Base resistance is given by the relation:

$$R_B = \frac{V_i}{I_B}$$

$$= \frac{0.01}{1000} = 10 \times 10\mu A$$

Therefore, the base current of the amplifier is 10 μA.

Question 14.10:

Two amplifiers are connected one after the other in series (cascaded). The first amplifier has a voltage gain of 10 and the second has a voltage gain of 20. If the input signal is 0.01 volt, calculate the output ac signal.

Answer

Voltage gain of the first amplifier, $V_1 = 10$

Voltage gain of the second amplifier, $V_2 = 20$

Input signal voltage, $V_i = 0.01$ V

Output AC signal voltage = V_o

The total voltage gain of a two-stage cascaded amplifier is given by the product of voltage gains of both the stages, i.e.,

$V = V_1 \times V_2$

$= 10 \times 20 = 200$

We have the relation:

$$V = \frac{V_0}{V_i}$$

$V_0 = V \times V_i$

$= 200 \times 0.01 = 2$ V

Therefore, the output AC signal of the given amplifier is 2 V.

Question 14.11:

A p-n photodiode is fabricated from a semiconductor with band gap of 2.8 eV. Can it detect a wavelength of 6000 nm?

Answer

Energy band gap of the given photodiode, E_g = 2.8 eV

Wavelength, λ = 6000 nm = 6000×10^{-9} m

The energy of a signal is given by the relation:

$$E = \frac{hc}{\lambda}$$

Where,

h = Planck's constant

$= 6.626 \times 10^{-34}$ Js

c = Speed of light

$= 3 \times 10^{8}$ m/s

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{6000 \times 10^{-9}}$$

$= 3.313 \times 10^{-20}$ J

But 1.6×10^{-19} J = 1 eV

$\therefore E = 3.313 \times 10^{-20}$ J

$$= \frac{3.313 \times 10^{-20}}{1.6 \times 10^{-19}} = 0.207 \text{ eV}$$

The energy of a signal of wavelength 6000 nm is 0.207 eV, which is less than 2.8 eV – the energy band gap of a photodiode. Hence, the photodiode cannot detect the signal.

Question 14.12:

The number of silicon atoms per m^3 is 5×10^{28}. This is doped simultaneously with 5×10^{22} atoms per m^3 of Arsenic and 5×10^{20} per m^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, $N = 5 \times 10^{28}$ atoms/m^3

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

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

Number of thermally-generated electrons, $n_i = 1.5 \times 10^{16}$ 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:

$n_e n_h = n_i^2$

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

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

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 semiconductor.

Question 14.13:

In an intrinsic semiconductor the energy gap E_g is 1.2 eV. Its hole 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 = Boltzmann constant = 8.62×10^{-5} eV/K

T = Temperature

n_0 = Constant

Initial temperature, T_1 = 300 K

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

$$n_{i1} = n_0 \exp\left[-\frac{E_g}{2k_B \times 300}\right] \quad \dots (1)$$

Final temperature, T_2 = 600 K

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

$$n_{i2} = n_0 \exp\left[-\frac{E_g}{2k_B \times 600}\right] \quad \dots (2)$$

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

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

$$= \exp\frac{E_g}{2k_B}\left[\frac{1}{300} - \frac{1}{600}\right] = \exp\left[\frac{1.2}{2 \times 8.62 \times 10^{-5}} \times \frac{2-1}{600}\right]$$

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

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

*********** END **********