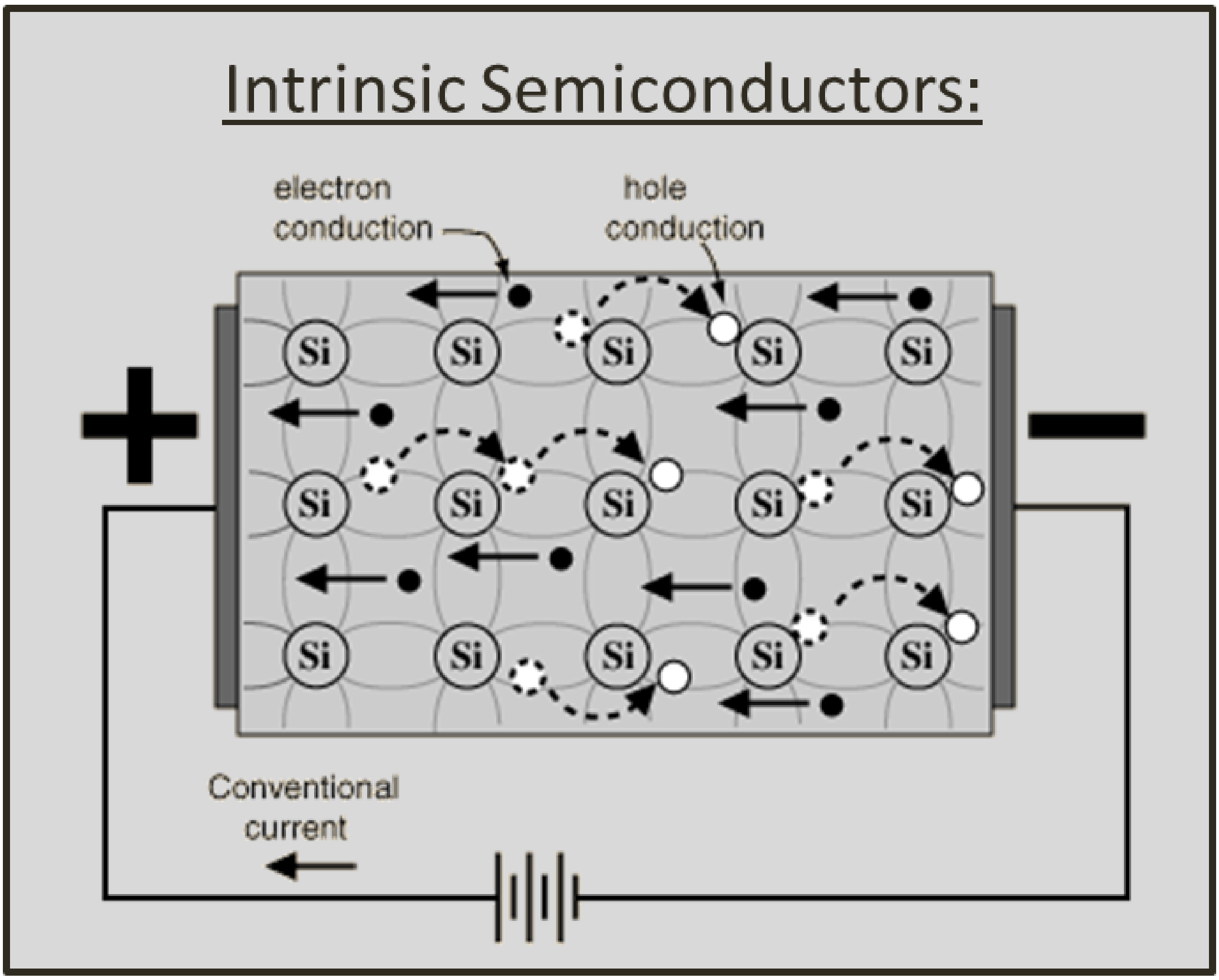
Physics Class 12 NCERT Solutions: Chapter 14 Semiconductor Electronics Materials Devices and Simple Circuits Part 3


Intrinsic Semiconductors:
electron conduction
hole conduction
Si
+
−
Conventional current

Q: 12. The number of silicon atom per m^3 is 5×10^{28} . This is doped simultaneously with 5×10^{22} atoms $perm^3$ of Arsenic and $5 \times 10^{20} perm^3$ atoms of Indium. Calculate the number of electrons and holes. Given that $n_i = 1.5 \times 10^{16} m^{-3}$. Is the material $n - type$ or $p - type$?

Answer:

Number of silicon atoms, $N = 5 \times 10^{28} \text{atoms}/m^3$

Number of arsenic atoms, $n_{\text{As}} = 5 \times 10^{22} \text{atoms}/m^3$

Number of silicon atoms, $n_{In} = 5 \times 10^{20} \text{atoms}/m^3$

Number of thermally-generated electrons, $N_i = 1.5 \times 10^{16} \text{electrons}/m^3$

Number of electrons, $N_e = 5 \times 10^{22} - 1.5 \times 10^{16} \approx 4.99 \times 10^{22}$

Number of holes $= n_h$

In thermal equilibrium, the concentrations of electrons and holes in a semiconductor are related as:

$$n_e n_h = n_i^2$$

$$\therefore n_h = \frac{n_i^2}{n_e}$$

$$\therefore n_h = \frac{\left(1.5 \times 10^{16}\right)^2}{4.99 \times 10^{22}} \approx 4.51 \times 10^9$$

Therefore, the number of electrons is approximately 4.99×10^{22} and the number of holes is about 4.51×10^9 . Since the number of electrons is more than the number of holes, the material is an $n - type$ simiconductor.

Q: 13. In an intrinsic semiconductor the energy gap E_g is $1.2\, eV$. Its whole mobility is much smaller than electron mobility and independent of temperature. What is the ratio between conductivity at $600K$ and that at $300K$? Assume that the temperature dependence of intrinsic carrier concentration n_i is given by $n_i = n_0 \exp\left[-\frac{E_g}{2k_B T}\right]$

Where n_0 is a constant

Answer:

Energy gap of the given intrinsic semiconductor, $E_g = 1.2\, eV$

The temperature dependence of the intrinsic carrier-concentration is written as:

$$n_i = n_0 \exp\left[-\frac{E_g}{2k_B T}\right]$$

Where,

$k_B = \text{Boltzmann costant} = 8.62 \times 10^{-5} eV/K$

$T = \text{Temperature}$

$n_0 = \text{Constant}$

Initial temperature, $T_1 = 300K$

The intrinsic carrier-concentration at this temperature can be written as:

$$n_i = n_0 \exp\left[-\frac{E_g}{2k_B \times 300}\right] \ldots (1)$$

Final temperature, $T_2 = 600K$

The intrinsic carrier-concentration at this temperature can be written as:

$$n_i = n_0 \exp\left[-\frac{E_g}{2k_B \times 600}\right] \ldots (2)$$

The ratio between the conductivities at $600K \text{and at} 300K$ is equal to the ratio between the respective intrinsic carrier-concentrations at these temperatures.

$$\frac{n_{i2}}{n_{i1}} = \frac{n_0 \exp\left[-\frac{E_g}{2k_B \times 600}\right]}{n_0 \exp\left[-\frac{E_g}{2k_B \times 300}\right]}$$

$$= \exp \frac{E_g}{2k_B T}\left[\frac{1}{300} - \frac{1}{600}\right] = \exp\left[\frac{1.2}{2 \times 8.62} \times \frac{2-1}{600}\right]$$

$$= \exp[11.6] = 1.09 \times 10^5$$

Therefore, the ratio between the conductivities is 1.09×10^5 .

Q: 14. In a p-n junction diode, the current I can be expressed as

$$I = I_0 \exp\left(\frac{eV}{2k_B T} - 1\right)$$

Where I_0 is called the reverse saturation current, V is the voltage across the diode and is positive for forward bias and negative for reverse bias, and is the current through the diode, k_B is the Boltzmann constant $(8.6 \times 10^{-5} eV/K)$ and T is the absolute temperature. If for a given diode $I_0 = 5 \times 10^{-12} A \text{and} T = 300K$, then

(A) What will be the forward current at a forward voltage of $0.6V$?

(B) What will be the in the current if the voltage across the diode is increased to $0.7V$?

(C) What is the dynamic resistance?

(D) What will be the current if reverse bias voltage changes from $1V \text{to} 2V$?

Answer:

In a p-n junction diode, the expression for current is given as:

$$I = I_0 \exp\left(\frac{eV}{2k_B T} - 1\right)$$

Where,

$I_0 = \text{Reverse saturation current} = 5 \times 10^{-12} A$

$T = \text{Absolute temperature} = 300K$

$k_B = \text{Boltzmann constant} = 8.6 \times 10^{-5} eV/K = 1.376 \times 10^{-23} JK^{-1}$

V = Voltage across the diode

(A) Forward voltage, $V = 0.6V$

$$\therefore \text{Current, } I = 5 \times 10^{-12} \left[\exp\left(\frac{1.6 \times 10^{-19} \times 0.6}{1.376 \times 10^{-23} \times 300}\right) - 1\right]$$

$$= 5 \times 10^{-12} \times \exp[22.36] = 0.0256A$$

Therefore, the forward current is about $0.0256A$.

(B) For forward voltage, $V' = 0.7V$, we can write:

$$I = 5 \times 10^{-12} \left[\exp\left(\frac{1.6 \times 10^{-19} \times 0.7}{1.376 \times 10^{-23} \times 300} - 1\right)\right]$$

$$= 5 \times 10^{-12} \times \exp[26.25] = 1.257A$$

Hence, the increase in current, $\Delta I = I - I$

$$= 1.257 - 0.0256 = 1.23A$$

(C) Dynamic resistance $= \dfrac{\text{Change in voltage}}{\text{Change in current}}$

$$= \frac{0.7 - 0.6}{1.23} = \frac{0.1}{1.23} = 0.081\Omega$$

(D) If the reverse bias voltage changes from $1V \text{to} 2V$, then the current (I) will almost remain equal to I_o in both cases. Therefore, the dynamic resistance in the reverse bias will be infinite.