TEERTHANKER MAHAVEER UNIVERSITY

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Delhi Road, Moradabad (U.P.)

SYLLABUS FOR RESEARCH APTITUDE TEST IN PHYSICS

The syllabus for Research Aptitude Test (RAT) in Physics is divided in two parts viz. Part A & Part B described below:

PART – A

Part A of the RAT shall be designed to assess the research skills/aptitude of the candidate consisting of questions from the following areas:

1. **Research Methodology:** meaning, characteristics, and ethical issues in research; types of research; research methods

2. **Logical Reasoning:** arguments, deductive and inductive research; logical and Venn diagram; inferences; analogies.

3. **Data Interpretation:** interpretation of data; mapping and analysis of data, tools for data analysis; quantitative and qualitative research.

4. **General Awareness about Basic Science:** basic science up to the level of SSC.

5. **Mathematical Reasoning:** number series, letter series, codes; relationships, classification.

PART – B

Part-B of RAT is designed to assess subject specific knowledge of the candidate covering the syllabus given as below:

Classical Mechanics: Lagrangian Formulation of Mechanics - Generalized coordinates, Langrange's equations of motion, properties of kinetic energy function, theorem on total energy, generalized momenta, cycliccoordinates, integrals of motion, Jacobi integrals and energy conservation, Concept of symmetry, invariance under Galilean transformation, velocity dependent potential; Hamiltonian Formulation of Mechanics - Hamilton's function and Hamilton's equation of motion, configuration space, phase-space and state space; Variational Principle - Variational principle, Euler's equation, applications of variational principle, shortest distance problem, brachistochrone, Geodesics of a Sphere; Rotational Motion - Rotating frames of reference, inertial forces in rotating frames, Larmour precision, electromagnetic analogy of inertial forces, effects of Coriolis force, Focoult's pendulum.

Mathematical Methods in Physics: Complex Analysis - Analytical functions, Cauchy-Riemann conditions, Line integrals, Cauchy's theorem, Cauchy integral formula, Derivatives of analytical functions, Power Series, Taylor's theorem, Laurent's theorem, Calculus of residues, revaluation of real definite integrals; Linear spaces and operators - Vector spaces and subspaces, Linear dependence and independence, Basis and Dimensions, linear operators, Inverses, Matrix representation, Similarity transformations, Eigenvalues and eigenvectors, Inner product, Orthogonality, Introduction only to Gramm-Schmidt orthogonalization procedure, Self adjoint and

Unitary transformations, Eigenvalues & eigenvectors of termitian & Unitary transformations, Diagonalizationp; Special Function - Legendre Hermite, Laguerre function: Generating function, Recurrence relations and their differential equations Orthogonality properties, Bessels's function of first kind, Spherical Bessel function, Associated Legendre function, Spherical harmonics; Fourier Series and Integral transforms- Fourier Series: Definition, Dirichlet's condition, Convergence, Fourier Integral and Fourier transform, Convolution theorem, Parseral's identity, Applications to the solution of differential equations, Laplace transform and its properties, Applications to the solution of differential equations, Fourier transform & Laplace transform of Dirac Delta function.

Classical Electromagnetism: Electrostatics and Magnetostatics: Mathematical preliminaries - boundary value problems using Green function techniques - special techniques for calculating potentials – electrostatics of dielectric media - magnetic vector potential and the gauge problem - Biot-Savart law - magnetic dipole moment and the Larmor precession; Maxwell Electrodynamics: Motion of charges in external fields - electromagnetic waves in vacuum and propagation through continuous media - gauge transformations - Lorentz covariant formulation of electrodynamics - energy-momentum of electromagnetic field and Poynting's theorem – Lagrangian and Hamiltonian formulation of electrodynamics; Thermodynamic and Statistical Physics: First- and second-order phase transitions. Diamagnetism, paramagnetism, and ferromagnetism. Ising model. Bose-Einstein condensation. Diffusion equation. Random walk and Brownian motion. Introduction to non-equilibrium processes.

Statistical Mechanics: Statistical Description of System of Particles - Specification of the state of the system, Macroscopic and Microscopic states, Phase space, Statistical ensemble, Postulate of equal a priori probability, Probability calculations, Behaviour of density of states, Liouville's theorem(Classical), Quasi-static processes; Statistical Thermodynamics - Equilibrium conditions and constraints, Distribution of energy between systems in equilibrium, Approach to thermal equilibrium, Temperature, Heat reservoir, Sharpness of the probability distribution, Dependence of the density of states on the external parameters, Equilibrium between interacting systems.

Quantum Mechanics: Free Particle - The Schrodinger equation, Hamiltonian, commutation relations, Wave functions, probability interpretation, currents, measurement, plane waves, normalization, boundary conditions, discrete space and regularization, delta function, wave packets, group velocity, postulates of quantum mechanics, bracket notation, Fourier transform, vector space - matrices, Hermitian and unitary matrices, tensor product, projection operator - Schrodinger and Heisenberg pictures, evolution operator; Spin-1/2 System - Stern-Gerlach experiment, illustrating quantum mechanics, atom in a magnetic field, dynamics of two level systems; Perturbation Theory - Time-independent (degenerate and non-degenerate) perturbation theory -time-dependent perturbation theory, sinusoidal perturbations, Fermi golden rule - scattering Theory; Relativistic Quantum Mechanics - Dirac equation and Klein-Gordon equation.

Atomic and Molecular Physics: 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 & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemical shift. Frank-Condon principle. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Lasers: spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping, population inversion, rate equation. Modes of resonators and coherence length.

Nuclear and Particle Physics: Basic nuclear properties: size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model. Nature of the nuclear force, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces. Deuteron problem. Evidence of shell structure, single-particle shell model, its validity and limitations. Rotational spectra. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission and fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions.

Condensed Matter Physics: Bravais lattices. Reciprocal lattice. Diffraction and the structure factor. Bonding of solids. Elastic properties, 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. Superconductivity: type-I and type-II superconductors. Josephson junctions. Superfluidity. Defects and dislocations. Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order. Quasi crystals.

Semiconductor devices: 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-detectors, LEDs). Operational amplifiers and their applications.

Electronics and Experimental Methods: Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). 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, box-car integrator, modulation techniques.