refraction. Polarization, Fresnel's laws; interference, coherence, and diffraction. Dynamics of charged particles in static and uniform electromagnetic fields. Dispersion relations in plasma. Lorentz invariance of Maxwell's equation. Transmission lines and wave guides. Radiation from moving charges and dipoles and retarded potentials.

IV Quantum Mechanics:

Wave-particle duality. Schrodinger equation (time-dependent and time-independent). Ehrenfest's theorem; basic postulates of quantum mechanics. Eigenvalue problems (Particle in a box, harmonic oscillator, etc), tunneling through a barrier. Wave function in coordinate and momentum representations. Commutators and Heisenberg uncertainity principle. Dirac notation for state vectors. Hydrogen atom: spherically symmetric potential, eigenvalues and eigenfunctions, angular momentum, angular momentum algebra; spin, addition of angular momenta. Time-independent perturbation theory and applications. Time dependent perturbation theory and Fermi's golden rule, selection rules. Variational method. Identical particles, Pauli exclustion principle. Spin-orbit coupling, fine structure. WKB approximation. Elementary theory of scattering: phase shifts, partial waves, Born approximation. Relativistic quantum mechanics: Klein-Gordon and Dirac equations, semi-classical theory of radiation.

V Thermodynamic and Statistical Physics

Laws of thermodynamics and their consequences; entropy, Carnot cycle. Thermodynamic potentials, Maxwell relations, chemical potential. Phase equilibrium, first and second phase transitions. Phase space, micro and macro-states. Basic postulates, micro-canonical, canonical and grand canonical ensembles and partition functions. Gibbs paradox, equipartition theorem. Free energy and its connection with thermodynamic quantities. Classical and quantum statistics; identical particles and symmetry requirements; ideal Bose and Fermi gases. Bose-Einstein condensation. Principle of detailed balance. Black-body radiation and Planck's distribution law. Ising model. Fluctuations and Irreversible processes: random walk and Brownian motion; diffusion equation. Introduction to nonequilibrium processes, Onsager relations, fluctuation-dissipiation theorem.

PART – 2

VI Electronics and Experimental methods:

Semiconductor devices: diodes, junctions, transistors, field effect devices; homo- and hetero-junction devices; device structure, device characteristics, frequency dependence and applications; opto-electronic devices (solar cells, photo-detector, LEDs). Operational amplifiers and their applications. Integrator and differentiator, active filters and oscillators Boolean laws and theorems, logic gates, Digital techniques and applications (registers, counters, comparators and similar circuits). A/D and D/A converters, Microprocessor and microcontroller basics. Transducers.

Measurement and control. Signal conditioning and recovery. Impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding. Fourier transforms, lock-in detector, modulation techniques, high frequency devices (including generators and detectors).

Data interpretation and analysis, precision and accuracy, error analysis, propagation of errors, least squares fitting, Linear and nonlinear curve fitting, chi-square test.

VII Optics and Atomic and Molecular Physics:

Geometric optics – Fermat's principle, reflection, refraction, dispersion. Physical optics – Huygen's principle, interference, diffraction, polarization.

Quantum states of an electron in an atom, electron spin, spectrum of helium and alkali atom, relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, LS and jj couplings. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules; Zeeman, Paschen-Back and Stark effects. Electron spin resonance; nuclear magnetic resonance, chemical shift. Frank-Condon principle. Born-Oppenheimer approximation. Lasers: spontaneous and stimulated emission, Einstein A and B coefficients, optical pumping, population inversion, rate equation, Modes of resonators and coherence length.

VIII Condensed Matter Physics:

Bravais lattices, Miller Indices, Reciprocal lattice, crystal diffraction and the structure factor. Bonding of solids. Elastic properties. One-dimensional monatomic and diatomic lattice vibrations, phonons, lattice specific heat, free electron theory and electronic specific heat, response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, band theory of solids – metals, insulators and semiconductors; concept of holes, intrinsic and extrinsic semiconductors. Diamagnetism, paramagnetism and ferromagnetism. Superconductivity: type-I and type-II superconductors; Josephson junctions, BCS theory. Liquid crystals – kinds of liquid crystalline order. Nanostructured materials: electronic and optical properties, quantum confinement effect, applications.

IX Nuclear and Particle Physics:

Basic nuclear properties: size, shape and charge distribution, spin and parity, Binding energy, liquid drop model, semi-empirical mass formula, Nature of the nuclear force, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces, Evidence of shell structure, single-particle shell model, its validity and limitations, Elementary ideas of alpha, beta and gamma decays and their selection rules. Nuclear fission and fusion, nuclear reactors. Nuclear reactions: reaction mechanism, Q-value, compound nuclei and direct reactions. Fundamental forces, classification, properties. Elementary particles and conservation of various quantum numbers (charge, spin, parity, isospin, strangeness, etc), Gellmann-Nishijima formula. Quark model, baryons and mesons; C,P and T invariance; application of symmetry arguments to particle reactions; parity non-conservation in weak interaction. Relativistic kinematics.