M.Sc. Physics Semester IV Paper XXVII
Physics of Nano-materials 23PHY24C2

Theory Marks: 80
Internal Assessment Marks: 20
Time: 3 Hours

COURSE OUTCOMES

CO1 Students would be able to explain the properties of Nanomaterials/nanostructures.
CO2 Students get enabled to analyze the density of states in various nanostructures and related effect on optical properties.
CO3 Students get acquainted with important techniques for preparation of Nanomaterials/nanostructures.
CO4 Understanding quantitatively, the experimental results of x-ray diffraction, photoluminescence and Raman spectra of Nanomaterials opens up avenues of future research.

Unit I

Free electron theory (qualitative idea) and its features, Idea of band structure: Kronig Penny model, Metals, insulators and semiconductors, Concept of effective mass, Derivation of density of states in 3D, 2D, 1D and 0D systems, Density of states in bands, Variation of density of states with energy, Variation of density of states and band gap energy with size of crystal, Electronicstructure from Bulk to quantum dot, Excitons: Frenkel and Mott-Wannier excitons

Unit II

Physics of reduced dimensional systems and devices: Quantum confinement, Electron confinement in one, two and three dimensional infinitely deep square well potentials, Various low dimensional systems: Quantum well structure; Idea of quantum well structure, Electron wave function and energy in quantum well structure (infinite well approximation), Density of states and optical absorption in quantum well, Quantum wires: Electron wave function and energy, Density of states, Quantum dots: Electron wave function and energy, Density of states, idea of hetero-junction LED, Quantum well laser and quantum dot laser, Coulomb blockade and Single electron transistor

Unit III

Synthesis of Nanomaterials/Nanostructures: Bottom up and top down approaches for synthesis of nano materials, Synthesis of zero-dimensional nanostructures (Nanoparticles): Sol-Gel Process, Epitaxial core-shell nanoparticles, Ball milling, One-dimensional nanostructures (Nanowires, Nanorods, Nanotubes): Electrochemical deposition, Lithography, Two-dimensional nanostructures (Thin Films & Quantum wells): Molecular beam epitaxy (MBE), MOCVD, Cluster beam evaporation, Ion beam deposition, Chemical bath deposition technique

Unit IV

Characterization of Nanomaterials/Nanostructures: Effect of particle size and Strain on width of XRD peaks of nanomaterials, Determination of crystallite/particle size and strain in nanomaterials using Debye Scherer's formula and Williamson–Hall's plot, Transmission electron microscopy: Basic principle, Brief idea of set up, Sample preparation, Imaging modes (Dark & Bright Field), Photoluminescence (PL) spectroscopy: Basic principle and idea of instrumentation, Shift in PL peaks with particle Size, Determination of alloy composition in thin films of compound semiconductors, Estimation for width of quantum wells, Raman spectroscopy: Basic principle and idea of instrumentation, Variations in Raman spectra of nanomaterials with particle size, Study of Raman spectra of carbon nanotubes and graphene.

Note: The syllabus is divided into four units. Nine questions will be set in all. Question No.1 will be compulsory having four to eight parts covering the whole syllabus. In addition there will be two questions from each unit and the student is to answer one question from each unit. A student has to attempt five questions in all.

Text and Reference Books:

[1] Physics of Low Dimensional Semiconductors by John H. Davies (Cambridge Univ. Press).
[2] Introduction to Nano-technology by Charles P. Poole & Jr. Frank J. Owens (Wiley Inter-science).
[3] Quantum Mechanics for Nanostructures by Vladimir V. Mitin, Dmitry I. Sementsov&Nizami Z. Vagidov (Cambridge University Press).
[4] Nanostructures & Nanomaterials: Synthesis, Properties & Applications by Guozhong Cao (Imperial College Press).