

CHAPTER - 45
SEMICONDUCTOR AND SEMICONDUCTOR DEVICES

1. $f = 1013 \text{ kg/m}^3, V = 1 \text{ m}^3$
 $m = fV = 1013 \times 1 = 1013 \text{ kg}$
 $\text{No. of atoms} = \frac{1013 \times 10^3 \times 6 \times 10^{23}}{23} = 264.26 \times 10^{26}$.
 a) Total no. of states = $2N = 2 \times 264.26 \times 10^{26} = 528.52 = 5.3 \times 10^{28} \times 10^{26}$
 b) Total no. of unoccupied states = 2.65×10^{26} .
2. In a pure semiconductor, the no. of conduction electrons = no. of holes
 Given volume = $1 \text{ cm} \times 1 \text{ cm} \times 1 \text{ mm}$
 $= 1 \times 10^{-2} \times 1 \times 10^{-2} \times 1 \times 10^{-3} = 10^{-7} \text{ m}^3$
 $\text{No. of electrons} = 6 \times 10^{19} \times 10^{-7} = 6 \times 10^{12}$.
 Hence no. of holes = 6×10^{12} .
3. $E = 0.23 \text{ eV}, K = 1.38 \times 10^{-23}$
 $KT = E$
 $\Rightarrow 1.38 \times 10^{-23} \times T = 0.23 \times 1.6 \times 10^{-19}$
 $\Rightarrow T = \frac{0.23 \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23}} = \frac{0.23 \times 1.6 \times 10^4}{1.38} = 0.2676 \times 10^4 = 2670$.
4. Bandgap = $1.1 \text{ eV}, T = 300 \text{ K}$
 a) Ratio = $\frac{1.1}{KT} = \frac{1.1}{8.62 \times 10^{-5} \times 3 \times 10^2} = 42.53 = 43$
 b) $4.253' = \frac{1.1}{8.62 \times 10^{-5} \times T}$ or $T = \frac{1.1 \times 10^5}{4.253 \times 8.62} = 3000.47 \text{ K}$.
5. $2KT = \text{Energy gap between acceptor band and valency band}$
 $\Rightarrow 2 \times 1.38 \times 10^{-23} \times 300$
 $\Rightarrow E = (2 \times 1.38 \times 3) \times 10^{-21} \text{ J} = \frac{6 \times 1.38}{1.6} \times \frac{10^{-21}}{10^{-19}} \text{ eV} = \left(\frac{6 \times 1.38}{1.6} \right) \times 10^{-2} \text{ eV}$
 $= 5.175 \times 10^{-2} \text{ eV} = 51.75 \text{ meV} = 50 \text{ meV}$.
6. Given :
 Band gap = 3.2 eV ,
 $E = hc / \lambda = 1242 / \lambda = 3.2$ or $\lambda = 388.1 \text{ nm}$.
7. $\lambda = 820 \text{ nm}$
 $E = hc / \lambda = 1242 / 820 = 1.5 \text{ eV}$
8. Band Gap = $0.65 \text{ eV}, \lambda = ?$
 $E = hc / \lambda = 1242 / 0.65 = 1910.7 \times 10^{-9} \text{ m} = 1.9 \times 10^{-5} \text{ m}$.
9. Band gap = Energy need to over come the gap
 $\frac{hc}{\lambda} = \frac{1242 \text{ eV} \cdot \text{nm}}{620 \text{ nm}} = 2.0 \text{ eV}$.
10. Given $n = e^{-\Delta E / 2KT}$, $\Delta E = \text{Diamond} \rightarrow 6 \text{ eV}; \Delta E \text{ Si} \rightarrow 1.1 \text{ eV}$
 Now, $n_1 = e^{-\Delta E_1 / 2KT} = e^{\frac{-6}{2 \times 300 \times 8.62 \times 10^{-5}}}$
 $n_2 = e^{-\Delta E_2 / 2KT} = e^{\frac{-1.1}{2 \times 300 \times 8.62 \times 10^{-5}}}$
 $\frac{n_1}{n_2} = \frac{4.14772 \times 10^{-51}}{5.7978 \times 10^{-10}} = 7.15 \times 10^{-42}$.

Due to more ΔE , the conduction electrons per cubic metre in diamond is almost zero.

$$11. \sigma = T^{3/2} e^{-\Delta E / 2KT} \text{ at } 4^\circ\text{K}$$

$$\sigma = 4^{3/2} = e^{\frac{-0.74}{2 \times 8.62 \times 10^{-5} \times 4}} = 8 \times e^{-1073.08}$$

At 300 K,

$$\sigma = 300^{3/2} e^{\frac{-0.67}{2 \times 8.62 \times 10^{-5} \times 300}} = \frac{3 \times 1730}{8} e^{-12.95}$$

$$\text{Ratio} = \frac{8 \times e^{-1073.08}}{[(3 \times 1730) / 8] \times e^{-12.95}} = \frac{64}{3 \times 1730} e^{-1060.13}$$

$$12. \text{ Total no. of charge carriers initially} = 2 \times 7 \times 10^{15} = 14 \times 10^{15} / \text{Cubic meter}$$

$$\text{Finally the total no. of charge carriers} = 14 \times 10^{17} / \text{m}^3$$

We know :

The product of the concentrations of holes and conduction electrons remains, almost the same.

Let x be the no. of holes.

$$\text{So, } (7 \times 10^{15}) \times (7 \times 10^{15}) = x \times (14 \times 10^{17} - x)$$

$$\Rightarrow 14x \times 10^{17} - x^2 = 79 \times 10^{30}$$

$$\Rightarrow x^2 - 14x \times 10^{17} - 49 \times 10^{30} = 0$$

$$x = \frac{14 \times 10^{17} \pm 14^2 \times \sqrt{10^{34} + 4 \times 49 \times 10^{30}}}{2} = 14.00035 \times 10^{17}$$

= Increased in no. of holes or the no. of atoms of Boron added.

$$\Rightarrow 1 \text{ atom of Boron is added per } \frac{5 \times 10^{28}}{1386.035 \times 10^{15}} = 3.607 \times 10^{-3} \times 10^{13} = 3.607 \times 10^{10}$$

$$13. (\text{No. of holes}) (\text{No. of conduction electrons}) = \text{constant}$$

At first :

$$\text{No. of conduction electrons} = 6 \times 10^{19}$$

$$\text{No. of holes} = 6 \times 10^{19}$$

After doping

$$\text{No. of conduction electrons} = 2 \times 10^{23}$$

$$\text{No. of holes} = x$$

$$(6 \times 10^{19}) (6 \times 10^{19}) = (2 \times 10^{23}) x$$

$$\Rightarrow \frac{6 \times 6 \times 10^{19+19}}{2 \times 10^{23}} = x$$

$$\Rightarrow x = 18 \times 10^{15} = 1.8 \times 10^{16}$$

$$14. \sigma = \sigma_0 e^{-\Delta E / 2KT}$$

$$\Delta E = 0.650 \text{ eV, } T = 300 \text{ K}$$

$$\text{According to question, } K = 8.62 \times 10^{-5} \text{ eV}$$

$$\sigma_0 e^{-\Delta E / 2KT} = 2 \times \sigma_0 e^{\frac{-\Delta E}{2 \times K \times 300}}$$

$$\Rightarrow e^{\frac{-0.65}{2 \times 8.62 \times 10^{-5} \times T}} = 6.96561 \times 10^{-5}$$

Taking in on both sides,

$$\text{We get, } \frac{-0.65}{2 \times 8.62 \times 10^{-5} \times T'} = -11.874525$$

$$\Rightarrow \frac{1}{T'} = \frac{11.874525 \times 2 \times 8.62 \times 10^{-5}}{0.65}$$

$$\Rightarrow T' = 317.51178 = 318 \text{ K.}$$

15. Given band gap = 1 eV
 Net band gap after doping = $(1 - 10^{-3})\text{eV} = 0.999 \text{ eV}$
 According to the question, $KT_1 = 0.999/50$
 $\Rightarrow T_1 = 231.78 = 231.8$
 For the maximum limit $KT_2 = 2 \times 0.999$
 $\Rightarrow T_2 = \frac{2 \times 1 \times 10^{-3}}{8.62 \times 10^{-5}} = \frac{2}{8.62} \times 10^2 = 23.2$
 Temperature range is (23.2 – 231.8).
16. Depletion region 'd' = 400 nm = $4 \times 10^{-7} \text{ m}$
 Electric field $E = 5 \times 10^5 \text{ V/m}$
 a) Potential barrier $V = E \times d = 0.2 \text{ V}$
 b) Kinetic energy required = Potential barrier $\times e = 0.2 \text{ eV}$ [Where e = Charge of electron]
17. Potential barrier = 0.2 Volt
 a) K.E. = (Potential difference) $\times e = 0.2 \text{ eV}$ (in unbiased condⁿ)
 b) In forward biasing
 $KE + Ve = 0.2e$
 $\Rightarrow KE = 0.2e - 0.1e = 0.1e$
 c) In reverse biasing
 $KE - Ve = 0.2e$
 $\Rightarrow KE = 0.2e + 0.1e = 0.3e$
18. Potential barrier 'd' = 250 meV
 Initial KE of hole = 300 meV
 We know : KE of the hole decreases when the junction is forward biased and increases when reverse biased in the given 'Pn' diode.
 So,
 a) Final KE = $(300 - 250) \text{ meV} = 50 \text{ meV}$
 b) Initial KE = $(300 + 250) \text{ meV} = 550 \text{ meV}$
19. $i_1 = 25 \mu\text{A}$, $V = 200 \text{ mV}$, $i_2 = 75 \mu\text{A}$
 a) When in unbiased condition drift current = diffusion current
 \therefore Diffusion current = $25 \mu\text{A}$
 b) On reverse biasing the diffusion current becomes 'O'.
 c) On forward biasing the actual current be x.
 $x - \text{Drift current} = \text{Forward biasing current}$
 $\Rightarrow x - 25 \mu\text{A} = 75 \mu\text{A}$
 $\Rightarrow x = (75 + 25) \mu\text{A} = 100 \mu\text{A}$
20. Drift current = $20 \mu\text{A} = 20 \times 10^{-6} \text{ A}$.
 Both holes and electrons are moving
 So, no. of electrons = $\frac{20 \times 10^{-6}}{2 \times 1.6 \times 10^{-19}} = 6.25 \times 10^{13}$.
21. a) $e^{aV/KT} = 100$
 $\Rightarrow \frac{V}{8.62 \times 10^{-5} \times 300} = 100$
 $\Rightarrow \frac{V}{8.62 \times 10^{-5} \times 300} = 4.605 \Rightarrow V = 4.605 \times 8.62 \times 3 \times 10^{-3} = 119.08 \times 10^{-3}$
 $R = \frac{V}{I} = \frac{V}{I_0(e^{eV/KT} - 1)} = \frac{119.08 \times 10^{-3}}{10 \times 10^{-6} \times (100 - 1)} = \frac{119.08 \times 10^{-3}}{99 \times 10^{-5}} = 1.2 \times 10^2$
 $V_0 = I_0 R$
 $\Rightarrow 10 \times 10^{-6} \times 1.2 \times 10^2 = 1.2 \times 10^{-3} = 0.0012 \text{ V}$.

c) $0.2 = \frac{KT}{e i_0} e^{-eV/KT}$

$K = 8.62 \times 10^{-5} \text{ eV/K}, T = 300 \text{ K}$

$i_0 = 10 \times 10^{-5} \text{ A}$

Substituting the values in the equation and solving

We get $V = 0.25$

22. a) $i_0 = 20 \times 10^{-6} \text{ A}, T = 300 \text{ K}, V = 300 \text{ mV}$

$i = i_0 e^{\frac{eV}{KT} - 1} = 20 \times 10^{-6} (e^{\frac{100}{8.62}} - 1) = 2.18 \text{ A} = 2 \text{ A}$

b) $4 = 20 \times 10^{-6} (e^{\frac{V}{8.62 \times 10^{-2}} - 1}) \Rightarrow e^{\frac{V \times 10^3}{8.62 \times 3}} - 1 = \frac{4 \times 10^6}{20}$

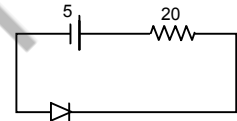
$\Rightarrow e^{\frac{V \times 10^3}{8.62 \times 3}} = 200001 \Rightarrow \frac{V \times 10^3}{8.62 \times 3} = 12.2060$

$\Rightarrow V = 315 \text{ mV} = 318 \text{ mV}$

23. a) Current in the circuit = Drift current

(Since, the diode is reverse biased = $20 \mu\text{A}$)

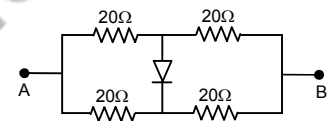
b) Voltage across the diode = $5 - (20 \times 20 \times 10^{-6})$
 $= 5 - (4 \times 10^{-4}) = 5 \text{ V}$



24. From the figure :

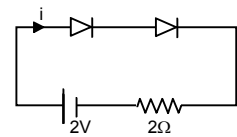
According to wheat stone bridge principle, there is no current through the diode.

Hence net resistance of the circuit is $\frac{40}{2} = 20 \Omega$.



25. a) Since both the diodes are forward biased net resistance = 0

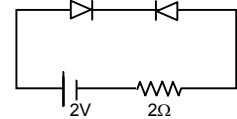
$i = \frac{2V}{2\Omega} = 1 \text{ A}$



b) One of the diodes is forward biased and other is reverse bias.

Thus the resistance of one becomes ∞ .

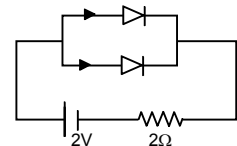
$i = \frac{2}{2 + \infty} = 0 \text{ A}$



Both are forward biased.

Thus the resistance is 0.

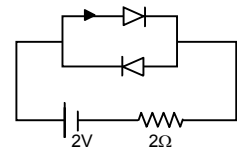
$i = \frac{2}{2} = 1 \text{ A}$



One is forward biased and other is reverse biased.

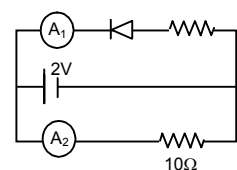
Thus the current passes through the forward biased diode.

$\therefore i = \frac{2}{2} = 1 \text{ A}$



26. The diode is reverse biased. Hence the resistance is infinite. So, current through A_1 is zero.

For A_2 , current = $\frac{2}{10} = 0.2 \text{ Amp}$.



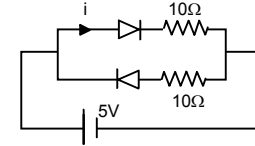
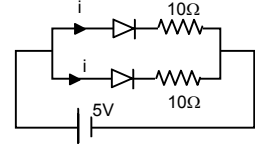
27. Both diodes are forward biased. Thus the net diode resistance is 0.

$$i = \frac{5}{(10+10)/10 \cdot 10} = \frac{5}{5} = 1 \text{ A.}$$

One diode is forward biased and other is reverse biased.

Current passes through the forward biased diode only.

$$i = \frac{V}{R_{\text{net}}} = \frac{5}{10+0} = 1/2 = 0.5 \text{ A.}$$



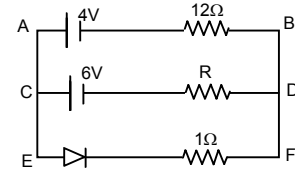
28. a) When $R = 12 \Omega$

The wire EF becomes ineffective due to the net (-)ve voltage.

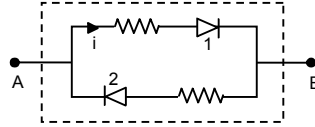
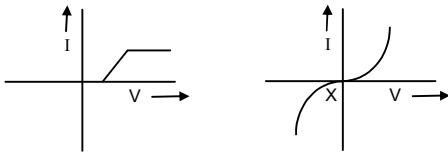
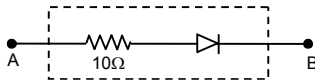
Hence, current through $R = 10/24 = 0.4166 = 0.42 \text{ A.}$

b) Similarly for $R = 48 \Omega$.

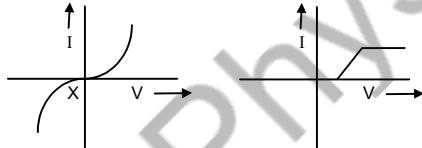
$$i = \frac{10}{(48+12)} = 10/60 = 0.16 \text{ A.}$$



29.



Since the diode 2 is reverse biased no current will pass through it.



30. Let the potentials at A and B be V_A and V_B respectively.

i) If $V_A > V_B$

Then current flows from A to B and the diode is in forward biased.

Eq. Resistance = $10/2 = 5 \Omega$.

ii) If $V_A < V_B$

Then current flows from B to A and the diode is reverse biased.

Hence Eq. Resistance = 10Ω .

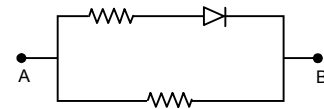
31. $\delta I_b = 80 \mu\text{A} - 30 \mu\text{A} = 50 \mu\text{A} = 50 \times 10^{-6} \text{ A}$

$\delta I_c = 3.5 \text{ mA} - 1 \text{ mA} = -2.5 \text{ mA} = 2.5 \times 10^{-3} \text{ A}$

$$\beta = \left(\frac{\delta I_c}{\delta I_b} \right) V_{ce} = \text{constant}$$

$$\Rightarrow \frac{2.5 \times 10^{-3}}{50 \times 10^{-6}} = \frac{2500}{50} = 50.$$

Current gain = 50.



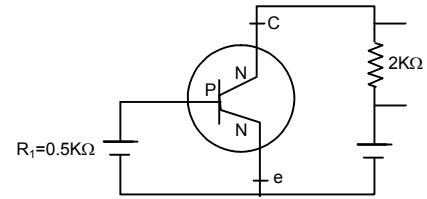
32. $\beta = 50, \delta I_b = 50 \mu\text{A},$

$$V_0 = \beta \times R_G = 50 \times 2/0.5 = 200.$$

a) $V_G = V_0/V_1 = \frac{V_0}{V_i} = \frac{V_0}{\delta I_b \times R_i} = \frac{200}{50 \times 10^{-6} \times 5 \times 10^2} = 8000 \text{ V}.$

b) $\delta V_i = \delta I_b \times R_i = 50 \times 10^{-6} \times 5 \times 10^2 = 0.00025 \text{ V} = 25 \text{ mV}.$

c) Power gain = $\beta^2 \times R_G = \beta^2 \times \frac{R_0}{R_i} = 2500 \times \frac{2}{0.5} = 10^4.$



33. $X = \overline{ABC} + \overline{BCA} + \overline{CAB}$

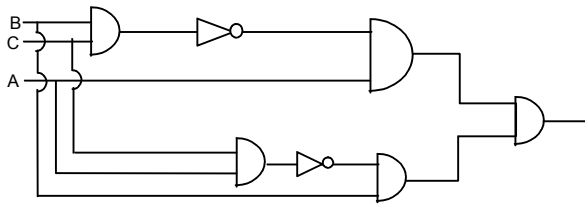
a) $A = 1, B = 0, C = 1$

$$X = 1.$$

b) $A = B = C = 1$

$$X = 0.$$

34. For $\overline{ABC} + \overline{BCA}$



35. LHS = $AB \times \overline{AB} = X + \overline{X}$ [$X = AB$]

If $X = 0, \overline{X} = 1$

If $\overline{X} = 0, X = 1$

$$\Rightarrow 1 + 0 \text{ or } 0 + 1 = 1$$

$$\Rightarrow \text{RHS} = 1 \text{ (Proved)}$$

