# 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) Intrinsic carrier concentration of a given semiconductor depends on
(a) bandgap (b) temperature
(c) bandgap & temperature (d) none of these.

(ii) 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.

(iii) 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.

(iv) The channel length modulation effect in MOSFET is observed in
(a) linear mode
(b) saturation mode
(c) cut-off mode
(d) both linear & saturation modes.

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

(vi) Which of the following has a negative resistance region?
(a) Zener diode (b) Tunnel diode
(c) Photodiode (d) LED.





(vii) Ideally the gate current of the MOSFET should be,
(a) greater than the drain current
(b) lesser than the drain current
(c) infinite
(d) zero.

(viii) Reverse saturation current of a p-n junction diode is
(a) diffusion current (b) drift current
(c) displacement current (d) none of these.

(ix) At 0K, the acceptor energy level
(a) is filled with electrons
(b) is empty
(c) accepts electrons from the valence band due to overlapping
(d) excites electrons to the conduction band.

(x) Avalanche breakdown primarily depends on the phenomenon of
(a) impact ionization (b) field ionization
(c) particle collision (d) impurity doping.

## Group – B

2. (a) Derive the expression of intrinsic Fermi energy level in semiconductor under thermal equilibrium.

(b) Explain the concept degeneracy in n-type doped semiconductor with proper energy band diagram.

(c) In a n-type semiconductor at T = 300K, the electron concentration varies linearly from $2 \times 10^{18}$ to $5 \times 10^{17}$ per cc over a distance of 1.5 mm and the diffusion current density is 360 A/cm$^2$. Find the mobility of electrons.

**4 + 4 + 4 = 12**

3. (a) Draw the energy band diagram of n-type and p-type semiconductors at equilibrium and explain the Fermi energy level shift with the help of Fermi – Dirac distribution function.

(b) How would you identify an unknown type of semiconductor sample using Hall effect?

(c) Define density of states and plot it for the bulk semiconductors.

**6 + 4 + 2 = 12**

## Group – C

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

   (b) Describe the basic operation of a solar cell and draw the V-I characteristic.

   (c) Explain the formation of 2D electron gas in a hetero-structure with proper energy band diagram.

**(2 + 2 + 1) + 4 + 3 = 12**

5. (a) Derive the expression for the electric field in the depletion region for a uniformly doped p – n junction. Draw the electric field profile for the same.

   (b) Evaluate the potential barrier across the p – n junction from the above expression.

   (c) Also derive the space charge width at unbiased condition.

**5 + 4 + 3 = 12**

## Group – D

6. (a) Explain the operation of an n-p-n transistor in forward active mode using proper energy band diagram.

   (b) Describe the hybrid-pi model of npn BJT in CE mode and draw the equivalent circuit.

**5 + (5 + 2) = 12**

7. (a) Draw and explain the energy band diagram of the n – p – n transistor at zero bias and forward active mode.

   (b) Draw and explain the current components of an n – p – n transistor.

   (c) Explain the punch – through effect using energy band diagram.

**4 + 5 + 3 = 12**

## Group – E

8. (a) Derive the flat-band voltage expression for a MOS device with p-type substrate.

   (b) Explain the operation of n-channel enhancement type MOSFET and draw the drain characteristics.





   (c) Write down the current equations for the above device for linear and saturation regions.

**5 + 5 + 2 = 12**

9. (a) Draw the energy band diagram of the MOS structure in the thermal equilibrium and find the expression of metal – semiconductor work function difference.

   (b) Any one of the depletion or enhancement type MOSFET is equally suitable for switching application --- Justify this statement.

   (c) Mention the condition for ohmic and saturation region of operation of the enhancement type MOSFET.

   An ideal n – channel MOSFET has the following parameters :
   $L$ = 1.3 μm, $\mu_n$ = 660 cm$^2$/V. sec, $C_{OX}$ = 7 × 10$^{-8}$ F/cm$^2$, $V_T$ = 0.66V. What should be the channel width such that $I_{D(sat)}$ = 5 mA for $V_{GS}$ = 5V ?

**6 + 2 + (2 + 2) = 12**