Vol 2 Chapter 23 – Semiconductor and Semiconductor Devices

1. f = 1013 kg/m^3, V = 1 m^3
   m = fV = 1013 × 1 = 1013 kg
   No.of atoms = $\frac{1013 \times 10^3 \times 6 \times 10^{23}}{23}$ = 264.26 × 10^{26}.
   a) Total no.of states = 2 N = 2 × 264.26 × 10^{26} = 528.52 = 5.3 × 10^{28} × 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 cm × 1 cm × 1 mm
   = 1 × 10^{-2} × 1 × 10^{-2} × 1 × 10^{-3} = 10^{-7} m^3
   No.of electrons = 6 × 10^{19} × 10^{-7} = 6 × 10^{12}.
   Hence no.of holes = 6 × 10^{12}.
3. E = 0.23 eV, K = 1.38 × 10^{-23}
   KT = E
   ⇒ 1.38 × 10^{-23} × T = 0.23 × 1.6 × 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 × 10^4 = 2670.
4. Bandgap = 1.1 eV, T = 300 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 K.
5. 2KT = Energy gap between acceptor band and valency band
   ⇒ 2 × 1.38 × 10^{-23} × 300
   ⇒ E = (2 × 1.38 × 3) × 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 × 10^{-2} eV = 51.75 meV = 50 meV.
6. Given :
   Band gap = 3.2 eV,
   E = hc / λ = 1242 / λ = 3.2 or λ = 388.1 nm.
7. λ = 820 nm
   E = hc / λ = 1242/820 = 1.5 eV
8. Band Gap = 0.65 eV, λ =?
   E = hc / λ = 1242 / 0.65 = 1910.7 × 10^{-9} m = 1.9 × 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 × 10^{-42}.
    Due to more ΔE, the conduction electrons per cubic metre in diamond is almost zero.

11. $\sigma = T^{3/2}\ e^{-\Delta E/2KT}$ 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 = 14×10^{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.

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

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,

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

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

$\Rightarrow T' = 317.51178 = 318$ 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 $E = 5 \times 10^5$ V/m

a) Potential barrier $V = E \times d = 0.2$ 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 biased in the given 'Pn' diode.

So,

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

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

19. $i_1 = 25\ \mu A$, V = 200 mV, $i_2 = 75\ \mu A$

a) When in unbiased condition drift current = diffusion current

∴ 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

$\Rightarrow x - 25\ \mu A = 75\ \mu A$

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

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.

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

$K = 8.62 \times 10^{-5}$ 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

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

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

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

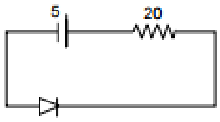
$\Rightarrow$ V = 315 mV = 318 mV.

23. a) Current in the circuit = Drift current

(Since, the diode is reverse biased = 20 μA)

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

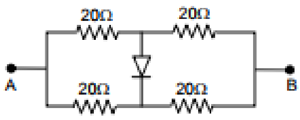
$= 5 - (4 \times 10^{-4}) = 5$ V.



24. From the figure :

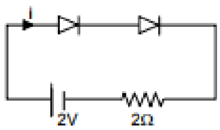
According to wheat stone bridge principle, there is no current through the diode.

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



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

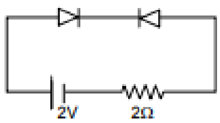
$i = \frac{2V}{2\Omega} = 1$ A



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

Thus the resistance of one becomes ∞.

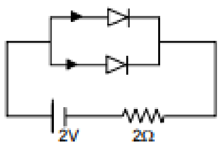
$i = \frac{2}{2+\infty} = 0$ A.



Both are forward biased.

Thus the resistance is 0.

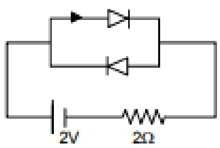
$i = \frac{2}{2} = 1$ A.



One is forward biased and other is reverse biased.

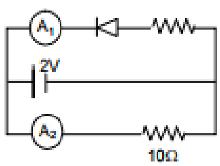
Thus the current passes through the forward biased diode.

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



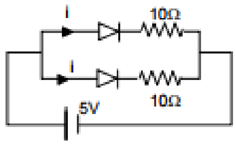
26. The diode is reverse biased. Hence the resistance is infinite. So, current through A_1 is zero.

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

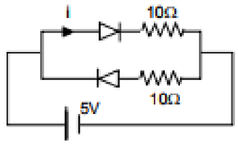


27. Both diodes are forward biased. Thus the net diode resistance is 0.

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



One diode is forward biased and other is reverse biased.



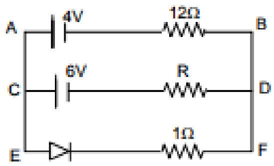
Current passes through the forward biased diode only.

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