ELECTRONIC 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) 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.

(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 x B (b) B x v (c) along v (d) opposite to v.

(iv) If for silicon n-p-n transistor, the base to emitter voltage (V_{BE}) is 0.7V and collector to base voltage (V_{CB}) is 0.2V, then the transistor is operating in the
(a) saturation mode (b) forward active mode
(c) cut-off mode (d) reverse active mode.

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

(vi) If V is the voltage applied to the metal with respect to the p-type semiconductor in a MOS capacitor, then V<0 corresponds to
(a) accumulation (b) depletion
(c) inversion (d) strong inversion.

(vii) The dc current gain of BJT is 50. Assuming that the emitter injection efficiency is 0.995, the base transport factor is
(a) 0.980 (b) 0.985 (c) 0.990 (d) 0.995.

(viii) 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.

(ix) Which one of the following provides negative resistance?
(a) Zener diode (b) Tunnel diode
(c) Avalanche diode (d) Capacitor.

(x) If fixed positive charges are present in the gate oxide of an n-channel enhancement type MOSFET, it will lead to
(a) a decrease in the threshold voltage
(b) channel length modulation
(c) an increase in substrate leakage current
(d) an increase in accumulation capacitance.

Group - B

2. (a) Show that the intrinsic Fermi level is not exactly in the middle of the forbidden energy gap. [(CO1)(Analyse/IOCQ)]
(b) Explain the concept degeneracy in n-type semiconductor with proper energy band diagram. [(CO5)(Understand/LOCQ)]
(c) At a given temperature, prove that a semiconductor has a minimum conductivity σ_m given by $\sigma_m = 2\, e\, n_i\, (\mu_n\, \mu_p)^{1/2}$, where the symbols have their usual meanings. [(CO1)(Analyze/IOCQ)]

4 + 4 + 4 = 12

3. (a) Under thermal equilibrium for extrinsic semiconductor, show that, $n_o p_o = n_i^2$; is equal to a constant; where, n_o is the electron concentration, p_o is the hole concentration & n_i is the intrinsic carrier concentration. [(CO1)(Apply/IOCQ)]
(b) A silicon sample A is doped with 10^{18} atoms/cm^3 of Boron. Another sample B of identical dimension is doped with 10^{17} atoms/cm^3 of Phosphorous. The ratio of electron to hole mobility is 3. Find the ratio of conductivity of the sample A to B. [(CO1)(Evaluate/HOCQ)]
(c) How the Hall Effect can be used to identify the n or p type semiconductor? [(CO3)(Evaluate/HOCQ)]

4 + 4 + 4 = 12

Group - C

4. (a) Explain the operating principle of a Tunnel diode along with V-I characteristic and proper energy band diagrams. [(CO5)(Analyze/IOCQ)]
(b) Construct a Schottky contact using n-type Si and a metal and draw the proper energy band diagram. [(CO6)(Create/HOCQ)]

(c) A p^+n junction has a built-in potential of 0.8V. The depletion layer width at a reverse bias of 1.2 V is 2μm. How much will be depletion layer width, for a reverse bias of 7.2 V? [(CO4)(Apply/IOCQ)]

5 + 4 + 3 = 12

5. (a) If acceptor, donor & intrinsic carrier concentrations are given by N_a, N_d & n_i respectively, then show that, the built-in potential of an unbiased p-n junction can be given by, $V_{bi} = V_T \ln(N_a N_d / n_i^2)$; where V_T is thermal voltage. [(CO1)(Apply/IOCQ)]

(b) Derive the p-n junction current expression and draw the V-I characteristic. [(CO2)(Remember/LOCQ)]

(c) Distinguish between zener & avalanche breakdown mechanisms. [(CO1)(Analyze/IOCQ)]

5 + 5 + 2 = 12

Group - D

6. (a) Explain base-width modulation and punch through in BJT with proper diagrams. How can you prevent the thermal runaway process in a BJT? [(CO4)(Remember/LOCQ)]

(b) Describe how a BJT is to be biased for switching operations. [(CO4)(Create/HOCQ)]

(c) Refer to the Fig.:1. At saturation V_{BE} = 0.85 V and V_{CE} = 0.22 V. If β of the transistor is 110 then find the operating region of the BJT. [(CO1)(Evaluate/HOCQ)]

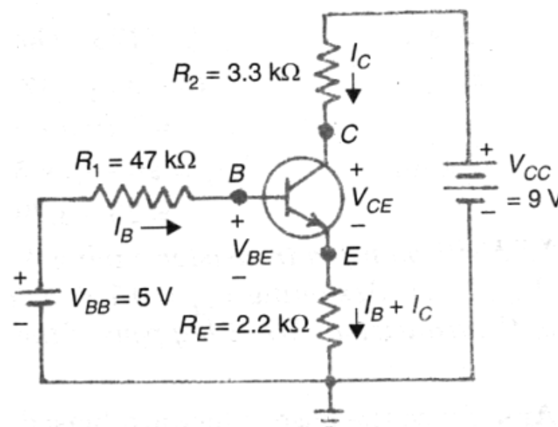

Fig.:1

(4 + 2) + 2 + 4 = 12

7. (a) Describe all the current components in a pnp BJT with proper diagram. [(CO4)(Understand/LOCQ)]

(b) Describe how a BJT is to be biased for switching operations. [(CO1)(Apply/IOCQ)]

(c) How does the Early Effect change the output characteristics of CE mode npn BJT? [(CO4)(Understand/LOCQ)]

5 + 3 + 4 = 12

Group - E

8. (a) Explain the formation of inversion layer in a MOS structure with p-type substrate using proper energy band diagrams. [(CO6)(Analyse/IOCQ)]
   (b) Define flat band voltage for a MOS capacitor. [(CO6)(Remember/LOCQ)]
   (c) Establish the expression of threshold voltage for MOS device and show that, it depends on flat band voltage. [(CO5)(Create/HOCQ)]

4 + 3 + 5 = 12

9. (a) Write V-I relations of n-channel MOSFET under linear and saturation modes and plot the corresponding characteristics considering ideal conditions. [(CO4)(Remember/LOCQ)]
   (b) How can channel length modulation affect the V-I relation of MOSFET? [(CO4)(Analyze/IOCQ)]
   (c) Consider an ideal n-channel MOSFET with channel length L=1.25 μm, mobility of electron μ_n = 650 cm^2/V-s, oxide capacitance per unit area $C_{ox} = 6.9 \times 10^{-8}$ F/cm^2 and threshold voltage V_T = 0.65 V. Design the channel width W such that saturation drain current I_D will be 4mA for applied gate to source voltage V_{GS} of 5 V. [(CO4)(Evaluate/HOCQ)]

4 + (2 + 2) + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	32.29	39.58	28.13

Course Outcome (CO):

After the completion of the course students will be able to

1. Apply the previous knowledge of basic electronics engineering to appreciate the contents of this paper. 2. Understand both the particle and wave natures of electrons in Solid State Devices.
3. Identify unknown extrinsic semiconductor type using Hall Effect.
4. Describe working principles of different devices using mathematical models and energy band diagrams.
5. Justify different operations of solid state devices using relative position of Fermi energy levels across p-n junctions in devices.
6. Evaluate performance of different hetero junctions in semiconductor devices.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question