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B. Tech
BSCP 2202

Fourth Semester Examination – 2008

PHYSICS OF SEMICONDUCTOR DEVICES

Full Marks – 70

Time : 3 Hours

Answer Question No. 1 which is compulsory
and any **five** from the rest.

The figures in the right-hand margin
indicate marks.

Assume any data if not given in the question.
You may use the physical constants given
anywhere in the question paper.

1. Answer the following questions : 2×10
- (a) Calculate the electron and hole concentration in a semiconductor in thermal equilibrium if intrinsic carrier concentration is $1.5 \times 10^{10} \text{ cm}^{-3}$ and holes are 36×10^4 times than the electrons per cm^3 .



- (b) “Conduction in a p-type semiconductor is due to holes in the conduction band.” State whether the statement is true or false. Justify your answer.
- (c) What is Einstein relation ? Write down the expression and define the terms.
- (d) Explain the process of excess carrier generation and recombination.
- (e) Draw the energy band diagram of a reverse biased p-n junction.
- (f) Differentiate between Zener breakdown and Avalanche breakdown.
- (g) If two p-n junction diodes are connected, such that both p sides are together, will the combined circuit behave as a transistor ? Give reasons for your answer.
- (h) Define Flat-Band voltage in a MOS.
- (i) Draw a CMOS inverter circuit.
- (j) If β of a transistor is 50, calculate α and γ .

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Contd.

2. (a) Derive the expression to determine the position of the Fermi energy level as a function of the doping concentration and temperature. 5

(b) A semiconductor material made of silicon has an acceptor impurity concentration of $N_a = 10^{16}$ per cm^3 . Calculate the concentration of donor impurity atoms that must be added so that the semiconductor is n-type and the Fermi energy is 0.13 eV below the conduction band edge.

Assume $kT = 0.26$ eV. 5

3. (a) What is drift current? Derive the expression for drift current density. 1+4

(b) A semiconductor sample of Ga As at 300°K has doping concentration $N_a = 0$ and $N_D = 10^{16}$ per cm^3 . If the electron and hole mobilities are 8500 and 400 Cm^2 per

volt.sec respectively, calculate the drift current density under complete ionisation.

5

4. (a) Why is the general ambipolar transport equation nonlinear? 4

(b) A semiconductor has the following:

$$n_o = 10^{15} \text{ cm}^{-3}$$

$$n_i = 10^{10} \text{ cm}^{-3}$$

Excess carrier lifetime is 10^{-6} s.

Determine the electron-hole recombination rate if the excess-hole concentration is $5 \times 10^{13} \text{ cm}^{-3}$. 6

5. (a) Calculate the built-in potential barrier in a p-n junction given that 3

Semiconductor = Silicon

Temperature = 27°C

$$N_a = 1.5 \times 10^{18} \text{ cm}^{-3}$$

$$N_d = 1 \times 10^{15} \text{ cm}^{-3}$$

Thermal voltage = 0.26 eV

$$n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$$

(b) Show that the total space charge width increases as a reverse bias voltage is applied. 5

(c) Determine the total width for Q5(a) if relative permittivity of the semiconductor is 11.7 and voltage applied is 5V. Assume permittivity in free space to be 8.85×10^{-14} F/cm. 2

6. (a) Calculate the ideal reverse saturation current density in a silicon p-n junction of 300°K temperature, where, 3

$$N_a = N_d = 10^{16} \text{ cm}^{-3}$$

$$n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$$

$$D_n = 25 \text{ cm}^2/\text{s}$$

$$D_p = 10 \text{ cm}^2/\text{s}$$

$$\tau_{po} = \tau_{no} = 5 \times 10^{-7} \text{ s}$$

$$\epsilon_r = 11.7$$

(b) Describe with illustrations how amplification takes place in a bipolar junction transistor. 5

(c) Draw the bipolar transistor common-emitter V-I characteristics. Indicate saturation, cut off an active region. Mention significance of load line. 2

7. (a) Is MOS a voltage controlled or current controlled device? Give reasons. 3

(b) Draw the energy band diagrams of MOS capacity with p-type substrate when a negative gate bias and a moderate positive gate bias is applied. Repeat for n-type substrate when positive gate bias and a moderate negative gate bias is applied. 5

(c) Calculate the oxide capacitance for MOS where thickness $t_{ox} = 500 \text{ \AA}$ and relative permittivity is 3.9. 2

8. Write short notes on : 2.5 × 4

(a) CMOS technology

(b) Hybrid – pi Model

(c) Frequency limitations in MOS

(d) Diffusion current.
