Registration No : | | | | | | | | | | |

Total Number of Pages : 03 **M.Sc.I**
FPYC704

7^{th} Semester Regular / Back Examination 2019-20
PHYSICS OF SEMICONDUCTOR DEVICES
BRANCH : M.Sc.I(AP)
Time : 3 Hours
Max Marks : 70
Q.CODE : HRB322
Answer Question No.1 which is compulsory and any five from the rest.
The figures in the right hand margin indicate marks.

Q1 **Answer the following questions :** **(2 x 10)**

a) For a degenerate n-type semiconductor at $E_c = E_F$, what is the donor impurity concentration at 300K? ($N_c = 2.8 \times 10^{19} cm^{-3}$ at 300K)

b) When do the Fermi – Dirac distribution changes to Boltzmann approximation? Write the expression for the same.

c) What are the factors that affect the mobility of the charge carrier in a crystal of semiconductor?

d) Calculate the minority carrier diffusion length for a p-type semiconductor with $D_n = 25 cm^2/V\text{-}s$ and $\tau_{n0} = 10^{-6}$s.

e) Is it necessary that the space charge width of n-side and p-side of the depletion region be same? Justify your answer.

f) Draw the energy band diagram for a p-n junction diode in forward bias condition.

g) In a bipolar transistor biased in the forward active region, the base current is $i_B = 6.0 \mu A$ and the collector current is i_c = 510 μA. Determine amplification factors α and β of the transistor.

h) What is the significance of threshold voltage in MOSFET?

i) With proper energy band diagram define donor level and acceptor level.

j) Draw energy band diagram for a MOS structure with positive gate voltage and n-type substrate.

Q2 **a)** What is meant by Freeze out and complete ionization for an extrinsic semiconductor? Using the concept of charge neutrality derive the expression for equilibrium electron and hole concentration for a compensated semiconductor assuming complete ionization. **(5)**

b) The value of p_0 in Silicon at T = 300 K is 10^{15} cm^{-3}. Determine the position of the Fermi energy level with respect to conduction band and hence calculate n_0. Given that for silicon at 300K, ($N_v = 1.04 \times 10^{19}$ cm^{-3} and E_g = 1.12eV) **(5)**

Q3 **a)** Derive an expression of induced electric field for graded impurity distribution in a semiconductor at thermal equilibrium. Using this expression derive the Einstein relationship relating the diffusion coefficient and mobility. **(5)**

b) The hole concentration in germanium at T = 300 K varies as per the relation $p(x) = 10^6 \exp\left(\frac{-x}{22.5}\right) cm^{-3}$. If the hole diffusion coefficient is D_p = 48 cm^2/s, determine the hole diffusion current density as a function of x. **(5)**

Q4 **a)** Derive continuity equation for electrons and holes present in a semiconductor. Write the Ambipolar transport equation for excess minority charge carriers. **(5)**

b) A semiconductor, in thermal equilibrium, has a hole concentration of $p_0 = 10^{16}$ cm^{-3} and an intrinsic charge concentration of $n_i = 10^{10}$ cm^{-3}. The minority carrier lifetime is 2×10^{-7} s. Determine the thermal equilibrium recombination rate of the electrons and the change in the recombination rate of electrons when excess electron concentration is $\delta n = 5 \times 10^{12}$ cm^{-3} . **(5)**

Q5 **a)** Derive an expression for electrical field in the space charge region for p-n junction at no biasing. How does the electric field vary inside the space charge region? Where do you get maximum electric field and what is its magnitude? **(5)**

b) An abrupt p-n junction at zero bias has dopant concentrations of $N_a = 10^{17}$ cm^{-3}, $N_d = 5 \times 10^{15}$ cm^{-3} and $n_i = 10^{10}$ cm^{-3} at T = 300 K. **(5)**

i) Calculate the Fermi level on each side of the junction with respect to the intrinsic Fermi level. From the result calculate V_{bi}.

ii) Sketch the equilibrium energy band diagram for the junction from the result of part (i) indicating all the parameters.

Q6 **a)** What is excess minority charge carrier in pn-junction diode in forward biasing? Write expressions for excess minority charge carrier in n-region and p-region. Using these relations, derive ideal current – voltage relationship for a p-n junction diode. **(5)**

b) A silicon p-n junction at 300 K has the following parameters: $n_i = 10^{10}$ cm^{-3}, $N_a = 5 \times 10^{16}$ cm^{-3}, $N_d = 1 \times 10^{16}$ cm^{-3}, $D_n = 25$ cm^2/s, $D_p = 25 cm^2/s$, $\tau_{no} = 5 \times 10^{-7}$s, $\tau_{po} = 1 \times 10^{-7}$s, $V_a = 0.625$ Volts. Calculate the: **(5)**

i) Minority electron diffusion current density at the edge of the space charge.

ii) Minority hole diffusion current density at the edge of the space charge.

Q7 Discuss different type of capacitor present in a MOSFET. Plot a graph to represent the variation of MOS capacitance with the applied gate voltage both for low and high frequency. An ideal n-channel MOSFET with following parameters: $L=1.25\mu m$, $\mu_n = 650 cm^2/V\text{-}s$, $C_{ox} = 6.9 \times 10^{-8} F/cm^2$, $V_T = 0.65V$. Calculate the channel width 'W' such that $I_D(sat) = 4mA$ for $V_{GS} = 5V$ **(10)**

Q8 **Write short answer on any TWO :** **(5 x 2)**

a) Working of a bipolar junction transistor using Ebers-Moll model

b) Early effect of a transistor

c) Flat band voltage

d) IV equation of p-n junction