



- KEEPING MOBILE PHONE/ANY ELECTRONIC GADGETS, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MALPRACTICE
- DON'T WRITE ANYTHING ON THE QUESTION PAPER

Answer ALL Questions

(10 X 10 = 100 Marks)

1. Differentiate between direct and indirect semiconductors with the help of examples. Show (E-k) diagrams for them (schematic).
2. a) Calculate the probability that a quantum state in the conduction band at $E = E_c + kT$ is occupied by an electron.
b) Calculate the thermal equilibrium electron concentration in silicon.
c) What is the type of material? Draw a neat band diagram.
(Assume Fermi Energy is 0.3 eV below conduction band, $N_c = 3 \times 10^{19} \text{ cm}^{-3}$ and $T = 300 \text{ K}$ for all the above).
3. Write down the difference between Zener and Avalanche breakdown. Support your answer with suitable diagrams and mathematical expressions if required.
4. Consider a silicon-based PN junction in thermal equilibrium at $T = 300 \text{ K}$. It is doped such that in the n-region the energy difference between the intrinsic fermi energy level and the fermi energy level is 0.390 eV and in the p-region it becomes 0.360 eV.
i) Find the impurity doping concentration in each region.
ii) Determine the built-in potential, ϕ_{bi} and Depletion Region Width, W_{dep} .
Assume $n_i = 1.07 \times 10^{10} \text{ cm}^{-3}$.
- 5.(a) What are solar cells? Analyze how carriers are generated in the solar cells. Also, obtain an expression for current and open circuit voltage.

OR

- 5.(b) What are stimulated emission and population inversion? Explain its application.
6. Describe the construction and operation of High Electron-Mobility Transistor (HEMT).

7.

A p-n-p transistor has the following current components:

$I_{Ep} = 2 \text{ mA}$, $I_{En} = 0.01 \text{ mA}$, $I_{cp} = 1.98 \text{ mA}$, and $I_{cn} = 0.001 \text{ mA}$. Determine:

- Base transport factor
- Emitter injection efficiency, γ
- Common base current gain, α
- Common emitter current gain, β
- Base current, I_B

8.(a) Explain various short-channel effects:

- Gate-induced drain leakage
- Drain Induced Barrier Lowering
- Hot carrier degradation

OR

8.(b)

Discuss the effects of Constant Field Scaling and Constant Voltage Scaling on MOS Device Performance.

9.

For an n-channel MOSFET with a gate oxide thickness of 10 nm , $V_T = 0.6 \text{ V}$, and $W = 25 \text{ } \mu\text{m}$, $L = 1 \text{ } \mu\text{m}$. Calculate the drain current at $V_G = 5 \text{ V}$ and $V_D = 0.1 \text{ V}$. Repeat for $V_G = 3 \text{ V}$ and $V_D = 5 \text{ V}$. Discuss what happens for $V_D = 7 \text{ V}$. Assume an electron channel mobility $= 200 \text{ cm}^2/\text{Vs}$.

10.

A p-MOS structure to be made on $N_D = 1 \times 10^{15} \text{ cm}^{-3}$ silicon material. The gate is made of aluminium with ϕ_m as 4.1 eV and the gate oxide is 100 nm thick.

- What is the value of ϕ_{ms} for this structure?
- Calculate the oxide capacitance per unit area, C_{ox}
- Calculate the capacitance per unit area at the onset of strong inversion, C_{min} .

Given that the material is silicon with $n_i = 1.07 \times 10^{10} \text{ cm}^{-3}$, $N_c = 2.84 \times 10^9 \text{ cm}^{-3}$, $N_v = 3.08 \times 10^{19} \text{ cm}^{-3}$, $\chi_{Si} = 4.05 \text{ V}$, and $E_{g,Si} = 1.125 \text{ eV}$, $T = 300 \text{ K}$, $V_T = 25.852 \text{ mV}$, $\epsilon_{ox} = 3.9$, $\epsilon_{Si} = 11.7$.

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