CHAPTER - 45
SEMICONDUCTOR AND SEMICONDUCTOR DEVICES

1. $f = 1013\ kg/m^3$, $V = 1\ m^3$

   $m = fV = 1013 \times 1 = 1013\ kg$

   $$\text{No.of atoms} = \frac{1013 \times 10^3 \times 6 \times 10^{23}}{23} = 264.26 \times 10^{26}.$$

   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 $= 2.65 \times 10^{26}$.

2. In a pure semiconductor, the no.of conduction electrons = no.of holes

   Given volume = 1 cm × 1 cm × 1 mm

   $= 1 \times 10^{-2} \times 1 \times 10^{-2} \times 1 \times 10^{-3} = 10^{-7}\ m^3$

   No.of electrons $= 6 \times 10^{19} \times 10^{-7} = 6 \times 10^{12}$.

   Hence no.of holes $= 6 \times 10^{12}$.

3. $E = 0.23\ eV$, $K = 1.38 \times 10^{-23}$

   $KT = E$

   $\Rightarrow 1.38 \times 10^{-23} \times T = 0.23 \times 1.6 \times 10^{-19}$

   $$\Rightarrow T = \frac{0.23 \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23}} = \frac{0.23 \times 1.6 \times 10^4}{1.38} = 0.2676 \times 10^4 = 2670.$$

4. Bandgap = 1.1 eV, T = 300 K

   a) $$\text{Ratio} = \frac{1.1}{KT} = \frac{1.1}{8.62 \times 10^{-5} \times 3 \times 10^2} = 42.53 = 43$$

   b) $$4.253' = \frac{1.1}{8.62 \times 10^{-5} \times T} \text{ or } T = \frac{1.1 \times 10^5}{4.253 \times 8.62} = 3000.47\ K.$$

5. $2KT$ = Energy gap between acceptor band and valency band

   $\Rightarrow 2 \times 1.38 \times 10^{-23} \times 300$

   $$\Rightarrow E = (2 \times 1.38 \times 3) \times 10^{-21}\ J = \frac{6 \times 1.38}{1.6} \times \frac{10^{-21}}{10^{-19}} eV = \left(\frac{6 \times 1.38}{1.6}\right) \times 10^{-2} eV$$

   $= 5.175 \times 10^{-2}\ eV = 51.75\ meV = 50\ meV.$

6. Given :

   Band gap = 3.2 eV,

   $E = hc / \lambda = 1242 / \lambda = 3.2$ or $\lambda = 388.1\ nm.$

7. $\lambda = 820\ nm$

   $E = hc / \lambda = 1242/820 = 1.5\ eV$

8. Band Gap = 0.65 eV, λ =?

   $E = hc / \lambda = 1242 / 0.65 = 1910.7 \times 10^{-9}\ m = 1.9 \times 10^{-5}\ m.$

9. Band gap = Energy need to over come the gap

   $$\frac{hc}{\lambda} = \frac{1242 eV - nm}{620 nm} = 2.0\ eV.$$

10. Given $n = e^{-\Delta E / 2KT}$, ΔE = Diamon → 6 eV ; ΔE Si → 1.1 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.

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11. $\sigma = T^{3/2}\ e^{-\Delta E / 2KT}$ at 4°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. Total no.of charge carriers initially = $2 \times 7 \times 10^{15} = 14 \times 10^{15}$/Cubic meter

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

We know :

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

Let x be the no.of holes.

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 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. (No. of holes) (No.of conduction electrons) = constant.

At first :

No. of conduction electrons = 6×10^{19}

No.of holes = 6×10^{19}

After doping

No.of conduction electrons = 2×10^{23}

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

$\Delta E = 0.650$ eV, T = 300 K

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

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

$$\Rightarrow \frac{1}{T'} = \frac{11.574525\times 2\times 8.62\times 10^{-5}}{0.65}$$

$\Rightarrow T' = 317.51178 = 318$ K.

15. Given band gap = 1 eV

Net band gap after doping = $(1 - 10^{-3})$eV = 0.999 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 = 4×10^{-7} m

Electric field E = 5×10^5 V/m

a) Potential barrier V = E × d = 0.2 V

b) Kinetic energy required = Potential barrier × e = 0.2 eV [Where e = Charge of electron]

17. Potential barrier = 0.2 Volt

a) K.E. = (Potential difference) × e = 0.2 eV (in unbiased cond^n)

b) In forward biasing

KE + Ve = 0.2e

$\Rightarrow$ KE = 0.2e – 0.1e = 0.1e.

c) In reverse biasing

KE – Ve = 0.2 e

$\Rightarrow$ 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 blased in the given 'Pn' diode.

So,

a) Final KE = (300 – 250) meV = 50 meV

b) Initial KE = (300 + 250) meV = 550 meV

19. i_1 = 25 μA, V = 200 mV, i_2 = 75 μA

a) When in unbiased condition drift current = diffusion current

$\therefore$ Diffusion current = 25 μA.

b) On reverse biasing the diffusion current becomes 'O'.

c) On forward biasing the actual current be x.

x – Drift current = Forward biasing current

$\Rightarrow$ x – 25 μA = 75 μA

$\Rightarrow$ x = (75 + 25) μA = 100 μA.

20. Drift current = 20 μA = 20×10^{-6} 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) $e^{aV/KT} = 100$

$\Rightarrow e^{\frac{V}{8.62 \times 10^{-5} \times 300}} = 100$

$\Rightarrow \frac{V}{8.62 \times 10^{-5} \times 300} = 4.605 \Rightarrow V = 4.605 \times 8.62 \times 3 \times 10^{-3} = 119.08 \times 10^{-3}$

$R = \frac{V}{I} = \frac{V}{I_0(e^{ev/KT}-1)} = \frac{119.08 \times 10^{-3}}{10 \times 10^{-6} \times (100-1)} = \frac{119.08 \times 10^{-3}}{99 \times 10^{-5}} = 1.2 \times 10^2$.

$V_0 = I_0 R$

$\Rightarrow 10 \times 10^{-6} \times 1.2 \times 10^2 = 1.2 \times 10^{-3} = 0.0012$ V.

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c) $0.2 = \frac{KT}{ei_0} e^{-eV/KT}$

K = 8.62×10^{-5} eV/K, T = 300 K

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

Substituting the values in the equation and solving

We get V = 0.25

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

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

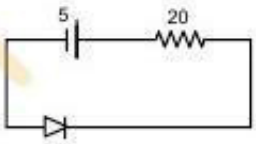
b) $4 = 20 \times 10^{-6}(e^{\frac{V}{8.62 \times 3 \times 10^{-2}}} - 1) \Rightarrow e^{\frac{V \times 10^3}{8.62 \times 3}} - 1 = \frac{4 \times 10^6}{20}$

$\frac{V \times 10^3}{8.62 \times 3}$ $\quad$ $\frac{V \times 10^3}{}$

$\Rightarrow e^{8.62\times3} = 200001 \Rightarrow \frac{\quad}{8.62\times3} = 12.2060$

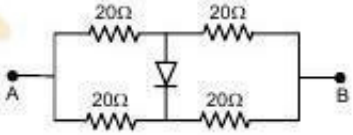
$\Rightarrow V = 315\ mV = 318\ mV.$

23. a) Current in the circuit = Drift current
(Since, the diode is reverse biased = 20 μA)



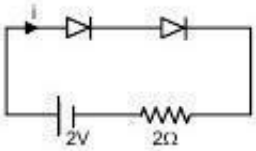
b) Voltage across the diode = $5 - (20 \times 20 \times 10^{-6})$
$= 5 - (4 \times 10^{-4}) = 5\ V.$

24. From the figure :
According to wheat stone bridge principle, there is no current through the diode.



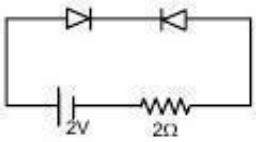
Hence net resistance of the circuit is $\frac{40}{2} = 20\ \Omega.$

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



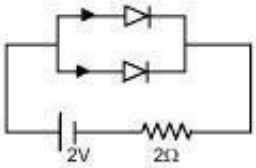
$i = \frac{2V}{2\Omega} = 1\ A$

b) One of the diodes is forward biased and other is reverse biase.
Thus the resistance of one becomes ∞.



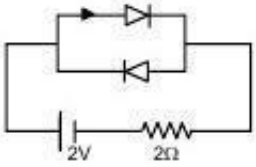
$i = \frac{2}{2+\infty} = 0\ A.$

Both are forward biased.
Thus the resistance is 0.



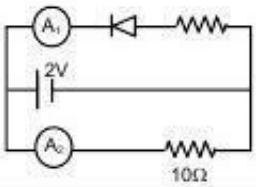
$i = \frac{2}{2} = 1\ A.$

One is forward biased and other is reverse biased.
Thus the current passes through the forward biased diode.



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

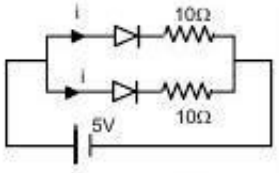
26. The diode is reverse biased. Hence the resistance is infinite. So, current through A_1 is zero.



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

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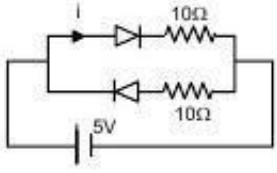
27. Both diodes are forward biased. Thus the net diode resistance is 0.



$i = \frac{5}{(10+10)/10.10} = \frac{5}{5} = 1\ A.$

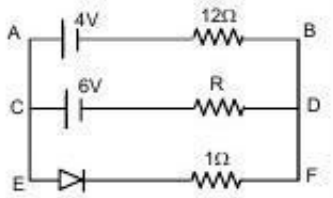
One diode is forward biased and other is reverse biased.

Current passes through the forward biased diode only.



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

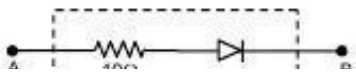
28. a) When R = 12 Ω
The wire EF becomes ineffective due to the net (–)ve voltage.
Hence, current through R = 10/24 = 0.4166 = 0.42 A.

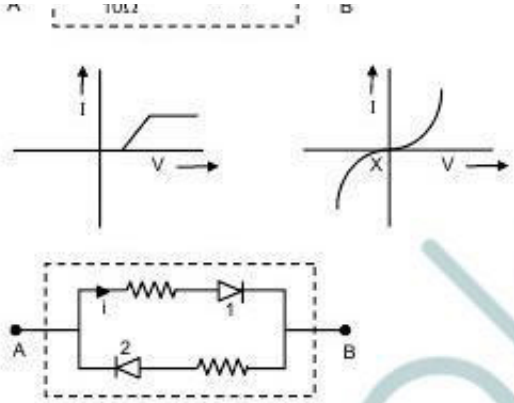


b) Similarly for R = 48 Ω.

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

29.

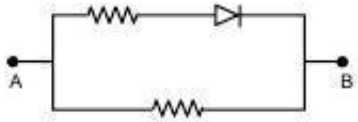




Since the diode 2 is reverse biased no current will pass through it.



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 Ω.

ii) If $V_A < V_B$

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

Hence Eq.Resistance = 10 Ω.

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

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

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

$$\Rightarrow \frac{2.5\times10^{-3}}{50\times10^{-6}} = \frac{2500}{50} = 50.$$

Current gain = 50.

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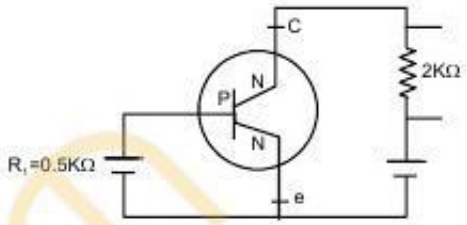
32. $\beta = 50$, $\delta I_b = 50\ \mu A$,

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

a) $VG = V_0/V_i = \dfrac{V_0}{V_i} = \dfrac{V_0}{\delta I_b \times R_i} = \dfrac{200}{50\times10^{-6}\times5\times10^{2}} = 8000$ V.

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

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



33. $X = A\overline{BC} + B\overline{CA} + C\overline{AB}$

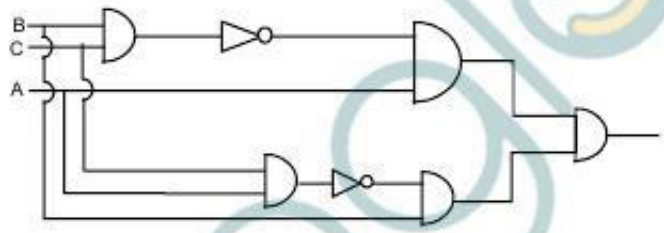
a) A = 1, B = 0, C = 1

X = 1.

b) A = B = C = 1

X = 0.

34. For $A\overline{BC} + B\overline{CA}$



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 or 0 + 1 = 1

$\Rightarrow$ RHS = 1 (Proved)