DEPARTMENT OF PHYSICS

Syllabus for Written Test to Ph. D Programme, July 2016.

PART A:

(30 Marks: MCQ)

This is qualifying group [marks will not be counted for short listing]- 30% (i.e 9) is the qualifying marks

I. **Aptitude, Data analysis and General English:** Number System, Percentage, Algebra, Trigonometry, Geometry, Average, Data Interpretation, etc; Vocabulary, comprehension, grammar correction, etc; General information on science and its interface with society to test the candidate's awareness of science.

PART B:

(40 Marks: MCQ)

I. **Mathematical Methods of Physics :** Dimensional analysis; Vector algebra and vector calculus; Linear algebra, matrices, Cayley-Hamilton Theorem; Eigen values and eigen vectors; Linear ordinary differential equations of first & second order, Special functions (Hermite, Bessel, Laguerre and Legendre functions); Fourier series, Fourier and Laplace transforms; Elements of complex analysis, analytic functions, Taylor & Laurent series, poles, residues and evaluation of integrals; Elementary probability theory, random variables, binomial, Poisson and normal distributions, Central limit theorem.

II. **Classical Mechanics :** Newton's laws; Dynamical systems, Phase space dynamics, stability analysis; Central force motions; Two body Collisions - scattering in laboratory and centre of mass frames; Rigid body dynamics - moment of inertia tensor; Non - inertial frames and pseudoforces; Variational principle; Generalized coordinates; Lagrangian and Hamiltonian formalism and equations of motion; Conservation laws and cyclic coordinates; Periodic motion : small oscillations, normal modes; Special theory of relativity - Lorentz transformations, relativistic kinematics and mass–energy equivalence.

III. **Electromagnetic Theory :** Electrostatics : Gauss's law and its applications, Laplace and Poisson equations, boundary value problems; Magnetostatics : Biot-Savart law, Ampere's theorem; Electromagnetic induction; Maxwell's equations in free space and linear isotropic media; boundary conditions on the 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; Dynamics of charged particles in static and uniform electromagnetic fields.

IV. **Quantum Mechanics :** Wave-particle duality; Schrödinger equation (time-dependent and time-independent); Eigen value problems (particle in a box, harmonic oscillator, etc.); Tunneling through a barrier; Wave-function in coordinate and momentum representations; Commutators and Heisenberg uncertainty principle; Dirac notation for state vectors; Motion in a central potential : orbital angular momentum, angular momentum algebra, spin, addition of angular momenta; Hydrogen atom; Stern-Gerlach experiment; Time - independent perturbation theory and applications; Variational method; Time dependent

perturbation theory and Fermi's golden rule, selection rules; Identical particles, Pauli exclusion principle, spin-statistics connection.

V. **Thermodynamic and Statistical Physics :** Laws of thermodynamics and their consequences; Thermodynamic potentials, Maxwell relations, chemical potential, phase equilibria; Phase space, micro- and macro-states; Micro-canonical, canonical and grand-canonical ensembles and partition functions; Free energy and its connection with thermodynamic quantities; Classical and quantum statistics; Ideal Bose and Fermi gases; Principle of detailed balance; Blackbody radiation and Planck's distribution law.

VI. **Electronics and Experimental Methods :** Linear and nonlinear curve fitting, chi-square test; 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; High frequency devices (including generators and detectors).

VII. **Nuclear and Particle Physics :** Basic nuclear properties : size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Liquid drop model; Fission and fusion; Nature of the nuclear force, form of nucleon-nucleon potential; Charge-independence and charge-symmetry of nuclear forces; Isospin; 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; Nuclear reactions, reaction mechanisms, compound nuclei and direct reactions; Classification of fundamental forces; Elementary particles (quarks, baryons, mesons, leptons); Spin and parity assignments.

PART C:

(30 Marks: Descriptive)

I. **Mathematical Methods of Physics :** Green's function; Partial differential equations (Laplace, wave and heat equations in two and three dimensions); Elements of computational techniques : root of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule; Solution of first order differential equations using Runge-Kutta method; Finite difference methods; Tensors.

II. **Classical Mechanics :** Dynamical systems, Phase space dynamics, stability analysis; Poisson brackets and canonical transformations; Symmetry, invariance and Noether's theorem; Hamilton-Jacobi theory.

III. **Electromagnetic Theory :** Dispersion relations in plasma; Lorentz invariance of Maxwell's equation; Transmission lines and wave guides; Radiation from moving charges and dipoles and retarded potentials.

IV. **Quantum Mechanics :** Spin-orbit coupling, fine structure. WKB approximation; Elementary theory of scattering : phase shifts, partial waves, Born approximation; Relativistic quantum mechanics : Klein-Gordon and Dirac equations; Semi-classical theory of radiation.

V. **Thermodynamic and Statistical Physics :** First-order and second-order phase transitions; Diamagnetism, paramagnetism, and ferromagnetism; Ising model; Bose-Einstein condensation.

VI. **Atomic & 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.

VII. **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.