Exercises

Question 14.1:

In an n-type silicon, which of the following statement is true:

(a) Electrons are majority carriers and trivalent atoms are the dopants.

(b) Electrons are minority carriers and pentavalent atoms are the dopants.

(c) Holes are minority carriers and pentavalent atoms are the dopants.

(d) Holes are majority carriers and trivalent atoms are the dopants.

Answer 14.1:

The correct statement is (c).

In an n-type silicon, the electrons are the majority carriers, while the holes are the minority carriers. An n-type semiconductor is obtained when pentavalent atoms, such as phosphorus, are doped in silicon atoms.

Question 14.2:

Which of the statements given in Exercise 14.1 is true for p-type semiconductors.

Answer 14.2:

The correct statement is (d).

In a p-type semiconductor, the holes are the majority carriers, while the electrons are the minority carriers. A p-type semiconductor is obtained when trivalent atoms, such as aluminium, are doped in silicon atoms.

Question 14.3:

Carbon, silicon and germanium have four valence electrons each. These are characterised by valence and conduction bands separated by energy band gap respectively equal to $(E_g)_C$, $(E_g)_{Si}$ and $(E_g)_{Ge}$. Which of the following statements is true?

(a) $(E_g)_{Si} < (E_g)_{Ge} < (E_g)_C$

(b) $(E_g)_C < (E_g)_{Ge} > (E_g)_{Si}$

(c) $(E_g)_C > (E_g)_{Si} > (E_g)_{Ge}$

(d) $(E_g)_C = (E_g)_{Si} = (E_g)_{Ge}$

Answer 14.3:

The correct statement is (c).

Of the three given elements, the energy band gap of carbon is the maximum and that of germanium is the least.

The energy band gap of these elements are related as: $(E_g)_C > (E_g)_{Si} > (E_g)_{Ge}$.

Question 14.4:

In an unbiased p-n junction, holes diffuse from the p-region to n-region because

(a) free electrons in the n-region attract them.

(b) they move across the junction by the potential difference.

(c) hole concentration in p-region is more as compared to n-region.

(d) All the above.

Answer 14.4:

The correct statement is (c).

The diffusion of charge carriers across a junction takes place from the region of higher concentration to the region of lower concentration. In this case, the p-region has greater concentration of holes than the n-region. Hence, in an unbiased p-n junction, holes diffuse from the p-region to the n-region.

Question 14.5:

When a forward bias is applied to a p-n junction, it

(a) raises the potential barrier.

(b) reduces the majority carrier current to zero.

(c) lowers the potential barrier.

(d) None of the above.

Answer 14.5:

The correct statement is (c).

When a forward bias is applied to a p-n junction, it lowers the value of potential barrier. In the case of a forward bias, the potential barrier opposes the applied voltage. Hence, the potential barrier across the junction gets reduced.

Question 14.6:

For transistor action, which of the following statements are correct:

(a) Base, emitter and collector regions should have similar size and doping concentrations.

(b) The base region must be very thin and lightly doped.

(c) The emitter junction is forward biased and collector junction is reverse biased.

(d) Both the emitter junction as well as the collector junction are forward biased.

Answer 14.6:

The correct statement is (b), (c).

For a transistor action, the junction must be lightly doped so that the base region is very thin. Also, the emitter junction must be forward-biased and collector junction should be reverse-biased.

Question 14.7:

For a transistor amplifier, the voltage gain

(a) remains constant for all frequencies.

(b) is high at high and low frequencies and constant in the middle frequency range.

(c) is low at high and low frequencies and constant at mid frequencies.

(d) None of the above.

Answer 14.7:

The correct statement is (c).

The voltage gain of a transistor amplifier is constant at mid frequency range only. It is low at high and low frequencies.

Question 14.8:

In half-wave rectification, what is the output frequency if the input frequency is 50 Hz. What is the output frequency of a full-wave rectifier for the same input frequency?

Answer 14.8:

Input frequency = 50 Hz

For a half-wave rectifier, the output frequency is equal to the input frequency.

∴ Output frequency = 50 Hz

For a full-wave rectifier, the output frequency is twice the input frequency.

∴ Output frequency = 2 × 50 = 100 Hz

Question 14.9:

For a CE-transistor amplifier, the audio signal voltage across the collected resistance of 2 kΩ is 2 V. Suppose the current amplification factor of the transistor is 100, find the input signal voltage and base current, if the base resistance is 1 kΩ.

Answer 14.9:

Collector resistance, R_C = 2 kΩ = 2000 Ω

Audio signal voltage across the collector resistance, V = 2 V

Current amplification factor of the transistor, β = 100

Base resistance, R_B = 1 kΩ = 1000 Ω

Input signal voltage = V_i

Base current = I_B

We have the amplification relation as: $= \frac{V}{V_1} = \beta \frac{R_C}{R_B}$

Voltage amplification

$$V_i = \frac{V}{\beta} \frac{R_B}{R_C} = \frac{2 \times 1000}{100 \times 2000} = 0.01 \text{ V}$$

Therefore, the input signal voltage of the amplifier is 0.01 V.

Base resistance is given by the relation:

$$R_B = \frac{V_i}{I_B} = \frac{0.01}{1000} = 10 \times 10^{-6} \mu A$$

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 14.10:

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 14.11:

Energy band gap of the given photodiode, $E_g = 2.8$ eV
Wavelength, $\lambda = 6000 \text{ nm} = 6000 \times 10^{-9}$ m
The energy of a signal is given by the relation:

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

Where,
h = Planck's constant = 6.626×10^{-34} Js
c = Speed of light = 3×10^8 m/s

$$E = \frac{6.626\times10^{-34}\times3\times10^8}{6000\times10^{-9}} = 3.313 \times 10^{-20} \text{ J}$$

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.