Syllabus: Research Methodology in Applied Physics

1. **Research Methodology of Science:**
   Areas of Science, Philosophy of science, Characteristics of Research, Types of research, Research process; Methodology: Topic selection, Hypothesis, Designing experiment, Analysis, Results, Models; Critical thinking and Science: Strategies and common fallacies.
2. **Research process and tools:**
   Design of experiments, testing and characterization; Measurement - Standardization, calibration and sampling; Primary and secondary data; Computer programming, theory, modelling and simulation; Data acquisition, processing, observation, critical analysis and interpretation; Presentation of data; Reliability and reproducibility.
3. **Computer applications and tools:**
   Software for documentation, graphs, graphics, drawing and presentation. Web literature search; International standards, reference data and constants
4. **Communicating research results and Research ethics:**
   Journal paper – types of available publishing services; Research proposal, Report, Thesis; Presentation in Seminar and conference; Journal abbreviations, Bibliography standards; Indices of quality assessment of publications. Ethics code of American Psychological Association; Collaboration, cooperation and teamwork; Research outcome; Intellectual property right, Copy-right, patent.

Text Books:

1. The Scientific Endeavor -Methodology and Perspectives of Sciences- Jeffrey A. Lee, Pearson India (2010)
2. Research Methodology: The Aims, Practices and Ethics of Science, P. Pruzan, Springer, 2016
3. Research Methods for Science, M. P. Marder, Cambridge University, 2011
4. Fundamentals of Research Methodology and Statistics, Y.K. Singh, New Age, 2006

Reference Books:

1. Research Methodology: An Introduction for Science and Engineering Students; Melville and Goddard, Juta, 1996
2. Research Methods in Science and Engineering, Scott A. Gold, CRC Press, 2016

Syllabus: Ph.D. (Applied Physics) Entrance Test

Mathematical Methods in Physics:

Vector Analysis and Curved Coordinates: Elementary Approach, Scalar or Dot Product, Vector or Cross Product, Triple Scalar and Vector Product, Gradient, Divergence, Curl, Vector Integration, Gauss's Theorem, Stoke's Theorem, Potential Theory, Gauss's Law and Poisson's Equation, Dirac Delta Function. Rectangular, Cylindrical and Polar Coordinates. **Complex Variables:** Complex Algebra, CauchyRiemann Condition, Cauchy's Integral Theorem, Cauchy's Integral Formula, Laurent Expansion, Mapping, Singularities, Calculus of Residues **Fourier series and Integral Transform:** General Properties, Advantages and Uses of Fourier series, Complex Fourier Series, Properties of Fourier Series Fourier Transform, Inversion Theorem, Fourier Transform and Derivatives, Convolution Theorems, Application. Elementary Laplace's Transform, Laplace's Transform and Derivatives, Convolution Theorems, Inverse Laplace's Transform

Applied Quantum Mechanics:

The Schrodinger Equation and Stationary States: Introduction- A free particle in one dimension- Generalization to three dimensions- The operator correspondence and the Schrodinger equation for a particle subject to forces Physical interpretation and conditions on Ψ- Normalization and probability interpretation Non-normalizable wave functions and Box normalization- Expected values: Ehrenfest's theorem- Admissibility conditions on the wave function-Stationary states: The time dependent Schrodinger equation- Problems. **General Formalism of Wave Mechanics:** Introduction- The Schrodinger equation and the probability interpretation for an N particle system- The fundamental postulates of wave mechanics- The adjoint of an operator and selfadjointness- The eigen value problem: Degeneracy- Eigen values and Eigenfunctions of self-adjoint operators- The Dirac Delta function- Observables: completeness and normalization of eigenfunctions- Problems. **Exactly Soluble Eigenvalue Problems:** Introduction- The Schrodinger equation and energy eigenvalues- The energy eigen functions Properties of stationary waves- The angular momentum operators- The eigenvalue equation for L_2 ; separation of variables- Admissibility conditions on solutions; Eigenvalues- The eigenfunctions: Spherical harmonics- Physical interpretation- Parity- The Hydrogen atom Problems.

Electrodynamics and Statistical Physics:

Electrodynamics: Coulomb's law and field intensity, Field due to continuous charge distributions, electric flux density, Gauss's Law- Maxwell's Equation, Electrical Potential, Relationship between E and V – Maxwell's Equation, Concepts of An electric dipole and energy density in electrostatic fields Convention and Conduction currents, conductors, polarization in dielectrics, dielectric constant and strength, continuity equation, Boundary Conditions Poisson's and Laplace's equations, Biot Savart's law, Ampere's circuit law, Magnetic Flux density, Maxwell's equations for static EM fields

,Concept of Magnetization in materials, magnetic boundary conditions, Magnetic Energy, Maxwell's Equations: Faraday's law, Transformer and Motional EMF's, Displacement current, Maxwell's Equation in Final Forms , Power and the pointing vector, Concept of Reflection of a plane wave at Normal and oblique incidence. **Statistical Physics:** Ensembles: Micro canonical, canonical, Grand canonical Ensembles, Uses of Ensembles, Statistical Equilibrium, Thermal Equilibrium, Mechanical Equilibrium, Particle Equilibrium, Microstates and Macro states, Sterling's theorem, Thermodynamic Probability, General Statistical distribution law, Most Probable distribution, Division of Phase space into cells, Principle of Equipartition of Energy, Connection between partition function and thermodynamic quantities, **Ideal**

Bose Systems: Photon gas, Einstein's derivation of Planck's law, Bose Einstein Condensation, Specific heat from lattice vibrations, Debye's model of Solids: Phonon gas, **Ideal Fermi Systems:** Fermi energy, An alternate derivation of Fermi energy, Fermi gas in Metals, Atomic nucleus as an Ideal Fermi gas, White Dwarfs and Chandrasekhar Mass limit

Applied Condensed Matter Physics:

Crystal Structure and its Determination: Basic definitions, Symmetry elements, Types of diffractions, Experimental methods of XRD, Some common crystal structures **Defects in Solids:** Types of defects**,** Vacancy defects, Schottky and Frankel defects, Colour centres, Line defects and Plane defects. **Band Theory of Solids:** Concept of energy band, Bloch Theorem, Kronning Penny model, Origin of energy gap, Concept of effective mass, Metals, Insulators and Semiconductors, Experimental techniques for Band Structure study. **Superconductivity and Magnetism: Superconductivity:** Definition, Discovery, Properties of Superconductors, Types of Superconductors, Meissener effect, BCS theory of Superconductors (Qualitative approach) **Magnetism:** Basic definitions, Classification of magnetic materials, Diamagnetism, Para magnetism in rare earth and iron group ions, Ferromagnetism and its applications, Antiferromagnetism and Ferrimagnetism.

Electronic Devices and Applications:

Introduction and History of Semiconductor Power Devices: Applications of power electronics, Power semiconductor devices, Control characteristics of power devices, characteristics and specifications of switches, Types of power electronic circuit, design of power electronic equipment. **Power Semiconductor Diodes and Circuits:** Semiconductor basics, diode characteristics, reverse recovery characteristics, power diode types, silicon carbide diodes, series and parallel connected diodes. **Power Electronics Devices: 1. Diode Rectifiers:** Single phase: half wave rectifiers, full wave rectifiers, Multiphase star rectifiers, three phase bridge rectifiers and further analysis,**2. Power Transistors:** Bipolar junction transistors, power MOSFETs, COOLMOS, SITs, IGBTs, Service and parallel operations. **DC to DC Converters DC-DC Converters:** Principles of step down and step up operation, step down with RL load, step up with resistive load, Converter classification, switching mode regulators comparison of regulators, chopper circuit design. **Thyristors:** Thyristor characteristics, Turn ON, Turn OFF, Types of Thyristors – Phase controlled, BCT, Fast switching etc.

Advanced Experimental Techniques for Materials Characterization:

Structural & Microstructural Analysis: X-Ray diffraction: Phase identification, indexing and lattice parameter determination, fitting of various models. Neutron diffraction: Reflexion High Energy Electron Diffraction (RHEED), Low Energy Electron Diffraction (LEED), Scanning Electron Microscope (SEM), Tunnelling Electron Microscope (TEM), Rutherford Back Scattering (RBS), Atomic Force Microscope (AFM) **Thermal Analysis Techniques:** Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Thermogravimetric Analysis (TGA) **Electrical & Magnetic Characterization:** Electrical resistivity in bulk and thin films (two & four probes), Hall effect, Magnetoresistance, M-H loops, temperature dependent magnetization, time dependent magnetization, measurements using AC & DC susceptibility. **Optical Characterization Techniques:** UV-Vis Spectroscopy, Fourier Transform Infrared spectroscopy (FTIR), Raman Spectroscopy, X-Ray photoelectron spectroscopy (XPS).

Advanced Materials and Applications:

Functional Materials – I: CMR Manganites – Structure and properties of Mixed valent Manganites, Magnetoresistance (MR): concept and types, Zener Double Exchange and Jahn Teller Effect in Manganites, Applications of manganites High Tc Superconductors (HTSC) – Discovery, families, salient features of HTSC, synthesis of Y123 (YBCO), structure -property correlations, Role of Cu and Oxygen, Applications of HTSC, **Functional Materials – II:** Multiferroics (MF)–Basic concepts, types of MFs, Magnetoelectric (ME) effect, $BiFeO_3$ MF: structure & properties, Applications of MFs Ferrites – Fundamentals, synthesis methods, soft and hard ferrites, Applications of ferrites **Composites:** Basic concepts, Particle -Reinforced Composites, Fiber-Reinforced Composites :conventional fiber glass, advanced composites, wood - natural composite, Polymer – Matrix Composites, Metal-Matrix Composites, Ceramic – Matrix Composites, Carbo-Carbon Composites, Hybrid Composites, mechanical properties, processing of composites, Applications of composites **Polymers:** Introduction, Polymerization, Structural features of Polymers, Thermoplastic and Thermosetting Polymers, Additives, Polymer processing, Mechanical behaviour of Polymers, Crystallization, Melting and Glass transition phenomena in Polymers, Polymer types, Polymerization, Polymer Additives, Applications of Polymers

Applied Nuclear Physics:

Constituents of nuclei, Nuclear size, Binding Energy, Semi-empirical mass formula, Magic numbers, Nuclear shell model, Discovery of Radioactivity, Rate of decay, Halflife, Mean life, Conservation law in radioactive decay, Radioactive equilibrium, Radioactive dating, Alpha decay, Theory of alpha decay, Beta decay, Electron Emission, Positron Emission, Electron Capture, Theory of Beta decay, Gamma decay, Kinds of Nuclear reactions, Conservation laws, Nuclear reaction kinematics, Q equation, Solution of Q equation, Introduction of Nuclear fission and fusion, **Particle Detectors and accelerators:** Ionization chamber, Geiger Counter, Scintillation counter, Semiconductor junction detector, Cloud Chamber, Bubble chamber, other detectors, Van-de-graph generator, Cyclotron, Synchrocyclotron, Synchrotron, linear Accelerator