# JSPM UNIVERSITY PUNE

# SYLLABUS

## RPET 2023

Research Program Entrance Test

**Subject Concerned Syllabus**

**Physics (Ph.D.)**

## I. Mathematical Methods of Physics

Elementary probability theory, random variables, binomial, Poisson and normal distributions; Vector algebra and vector calculus; Linear algebra, matrices; Linear differential equations; Special functions ; Fourier series, Fourier and Laplace transforms; Elements of complex analysis: Laurent series-poles, residues and evaluation of integrals; Elementary ideas about tensors; Introductory group theory, SU(2), O(3). Infinite dimensionalvector space.

Numerical Methods: roots of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule.

## II. Classical Mechanics

Newton's laws; Phase space dynamics; Central-force motion; Collision and scattering; Classical mechanics of system of particles; Rigid body dynamics, moment of inertia tensor, non-inertial frames and pseudoforces; Variational principle, Lagrangian and Hamiltonian formalisms and equations of motion; Poisson brackets and canonical transformations; Symmetry, invariance and conservation laws, cyclic coordinates; Periodic motion, small oscillations and normal modes; Wave equation, phase velocity and group velocity, dispersion; Special theory of relativity, Lorentz transformations, relativistic kinematics and mass–energy equivalence.

## III. Electromagnetic Theory

Electrostatics: Gauss' Law and its applications; Laplace and Poisson equations, boundary value problems, multiple expansion; Magnetostatics: Biot-Savart law, Ampere's theorem, electromagnetic induction; Maxwell's equations in free space and linear isotropic media; boundary conditions on fields at interfaces; Scalar and vector potentials; Gauge invariance; Electromagnetic waves in free space, dielectrics, and conductors; Reflection and refraction, polarization, Fresnel's Law, interference, coherence, and diffraction; Transmission lines and wave guides; Dynamics of charged particles in static and uniform electromagnetic fields; Radiation from moving charges, dipoles.

## IV. Quantum Mechanics

Wave-particle duality; Wave functions in coordinate and momentum representations; Commutators and Heisenberg's uncertainty principle; Schroedinger equation; Particle moving in a one-dimensional potential; Tunneling through a barrier; Motion in a central potential, symmetry, conservation laws and degeneracy; Orbital angular momentum, Angular momentum algebra, spin; Addition of angular momenta; Dirac's bra and ket notation; Matrix representation; Hydrogen atom, spin-orbit coupling, fine structure; Time- independent perturbation theory (non-degenerate and degnerate) and applications; Variational method; WKB approximation; Time dependent perturbation theory and Fermi's Golden Rule; Selection rules; Semi-classical theory of radiation; Elementary theory of scattering, phase shifts, partial waves, Born approximation; Identical particles, Pauli's exclusion principle, spin-statistics connection; Relativistic quantum mechanics: Klein Gordon and Dirac equations.

**V. Thermodynamic and Statistical Physics**

Laws of thermodynamics and their consequences; Thermodynamic potentials, Maxwell relations; Chemical potential, phase equilibria; Phase space, micro- and macrostates; Microcanonical, canonical and grand-canonical ensembles and partition functions; Free Energy and connection with thermodynamic quantities; paramagnetism due to localized moments; Thermodynamics of interacting systems, Van der Wall gas, Ising model; Classical and quantum statistics; ideal Bose gases, Bose-Einstein statistics, Principle of detailed balance; Blackbody radiation and Planck's distribution law; Bose-Einstein condensation; Einstein and Debye models for lattice specific heat; ideal Fermi gases, Fermi-Dirac statistics, Free electrons in metal, Fermi energy, Fermi momentum, electron specific heat; Elementary ideas on phase transition, First- and second-order phase transitions.

Random walk and Brownian motion; Introduction to nonequilibrium processes; Diffusion equation.

**VI. Electronics**

Semiconductor device physics, including diodes, junctions, transistors, field effect devices, homo and heterojunction devices, device structure, device characteristics, frequency dependence and applications; Optoelectronic devices, including solar cells, photodetectors, and LEDs; High-frequency devices, including generators and detectors; Operational amplifiers and their applications; Digital techniques and applications (registers, counters, comparators and similar circuits); A/D and D/A converters; Microprocessor and microcontroller basics.

**VII. Experimental Techniques and data analysis**

Data interpretation and analysis; Precision and accuracy, error analysis, propagation of errors, least squares fitting, linear and nonlinear curve fitting, chi-square test; Transducers (temperature, pressure/vacuum, magnetic field, 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.
Applications of the above experimental and analytical techniques to typical undergraduate and graduate level laboratory experiments.

**VIII. Atomic & Molecular Physics**

Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen atom; and alkali atoms Relativistic corrections for energy levels of hydrogen; Hyperfine structure, selection rules; width of spectral lines; LS & JJ coupling, Hund's rule; Mechanism of line broadening, Zeeman, Paschen Back & Stark effect; X-ray spectroscopy; Principle of resonance spectroscopy, Electron spin resonance, Nuclear magnetic resonance, chemical shift; Molecular physics, rotational, vibrational, electronic, and Raman spectra of diatomic molecules, symmetry groups of molecules, point groups and classification of molecules; Frank – Condon principle and selection rules; Spontaneous and stimulated emission, Einstein A & B coefficients; Lasers, optical pumping, population inversion, rate equation, He-Ne lasers; Modes of resonators and coherence length.

**IX. Condensed Matter Physics**

Bravais lattices; Reciprocal lattice, diffraction and the structure factor; Defects and dislocations; Ordered phases of matter, translational and orientational order, kinds of liquid crystalline order, Quasicrystals and glasses. Bonding of solids; Elastic properties, phonons, lattice specific heat; Free electron theory, electronic specific heat, Pauli paramagnetic susceptibility; Response and relaxation phenomena; Drude model; Hall effect and thermoelectric power; Electron motion in a periodic potential, band theory of metals, insulators and semiconductors, tight- binding approximation, impurity levels in doped semiconductors; Diamagnetism, paramagnetism, and ferromagnetism; Superconductivity, Meissner effect, type – I and type - II superconductors, London theory of superconductivity, Josephson junctions.

**X. Nuclear and Particle Physics**

Basic nuclear properties: size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Liquid drop model; Nuclear stability, radioactive decay, fission and fusion; Nature of the nuclear force, form of nucleon-nucleon potential; Charge- independence and charge-symmetry of nuclear forces; Isospin; Deuteron problem; Low energy N-N scattering; 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; Nuclear reactions, reaction mechanisms, compound nuclei and direct reactions; Classification of fundamental forces; Elementary particles (quarks, baryons, mesons, leptons); Spin and parity assignments, isospin, strangeness; Gell-Mann-Nishijima formula; C, P, and T invariance and applications of symmetry arguments to particle reactions, parity non-conservation in weak interaction.