

**NANOELECTRONICS & NANOPHOTONICS**  
**(ECEN 4244)**

**Time Allotted : 2½ hrs**

**Full Marks : 60**

*Figures out of the right margin indicate full marks.*

*Candidates are required to answer Group A and  
any 4 (four) from Group B to E, taking one from each group.*

*Candidates are required to give answer in their own words as far as practicable.*

**Group – A**

1. Answer any twelve:

**12 × 1 = 12**

*Choose the correct alternative for the following*

- (i) For a particle inside a box, the potential is maximum at  $x =$   
(a)  $2L$       (b)  $L/2$       (c)  $L$       (d)  $\sqrt{L}/2$ .
- (ii) Find the De Broglie wavelength of a baseball moving with a speed  $v = 10$  m/sec and mass 1 kg.  
(a)  $6.6 \times 10^{-35}$  m      (b)  $6.7 \times 10^{-30}$  m  
(c)  $6.9 \times 10^{-35}$  m      (d)  $6.6 \times 10^{-25}$  m.
- (iii) The concept of matter wave was suggested by  
(a) Laplace      (b) Schrodinger  
(c) De Broglie      (d) Heisenberg.
- (iv) If only one length of a three-dimensional nanostructure is of an nano dimension, the structure is known as a  
(a) Quantum wire      (b) Quantum well  
(c) Wave number      (d) Free particle.
- (v) What is the building block of carbon nanotubes?  
(a) Unit Cell      (b) Graphene  
(c) Tubes      (d) Lattice.
- (vi) The square of the magnitude of the wave function is called  
(a) current density      (b) probability density  
(c) impurity density      (d) volume density.
- (vii) Which one of the following is an example for electrical properties of nanostructure?  
(a) Melting temperature  
(b) Tunnelling current  
(c) Absorption and scattering of light  
(d) None of above.

- (viii) Which of the following is not an advantage of nanowires?  
 (a) High electron mobility  
 (b) Greater dielectric constant  
 (c) Shorter response time  
 (d) Asymmetric electron-hole characteristic.
- (ix) Which of the following is not a requirement for an ideal semiconductor nanostructure?  
 (a) Uniformity (b) Density  
 (c) Low melting point (d) Confinement potential.
- (x) What is the purpose of 1D photonic crystals made of polymers?  
 (a) Act as detectors of volatile organic compounds  
 (b) Act as a far infrared filter  
 (c) Act as sensing device for bacterial contamination  
 (d) Act as low loss surface plasmons for waveguides.

*Fill in the blanks with the correct word*

- (xi) The dimension range of nanorods are from \_\_\_\_\_ nanometers.
- (xii) The melting point of particles in nano form \_\_\_\_\_.
- (xiii) Chiral vector of the graphene layer determines the \_\_\_\_\_ properties of nanotubes.
- (xiv) Carbon atoms make \_\_\_\_\_ type of bond with other carbon atoms.
- (xv) The optical properties of CNT are due to \_\_\_\_\_ of photoluminescence.

### Group - B

2. (a) Derive expression for time independent Schrödinger wave equation. [[CO2](Remember/LOCQ)]  
 (b) If the normalized wave function of a particle in a box  $\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$ .  
 Evaluate expectation value. [[CO2](Apply/HOCQ)]  
**7 + 5 = 12**
3. (a) Find the Eigen value and Eigen function for free particle. [[CO1](Remember/LOCQ)]  
 (b) Find the probability density for the simple harmonic oscillator with lowest energy state wave function  

$$\psi(x, t) = Ae^{-(\sqrt{Gm/2\hbar})x^2} e^{-(i/2)\sqrt{C/mt}}$$
 [[CO1](Analyse/HOCQ)]  
 (c) Explain Heisenberg's uncertainty principle. [[CO1](Remember/LOCQ)]  
**7 + 3 + 2 = 12**

### Group - C

4. (a) Evaluate the transition probability rate for an electron that is excited by a photon from the valence band to the conduction band in a direct band-gap semiconductor using Fermi's golden rule. [[CO3](Apply/HOCQ)]

- (b) Describe Quantum dot Cellular Automata and mention its application. [[CO3](Remember/LOCQ)]  
**6 + 6 = 12**

5. (a) Explain the structure of superlattice and also mention its application. [[CO3](Remember/LOCQ)]  
 (b) Explain resonant tunnelling diode in nano scale domain. [[CO4](Understand/LOCQ)]  
 (c) State Fermi Golden rule. [[CO2](Remember/IOCQ)]  
**5 + 5 + 2 = 12**

### Group - D

6. (a) Describe the piezoresistive properties of carbon nanotube. [[CO4](Remember/LOCQ)]  
 (b) Describe multiple well carbon nano tube with structure. Also mention its applications. [[CO4](Remember/LOCQ)]  
**6 + 6 = 12**
7. (a) Explain ballistic transport mechanism in a metallic carbon nano tubes. [[CO4](Analyse/HOCQ)]  
 (b) Explain working principle of CN-FET. [[CO4](Remember/LOCQ)]  
**6 + 6 = 12**

### Group - E

8. (a) Define PBG and discuss different methods which are used to design precise PBG for photonic crystal. [[CO5](Remember/LOCQ)]  
 (b) Mention and explain briefly the features of photonic crystals. [[CO5](Remember/LOCQ)]  
 (c) Mention some applications of photonic crystal. [[CO5](Remember y/LOCQ)]  
**5 + 5 + 2 = 12**
9. (a) Define plasma frequency and also derive plasma frequency using Drude model. [[CO5](Analyse/IOCQ)]  
 (b) Apply nanomaterials to design a biosensor. [[CO6](Apply/HOCQ)]  
**7 + 5 = 12**

| Cognition Level         | LOCQ  | IOCQ | HOCQ  |
|-------------------------|-------|------|-------|
| Percentage distribution | 64.58 | 9.38 | 26.04 |

#### Course Outcome (CO):

After the completion of the course students will be able to

- Understand the quantum mechanical properties and phenomena for low-dimensional systems
- Apply the concept of band gap engineering, novel electronic transport & optical interaction properties of nanostructures for diverse practical applications
- Understand the fundamentals of nanophotonics, and photonic crystals

4. Identify the application areas of nanophotonics and photonic crystals
5. Understand the basic concepts of plasmonics as a developing field from nanophotonics
6. Identify and analyze the latest research trends & challenges in the real life applications of nanoelectronics and nanophotonics.

*\*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*