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) At threshold inversion point of the MOSFET
- (a) The electron concentration at the surface is same as the hole concentration in the bulk material
- (b) The electron concentration at the surface is greater than the hole concentration in the bulk material
- (c) The electron concentration at the surface is lesser than the hole concentration in the bulk material
- (d) The electron concentration at the surface is equal to the oxide charge.

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

(iii) If I_{nE} is the current due to the electrons crossing from emitter into the base and I_{pB} is the current due to holes crossing from the base into the emitter, then heavy doping w.r.t. base ensures
- (a) I_{nE} / I_{pB} high
- (b) I_{nE} / I_{pB} low
- (c) $I_{nE} / I_{pB} = 0$
- (d) $I_{nE} / I_{pB} = 1$

(iv) At high electric field, the carrier drift velocity
- (a) increases linearly with electric field
- (b) increases exponentially with electric field
- (c) decreases linearly with electric field
- (d) saturates.

(v) 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.

(vi) Einstein relation is given by
(a) $D_n / \mu_n = q / kT$ (b) $D_n / \mu_n = k / qT$
(c) $D_n / \mu_n = kT / q$ (d) $\mu_n / D_n = kT / q$

(vii) *p-i-n* photodiode is operated under
(a) forward bias in presence of optical illumination
(b) forward bias
(c) reverse bias in presence of optical illumination
(d) reverse bias.

(viii) The scale current (I_S) of the BJT is
(a) Directly proportional to base width and inversely proportional to the area of the *EBJ*
(b) Inversely proportional to base width and area of the *EBJ*
(c) Directly proportional to base width and area of the *EBJ*
(d) Inversely proportional to base width and directly proportional to the area of the *EBJ*

(ix) MOSFET being symmetric device
(a) source/drain terminals are interchangeable
(b) source/drain terminals are interchangeable when $V_{SB} = 0$
(c) source/drain terminals are interchangeable for linear region of operation
(d) source/drain terminals are interchangeable for saturation region of operation.

(x) The channel length modulation effect of the MOSFET is observed in
(a) Linear mode (b) Saturation mode
(c) Cut – off mode (d) Both linear and saturation modes.

Group – B

2. (a) How would you identify an unknown semiconductor sample using Hall effect?

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

(c) In an intrinsic semiconductor (band gap = $1.1eV$), $4000 EHP/cm^3$ are created under an applied electric field. The valence band contribution to the current density is about $14.14\times10^{-10}\ A/m^2$. Assuming that all the holes are moving in the same direction, calculate the drift velocity of one of the group of holes (out of four groups, each with 1000holes), if the values for the remaining three groups are $3\times10^5\ m/s$, $5\times10^6\ m/s$, and $6\times10^6\ m/s$.

5 + 4 + 3 = 12

3. (a) Briefly discuss the effect of doping and temperature on the shift of Fermi level.

(b) Explain the concept of effective mass.

(c) A *Si* wafer is doped with 10^{16} *P atoms / cm*^{3}. Calculate the equilibrium hole concentration P_0 at 300K. How is E_F located relative to E_i ? Sketch the resulting band diagram. Take $n_i = 1.5\times10^{10}\ cm^{-3}$ and $k = 1.38\times10^{-23}\ J / Kelvin$.

4 + 4 + 4 = 12

Group – C

4. (a) Explain the principle of operation of Tunnel diode with proper energy band diagram and draw its I – V characteristics.

(b) Metal – semiconductor junctions can be ohmic in nature — explain with proper energy band diagram.

(c) A p – n junction has doping densities $N_a = 5\times10^{18}\ cm^{-3}$ and $N_d = 5\times10^{15}\ cm^{-3}$ in the two regions. Assuming $n_i = 1.5\times10^{10}\ cm^{-3}$, calculate the built – in potential at 300K.

5 + 5 + 2 = 12

5. (a) Briefly explain the principle of operation of a reverse biased *p-n* junction diode with proper energy band diagram.

(b) Derive the expression of space charge width of a *p-n* junction at unbiased condition.
A silicon *p-n* junction has doping concentrations of $N_a = 5\times10^{18}\ cm^{-3}$ and $N_d = 5\times10^{15}\ cm^{-3}$. Determine the space charge region width of the junction at $T = 300K$ and at $V_R = 4V$. Assume $\varepsilon_s = 11.7$, $V_{bi} = 0.838V$ and $n_i = 1.5\times10^{10}\ cm^{-3}$.

(c) Under the application of a bias, in a typical *p-n* junction structure, the hole current contribution is around *40%* of the total current. As a designer, what will you do to increase this hole current contribution to *80%*? Keeping in mind the Diode equation, suggest two possible approaches.

3 + (5 + 2) + 2 = 12

Group – D

6. (a) Explain the input and output characteristics of a BJT in CE mode with proper diagrams.

(b) Draw and explain the energy band diagram of the *n-p-n* transistor at zero bias and forward active mode.

(c) Determine the base, collector and emitter currents and V_{CE} for a CE circuit shown in *Fig. 1*. Consider $V_{BE(on)} = 0.7V$ and $\beta = 200$.

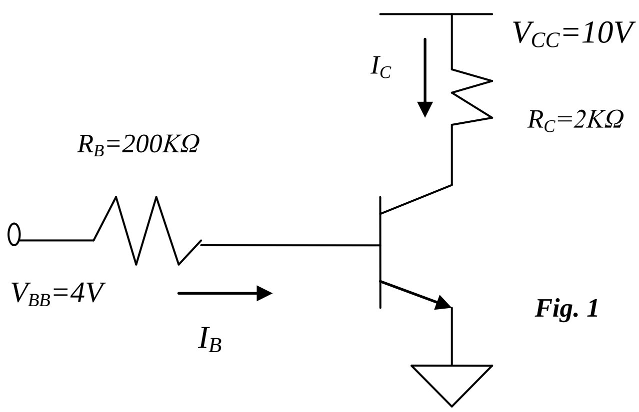

Fig. 1

5 + 4 + 3 = 12

7. (a) Explain the minority carrier concentration profile in the base and emitter of an *n – p – n* transistor operative in the active mode.

(b) Draw the large signal equivalent circuit models for the common – base and common – emitter configuration of the npn BJT operating in the forward active mode.

(c) Explain Early effect in BJT.

5 + 4 + 3 = 12

Group – E

8. (a) Explain the operation of two – terminal MOS structure as capacitor mentioning the type of the substrate chosen and energy band diagrams corresponding to the positive and negative gate bias.

(b) Consider an MOS structure with a *p* – type substrate doped to $N_a = 10^{16}\ cm^{-3}$, a Silicon Dioxide insulator with a thickness of $t_{OX} = 500\ A^0$ and relative permittivity $\varepsilon_r = 3.9$ and an n+ polysilicon gate. Assume that $Q_{SS}' = 10^{11}$ *electronic charges per* cm^2 and $\varphi_{mS} = -\ 1.1\ V$. Calculate the flat – band voltage for this MOS capacitor.

8 + 4 = 12

9. (a) Draw and explain the C-V characteristics of a MOS capacitor for both low and high frequency operation.

(b) Mention the condition for operation of a MOSFET in linear and saturation region and also write down the relevant current equations.

(c) For the *N-channel* MOSFET shown in *Fig.2*, $V_{TN} = -2V$ and $K_N = 0.1mA/V^2$. Assume that $V_{DD} = 5V$ and $R_S = 5K\Omega$. Determine I_D and V_{DS}.

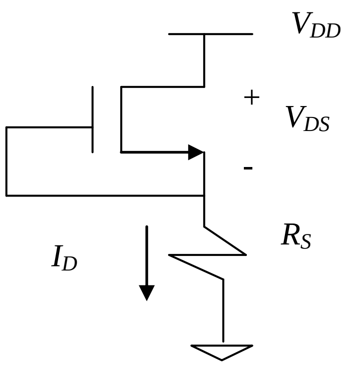

Fig.2

6 + 3 + 3 = 12

Department & Section	Submission Link
ECE Sec A	https://classroom.google.com/u/3/w/MzExOTA1MzM5NjYy/tc/Mzc0Mjg3MDQyMjEy
ECE Sec B	https://classroom.google.com/w/MzExOTIzMDExODk0/tc/Mzc0MjgxMjA3MDc0
ECE Sec C	https://classroom.google.com/w/MzEyODkyNTYyMjEy/tc/MzcxNjg1MjQ2Nzk3
BACKLOG	https://classroom.google.com/w/Mzc0Mjg3OTY5MDU5/tc/Mzc0MjgxMjA3MzE3