Name : ....
Roll No. : ....
Invigilator's Signature : ....

CS/M.Tech (ECE-VLSI)/SEM-2/MVLSI-204A/2013

2013
QUANTUM AND NANO-SCIENCE

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.

GROUP – A
(Objective Type Questions)

1. Fill in the blanks of the following : $10 \times 1 = 10$

   a) A .... is a quantum of vibrational mechanical energy.

   b) In HEMT spacer layer is .... doped.

   c) Inter band transitions in an .... band gap semiconductor involve a photon and a phonon.

   d) Wavelengths of UV rays and *X*-rays are expressed in ....

   e) In SI unit the value of Planck's constant is ....

   f) Quantum island is also known as .... island.

g) In quantum .... electrons will feel the boundaries along *x, y* and *z* directions.

h) In quantum mechanics total energy operator is also known as .... operator.

i) At absolute zero of temperature, the Fermi level represents the .... occupied energy level.

j) For LASER action we need .... emission.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. a) Discuss the wave-particle duality of light.

   b) Explain the uncertainty principle. 3 + 2

3. Find the wave function of a particle trapped in a box of infinite potential well.

4. Explain the formation and the features of a quantum well.

5. Calculate the deBroglie wavelength of an electron of energy 10 keV and compare it with the wavelength of electromagnetic radiation for which the photon has the same energy.

6. What do you mean by strained-Si structure ? Why is strained-Si used in MOSFET ?

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

7. a) Derive the one-dimensional form of time independent Schrödinger wave equation for a free particle of mass m moving along positive x direction. 7

   b) Define position probability density and relate it to the probability current density. 2 + 6

8. a) Discuss FD statistics.

   b) Explain the significance of Fermi energy. 10 + 5

9. a) Explain briefly the Coulomb blockage phenomenon. Discuss the principle of operation of single electron transistors. 5 + 4

   b) Narrate the principle of operation of quantum well laser. 6

10. a) Obtain the kinetic energy operator (k) and momentum operator (p) for a free particle moving along positive x direction. Hence find $[\ x,\ p\ ]$. Do position and momentum operators commute with each other ? 3 + 3 + 2 + 1

    b) What are eigenfunction and eigenvalue equation ? 3

    c) Prove that $[AB, C] = [A, C]\ B + A\ [B, C]$ where A, B, C are three operators. 3

11. a) Explain how mobility enhancement can be done in HEMT. Hence justify the HEMT is known as MODFET. 6 + 2

b) Write the DOS functions for 3D, 2D, 1D systems and sketch their variations with energy. Assume the *E-k* relation to be parabolic. 3 + 3

12. Write short notes on any three of the following : 3×5

a) Quantum Hall effect

b) Quantum wire

c) Super lattice

d) Scattering mechanisms in a semicondoctor.