(b) Distinguish between the transfer characteristics of the depletion and enhancement type MOSFET.

(c) Explain the principle of operation of the CMOS inverter circuit.

4 + 4 + 4 = 12

9. (a) Draw and explain the small signal equivalent model of an n-channel MOSFET and simplify it for low frequency cases.

(b) Derive the expression of metal semiconductor work function difference in MOS structure using proper energy band diagram.

(6 + 2) + 4 = 12

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) Electron effective mass depends on
(a) band gap (b) doping concentration
(c) curvature of band (d) temperature.

(ii) A varactor diode is operated under
(a) zero bias (b) reverse bias
(c) without bias (d) forward bias.

(iii) Solar cell operates in
(a) first quadrant of I – V characteristics
(b) second quadrant of I – V characteristics
(c) third quadrant of I – V characteristics
(d) fourth quadrant of I – V characteristics.

(iv) Piezoelectricity is exhibited by
(a) silicon (b) quartz
(c) germanium (d) GaAs.

(v) Which one of the following devices offers highest input impedance
(a) BJT (b) JFET
(c) photo diode (d) MOSFET.

(vi) The channel length modulation effect of the MOSFET is observed in
(a) linear mode (b) saturation mode
(c) both linear and saturation modes (d) cut – off mode.

(vii) The band-gap of Silicon at room temperature is
(a) 1.3eV (b) 0.7eV (c) 1.1eV (d) 1.4eV.

(viii) Dynamic conductance of a p-n junction diode is directly proportional to
(a) the applied voltage (b) the temperature
(c) the thermal voltage (d) the current.

(ix) Choose proper substitutes for X and Y to make the following statement correct. Tunnel diode and Avalanche photodiode are operated in X-bias and Y-bias respectively.
(a) X: Reverse, Y: Reverse (b) X: Reverse, Y: Forward
(c) X: Forward, Y: Reverse (d) X: Forward, Y: Forward.

(x) The substrate bias effect in MOSFETs results in
(a) increase in the value of transconductance
(b) change in the value of threshold voltage
(c) decrease in the value of transconductance
(d) increase in the value of output resistance.

Group - B

2. (a) Derive the E–K relation for a single free electron in one–dimensional motion and draw the corresponding E–K diagram. Is GaAs suitable for optoelectronic device application ? Explain from E–K diagram.

(b) Derive the expression of the net drift current density in a semiconductor sample.

(3 + 3) + 6 = 12

3. (a) Define the concept of effective mass of electron and show that, the effective mass of electron is positive in conduction band.

(b) Explain the effects of doping and temperature on the Fermi energy level with proper plots.

(c) The electron concentration in a sample of uniformly doped n-type silicon at 300K varies linearly from $10^{17}/cm^3$ at x = 0 to $6\times10^{16}/cm^3$ at x = 2μm. Assume a situation that electrons are supplied to keep this concentration gradient constant with time. If electronic charge is 1.6×10^{-19} Coulomb and the diffusion constant $D_n = 35cm^2/s$, find the current density in the silicon considering no electric field present.

(2 + 2) + 5 + 3 = 12

Group - C

4. (a) Derive the expression of Diode equation for a p–n junction diode.

(b) Boron is implanted into an n–type Si sample ($N_d = 10^{16}\ cm^{-3}$), forming an abrupt junction of square cross section with area = $2\times10^{-3}\ cm^2$. Assume that the acceptor concentration in the p-type region is $N_a = 4\times10^{18}\ cm^{-3}$. Calculate V_0, x_{n0}, x_{p0}, Q_+ and E_0 for this junction at equilibrium (300K). Sketch E(x) and charge density to the scale, where the notations have their usual significance.

6 + 6 = 12

5. (a) Explain the operating principle of Solar cell with V-I characteristic and define the efficiency & fill factor of it.

(b) Derive the expressions of junction & diffusion capacitances of a p-n junction and draw the C-V characteristics.

(c) Explain the operation of a phototransistor and show that it enhances the photo-current.

(3 + 2) + 4 + 3 = 12

Group - D

6. (a) Explain the energy band diagram of an n–p–n transistor at zero bias and forward active mode.

(b) Explain the Ebers–Moll model with proper diagrams showing biasing arrangement, current directions for transistor and equivalent circuit.

(c) A BJT has the following significant parameters at T = 300K. $\alpha_F = 0.98$, $\alpha_R = 0.18$, $I_C = 2$ mA, $I_B = 60$ μA. Calculate the collector–emitter voltage at saturation.

4 + 5 + 3 = 12

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

(b) Describe how a BJT is to be biased for switching operations.

(c) How can you prevent the thermal runaway process in a BJT?

(d) Derive the relation between current gains in CE & CB modes of a BJT.

6 + 2 + 2 + 2 = 12

Group - E

8. (a) Explain the principle of operation of the enhancement type MOSFET.