University of Lucknow
Ph. D. Coursework in Physics

Paper 1
Research Methodology
(4 Credits)

UNIT I (12 Lectures)

General: Definition of research, qualities of researcher, components of research problem, Various steps in scientific research: hypotheses, research purposes, research design, literature survey. Structure and components of research report, types of report - Research papers, thesis, research project reports, pictures and graphs, citation styles, ethics in research. Review of published research in relevant field and presentation.

UNIT II (13 Lectures)

Theoretical Techniques: Technological methods and surveys used in testing general relativity and mapping the large-scale structure of the universe. Foundations of quantum chemistry, fundamentals of electronic structure theory, various quantum chemistry software. Introduction to Linux operating system: Elementary programming in C++, graphical representation of equations.Introduction to simulation tools in High Energy Physics. Error Analysis-Types of errors: Statistical and systematic errors, determining the precision, rejection of measurements, calibration and accuracy.

UNIT III (13 Lectures)

Experimental Techniques: (Part I)-Structural Characterization and Imaging Techniques: Basic principles and elementary ideas of X-ray diffraction (XRD), electron and neutron diffraction, photoelectron spectroscopy (PES), atomic resolution electron microscopy, scanning tunneling and atomic force microscopy (STM, AFM) techniques, scanning electron microscopy (SEM), high resolution transmission electron microscopy (TEM), profilometry.

UNIT IV (12 Lectures)

Experimental Techniques: (Part-II)-Optical Characterization and Spectroscopic Techniques: Fundamentals of infrared, Raman and ultraviolet / visible (UV/Vis) absorption spectroscopy, fluorescence spectroscopy, laser-based non-linear techniques. Plasmon resonance. Vacuum techniques (HV and UHV), monochromators and spectrographs, CCD and ICCD detectors.

Paper 2
Condensed Matter Physics
(4 Credits)

UNIT I (12 Lectures)

Nanomaterials and nanotechnology, sensors/actuators/transducers; humidity and gas sensing; ceramics/metal oxides for humidity and gas sensing: Issues of hysteresis, reproducibility and aging in metal oxides; adsorption: physisorption, chemisorption, Grotthuss chain reaction. Gas sensor for detecting environmental pollution.Fabrication techniques of chemical and bio-chemical sensors.Fundamentals of fiber optics,optical and fiber optic sensors and optoelectronic devices,materials and their applications such as semi-conductors.

UNIT II (12 Lectures)

Glass and ceramics. Synthesis of materials - Bulk, film, crystal, solution etc. Introduction to chalcogenides. Liquid crystal, electro-optical parameters related with displays. Introduction to low temperature physics – production and measurement, quantum Hall effect, superconductivity and superfluidity andelectrical conductivity measurement (four probe method).

UNIT III (12 Lectures)

Applications of vibrational spectroscopy (infrared, Raman and terahertz spectroscopy) and quantum chemistry to materials research. Applications of X-ray diffraction (XRD) for structural studies, scanning electron microscopy (SEM) and atomic force microscopy (AFM) for surface morphology.

UNIT IV (12 Lectures)

Dielectric relaxation: Theory and application, superconductors, acoustics and their application including materials characterization, polymer experimental details. Basics of circuit and measurement systems including transducers and control systems, Instrumentation - electronic measurement and process control. Molecular interactions in biologically important systems through physicochemical techniques, rheological and dielectric characterization.

Paper 3
Elements of Theoretical Physics and Computational Research
(4 Credits)

UNIT I (12 Lectures)

Plasmas in nature and laboratory, definition of plasma and brief history of plasma physics, plasma parameters, Debye shielding, quasi neutrality, collisions, instabilities and magnetic properties of plasma. Interaction of electromagnetic waves with cold plasma, dispersion relation, phase and group velocity. Nonlinear laser-plasma interaction and its applications.

UNIT II (12 Lectures)

Phonons, surface optical-plasmons, surface polaritons interaction, magneto-plasmons, band attenuation properties of polar semi-conductor surfaces, filtering properties of curved surface of crystals. Space weather and space climate: solar wind, coronal mass ejections, solar flares etc.; geomagnetic storms, sub-storms, auroras, sun-earth interactions; atmospheric layers - ionosphere and magnetosphere in particular, Generation and propagation of ELF/VLF waves.

UNIT III (12 Lectures)

Quantum theoretical methods, concepts of atomic and molecular orbitals, Slater orbitals, Gaussian orbitals, basis sets, semi-empirical molecular orbital methods, Hartree-Fock theory, post Hartree-Fock methods, density functional theory, geometry optimization, charge density distribution in molecules, dipole moment, molecular electrostatic potential and calculation of vibrational wavenumbers.

UNIT IV (12 Lectures)

Friedmann models, dark matter and dark energy, modified and emergent gravity, cosmic microwave background radiation. Strings basics: a brief Introduction, nonrelativistic strings, relativistic strings. Introduction to neutrino physics and neutrino oscillation physics. Particle detection(with magnetic field) and study of energy and angular resolution of detector: Reconstruction of energy of charged particles passing through the detector.

***Note**: Each student has to study a common course (Paper 1) of 4 credits, and choose one out of the two courses (Paper 2/ Paper 3), each of 4 credits.*