9. (a) Define flat voltage with respect to MOS devices. Consider p-type silicon substrate with aluminium gate at T = 300K doped to $N_a = 10^{14}$ cm^{-3}. Assume $Q'_{ss} = 10^{10}$ cm^{-2}, t_{ox} = 500 Å, Φ_{ms} = -0.83V and the oxide is silicon dioxide. Relative permittivity for Silicon and Silicon-dioxide are 11.7 and 3.9 respectively. Find out the threshold voltage of the MOS system. Draw and explain the CV dependence curve for a MOS capacitor indicating the three different regions.

(b) Plot the variation of the surface charge density of a MOS system as a function of the surface potential.

(2 + 4) + (4 + 2) = 12

B.TECH/ECE/4TH SEM/ECEN 2204/2017

SOLID STATE DEVICES
(ECEN 2204)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Consider two energy levels: E_1(E eV above the Fermi Level) and E_2(E eV below the Fermi Level). P_1 & P_2 are respectively the probabilities of E_1 being occupied by electron and E_2 being empty. Then
(a) $P_1 > P_2$ (b) $P_1 = P_2$
(c) $P_1 < P_2$ (d) none of these.

(ii) Diffusion current in a semiconductor depends on the
(a) applied voltage (b) concentration of carriers
(c) concentration gradient of carriers (d) mobility of carriers.

(iii) The majority carriers in an n-type semiconductor have an average drift velocity v in a direction perpendicular to a uniform magnetic field B. The electric field E induced due to Hall Effect acts in the direction
(a) v × B (b) B × v
(c) along v (d) opposite to v.

(iv) Drift current in semiconductors depends upon
(a) only the electric field
(b) only the carrier concentration gradient
(c) both the electric field and the carrier concentration
(d) both the electric field and the carrier concentration gradient.

(v) A Zener diode works on the principle of
(a) tunnelling of charge carriers across the junction
(b) thermionic emission
(c) diffusion of charge carriers across the junction
(d) hopping of charge carriers across the junction.

(vi) A voltage variable capacitance can be realized in
(a) Tunnel diode (b) Varactor diode
(c) Zener diode (d) Schottky diode.

(vii) Which of the following is not associated with a p-n junction?
(a) Junction capacitance (b) Charge storage capacitance
(c) Depletion capacitance (d) Channel length modulation.

(viii) A bipolar junction transistor (BJT) when used as a switch operates in
(a) active and cut-off region (b) cut-off and saturation region
(c) active and saturation region (d) none of these.

(ix) Inversion layer in a MOS device can be created by
(a) doping (b) impact ionization
(c) tunneling (d) electric field.

(x) In an n-channel MOSFET, the source and drain regions are doped with
(a) n-type impurity
(b) p-type impurity
(c) drain with n-type and source with p-type impurity
(d) drain with p-type and source with n-type impurity.

Group – B

2. (a) Explain the difference between direct and indirect band gap semiconductors with suitable examples. Write down the expression for the density of states in the valence band and conduction band and plot them as a function of energy.

(b) Calculate the thermal equilibrium hole concentration in silicon at T = 400K. Assume that the Fermi energy is 0.27 eV above the valence band energy and N_v at T = 300K is 1.04×10^{19} cm^{-3}.

(c) Explain the effect of doping & temperature on Fermi energy level.

(3 + 3) + 3 + 3 = 12

3. (a) What do you mean by Quasi-Fermi energy levels? Consider an n-type semiconductor at T = 300K with carrier concentrations of $n_0 = 10^{15}$ cm^{-3} and $p_0 = 10^5$ cm^{-3}. In non-equilibrium, assume that the excess carrier concentrations are $\delta n = \delta p = 10^{13}$ cm^{-3}. Calculate the quasi Fermi-energy levels.

(b) Under thermal equilibrium, show that, $n_o p_o = n_i^2$ is equal to a constant.

(c) Explain different carrier scattering effects in low and high temperatures.

(2 + 3) + 4 + 3 = 12

B.TECH/ECE/4TH SEM/ECEN 2204/2017

Group – C

4. (a) Derive the expression of junction capacitance for a normal p-n junction. Modify the expression for one sided junction.

(b) Explain the operating principle of Solar cell and define the efficiency & fill factor of it.

(c) A p^+n junction has a built in potential of 0.8V. The depletion layer width at a reverse bias of 1.2V is 2μm. How much will depletion layer width be for a reverse bias of 7.2V?

(3 + 1) + 5 + 3 = 12

5. (a) Explain the origin of negative resistance region in a tunnel diode. Draw the I-V characteristics of a tunnel diode.

(b) Explain the difference between rectifying contact and ohmic contact in the light of Schottky barrier diode.

(5 + 1) + 6 = 12

Group – D

6. (a) Explain the Ebers-Moll Model for a Bipolar Junction transistor.

(b) Explain the operation of an npn transistor in forward-active mode. Draw the relevant band diagrams of the transistor under zero bias and under a forward-active mode bias.

6 + (3 + 3) = 12

7. (a) Explain the Hybrid Pi model of BJT in CE mode of operation.

(b) Write short notes on: SCR & photo-transistor.

6 + 6 = 12

Group – E

8. (a) Explain the operation of an n-channel depletion type MOSFET in both the depletion and enhancement modes along with V-I characteristics.

(b) Draw the energy band diagrams for two terminal MOS capacitor with p-type substrate separately under positive and negative gate to substrate biasing and define the concept of Threshold voltage using it. Also derive the depletion layer thickness for the same.

5 + (5 + 2) = 12