M.Tech. VLSI Design and Microelectronics Technology, 2024
Second Year First Semester

QUANTUM AND NANOELECTRONIC DEVICES

Time: **3 Hours** Full Marks: **100**

Answer ***any FIVE*** Questions.

Q1.a) Describe features of three different types of band edge line-ups that may occur at a Heterojunction. Also mention one example of each category. 8

b) With adequate band diagram, show that in above cases band gap offset (ΔE_g) is either the sum or the difference of conduction band discontinuity (ΔE_c) and valence band discontinuity (ΔE_v). 6

c) Describe a scheme for the experimental determination of the value of Q (= $\Delta E_c/\Delta E_g$). Use a parabolic quantum well for that. 6

Q2.a) Describe Poisson effect in context with the pseudomorphic growth of an epitaxial layer over an appropriate semiconductor substrate. 8

b) Verify whether pseudomorphic growth of *SiGe* alloy on *Si* substrate is feasible or not. If possible, determine the critical thickness (d_c) of the $Si_{1-x}Ge_x$ layer for x = 0, 0.1, 0.3, 0.5, 0.7, 1; and form the boundary between regions for Pseudomorphic and Metamorphic growths. Take lattice constants for *Si* and *Ge* as 5.43 Å and 5.65 Å respectively. 2+8+2

Q3.a) Formulate the time-independent Schrodinger equation from the general time-dependent Schrodinger equation. 6

b) Elaborate an appropriate scheme for determination of the following: 8+6

(i) Energies of an electron confined in a well with finite barrier,

(ii) Transmission co-efficient of an electron through a double-barrier system.

Consider appropriate structures and make necessary assumptions for each case.

Q4.a) Write (**no derivation**) the general form of DOS function for bulk semiconductor. Next, determine the (i) DOS function and (ii) Carrier 1+7+6

concentration for a long semiconductor wire of rectangular cross-section $d_y d_z$, where both d_y and d_z are comparable to the electron wavelength.
Assume the $E-k$ dispersion relation for the semiconductor to be parabolic.

b) Sketch variations in *DOS functions* with *Energy* for Bulk, QW, QWW and QD **in a single figure**. 6

Q5.a) Discuss a model that helps in determining the ordering of atoms A and B in alloy A_xB_{1-x}. 6

b) Explain how the Heavy hole (HH) and Light hole (LH) bands originate. 6

c) What is Landau quantization and what are the conditions favorable to such quantization? Describe the changes in electron distribution under its influence. 4+4

Q6.a) Explain *Resonant Tunneling*. Describe the *J-V* characteristics of a Resonant tunneling diode (RTD) with appropriate energy band diagrams. 4+8

b) Determine the no. of *NDR* regions expected in an RTD comprising of a 30 *nm* *GaAs* QW sandwiched between $Al_{0.3}Ga_{0.7}As$ barriers. 8
Given that: for *AlAs* $E_g = 2.16\ eV$, for *GaAs* $E_g = 1.42\ eV$ and $m_n^* = 0.067\ m_0$, m_0 being the free electron mass, $Q\ (= \Delta E_c/\Delta E_g) = 0.62$ at above heterojunctions.

Q7. Differentiate: 6+8+6
a) Maxwell – Boltzmann distribution and Fermi – Dirac distribution,
b) Compositionally graded superlattice and *n-i-p-i* superlattice,
c) Acoustic phonon and Optic phonon.

Q8. Write notes on ***any TWO***: 2x10

a) Real Space Transfer of electrons,
b) Quantum Hall Effect,
c) SEED as an optical switch,
d) Single Electron Transistor.