Syllabus for Ph.D. Entrance Exam in physics 2016

MATHEMATICAL METHODS FOR PHYSICS

Unit I

Complex Variables:
Complex numbers. Equations to curves in the plane in terms of z and z*. The Riemann sphere and stereographic projection. Analytic functions of z and the Cauchy Riemann conditions. The real and imaginary parts of an analytic function. The derivative of an analytic function. Power series as analytic functions. Convergence of power series. Cauchy's integral theorem. Singularities, removable singularity, simple pole, multiple pole, essential singularity. Laurent series. Singularity at infinity. Accumulation point of poles. Meromorphic functions. Cauchy's integral formula Solution of differential equations using generating functions and contour integration. Summation of series using contour integration. Evaluation of definite integrals using contour integration.

Unit II

Multivalve functions; integral representations
Branch points and branch cuts. Algebraic and logarithmic branch points, winding point. Riemann sheets. Contour integrals in the presence of branch points. An integral involving a class of rational functions. Contour integral representation for the gamma function. Contour integral representations for the beta function and the Riemann zeta function. Connection with Bernoulli numbers. Zeroes of the zeta function. Statement of the Riemann hypothesis. Contour integral representations of the Legendre functions of the first and second kinds. Singularities of functions defined by integrals. End-point and pinch singularities, examples. Singularities of the Legendre functions. Dispersion relations for the Legendre functions.

Unit III

Laplace transforms and Green Function
Definition of the Laplace transform. The convolution theorem. Laplace transforms of derivatives. The inverse transform, Mellin's formula. The LCR series circuit. Laplace transform of the Bessel and modified Bessel functions of the first kind. Laplace transforms and random processes: the Poisson process. Laplace transforms and random processes: biased random walk on a linear lattice and on a d-dimensional lattice.

Green functions. Poisson's equation. The fundamental Green function for thelaplacian operator. Solution of Poisson's equation for a spherically symmetric source. The Coulomb potential in d dimensions. Ultraspherical coordinates. A divergence problem. Dimensional regularization. Direct derivation using Gauss' Theorem. The Coulomb potential in d = 2 dimensions.

Text Books

1. L.A. Pipes and L.R. Harvill, Applied Mathematics for Engineers and Physicists, McGraw-Hill (1970).
2. G. B. Arfken and H.J. Weber, Mathematical Methods for Physicists, 5th edition, Academic Press (2001).
3. E. Kreyszig, Advanced Engineering Mathematics, 8th edition, John Wiley & Sons Inc. (1999).
4. W.W Bell: Special functions for scientists and engineers.
5. J. Mathews and R L Walker: Mathematical Methods of Physics.

CLASSICAL MECHANICS

Unit I

Lagrangian Formulation

Newtonian mechanics and its limitations. Constrained motion. Constraints and their classification. Principle of virtual work. D' Alembert's principle. Generalized coordinates. Deduction of Lagrange's equations from D' Alembert's Principle. Generalized momenta and energy. Cyclic or ignorable coordinates. Rayleigh' s dissipation function. Integrals of motion. Symmetries of space and time with conservation laws. Problems. Rotating frames. Inertial Forces. Electromagnetic analogy of inertial forces. Terrestrial and astronomical applications of Conolis force. Foucault's pendulum. Problems.

Unit II

Central Force Problem

Central force. Definition and properties of central force. Two-body central force problem. Stability of orbits. Conditions for closure. General analysis of orbits. Kepler's laws. Kepler's equation. Artificial satellites. Rutherford scattering. Problems.

Principle of least action. Hamilton's principle. The calculas of variations. Derivation of Hamilton's equations of motion for holonomic systems from hamilton's principle. Hamilton's principle and characteristic functions.

UNIT III

Canonical Transformations

Generating functions. Poisson bracket. Poisson's Theorem. Invariance of PB under canonical transformations. Angular momentum PBs. Hamilton-Jacobi equation. Connection with Classical Mechanics canonical transformation. Problems. Small oscillations. Normal modes and coordinates. Problems.

Unit IV

Theory of Relativity

Principles and postulates of relativity, Lorentz Transformation, Effects thereof, Tensors, transformation properties, symmetric and anti-symmetric properties, Four Vector notation, Energy Momentum four vector for a particle, relativistic invariance of Physical Laws. Lagrangian and Hamiltonian of a relativistic particle.

Text Books

1. H. Goldstein, C. poole and J. Safko, Classical Mechanics, 3nd edition, Addison & Wesley(2000).
2. L.D. Landau and E.M. Lifshitz, Mechanics, Buttorworth-Heinemann (1976).
3. W. Greiner, Classical Mechanics – Point particles and Relativity, Springer-Verlag (1989).
4. N.C Rana and P.S Joag, Classical Mechanics.
5. A.P French: Special Relativity.

QUANTUM MECHANICS

UNIT I

Fundamental Concepts

Basic postulates of quantum mechanics. Linear operators Hermitian operators. Orthogonality of Eigen functions of a Hermitian operator. Completeness of Eigen functions. Commuting operators and their Eigen functions. Dirac's bra and ket notation. Representation of operators as matrices. Change of basis. Unitary transformation and its significance. Equations of motion. Schrodinger picture and Heisenberg picture. Interpretation of the wave function. Schwartz Inequality and Uncertainty Principle. Classical limit of the Schrodinger equation. operator methods in Q Mechanics, Double Stren-Gerlach experiment for spin half system.

UNIT II

Angular Momentum

Definition of generalized angular momentum, operators for J_+, J_- , J_z commutation relation of angular momentum with r & p. Spectrum of Eigen values of J^2 and Jz, operators for orbital angular momentum L in spherical polar coordinates, Eigen values and Eigen functions of L^2 & L_z. Spin angular momentum, Eigen values and Eigen functions of S^2 & S_z.

Matrix representation of J^2, J_z, J_+, J_-, J_x, J_y for j=1/2, 1. Pauli's Spin Matrices and their properties. Addition of two angular momenta, coupled & uncoupled representation, Clebsch Gorden co-efficients, Spectrum of eigen values of total angular momentum. Calculation of C.G. co-efficients when (1) $j_1=1/2$, $j_2=1/2$ (2) $j_1=1/2$, $j_2= 1$

UNIT III

Approximate Methods

Time independent perturbation theory. Perturbation of non-degenerate states. First order perturbation. Second order perturbation. Perturbation of an oscillator. Perturbation of degenerate states. Removal of degeneracy. First order Stark effect in hydrogen atom. Time dependent perturbation theory. Transition probability. The variation method with simple applications. Green's functions incoming and outgoing solutions.

Text Books

1. P.M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw-Hill (1977).
2. J.L. Powell and B. Crasemann, Quantum Mechanics, Narosa Publishing House (1993).
3. J.J. Sakurai, Modern Quantum Mechanics, Addison-Wesley (1999).
4. E. Merzbacher: Quantum Mechanics.
5. Cohen and Tanandji: Quantum Mechanics.

SOLID STATE PHYSICS

UNIT I

Crystal Structure

Bravais lattices- primitive vectors, primitive unit cells, conventional unit cells, Wigner Seitz Cell, Symmetry operations and classifications of two and three dimensional Bravias lattices, crystal structure, simple crystals, Miller indices, lattice planes, Bragg's law (SS), structure determination, Laue's method, powder crystal method, rotating crystal method, electron diffraction, neutron diffraction, reciprocal lattice, Ewald's construction, symmetry operations.

UNIT II

Energy band theory of solids

Classical free electron theory of metals, drift current, conductivity, mobility, Hall effect (SS). Wave mechanical treatment of electron in a box, electrons in a periodic potential, Bloch's theorem, Kronig-Penney Model, Brillouin zones, energy band structure in conductors, semiconductors, insulators, Fermi-Dirac distribution, Fermi energy density of states, Fermi surface, effective mass.

UNIT III

Magnetism Properties of solids

Classification of magnetic materials, Langevin's theory of paramagnetism, ferromagnetism, hysteresis, ferromagnetic domains, antiferromagnetism, ferrimagnetism, ferrites, Curie's law, magnetic ordering, Weiss theory of paramagnetism, quantum theory of para & ferromagnetism, paramagnetic resonances, Nuclear magnetic resonance

Text Books

1. Charles Kittel, Introduction to Solid State Physics, Wiley Eastern, 5th edition (1983).
2. B.S. Saxena, R.C. Gupta, P.N.Saxena, Fundamentals of solid state physics, Pragati prakashan, 7th edition (1999).
3. M.A. Wahab: Fundamentals of Solid State Physics.
4. O. Pillay: Solid State Physics.
5. J.P Srivastava: Elements of Solid State Physics.

CLASSICAL ELECTRODYNAMICS

UNIT I

Electrostatics

The concept of a scalar potential. Poisson's and Laplace's equations for scalar potential. Green's theorem, Electrostatic field energy density. Solutions of Laplace's equation in rectangular, spherical and cylindrical coordinates using the method of separation of variables. Multipole expansion of potential due to a localized charge distribution. Dipole and quadrupole fields. Interaction energy of dipole and quadrupole in an external field. Electrostatics in matter; Polarization and electric displacement vector. Electric field at the boundary of an interface. Clausius - Mossotti equation.

UNIT II

Magnetostatics,

Foundations of Magnetostatiscs, Scalar and Vector potentials, Magnetic moment of a current distribution. Macroscopic magnetostatics, Magnetization. M and H vectors, Maxwell's displacement current. Maxwell's equations. Vector and scalar potential. Lorentz and Coulomb gauge. Conservation of energy and momentum of a system of charged particles and electromagnetic fields. Field energy and field momentum.

UNITIII

Solutions of Maxwell's Equations and Radiation

Plane waves in dielectric media. Polarization, reflection and refraction at a plane interface between dielectrics, Fresnel's equations. Phase velocity and group velocity, spreading of a pulse propagating in a dispersive medium, propagation in a conductor, skin depth. Waveguides and cavity resonator. Radiation due to localized oscillatory source, near and far zones, radiated power due to an electric dipole, magnetic pole, example of a centre - fed linear antenna as an electric dipole radiator. Retarded Green's function.

Text Books

1. J.D. Jackson, Classical Electrodynamics, John Wiley & Sons, 2nd edition (1990).
2. D. J. Griffiths, Introduction to Electrodynamics, Pearson Prentice Hall, 3rd edition (1999).
3. J.R. Reitz., F.J. Milford and R.W. Christy, Foundations of Electromagnetic Theory, 3rd edition, Narosa Publishing House (1979).
4. L.C Landau and E.M. Lifshitz Classical theory of fields.
5. Panofsky and Phillips: Classical Electrodynamics.

THERMODYNAMICS AND STATISTICAL MECHANICS

UNIT I

Thermodynamics and its Statistical Basis

Review of thermodynamic concepts required for Statistical Mechanics, the macroscopic and the microscopic states, specification of states of a thermodynamic system, the principle of maximum entropy, thermodynamic potentials, contact between statistical mechanics and thermodynamics, Euler's equation and the Gibbs-Duhem relation, the Legendre transformation , classical ideal gas, entropy of mixing and Gibb's paradox.

Systems in contact with heat reserviour, expression of entropy, Canonical partition function, Helmholtz free energy, systems in contact with a particle reserviour, chemical potential, grand canonical partition function, fluctuation of particle number, Chemical potential of ideal gas.

UNIT II

Classical Statistical Mechanics

Micro-canonical ensemble, phase space, trajectories and density of states, Liouville's theorem, canonical and grand canonical ensembles; partition function, calculation of statistical quantities, Energy and density fluctuations.

UNIT III

Quantum Statistical Mechanics

Density matrix, statistics of ensembles, statistics of indistinguishable particles, Maxwell-Boltzmann, Fermi-Dirac and Bose Einstein statistics, properties of ideal Bose and Fermi gases, Bose-Einstein condensation.

Real gases, Mayer's cluster expansion for a classical gas, Viral equation of state, Using model, mean-field theories of the Ising model in two and one dimensions. Landau theory of phase transition, critical indices, scale transformation and dimensional analysis. Calculations of exponents from mean field Theory and Laundos theory, Upper critical dimension.

Text Books

1. F. Reif, Fundamentals of Statistical and Thermal Physics, International Students edition, Tata McGraw-Hill (1988).
2. K. Haung, Statistical Mechanics, Wiley Eastern (1991).
3. F.W. Sears and G.L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, 3rd edition, Narosa Publishing House (1998).
4. H.B Callen: Thermodynamics and an introduction to thermostatics.
5. R. Kubo: Statistical Mechanics.

ATOMIC AND MOLECULAR PHYSICS

UNIT I

Hydrogen atom Gross Structures:

Schrödinger's equation, stationary states, Solution of' Schroedinger's equation for Coulomb field, quantum numbers n, l, m, Comparison with Bhor's model, the hydrogen spectrum Problems. The hydrogen atom Fine structure: Electron Spin, Stern-Gerlach experiment, the interaction terms, relativistic correction, spin-orbit interaction, vector model, spectroscopic terms and selection rules, lamb shift, summary of the hydrogen spectrum, Problems.

UNIT II

Two electron system:

Electrostatic interaction and exchange degeneracy ground and excited states of helium, Electron spin functions and Pauli's exclusion principle, periodic table. The central field approximation: the central field, Thomas Fermi-potential, The gross structure of alkalis atoms. Problems

UNIT III

Angular problems in many-electron atoms:

The LS-coupling approximation, allowed term in LS coupling, fine structure in LS coupling, J-J coupling. Problems, hyperfine structures. Interaction with external field: Zeeman, Paschen-Back and Stark effects, problems.

Covalent ionic and Vander Waal's interaction. Rotational, Vibrational, Rotational-Vibrational and electronic spectra of di-atomic molecules, selection rules, Frank-Condon principle. Raman effect and Raman spectra.

Fortrat diagram, Electronic angular momentum in diatomic and classification of states with example of spectrum of molecular hydrogen. Basic principle and use of ESR, NMR and Mossbauer spectroscopy.

Text Books

1. C.N. Banwell, Fundamentals of Molecular Spectroscopy, 4th edition, McGraw-Hill, New York (2004).
2. Manas chanda, Atomic Structure and Chemical Bond, Tata McGraw-Hill, New Delhi (2003).
3. Arthur Beiser, Concepts of Modern Physics, 6th edition, Tata McGraw-Hill, New Delhi (2003).
4. G. Aruldhas, Molecular Structure and Spectroscopy, Prientice Hall of India, NewDelhi (2002).
5. B.H Bransden and C.J Joachain: Physics of atoms and Molecules.

NUCLEAR AND PARTICLE PHYSICS

UNIT I

Nuclear Properties

Basic nuclear properties, Nuclear size and distribution of nucleons, Energies of nucleons in the nucleus, Angular momentum, Parity and symmetry, Magnetic dipole moment and electric quadrupole moment, Energy levels and mirror nuclei. Characteristics of nuclear forces - Range and strength, Simple theory of two nucleon system-deuterons, Spin states of two nucleon system, Effect of Pauli's exclusion principle, Magnetic dipole moment and electric quadrupole moment of deuteron -The tensor forces.

UNIT II

Experimental Methods of Nuclear & Particle Physics

Interaction of charged particles with matter. Stopping power and raige. Detectors for energetic charged particles; Solid State or Semiconductor detector; Bubble chamber; Nuclear emulsions. Composite relations. E rays, Ionization and scattering measurements in nuclear emulsions, Identification of particles. Need for accelerator of charged particles, Classification of types of accelerators, Proton Synchrotron, Betatron; alternating gradient accelerator, Colliding beam accelerator.

UNIT III

Nuclear reactions and fission

Different types of reactions, Quantum mechanical theory, Resonance scattering, Compound nucleous formation, Statistical theory of nuclear reactions and evaporation probability.

Classification and properties of elementary particles, Leptons, Baryons, mesons particles and antiparticles excited states and resonances. Various types of interactions - gravitational, electromagnetic, weak and strong interactions and their mediating quanta, Conservation rules in fundamental interactions. Charge symmetry and charge independence, Parity and charge conjugation, Conservation of parity and its violation in different types of interactions. Strange particles, associated production, strangeness and decay modes of charged Kaons, Isospin and its conservation. Idea of eight fold way and quarks.

Text Books

1. Heral Enge, Introduction to Nuclear Physics, Addison Wesley (1981).
2. D.C. Tayal, Nuclear Physics, 4th edition, Himalaya House, Bombay (1980).
3. W.C. Burcham, Elements of Nuclear Physics, ELBS (1979).
4. Kenneth S. Krane, Introductory Nuclear Physics, John Wiley & Sons, New York (1988).
5. J.S Lilley: Nuclear Physics.

Electronics

UNIT I

Transistors

Types operation and characteristics, Ebers-Moll model, CE, CB and CC configuration input, output characteristics and graphical analysis of basic amplifier circuits, Biasing and Bias stability, Low frequency, h-parameter model, Analysis and Design of transistor amplifier circuits using h-parameters. High frequency hybrid – pi model, analysis and design of transistor amplifier circuits at high frequencies. Multistage amplifiers, phototransistors, Transistor as a switch, SCR's and Thyistors. Operation and characteristics, model Application at low and high frequency, amplifiers, switching circuits, MOSFET TYPES, Operation and characteristics.

UNIT II Semiconductor Devices, Amplifiers and Oscillators

p-n junction diodes: tunnel diode, Schottky barrier diode – Microwave diodes: varactor diode, p-i-n diode – Optoelectronic devices: solar cell, photodetector, LED, semiconductor laser – basic principles, biasing and characteristics of BJT and JFET – MOSFET: enhancement and depletion modes of operation – basic idea of charge coupled devices.

Low frequency and high frequency amplifiers – power amplifiers – oscillator principle – oscillator types – frequency stability, response – phase shift oscillator – Wein bridge oscillator – LC tunable oscillators – multivibrators – monostable and astable – sine wave and triangle wave generation – clamping and clipping – crystal oscillators and their applications.

UNIT III

Operational Amplifiers and Digital Circuits

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 – A.C.amplifiers – instrumentation amplifiers, comparators, filters, PLL. Logic gates – half adder, full adder – comparators, decoders, multiplexers, demultiplexers – design of combinational circuits – sequential circuits – *Flip-flops:* RS flip-flop, JK flip- flop, JK master-slave flip-flops, T flip-flop, D flip-flop – synchronous and asynchronous counters, registers – A/D and D/A conversion – characteristics.

Text Books

1. C.L Wadhwa, Network Analysis and Synthesis, New Age International Publishers, (2007).
2. J. Milman and C.C. Halkias, Electronic Devices and Circuits, McGraw-Hill (1981).
3. R. L. Boylsted and L. Nashelsky, Electronic Device and Circuits, Pearson Education (2003).
4. R.J. Higgins, Electronics with Digital and Analogue Integrated Circuits, Prentice Hall (1983).
5. A.P. Malvino, Electronics: Principles and Applications, Tata McGraw-Hill (1991).