

U.G. 6th Semester Examination-2025**PHYSICS****[HONOURS]****Discipline Specific Elective (DSE)****Course Code : PHY-H-DSE-T-03****(Nanomaterials and Applications)****[Old Syllabus]**

Full Marks : 60

Time : $2\frac{1}{2}$ Hours*The figures in the right-hand margin indicate marks.**Candidates are required to give their answers in their own words as far as practicable.***GROUP-A**

1. Answer any five questions: $2 \times 5 = 10$
- a) How do quantum dots enhance the efficiency and color tunability of light-emitting diodes (LEDs)?
 - b) Explain the difference between bright-field and dark-field imaging in optical microscopy.
 - c) How can the size-dependent optical properties of quantum dots be leveraged for improving solar cell efficiency?
 - d) What are the key factors influencing carrier transport in carbon nanotubes?
 - e) How is the binding energy of an exciton calculated in a quantum dot?

[Turn Over]

- f) What is the general mechanism of photon absorption in nanostructures?
- g) What factors determine the luminescence efficiency in semiconductor nanostructures?
- h) How do heterostructures influence the photoluminescence spectra of nanomaterials?
- i) How does the wavelength of light affect the resolution in photolithography?
- j) Name two techniques that use the top-down approach for nanomaterial fabrication.
- k) How do quantum wells in heterostructures enhance optical absorption compared to bulk materials?

GROUP-B

2. Answer any four questions: $5 \times 4 = 20$
- a) Compare and contrast the structural and electronic properties of 1D (nanowires, nanorods), 2D (thin films), and 3D (nanodots) nanostructures, highlighting their unique applications in nanotechnology. 5
 - b) Using the Schrödinger equation for an infinite potential well, describe how quantum confinement affects the energy levels and carrier behavior in 1D, 2D, and 3D nanostructures. 5
 - c) What are the key differences between top-down and bottom-up approaches in nanomaterial synthesis, and how do these differences impact the scalability and precision of producing nanostructures like quantum dots or nanowires? 5

- d) Explain how molecular beam epitaxy (MBE) is used to grow quantum dots with precise control over size and composition, and compare this with colloidal methods in terms of throughput, structural quality, and potential applications in optoelectronic devices. 5
- e) How does an optical microscope form an image? Why is the resolution of optical microscopy limited compared to electron microscopy techniques? 3+2
- f) What is the role of secondary electrons versus backscattered electrons in SEM imaging? How does TEM differ from SEM in terms of sample preparation and imaging mechanism? 2+3
- g) Explain how thin films are used to optimise the performance of photovoltaic cells in solar energy applications. 5
- h) What are the advantages of using nanoparticles in the active layers of LEDs compared to traditional bulk materials? 5
- i) What are the potential applications of single-electron devices in low-power electronics? 5

GROUP-C

3. Answer any three questions: $10 \times 3 = 30$
- a) Discuss the differences between chemical vapour deposition and sol-gel methods for synthesising nanomaterials, focusing on their ability to control composition, uniformity, and their suitability for producing specific

nanostructures like thin films or nanoparticles.

10

- b) How does X-ray diffraction enable the determination of crystal structures in materials? Explain the role of Bragg's Law in interpreting X-ray diffraction patterns. What are the limitations of XRD when analyzing amorphous or poorly crystalline samples? 2+3+5
- c) How can the size-dependent optical properties of quantum dots improve solar cell efficiency? What challenges arise when integrating nanowires or thin films into large-scale photonic device manufacturing? 5+5
- d) What is the role of impurities in creating deep-level traps in semiconductor nanostructures? How do surface defects contribute to recombination processes in nanostructured photovoltaic devices? 5+5
- e) What are the fundamental principles of photolithography, and how does it enable precise patterning in microelectronics fabrication? 5+5
- f) What are the main differences between physical vapor deposition (PVD) and chemical vapor deposition (CVD) in terms of process mechanisms and applications? 5+5