SCHOOL OF BASIC SCIENCES

Syllabus for Ph.D. Entrance Examination in Physics

Definitions and types of matrices; Solution of linear algebraic equations; Characteristic equation, Diagonal form; Eigen values and Eigen vectors; Cayley - Hamilton theorem; Functions of matrices; Application in solving linear differential equation.Function of complex variables; Cauchy-Riemann differential equations; Cauchy's integral theorem, Cauchy's integral formula; Taylor's Series, Laurent series; Cauchy residue theorem; Singular points of an analytical function; Evaluation of residues & definite integrals.Dirac delta function, Delta sequences for one dimensional function, Properties of delta function; Gamma function, factorial notation and applications; Beta function.Partial differential equations in theoretical physics, Boundary value problems, Neumann &Dirichlet Boundary conditions, Separation of variables, Singular points, Series solutions.Introduction to probability theory, Random variables, Binomial, Poisson and Normal distribution.D'Alembert's principle; Lagrange's equations; Velocity-dependent potentials; Simple applications of the Lagrangian formulation; Hamilton's principle; Derivation of Lagrange's equations from Hamilton's principle; Lagrange Multipliers and constraint optimization Problems. Conservation theorems and symmetry properties, Energy Function and the conservation of energy; Two-Body Central Force Problem, Reduction to the equivalent one body problem; Equations of motion and first integrals; Equivalent one-dimensional problem and classification of orbits; Differential equation for the orbit and integrable power-law potentials; Kepler problem, Inverse square law of force; Scattering in a central force field, Transformation of the scattering problem to laboratory coordinates. Small Oscillations, Formulation of the problem, The eigenvalue equation and the principal axis transformation; Frequencies of free vibration and normal coordinates; Legendre transformations and the Hamilton equations of motion, Derivation of Hamilton's equations from a variational principle.

Postulates of QM; Observables and operators, measurements; the state function and expectation values; the time-dependent Schrodinger equation; time development of state functions; solution to the initial value problem. Dirac notation; superposition principle; commutator relations; their connection to the uncertainty principle; complete sets of commuting observables; Time development of state functions and expectation values; parity. Hilbert space; Hermitian operators and their properties; Matrix mechanics, Basis and representations, matrix properties; Unitary and similarity transformations; the energy representation. General properties of one-dimensional Schrodinger equation; Finite potential well, Harmonic oscillator; Unbound states; barrier problems. Ladder operators; eigen values and eigen functions of L^2 and L_z using spherical harmonics Radial equation for a spherically symmetric central potential; Hydrogen atom, Eigenvalues and radial eigenfunctions, degeneracy, probability distribution, angular momentum and rotations. Total angular momentum J; eigenvalues of J^2 and J_z; Addition of angular momentum; coupled and uncoupled representation of eigen functions, Clebsch Gordon coefficients for $j_1=j_2=1/2$ and $j_1= 1$, $j_2 =1/2$, Angular momentum matrices; Pauli spin matrices; spin eigen functions

Kirchoff's laws; Thevenin& Norton theorems; Superposition; Reciprocity; Compensation theorems; Source transformation; Delta and Star transformations; Laplace Transformation; Convolution integral. PN Junction, contact potential and Space Charge phenomena, I-V relationships, biasing of PN Junctions, characteristics of crystal and

ideal diode, Limitations in the Operating Conditions of *p-n* Junction, Breakdown phenomena- avalanche and Zener processes.Zener diode, Zener regulated power supply, Rectification- Half wave, Full wave, Centre-Tap Full-Wave and Bridge rectifier, Diode as a circuit element: Filter Circuits, clipping, clamping with first and second approximation, Voltage-Multiplier Circuits. Low frequency and high frequency and Power amplifiers using transistors (Class A, B and C); Sine wave generators, Negative feedback: Emitter follower, Darlington Amplifier, Switching Transistors: Multi-vibrator circuits (Astable, monostable and Bistable); Differentiating and integrating circuit (Triangle and square wave generation) Ideal operational amplifier: Characteristics; Feedback types; Applications: Basic scaling circuits, current to voltage and voltage to current conversion; Sum and difference amplifiers; Integrating and differentiating circuits; R.C. Amplifiers; Filters.

Concept of phase space; Statistical definition of entropy; Gibb's paradox; Ensembles: microcanonical, canonical and grand canonical; partition function and derivation of thermodynamics; Entropy as an ensemble average; Classical ideal gas.Density operator; Liouville theorem, Quantum microcanonical, Canonical and grand canonical ensembles; Specific heat of solids (Einstein and Debye theory), Distribution function (MB, FD and B-E), Ideal Fermi gas, Fermi-Dirac statistics.Bose-Einstein statistics; Applications of the formalism to Ideal Bose gas; properties of black-body radiation, Bose-Einstein condensation, Examples of BEC, BEC in a harmonic potential.Brownian motion: as a random walk (Einstein theory), as a diffusion process; Langevin theory of Brownian motion; Fluctuation-dissipation theoremLandau theory of phase transition, Paramagnetism, Ferromagnetism, Ising model in 2-Dimension, Curie temperature.

Lorentz transformation as orthogonal transformation in 4- dimension, Relativistic equation of motion, Applications of energy momentum conservation, Disintegration of a particle, C.M. System and reaction thresholds.Four vectors in Electrodynamics, 4-current density, 4-potential, Covariant continuity equation, Wave equation, Covariance of Maxwell equations, Electromagnetic field tensor, Transformation of EM fields, Invariants of the EM fields, Energy momentum tensor of the EM fields and the conservation laws. Lienard-Wiechert Potentials, Field of a charge in arbitrary motion and uniform motion, Radiated power from an accelerated charge at low velocities.Radiation from a charged particle with collinear velocity and acceleration.Radiation from a charged particle in a circular orbit, Radiation from an ultra-relativistic particle, Radiation reaction.Rayleigh scattering, absorption of radiation by bound electron.

Hydrogen atom spectrum; Electron spin; Spin Orbit interaction; Lande interval rule; Two electron systems; LS – JJ coupling Schemes; Fine structure; Spectroscopic terms and selection rules; Hyperfine structure; Exchange symmetry of wave function; Pauli's exclusion principle; Spectrum of Helium and Alkali atom.Zeeman and Paschen Back Effect of one and two electron systems; Stark effect; X-ray – Auger transitions; Compton Effect; NMR – Basic principles; Classical and Quantum mechanical description; Magnetic dipole coupling; Chemical shift; ESR – Basic principles; Nuclear interaction and Hyperfine Structure.Rotational spectra of diatomic molecules; Rotation spectra of polyatomic molecules; Linear, symmetric top and asymmetric top molecules; Experimental Techniques; Diatomic vibrating rotator; Linear, Symmetric top molecule; Analysis by infrared techniques.Raman Effect; Quantum theory of Raman effect; Electronic, rotational, vibrational and Raman spectra of diatomic molecules; Raman spectra of polyatomic molecules (tentative); Experimental techniques.Electronic spectra of diatomic

molecules; Frank-Condon principle; Dissociation energy and dissociation products; Rotational fine structure of electronic vibration transitions.

Basic nuclear properties; Size, Shape and charge distribution; Spin and parity; Binding energy, liquid drop model and semi-empirical mass formula, nature of the nuclear force form of nucleon-nucleon potential; Charge independence and charge-symmetry of nuclear forces; Deuteron problem.Basic properties of nuclear shell model, Evidence of shell structure; Single-particle shell model, its validity and limitations; Rotational spectra; Magnetic moments and Schmidt lines; Iso-spins. Decay-range; Particle spectra; Gamow theory; Beta decay; Fermi decay of beta decay; Shape of the beta spectrum; Total decay rate; Angular momentum and parity selection rules; Parity violation; Detection and properties of neutrino; Angular momentum and parity selection rules; Internal conversion; Nuclear isomerism.Reaction dynamics; The Q equation; Theory of Nuclear reaction; Partial wave analysis; Compound nucleus formations and break up; Resonance scattering and reactions; Theory of stripping reactions; The Fission process; Neutron released in the fission process; Fusion process. Types of interaction between elementary particles; Hadrons and leptons; Symmetry and conservation laws; Elementary ideas of CP and CPT invariance; Classification of hadrons quark model SU(2) SU(3) multiplets; Gell-Mann-Okubo mass formula for octet decuplet hadrons.Introduction to scattering, spin dependence of the interaction: singlet and triplet scattering lengths; coherent scattering from ortho and para-hydrogen; singlet state of the deutron; np, pp, nn scattering; exchange forces and saturation.Residual interaction single particle model and individual particle model; justification of Nordheims rule; configuration mixing; anti-symmetrization of wave functions two and three nucleons in unfilled shell; coefficients of fractional parentage; Pairing interaction and its effects.

Energy band formation, Kronig-Penny model-allowed and forbidden energy band-E-k diagram, one dimensional Brillouin zone, effective mass, direct and indirect band gap, electrons and holes, intrinsic and extrinsic semiconductors, elemental and compound semiconductor, generation, recombination and injection of carriers, basic governing equations in semiconductors-Poisson's equation, continuity equation.Carrier concentration and Fermi level of intrinsic and extrinsic semiconductor, Thermal Effect, conductivity and carrier mobility in semiconductor, Drift and diffusion of carriers, Carrier scattering-Ionized Impurity and Phonon Scattering, Hall effect in semiconductor and its application.The P-N junction formation mechanism, built in potential, Space Charge phenomena, biased pn junction, Boltzmann's Approximation: Density of carriers injected to the limits of depletion layer, Minority currents in neutral region, Junction breakdown: avalanche and zener processes, Junction capacitance.Bipolar junction transistor (BJT), definition of h-parameters and applications, Field Effect Transistors (FET), MOSFET and applications.Introduction to Schottky diodes, Full depletion analysis,
Introduction to high frequency diodes: Gunn diode, Trapatt diode and Impatt diode.

Feedback concepts, Oscillatory Circuit, Colpitt's oscillator, Hartley oscillator, Phase shift oscillator, Wien Bridge oscillator, Limitations of LC and RC Oscillators: Crystal oscillator, negative resistance oscillator: tunnel diode oscillator, Unijunction Oscillator.Digital systems-Boolean algebra and Logic gates, Gate level minimization, K - Map , Combinational Logics- Half adder-sub-tractor (half & full) Comparators; Encoder-Decoders; Multiplexers; De-multiplexers; decimal adders and Subtractors.
Sequential circuits, Latches, Flip-flops triggering of flip-flop – D and T type flip-flops - asynchronous,

synchronous, Registers , decade and modulo – N counters.Analog Switches, High speed sample- and- hold Circuits, Types of D/A Converter, Current driven DAC, Switches for DAC, A/D converter-Flash, Single slope, Dual slope, Successive approximation, Delta Sigma Modulation, Voltage to Time converters.Introduction to 8085, basic concepts of microprocessors CPU, I/O devices, clock, memory, bussed architecture, tristate logic, address bus, data bus and control bus, microprocessor architecture: intel 8085A microprocessor, pin description and internal architecture.Introduction to display devices: Electro Luminescence display, Plasma display, Liquid Crystal Display (LCD), LED Display, Organic Light Emitting Devices (OLED), Elements of measuring instruments – capacitive transducer – inductive transducer- electrical strain gauges –resistance thermometer –piezoelectric and photoelectric transducers.

Phase Diagram - Basic principle - Simple binary systems - Solid solutions - Eutectic systems - Application. Solid Solution - Interstitial and substitutional solid solutions - Super lattices - Intermediate and interstitial phases - Intermetallic compounds, Elementary ideas of corrosion - Oxidation - Creep and fracture. Liquid crustal ordering, Phases of liquid crystal, Landau-De Gennes theory of nematic liquid crystals.Point defects - Schottky and Frenkel defects - number of defects as a function of temperature - Diffusion in metals - Diffusion and ionic conductivity in inonic crystals - Dislocations - Edge and screw dislocations - Motion of dislocations under uniform shear stress - Stress fields around dislocations - Effect of grain size on dislocation. Internal electric field in a dielectric - Clausius - Mossotti and Lorentz - Lorenz equations - Dielectric dispersion and loss, Ferroelectrics - Ferro electricity - General properties - Dipole theory - Ionic displacements and the behaviors of $BaTiO_3$ - Spontaneous polarization of $BaTiO_3$ - Thermodynamics of Ferro electric transitions.Atomic model of elastic behaviour - Elastic deformation - Relaxation process - Model for viscoelastic behavior, Polymerization mechanism - Polymer structures - Deformation of polymers - Effect of structure on the behaviour of ceramic phases - composites.Super conductivity – –Meissner effect – Type I and II superconductors – thermal properties of superconductors – High frequency phenomenological properties – coherence length – London model –Ginzburg-Landau theory – flux quantisation – BCS theory – Josephson effect (AC and DC) – High temperature superconducting oxides – Technological applications

Crystal Diffraction Methods for X rays, Laue, Rotating Crystal, Powder Method; Reciprocal Lattice and Brillouin Zones; Reciprocal Lattice to sc, bcc, fcc.; Scattered wave amplitude; Fourier analysis of the basis; Structure Factor of lattices (sc, bcc, fcc); Atomic Form Factor.Electrons in periodic potential, Band Theory, Tight Binding, Cellular and Pseudo potential methods, Symmetry of energy bands, density of states, Fermi surface, De Haas von Alfen effect, Elementary ideas of quantum Hall effect.Vibrations of Monoatomic Lattice, normal mode frequencies, dispersion relation; Lattice with two atoms per unit cell; normal mode frequencies, dispersion relation: Quantization of lattice vibrations, phonon momentum; Anharmonic Crystal Interaction; Thermal conductivity, Lattice Thermal Resistivity.Langevin diamagnetic equation; diamagnetic response; Quantum mechanical formulation; core diamagnetism; Quantum Theory of Paramagnetism; Crystal Field Splitting and Quenching of orbital angular momentum; Paramagnetic susceptibility of conduction electrons. Ferromagnetic order, Exchange Integral, Saturation magnetization; Magnons, neutron magnetic scattering; Spinels, Yttrium Iron Garnets; Anti Ferromagnetic order; Anisotropy energy, transition region between domains.

Text Books:

1. Arfken& Weber, Mathematical methods for physicists, 4th ed., Academic Press, San Diego, 1995.
2. H. Goldstein, Poole and Salko, Classical Mechanics, 3rd ed., Narosa Publication, New York,2001.
3. Simon, Classical Mechanics, 4th ed., Addison-Wesley, New York, 1977.
4. DJ Griffiths, Introduction to Quantum Mechanics,5th ,Pearson Prentice Hall, USA,1995.
5. Milman J. and Halkias C.C., Electronic Devices and Circuits, Tata McGraw Hill, 2nd Edition, New York, 1996.
6. L. Boylestad and Louis Nashelsky, Electronic Devices and Circuits, RPearson/Prentice Hall, 9th Edition, Ohio, 2006.
7. Greiner, Neise and Stocker,Thermodynamics and Statistical Mechanics, Springer,Verlag, 1995.
8. RK Pathria and PD Beale, Statistical Mechanics, 3rd ed., Elsevier, 2011.
9. D.J. Griffiths, Introduction to Electrodynamics,4thed.,Pearson, USA, 2013.
10. Raj Kumar, Atomic and molecular spectra and laser, KedarNath Ram Nath Publications Meerut, 2012
11. Harvey Elliott White, Introduction to Atomic Spectra, McGraw Hill, 1963.
12. Arthur Beiser, Concepts of Modern Physics, 6thed.,McGraw Hill, New Delhi, 2008.
13. R.A. Gayakwad, Op- Amps. and Linear Integrated circuits, 3rd ed., Printice Hall, 1993.
14. Charles Kittel, Introduction to Solid State Physics, 7th edition, John Wiley & sons, USA,1996.
15. A J Dekker, Solid State Physics, Prentice-Hall, New York, 1957.
16. B.L. Cohen, Concepts of Nuclear Physics, McGraw Hill,USA, 1971.