# Ph.D. Entrance Test - SYLLABUS

# Physics Part – 1

## (Research Methodology) (50%)

NB: The Research Methodology of 50 MCQs will constitute questions related to English Proficiency, Reasoning Ability, Basic Computer Skills; each of 5 questions – total 15 and 35 Questions of subject specific Research Methodology

## Synthesis and characterization methods for Materials

**Solid State Reaction (Ceramic) Method**

General Principles, Experimental Procedure: Reagents, Mixing, Container Material, HeatTreatment, Analysis, Kinetics of Solid State Reaction, Disadvantages

**Microwave Synthesis**

Background & General Principle, Preparation of $YBa_2Cu_3O_{7-\delta}$ Superconductor throughMicrowave Synthesis, Importance

**Sol-gel Method**

Principle, Lithium Niobate ($LiNbO_3$), Doped Tin Dioxide

**Co-precipitation Method**

Co-precipitation as a precursor to Solid State Reaction, Advantages & Disadvantages,Synthesis of CMR Manganites

**Thin Film Synthesis**

Vacuum Evaporation, Sputtering, Spin Coating, Pulsed Laser Deposition (PLD)

**Growth of Single Crystals**

Introduction to Methods of Growth of Crystals, Czochralski Method, Bridgman andStockbarger Methods, Zone Melting and Zone Refining Methods, Impurity LevelingFactor, Verneuil Method, Molten Flux Method.

**Vapor Phase Transport Methods and Thin Film Growth**

Hydrothermal Methods, Vapor Methods, Fundamental of Epitaxial Growth of Thin Layers.

**X-ray Diffraction**

X-rays and their Generation, Diffraction: Diffraction of Light by an Optical Grating,Crystals and the Diffraction of X-rays, d-spacing & Unit Cell Formulae, Overview of Powder Diffractometer, Effect of Crystal Size on the Powder Pattern; Particle Size Measurement, Effect of Stresson a Powder Pattern, Refinement of Unit Cell Parameters and Indexing of PowderPatterns, A Powder Pattern as a Crystal‟ s „Fingerprint‟ , Structure Determination fromPowder Patterns, Powder Patterns Calculated from Crystal Structure Data, Influence ofCrystal Symmetry and Multiplicities on Powder Patterns.

**Imaging Techniques (Microscopy)**

**Scanning Electron Microscopy (SEM)**

Physical Basis and Primary Modes of Operation, Instrumentation, Sample Requirements, FESEM, Advantages over conventional SEM, Applications

**Transmission Electron Microscopy (TEM)**

Basic Principle, Resolution, Sensitivity, TEM Operation, Image Mode, Specimen Preparation

**Scanning Tunneling Microscopy (STM) and Scanning Force Microscopy (SFM)**

Introduction, Instrumentation, Topography, Profilometry, Sample Requirements

**Resistivity**

Two point-four point probes, Derivation of four point probe expression, Correction factors, Measurement errors and precautions factors:- sample size, Carrier injection, probe spacing, current, temperature, surface preparation, high sheet resistance material, Van der Pauw method – measurement of arbitrary shape samples

**Dielectric Study**

Dielectric materials, types of polarizability, dielectric behavior with frequency, introduction to Cole- Cole plot, Ferro-electricity, P-E loop.

**UV-Vis**

Introduction, principle of UV-vis spectroscopy, Beer-Lambert‟ s law, molar absorbility, absorbing species, containing π, σ and η electrons, charge transfer absorption, Instrumentation of UV-vis spectroscopy: Radiation Sources, Wavelength Selectors, Monochromators, Sample Handling, Detectors, Signal Processing and Output Devices, Types of UV-Visible Spectrometers: Single Beam Spectrometers, Double Beam Spectrometers, Photodiode Array Spectrometer, applications

**FT-IR**

What is FT-IR, Why IR spectroscopy, Principle of IR spectroscopy, Theory of infrared absorption, vibrational modes, infrared ranges, Typical Instrumentation, use of FT-IR, typical spectral analysis

**Magnetometry**

Basic principle, Vibrating sample magnetometer, SQUID magnetometer

**Thermogravimetry**

Principle, Apparatus, application, Differential thermal analysis and Differential Scanning Calorimetry, Principles, Apparatus and Applications

Radiation sources, Radiation interactions, Radiation detectors – gas filled detectors – scintillation detectors – semiconductor detectors

Introduction to production of X-ray & X-ray spectra, Instrumentation, X-ray generation,collimators, filters, detectors, X-ray absorption methods, X-ray fluorescence methods, XF– Spectrometer (XFS), Electron spectroscopy for chemical analysis (ESCA)

Nuclear Magnetic Resonance (NMR) spectroscopy, basic principles, nuclear magneticenergy levels, magnetic resonance, NMR SpectrometerElectron Spin Resonance spectroscopy, ESR spectrometer, ESR spectra, Hyperfineinteractions.

Mass spectroscopy – principle, spectrometer, and its operation, resolution, Mass spectrum, applications Infrared Spectroscopy, correlation of IR spectra with molecular structure, Instrumentation.

Mossbauer Spectroscopy – Mossbauer effect, spectrometer, 57 Fe Mossbauer spectroscopy, nuclear hyperfine interactions Neutron diffraction, neutron diffractometer (position sensitive diffractometer).

## Numerical Analysis and Computer Awareness

Methods of solving of linear and non-linear algebraic equations, transcendentalequations, Convergence of Solutions, Solution of simultaneous linear equations, Gaussianelimination Finite differences, interpolation with equally spaced and unevenly spaced points, Curvefitting, Polynomial, Least squares and Cubic Spline fitting

Numerical differential and integration, error estimates. Numerical solutions of ordinarydifferential equations – Euler and Runge-Kutta methodsHarmonic Analysis and FFT techniques.

Elementary information about digital computers, Introduction to compilers and Operatingsystems.

MS Office, Excel, Power Point, Internet Awareness

# Part – 2 (Core subject) (50%)

## CSIR-UGC National Eligibility Test (NET) for Junior Research Fellowship and Lecturer-ship

## PHYSICAL SCIENCES

## PART 'A' CORE

### I. Mathematical Methods of Physics

Vector algebra and vector calculus. Linear algebra, matrices, Eigenvalues and eigenvectors. 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; Elementary probability theory, random variables, binomial, Poisson and normal distributions.

### 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. Schrodinger equation (time-dependent and time-independent). Eigenvalue 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.

**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**

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. Digital techniques and applications (registers, counters, comparators and similar circuits). A/D and D/A converters.

Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting,

# PART 'B' ADVANCED

**I. Mathematical Methods of Physics**

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 equation using Runge-Kutta method. Finite difference methods.

**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. 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.

**V. 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 nonequilibrium processes.

## VI. Electronics and Experimental Methods

Linear and nonlinear curve fitting, Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors) Impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding. Fourier transforms, modulation techniques.

High frequency devices (including generators and detectors).

## VII. 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.

## VIII. 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. 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. kinds of liquid crystalline order. Quasi crystals.

## IX. 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, Evidence of shell structure, single-particle shell model, its validity and limitations. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission and fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions.

Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Quark model, baryons and mesons. C, P, and T invariance.. Parity non-conservation in weak interaction.

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