2023-24

Ph.D. 427 Physics

2021

SYLLABUS FOR Ph.D. ENTRANCE EXAMINATION

[Part A] : RESEARCH METHODOLOGY

Research Aptitude : Research: meaning, characteristics and types , Steps of research, Method of research, Research Ethics, Paper, article, workshop, seminar, conference and symposium,Thesis writing: its characteristics and format. Nature of research problem: theoretical research, experimental research, case study, survey.

Reading Comprehension : A passage to be set with questions to be answered

Library Resources and Communication : Different types of data and their sources, Survey of literature, Sources of information, Bibliography, Communication: Nature, characteristics, types, barriers and effective report writing and communication

Reasoning (Including Mathematical) : Number series; letter series; codes, Relationships; classification

Logical Reasoning : Understanding the structure of arguments, Evaluating and distinguishing deductive and inductive reasoning, Verbal analogies: Word analogy – Applied analogy, Verbal classification, Reasoning Logical Diagrams: Simple diagrammatic relationship, multi-diagrammatic Relationship, Venn diagram; Analytical Reasoning

Data Interpretation : Sources, acquisition and interpretation of data, Quantitative and qualitative data, Graphical representation and mapping of data

Information and Communication Technology (ICT) : ICT: meaning, advantages, disadvantages and uses, General abbreviations and terminology, Basics of internet and e-mailing

Basic Statistical Techniques : Uni-variate Analysis: Mean, Mode, Median, Standard Deviation, Bivariate / Multivariate analysis: Correlation, Regression, Probability and Probability distributions

Higher Education System: Governance, Polity and Administration : Structure of the institution of higher learning and research in India, Formal and distance education, State and Private domain of higher education, Professional/ technical and general education, Governance, polity and administration, vi. Educational commissions and higher education policy

Educational Methodology : Teaching: Nature, objectives, characteristic and basic requirements, Learner's characteristics, Factors affecting teaching, Method of teaching, Teaching aids Evaluation systems

21/1/2021 21.1.2021 21/1/21 Dshukla 21/1/21

[Part B] : PHYSICS

Mathematical Physics : Differential equations and special functions: Second order linear ODEs with variable coefficient, solutions by series expansion; Legendre, Bessel equations, generating functions, recursion relations.

Integral Transforms: Laplace transforms, first and second shifting theorems, Inverse LT by partial fractions, LT of derivatives, and integral of functions, Fourier transform, Fourier Integral and transform of delta functions.

Green's functions: Non- homogenous boundary value problems, Green's function for one dimensional problem, Eigen function expansion of Green's function. Green's function for electrostatic boundary value problems and quantum mechanical scattering problem.

Complex Variables: Analyticity of complex functions, Cauchy Riemann equations.

Couchy theorem, Cauchy integral formula, Taylors, Maclaurin, Laurent series. Theorem of residues, simple cases of contour integration, Jordan's lemma.

Classical Mechanics : Newtonian mechanics of one and many particles systems, Conservation laws, constraints and their classification, principle of virtual work. D' Almbert's principle in generalized coordinates, The Lagrange's equation from D' Almbert's principle.

Hamilton's principle, Hamilton's principle from Lagrange's equation. Generalized momenta and Lagrangain formulation of the conservation theorems, Reduction to the equivalent one body problem; the equation of motion and first integrals, the differential equation for the orbit.

The equations of canonical transformation and generating functions. Hamilton - Jacobi theorem, Action and angle variables.Poisson's brackets, simple algebraic properties of Poisson's brackets. The equation of motion in Poisson's Brackets notation. Poissons theorem, Principle of least action.

Theory of small oscillations, Equations of motion, Eigen frequencies and general motion, normal modes and coordinates.

21/1/2021 21/1/2021 21/1/2021 Dshukla

Elementary treatment of Eulerian coordinates and transformation matrices. Angular momentum inertia tensor, torque free motion for a rigid body. Covariant four dimensional formulation, 4-vectors and 4-scalers, Relativistic generalization of Newton's laws, 4-momentum and 4-force, Variance under Lornetz transformation, relativistic mechanics, covariant Lagrangian, covariant Hamiltonian.

Digital Electronics and Operational Amplifier : Number system and digital combinational circuits: Binary, octal and Hexa decimal number and their inter-conversion, Addition and subtraction, Logic gates: AND, OR, NOT, NAND, NOR, XOR, XNOR, AOI gates. Binary adders: Half adder, Full adder and parallel adders. Multiplexer and Demultiplexer, Encoders and Decoders.

Operational Amplifiers: Differential Amplifier: DC and AC analysis, CMRR Inverting and Non-inverting, Block Diagram of operational amplifier, Operational amplifiers with negative feedback: Voltage Series and Voltage shunt.

Atomic, Molecular and Laser Physics : Review of one-electron and two-electron atoms: spectrum of hydrogen, helium and alkali atoms; Many electron atoms: central field approximation, Thomas-Fermi model, Slater determinant, Hartee Fock and self-consistent field methods, Hund's rule, L-S and j-j coupling, Equivalent and nonequivalent electrons, Spectroscopic terms, Lande interval rule.

Interaction with Electromagnetic fields: Zeeman, Paschen Back and Stark effects; Hyperfine structure and isotope shift, selection rules; Lamb shift; Molecular spectra: rotational, vibrational, electronic, Raman and Infra-red spectra of diatomic molecules; electronic and nuclear spin, Hund's rule, Frank–Condon principle and selection rules.

Lasers: spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping; population inversion, three level and four level laser system and rate equation. Optical resonators, Stability of resonators, Characteristics of Gaussian beam, He-Ne and Ruby Lasers.

Quantum Mechanics : General Formalism of Quantum Mechanics: Linear vector space, basis and expansion theorem, Hilbert space, linear operators, eigen values and eigen functions, Hermitian operators and their properties, postulates of quantum mechanics, simultaneous eigen functions, general uncertainty relation, Dirac's notation for state vectors, Application of operator method: simple harmonic oscillator, creation and annihilation operators.

Matrix representation of state vectors and operators, change of basis: unitary transformation, Application of matrix method: simple harmonic oscillator.

21/11/2021 21.11.2021 21/11/2021

Angular Momentum and Spin: Angular momentum operators, angular momentum commutation relations, eigenvalues of L^2 and L_z. General angular momentum, eigenvalues of J^2 and J_z, angular momentum matrices, spin angular momentum, spin – (½) systems, spin vectors for spin – (½) system, Addition of angular momenta , Clebsch - Gordan coefficients.

Time-Independent Approximation Method – I: Basic concepts, non-degenerate and degenerate energy levels, Applications: ground state of He-atom, An-harmonic oscillator, Stark effect in hydrogen.

Time-Independent Approximation Method – II:

The Variation method: The variational principle, Rayleigh – Ritz method, Applications: ground state of He-atom, hydrogen-molecular ion and deuteron.

The WKB approximation method: WKB method, validity of WKB method, connection formula penetration of a barrier, Application: α–decay.

Electrodynamics and Plasma Physics: Maxwell's equations, Scalar and vector potentials, gauge transformation, Lorentz gauge, Coulomb Gauge, radiations by moving charges, retarded potentials, Lienard Wiechrt potentials, fields of charged particles in uniform motion, fields of arbitrarily moving charged particle.

Fields of an accelerated charged particles at low velocity and high velocity, angular distribution of power radiated, Review of four vector and Lorentz transformation in 4-dimensional spaces, Invariance of electric charge, relativistic transformation properties of E and H fields.

Elementary concept of occurrence of plasma, Gaseous and solid state plasma, Production of gaseous and solid state plasma, Plasma parameters, Plasma confinement pinch effect, instability in a pinched-plasma column, Electrical neutrality in a plasma, Debye screening distance. Plasma oscillations: Transverse oscillations and longitudinal oscillations.

Domain of Magnetohydordynamics and plasma Physics : Magnetohydrodynamic equations, magneto hydrodynamic waves: Magneto-sonic and Alfven waves, particle orbits motion of charged particles in electromagnetic fields, (uniform E and B Fields) and drift motion in a plasmas.

Electronics Devices : BJT: Construction, transistor biasing in active region, transistor operation in active. JFET: Construction, Biased JFET, JFET characteristics. MOSFET: Depletion and Enhancement type MOSFET, MESFET. Photonic Devices: Light dependent resistor (LDR), diode

photo detectors, Solar cell (I-V characteristics, Spectral response, fill factor), LED, diode lasers. Semiconductor Memories: Memory organization, Expanding memory size, classification of memories. ROM and RAM chip. Charged compiled device (CCD) memory, content addressable memory.

Microprocessors and Microcontrollers : The 8085 pin configuration and functional Block Diagram, Interrupt, Register, Addressing mode, instruction set, instruction set and their classification, Addressing of I/o devices, DMA, Input/output port.

Condensed Matter Physics: Crystal Structure: Symmetry, crystal system, Bravais lattice, concept of point group, space group, Miller indices, Unit cell, Wigner-Seitz unit, reciprocal lattice, closed packed structure, (BCC,FCC, HCP, DC) coordination number & coordination geometry. Principle of powder diffraction method; Elementary idea about interpretation of power XRD Types of Crystal binding: Ionic, Covalent, Matellic , Vander walls bonding.

Free electron theory: Free electron theory of metals. Hall Effect, Elementary ideas of quantum Hall effect, Thermal and transport properties. Thermal conductivity in metals. Vibration in solid, normal modes, phonons, normal and unklopb processes, Mobility of charge carriers and Seeback coefficient, Wiedmann Franz law. Electronics specific heat. Bloch functions. Nearly free electron approximation. Formation of energy bands. gaps at Brillouin zone boundaries. Effective mass and concept of holes. Fermi surface.

Super Conductivity: Survey of important experimental result; critical temperature, persistent current, Meissner effect; Basic idea of BCS theory, Type I and Type II superconductor super conducting Material and their application. High Tc super conductivity.

Dielectric properties of solids: Complex dielectric and dielectric losses, relaxation time and Debye equation for orientational polarizabiltiy; theory of electronic and ionic polarization, Ferroelectricity-diplole theory, classifications of ferroelectric material.

Statistical Mechanics : Fundaments of statistical physics: Phase space, Liouville theorem and its consequence, specification of states of a system, statistical distribution function; Statistics of various Ensembles -Micro canonical, Canonical, grand canonical ensembles; Example of various ensemble – an electron in a magnetic field, a free particle in a Box, a linear harmonic oscillator; Basic postulates; Behaviour of the density of states; partition functions and their properties; calculation of thermodynamic quantities; the classical ideal gas; the entropy of mixing and

Gibbs paradox; the correct enumeration of microstates; The Equipartition theorem; Maxwell velocity distribution.

Isolated system; System in contact with reservoir; Stability conditions for homogeneous substance; Phase transformation; First order and second order phase transition; Equilibrium conditions between phases; The Clausius-Clapeyron equation.

Classical and Quantum statistics; Identical particles and symmetry requirements; the classical and quantum distribution functions; Maxwell-Boltzmann statistics, Bose-Einstein statistics, Fermi-Dirac statistics; Degeneracy criterion.

Bose systems: Thermodynamic behaviour of ideal Bose-gas; Thermodynamics of Black Body radiation; Bose-Einstein condensation; Super fluidity.

Fermi systems: Thermodynamics of ideal Fermi systems; Magnetic behaviour of an ideal Fermi gas; Pauli Paramagnetism; Landau diamagnetism; Degenerate Fermi systems - electron gas, Electron gas in metal- Thermionic emission and Photo-electric emission; Statistical equilibrium of White dwarf stars.

Systems of interacting particles; Harmonic lattice vibrations: Phonons; Einstein model and Debye model regarding the explanation of temperature dependent of specific-heat; Interaction between spins; Weiss molecular-field approximation regarding the explanation of ferromagnetism; Mean field theory of Ising model and its exact solution in one-dimension; Thermodynamic fluctuation; The Brownian motion; The Langevin theory; The Fokker-Planck equation; The fluctuation-dissipation theorem; The Onsager relation.

Nuclear and Particle Physics : Structure of nuclei: Basic Properties of Nuclei: Mass, Radii, Charge, Angular Momentum, Spin, Magnetic Moment (μ), Stability and Binding Energy. Nuclear size determination from electron scattering; nuclear form factor, Rutherford scattering.

Radioactivity : Law of Radioactive Decay. Half-life, Theory of Successive Radioactive Transformations. Radioactive Series, Binding Energy, Mass Formula, α-decay :- Range of α-particles, Geiger-Nuttal law and α-particle Spectra. Gamow Theory of Alpha Decay. β-decay :- Energy Spectra and Neutrino Hypothesis. Fermi theory of beta decay, neutrino detection method, parity violation in beta decay, properties of neutrino, γ-decay :- Origin of γ-rays, Nuclear Isomerism and Internal Conversion, measurements of gamma rays energies, selection rules for gamma emission, total decay rate, Angular momentum and parity selection rules.

Nuclear Models : Liquid Drop Model. Fermi Gas model, shell model, Experimental evidence of shell model. Spin orbit coupling in shell model. Magic numbers. Applications of liquid drop

model. Mass parabola. Beta stability. Angular momentum and parity determination using shell model for nuclear ground state. Collective nuclear model.

Nuclear Reactions : Types of Reactions and Conservation Laws. Concept of Compound and Direct Reaction. Compound Nucleus. Scattering Cross-section. Reaction Rate. Q-value of Reaction. Fission and Fusion.

Introduction to particle physics. Classification and fundamental interactions of elementary particles, conservations laws, Elementary idea about CP invariance. Properties of elementary particles. Quark model. Gell-mann Okubo mass formula for octal and decuplet hadrons, symmetry schemes of elementary particles, SU(2) and SU(3) symmetry.