DU Ph.D.

Total No. of Question: 50

Time: 2 Hours **Maximum Marks: 200**

SYLLABUS

There will be NEGATIVE MARKING for wrong answer. Each correct answer shall be awarded 4 marks, while one mark will be deducted for each wrong answer.

The Syllabus for Ph.D entrance test is based on the existing M.Sc Physics Core papers (w.e.f. 2009).

Type of question paper in the entrance examination:

Multiple Choice Questions (MCQ) with negative marking.

First Semester: Classical mechanics, Quantum Mechanics – I, Electromagnetic Theory & Electrodynamics, Nuclear & Particle Physics

Second Semester: Quantum Mechanics – II, Statistical Mechanics, Radiation Theory, Atomic & Molecular Physics, Electronics & Nuclear Physics, Solid State Physics and Waves & Optics

Third Semester: Practical Computer Programming

Fourth Semester: Physics at Nanoscale

FIRST SEMESTER

Classical mechanics

Types of constraints on dynamical systems, generalized coordinates, d'Alembert principle, Euler-Lagrange equations of motion, variational calculus and Hamilton's variational principle, Hamilton's canonical equations of motion, cyclic coordinates, Lagrnagian and Hamiltonian for central forces, electromagnetic forces, coupled oscillators and other simple systems. Canonical variables, Poisson's bracket, Jacobi identity.

Canonical transformations, generators of infinitesimal canonical transformations, symmetry principles and conservations laws. Hamilton-Jacobi theory, Action and angle variables, Centre of mass and laboratory systems, Kepler problem, precessing orbits.

Small oscillations, normal coordinates and its applications to chain molecules and other problems. Degrees of freedom for a rigid body, Euler angles. Rotating frame, Coriolis force, Foucault's pendulum, Eulerian coordinates and equations of motion of a symmetrical top.

Quantum Mechanics – I

Abstract formulation of Quantum Mechanics: Review of quantum postulates, Mathematical properties of linear vector spaces. Postulates of quantum mechanics. Eigenvalues and eigenvectors. Orthonormality, completeness, closure. Dirac's bra and ket notation. Matrix representation of operators. Generalized uncertainty principle. Change of basis and unitary transformation. Expectation values. Ehrensfest theorem.

Quantum Dynamics: Schrödinger picture. Heisenberg picture. Heisenberg equation of motion. Classical limit. Solution of harmonic oscillator problem by the operator method. Symmetries in Quantum Mechanics: General view of symmetries. Spatial translation-continuous and discrete. Time transition. Parity. Time reversal.

Angular Momentum: Commutation relations of angular momentum operators. Eigenvalues, eigenfunctions. Ladder operators

Electromagnetic Theory & Electrodynamics

Review of Maxwell's Equations: Fundamental problem of electromagnetic theory. Scalar and vector potential. Gauge Transformations. Coulomb and Lorentz gauges. Review of special theory of Relativity (STR) and its application to electromagnetic theory: Conceptual basis of STR. Thought experiments concepts of invariant interval. Light cone event and world line. Four vectors, tensors, Lorentz transformation as 4-vector transformations. Transformation properties of electric and magnetic field, E.M. field tensor. Covariance of Maxwell's equation (from tensorial arguments).

Relativistic charged particle dynamics in electromagnetic field: Motion in uniform static magnetic field, uniform static electric field and crossed electric and magnetic fields. Particle drifts (velocity and curvature) in non-uniform static magnetic fields. Adiabatic invariance of magnetic moment of a charged particle and torus principle of magnetic mirror.

Radiation: Green function for relativistic wave equation. Radiation from localized oscillating charges. Near and far zone fields. Multipole expansion. Dipole and quadrupole radiation. Centre fed linear antenna. Radiation from an accelerated point charge. Lienard-Wiechert potential. Power radiated by a point charge: Lienard's formula and its non-relativistic limit (Larmor's formula). Angular distribution of radiated power for linearly and circularly accelerated charges.

Lagrangian Formulation of Electrodynamics: Lagrangian for a free relativistic particle, for a charged particle in an *e.m.* field, for free electromagnetic field, for interacting charged particles and fields. Energy momentum tensor and related conservation laws.

Nuclear & Particle Physics

Static properties of Nuclei: Nuclear size determination from electron scattering, nuclear form factors. Angular momentum, spin and moments of nuclei.

Two nuclei system & Nuclear force: Dipole and quadrupole moment of the deuteron, central and tensor force, Evidence for saturation property, Neutron proton scattering, exchanges character, spin dependence (ortho and para-hydrogen), charges independence and charge symmetry. Isospin formalism General form of the nucleon-nucleon force D-wave effective range theory proton scattering. Evidence for hardcore potential.

Nuclear Models: The shell model, Nilson model, physics concepts of the unified model. Nuclear Decays and Reactions: Electromagnetic decays: selection rules, Fermi theory of beta-decay. Kurie plot Fermi and Gamow-Teller transitions. Party violation in beta-decay introduction to nuclear reactions.

Elementary Particles: Relativistic kinematics, Classification spin parity determination of pions and strange particles. Gell-Mann Nishijima scheme. Properties of quarks and their classification elementary ideas of $SU(2)$ and $SU(3)$ symmetry groups and hadrons classification. Introduction to the standard model electro weak interaction W & Z Bosons.

Nuclear Detectors: Interaction of radiation with matter, Ge and Si solid state detectors, calorimeter and their use for measuring jet energies. Scintillation and Cerenkov counters, qualitative ideas Hybrid detectors.

SECOND SEMESTER

Quantum Mechanics II

Approximation Methods for stationary system: Time independent perturbation theory (a) non-degenerate and (b) degenerate. Application to Zeeman effect, isotopic shift and stark effect. Variational method and its applications

Approximation Method for Time Dependent Problems: Interaction picture, Time dependent perturbation theory. Transition to a continue of final states-Fermi's Golden Rule. Application to constant and harmonic perturbations, Adiabatic and sudden approximations.

Scattering: Wave packet description of scattering. Formula treatment of scattering by Green function method. Born approximation and applications Partial wave analysis Optical theorem

Relativistic Quantum Mechanics: Klein-Gordon and Dirac equations. Properties of Dirac matrices plane wave solution of Dirac equation. Spin and magnetic moment of the electron Non relativistic reduction of Dirac equation Spin orbit coupling energy levels in a Coulomb field.

Statistical Mechanics

Classical Ensemble Theory: Phase space, Liouvilles's equation micro canonical and canonical and grand-canonical ensembles Boltzmann relation for entropy application to classical system of interacting particles.

Quantum Ensemble Theory: Density operator, Quantum Liouvilles's equation. Density operator for equilibrium micro canonical, grand canonical ensembles calculation of grand partition function and distribution function, Pauli Para magnetism.

General Theory of Phase Transitions: Bose Einstein transition and nature of discontinuity of specific heat. Landau's theory of liquid Helium II Phonon-proton spectrum, calculation of $^{\rho}s$ and $^{\rho}n$. Order parameter Landau's theory critical exponents order parameter fluctuations in Gaussian approximation scale invariance critical dimensionality concept of university of phase transitions. Ising and Heisenberg models Bethe approximation.

Radiation Theory

Classical Field Theory: Concept of a system with infinite degrees of freedom, classical fields, Lagrangian and Hamiltonian, equations of motion. Symmetric and invariance principal noether's theorem

Field Quantization: Fock space decomposition, Canonical quantization of a real scalar field and a complex scalar field (commutation relations). Interpretation of the quantized field (number density operators).

Radiation Field: Classical Maxwell field, Gauge invariance, Canonical quantization using radiation gauge. Discussion of ambiguities in quantization and their removal and Lorentz guage quantization

Dirac spinor field and its quantization (anti commutation relations)

Applications: Interaction of radiation with matter (spontaneous, stimulated emission, absorption). Planck's law, Kramer-Heisenberg formula, Coherent and Raman scattering, theory of line width, Elementary theory of photo electric effect non relativistic of Lamb shift.

Atomic & Molecular Physics

Atomics Physics: Fine structure of hydrogenic atoms-mass correction spin orbit term, Darwin term. Intensity of fine structure lines. The ground state of two electron atoms perturbation theory and variation method. Many electron atoms - *LS* and *jj* coupling scheme, Lande interval rule. The idea of Hartrec- Fock equations. The spectra pf alkalis using quantum defect theory. Selection rules for electric and magnetic Multipole radiation. Oscillator strengths and the Thomas Reiche Kuhn sum rule.

Molecular Structure: Born oppenheimer separation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules. Molecular orbital and valance bond methods for H_2^+ and H_2. Correlation diagram for heteronuclear molecules

Molecular spectra: Rotation, vibration rotation and electronic spectra of diatomic molecules. The Franck-Condon principal. The electron spin and Hund's cases. Idea of symmetry elements and point group for diatomic and polyatomic molecules.

Laser: Multilevel rate equations and saturation. Rabi frequency laser pumping and population inversion, He - Ne laser, Solid state laser, free electron laser, Non linear phenomenon Harmonic generation. Laser accelerator, liquid and gas lasers, semiconductor lasers.

THIRD SEMESTER

Practical Computer Programming

FOURTH SEMESTER

Physics at Nanoscale

Quantum confined systems: quantum confinement and its consequences, quantum wells, quantum dot. Electronic structure calculations by abinitio, tight binding, empirical potential and density functional methods. Electron states in direct and indirect gap semiconductors nanocrystals. Confinement in disordered and amorphous systems.

Dielectric properties: Coulomb interaction in nanostructures. Concept of dielectric constant for nanostrucures and charging of nanostructure. Quasi-particles and excitons: Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasi-particles and excitons. Charging effects. Optical properties and radiative processes: General formulation-absorption, emission and luminescence. Optical properties of heterostructures and nanostructures. Carrier transport in nanostructures: Coulomb blockade effect, tunnrilling and hopping conductivity. Defects and impurities. Deep level and surface defects.

Structure and thermodynamics at nanoscale. Crystalline phase transitions and geometric evolution of the lattice in nano crystals, thermodynamics of very small systems, evaporation-consequences, Growth of nanostructures-self-organization phenomena Characterization basics: Direct imaging, TEM, diffraction and optical methods Magnetism at nanoscale and Mechanical properties at nanoscale.