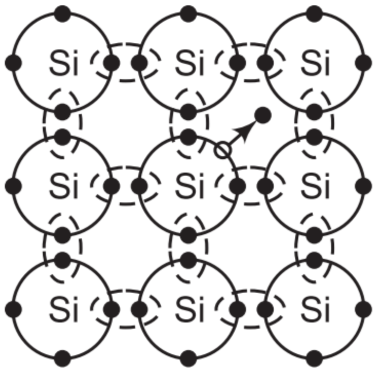
Semiconductor Electronics - Materials, Devices and Simple Circuits

Case Study Based Questions

Case Study 1

Consider a thin p-type silicon (p-Si) semiconductor wafer. By adding precisely a small pentavalent impurity, part of the p-Si wafer can be converted into n-Si. There are several processes by which a semiconductor can be formed. The wafer quantity of now contains p-region and n-region and a metallurgical junction between p and n-regions.



Two important processes occur during the formation of a p-n junction: diffusion and drift. We know that in an n-type semiconductor, the concentration of electrons is more compared to the concentration of holes. Similarly, in a p-type semiconductor, the concentration of holes is more than the concentration of electrons. During the formation of p-n junction and due to the concentration gradient across p and n-sides, holes diffuse from p-side to n-side (p → n) and electrons diffuse from n-side to p-side (n → p). This motion of charge carriers gives rise to diffusion current across the junction.

Read the given passage carefully and give the answer of the following questions:

Q1. How can a p-type semiconductor be converted into n-type semiconductor?

a. By adding pentavalent impurity

b. By adding trivalent impurity

c. By not possible

d. By heavy doping

Q2. Which of the following is true about n-type semiconductor?

a. Concentration of electrons is less than that of holes.

b. Concentration of electrons is more than that of holes.

c. Concentration of electrons is equal to that of holes.

d. None of the above

Q3. Which of the following is true about p-type semiconductor?

a. Concentration of electrons is less than that of holes.

b. Concentration of electrons is more than that of holes.

c. Concentration of electrons is equal to that of holes.

d. None of the above

Q4. Which of the following is the reason about diffusion current?

a. Diffusion of holes from p to n

b. Diffusion of electrons from n to p

c. Both a. and b.

d. None of the above

Solutions

1. (a) By adding pentavalent impurity

2. (b) Concentration of electrons is more than that of holes.

3. (a) Concentration of electrons is less than that of holes.

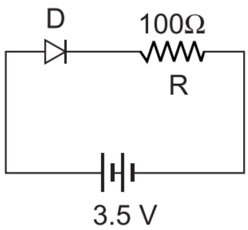
4. (c) Both a. and b.

Case Study 2

A semiconductor diode is basically a pn-junction with metallic contacts provided at the ends for the application of an external voltage. It is a two terminal device. When an external voltage is applied across a semiconductor diode such that p-side is connected to the positive terminal of the battery and n-side to the negative terminal, it is said to be forward biased. When an external voltage is applied across the diode such that n-side is positive and p-side is negative, it is said to be reverse biased. An ideal diode is one whose resistance in forward biasing is zero and the resistance is infinite in reverse biasing. When the diode is forward biased, it is found that beyond forward voltage called knee voltage, the conductivity is very high. When the biasing voltage is more than the knee voltage, the potential barrier is overcome and the current increases rapidly with increase in forward voltage. When the diode is reverse biased, the reverse bias voltage produces a very small current about a few microamperes which almost remains constant with bias. This small current is reverse saturation current.

Read the given passage carefully and give the answer of the following questions:

Q1. In the given figure, a diode D is connected to an external resistance R = 100 Ω and an emf of 3.5 V. If the barrier potential developed across the diode is 0.5 V, the current in the circuit will be:



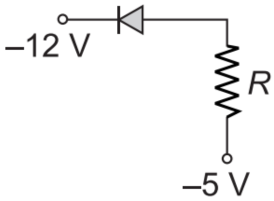
a. 40 mA

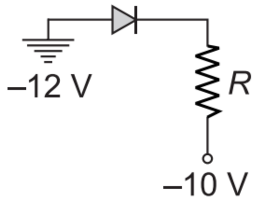
b. 20 mA

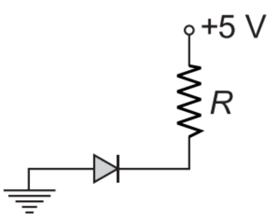
c. 35 mA

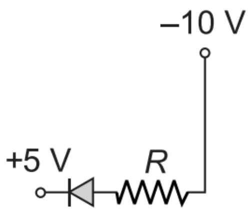
d. 30 mA

Q2. In which of the following figures, the pn diode is reverse biased?

a.


b.


c.


d.


Q3. Based on the V-/ characteristics of the diode, we can classify diode as:

a. bilateral device

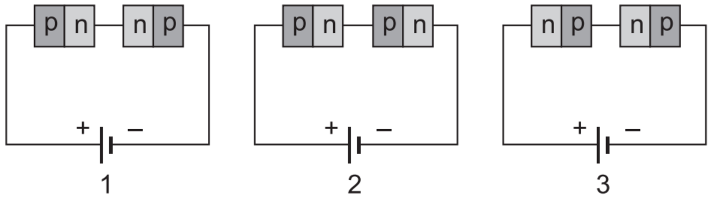
b. ohmic device

c. non-ohmic device

d. passive element

OR

Two identical pn-junctions can be connected in series by three different methods as shown in the figure. If the potential difference in the junctions is the same, then the correct connections will be



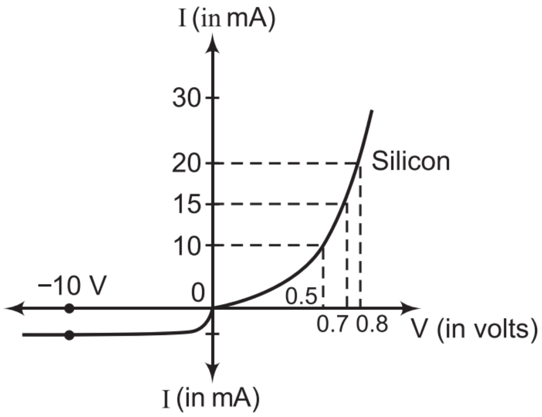
a. in the circuits (1) and (2)

b. in the circuits (2) and (3)

c. in the circuits (1) and (3)

d. only in the circuit (1)

Q 4.



The V-I characteristic of a diode is shown in the figure. The ratio of the resistance of the diode at / = 15 mA to the resistance at V = -10 V is: (CBSE SQP 2023-24)

a. 100 b. 10^6

c. 10 d. 10^{-6}

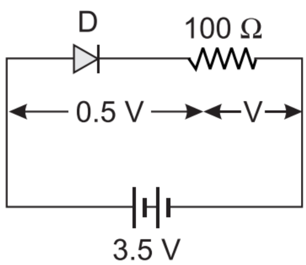
Solutions

1. (d) The potential difference across the resistance R is

$V = 3.5\text{ V} - 0.5\text{ V} = 3\text{ V}$

By ohm's law,

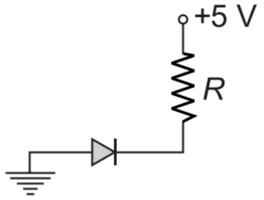
The current in the circuit,



$$I = \frac{V}{R} = \frac{3\text{V}}{100\,\Omega} = 3 \times 10^{-2}\text{ A}$$

$= 30 \times 10^{-3}$ A = 30 mA

2. (c)



3. (c) non-ohmic device OR (b) in the circuits (2) and (3)

4. (d) From the given curve, we have

$V = 0.8$ V for current $I = 20$ mA

and $V = 0.7$ V for current $I = 10$ mA

Resistance at $I = 15$ mA

$\therefore \quad \Delta I = (20 - 10)\text{ mA} = 10 \times 10^{-3}$ A

and $\Delta V = (0.8 - 0.7) = 0.1$ V

Thus $R = \dfrac{\Delta V}{\Delta I} = \dfrac{0.1}{10 \times 10^{-3}} = 10\,\Omega$

Resistance at V = – 10 V:

$I = -1\,\mu\text{A} = -1 \times 10^{-6}$ A

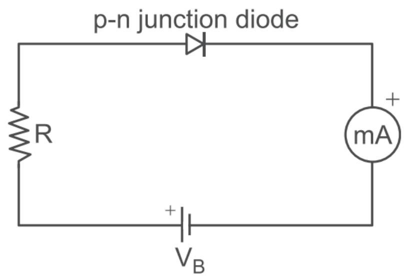
$$R = \frac{-10}{-1 \times 10^{-6}} = 1.0 \times 10^{7}\ \Omega$$

$$\therefore \text{ Ratio of resistance } = \frac{10}{1.0 \times 10^{7}} = 10^{-6}$$

Case Study 3

A silicon p-n junction diode is connected to a resistor R and a battery of voltage V_B through milliampere (mA) as shown in figure. The knee voltage for this junction diode is $V_N = 0.7$ V. The p-n junction diode requires a minimum current of 1 mA to attain a value higher than the knee point on the V-I characteristics of this junction diode. Assuming that the voltage V across the junction is independent of the current above the knee point.

A p-n junction is the basic building block of many semiconductors, devices like diodes. Important process occurring during the formation of a p-n junction are diffusion and drift. In an n-type semiconductor concentration of electrons is more as compared to holes. In a p-type semiconductor, concentration of holes is more as compared to electrons.



Read the given passage carefully and give the answer of the following questions:

Q1. If V_B = 5 V, then what will be the maximum value of R so that the voltage V is above the knee point voltage?

Q2. If V_B = 5 V, then what will be the value of R in order to establish a current to 6 mA in the circuit?

Q3. When the diode is reverse biased with a voltage of 6 V and V_{bi} = 0.63 V, calculate the total potential.

Q4. If V_B = 6 V, then calculate the power dissipated in the resistor R, when a current of 6 mA flows in the circuit.

Solutions

1. Voltage drop across R,

$$V_R = V_B - V_N = 5 - 0.7 = 4.3 \text{ V}$$

Given, $I_{min} = 1 \times 10^{-3}$ A

Maximum value of resistance,

$$R_{max} = \frac{V_R}{I_{min}} = \frac{4.3}{1 \times 10^{-3}}$$

$$= 4.3 \times 10^3 \ \Omega = 4.3 \text{ k}\Omega$$

2. Given, $I = 6 \text{ mA} = 6 \times 10^{-3}$ A;

$$V_R = V_B - V_N = 5 - 0.7 = 4.3 \text{ V}$$

$$R = \frac{V_R}{I} = \frac{4.3}{6 \times 10^{-3}} = 717 \ \Omega$$

3. Total potential, $V_t = V_{bi} + V_R = 0.63 + 6 = 6.63$ V

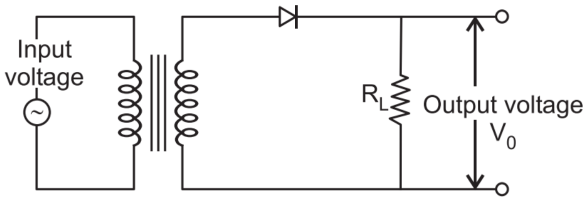
4. Given, $V_B = 6\text{V}$; $V_N = 0.7\text{V}$, $V_R = 6 - 0.7 = 5.3$ V

Power dissipated, $P = I \times V_R = (6 \times 10^{-3}) \times 5.3$

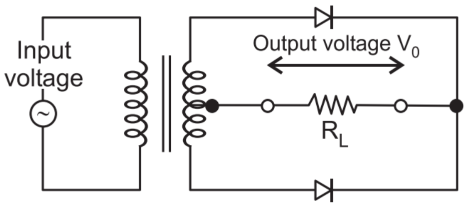
$$= 31.8 \times 10^{-3} \text{ W} = 31.8 \text{ mW}$$

Case Study 4

Rectifier is a device which is used for converting alternating current or voltage into direct current or voltage. Its working is based on the fact that the resistance of p-n junction becomes low when forward biased and becomes high when reverse biased. A half wave rectifier uses only a single diode while a full wave rectifier uses two diodes as shown in figures (a) and (b).



(a) Half wave rectifier



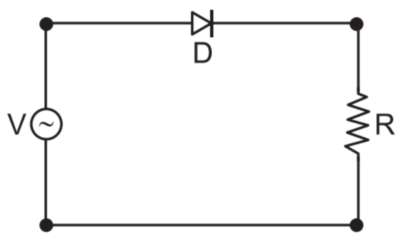
(b) Full wave rectifier

Read the given passage carefully and give the answer of the following questions:

Q 1. If the rms value of sinusoidal input to a full wave rectifier is $\frac{V_0}{\sqrt{2}}$, then what is the rms value of the rectifier's output?

Q2. When an input of frequency 200 Hz is fed at input, what will be the ratio of output frequencies of half wave rectifier and full wave rectifier?

Q3. A p-n junction diode is shown in figure can act as a rectifier. An alternating voltage source (V) is connected in the circuit. Show the waveform of current (*I*) in the resistor (R).



Q4. What will be the fundamental ripple frequency in a half wave rectifier circuit operating from 50 Hz mains frequency?

Solutions

1. The rms value of the output voltage at the load resistance,

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

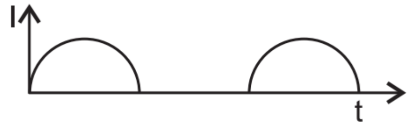
In full wave rectifier, the whole cycle is rectified so the value of input voltage will be same as output.

2. Output frequency of full wave rectifier is twice the output frequency of half wave rectifier.

Hence,

$$\frac{\text{Frequency of half wave rectifier}}{\text{Frequency of full wave rectifier}} = \frac{1}{2} = 1:2$$

3. The given circuit works as a half wave rectifier. In this circuit, we will get current through R when *p-n* junction diode is forward biased and no current flow when *p-n* junction diode is reverse biased. Thus, the current (I) through resistor (R) will be shown in the waveform.



4. As the output voltage obtained in a half wave rectifier, circuit has a single variation in one cycle of AC voltage, hence the fundamental frequency in the ripple of output voltage would be 50 Hz.

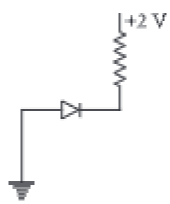
Solutions for Questions 5 to 14 are Given Below

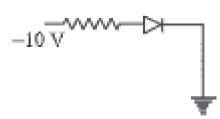
Case Study 5

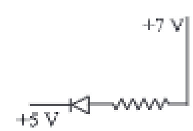
Biasing of Diode

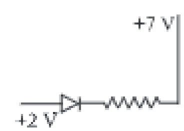
When the diode is forward biased, it is found that beyond forward voltage $V = V_k$, called knee voltage, the conductivity is very high. At this value of battery biasing for p-n junction,the potential barrier is overcome and the current increases rapidly with increase in forward voltage.
When the diode is reverse biased, the reverse bias voltage produces a very small current about a few microamperes which almost remains constant with bias. This small current is reverse saturation current.

(i) In which of the following figures, the p-n diode is forward biased.

(a) 

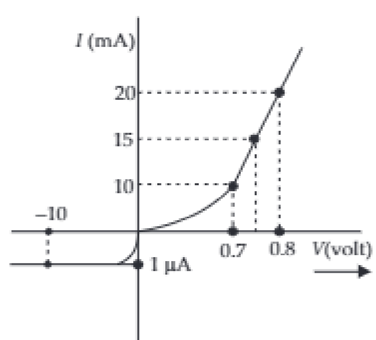
(b) 

(c) 

(d) 

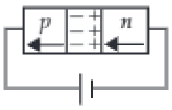
(ii) Based on the V-I characteristics of the diode, we can classify diode as
(a) bi-directional device (b) ohmic device
(c) non-ohmic device (d) passive element

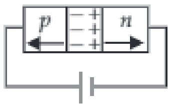
(iii) The V-I characteristic of a diode is shown in the figure. The ratio of forward to reverse bias resistance is

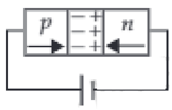


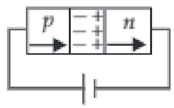
(a) 100 (b) 10^6 (c) 10 (d) 10^{-6}

(iv) In the case of forward biasing of a p-n junction diode, which one of the following figures correctly depicts the direction of conventional current (indicated by an arrow mark)?

(a) 

(b) 

(c) 

(d) 

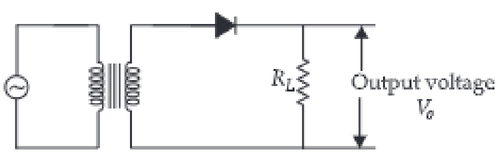
(v) If an ideal junction diode is connected as shown, then the value of the current I is

(a) 0.013 A (b) 0.02 A (c) 0.01 A (d) 0.1 A

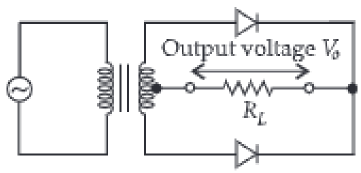
Case Study 6

Rectifier

Rectifier is a device which is used for converting alternating current or voltage into direct current or voltage. Its working is based on the fact that the resistance of p-n junction becomes low when forward biased and becomes high when reverse biased. A half-wave rectifier uses only a single diode while a full wave rectifier uses two diodes as shown in figures (a) and (b).



(a) Half wave rectifier

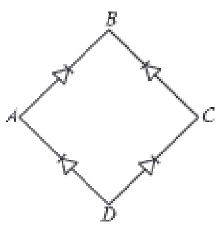


(b) Full wave rectifier

(i) If the rms value of sinusoidal input to a full wave rectifier is $\frac{V_0}{\sqrt{2}}$ then the rms value of the rectifier's output is

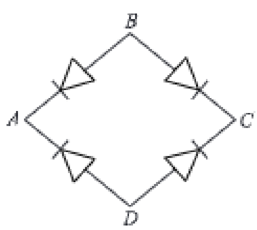
(a) $\frac{V_0}{\sqrt{2}}$ (b) $\frac{V_0^2}{\sqrt{2}}$ (c) $\frac{V_0^2}{2}$ (d) $\sqrt{2}V_0^2$

(ii) In the diagram, the input ac is across the terminals A and C. The output across B and D is



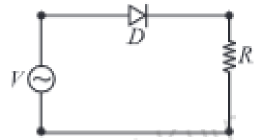
(a) same as the input (b) half wave rectified (c) zero (d) full wave rectified

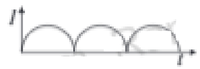
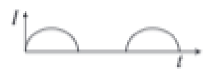
(iii) A bridge rectifier is shown in figure. Alternating input is given across A and C. If output is taken across BD, then it is



(a) zero (b) same as input (c) half wave rectified (d) full wave rectified

(iv) A p-n junction (D) shown in the figure can act as a rectifier. An alternating current source (V) is connected in the circuit. The current(I) in the resistor(R) can be shown by



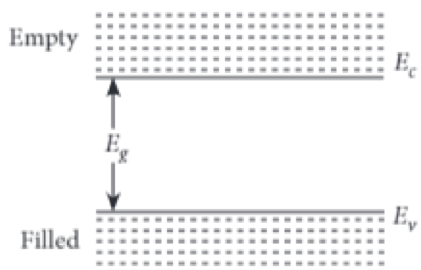
(a)  (b)  (c)  (d) 

(v) With an ac input from 50 Hz power line, the ripple frequency is
(a) 50 Hz in the dc output of half wave as well as full wave rectifier
(b) 100 Hz in the dc output of half wave as well as full wave rectifier
(c) 50 Hz in the dc output of half wave and 100 Hz in dc output of full wave rectifier
(d) 100 Hz in the dc output of half wave and 50 Hz in the dc output of full wave rectifier.

Case Study 7

Energy Band Gap

From Bohr's atomic model, we know that the electrons have well defined energy levels in an isolated atom. But due to interatomic interactions in a crystal, the electrons of the outer shells are forced to have energies different from those in isolated atoms. Each energy level splits into a number of energy levels forming a continuous band. The gap between top of valence band and bottom of the conduction band in which no allowed energy levels for electrons can exist is called energy gap.



(i) In an insulator energy band gap is
(a) $E_g = 0$ (b) $E_g < 3$ eV (c) $E_g > 3$ eV (d) None of the above

(ii) In a semiconductor, separation between conduction and valence band is of the order of
(a) 0 eV (b) 1 eV (c) 10 eV (d) 50 eV

(iii) Based on the band theory of conductors, insulators and semiconductors, the forbidden gap is smallest in
(a) conductors (b) insulators (c) semiconductors (d) All of these

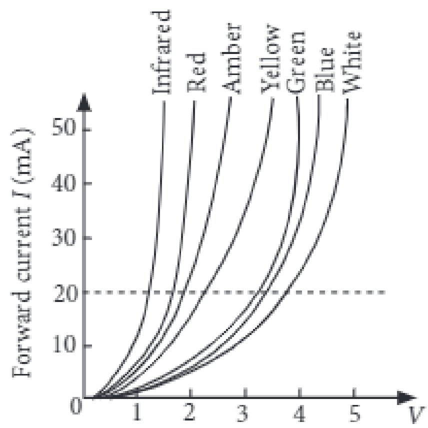
(iv) Carbon, silicon and germanium have four valence electrons each. At room temperature which one of the following statements is most appropriate ?
(a) The number of free electrons for conduction is significant only in Si and Ge but small in C.
(b) The number of free conduction electrons is significant in C but small in Si and Ge.
(c) The number of free conduction electrons is negligibly small in all the three.
(d) The number of free electrons for conduction is significant in all the three.

(v) Solids having highest energy level partially filled with electrons are
(a) semiconductor (b) conductor (c) insulator (d) none of these

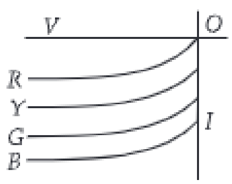
Case Study 8

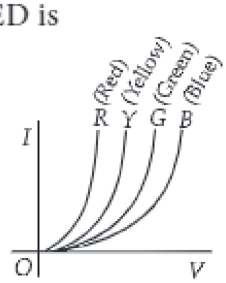
Light Emitting Diode (LED)

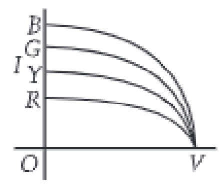
Light emitting diode is a photoelectric device which converts electrical energy into light energy. It is a heavily doped *p-n* junction diode which under forward biased emits spontaneous radiation. The general shape of the *I-V* characteristics of an LED is similar to that of a normal *p-n* junction diode, as shown. The barrier potentials are much higher and slightly different for each colour.

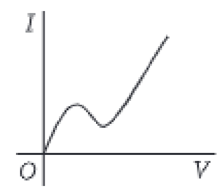


(i) The *I-V* characteristic of an LED is

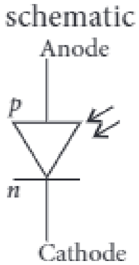
(a) 

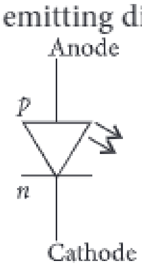
(b) 

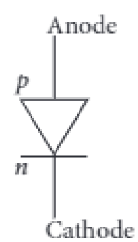
(c) 

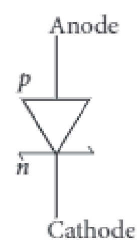
(d) 

(ii) The schematic symbol of light emitting diode is (LED)

(a) 

(b) 

(c) 

(d) 

(iii) An LED is constructed from a *p-n* junction based on a certain Ga-As-P semiconducting material whose energy gap is 1.9 eV. Identify the colour of the emitted light.

(a) Blue (b) Red (c) Violet (d) Green

(iv) Which one of the following statement is not correct in the case of light emitting diodes?

(a) It is a heavily doped *p-n* junction.
(b) It emits light only when it is forward biased.
(c) It emits light only when it is reverse biased.
(d) The energy of the light emitted is less than the energy gap of the semiconductor used.

(v) The energy of radiation emitted by LED is

(a) greater than the band gap of the semiconductor used
(b) always less than the band gap of the semiconductor used
(c) always equal to the band gap of the semiconductor used
(d) equal to or less than the band gap of the semiconductor used.

Case Study 9

Photodiode

A photodiode is an optoelectronic device in which current carriers are generated by photons through photo-excitation *i.e.*, photo conduction by light. It is a *p-n* junction fabricated from a photosensitive semiconductor and provided with a transparent window so as allow light to fall on its function. A photodiode can turn its current ON and OFF in nanoseconds. So, it can be used as a fastest photo-detector.

(i) A *p-n* photodiode is fabricated from a semiconductor with a band gap of 2.5 eV. It can detect a signal of wavelength

(a) 4000 nm (b) 6000 nm (c) 4000 Å (d) 6000 Å

(ii) Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gap of 2.5 eV, 2 eV and 3 eV, respectively. Which one will be able to detect light of wavelength 6000 Å ?

(a) D_1 (b) D_2 (c) D_3 (d) D_1 and D_2 both

(iii) Photodiode is a device

(a) which is always operated in reverse bias
(b) which of always operated in forward bias
(c) in which photo current is independent of intensity of incident radiation
(d) which may be operated in forward or reverse bias.

(iv) To detect light of wavelength 500 nm, the photodiode must be fabricated from a semiconductor of minimum bandwidth of

(a) 1.24 eV (b) 0.62 eV (c) 2.48 eV (d) 3.2 eV

(v) Photodiode can be used as a photodetector to detect

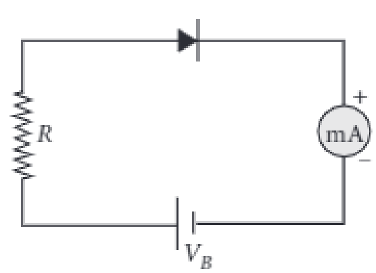
(a) optical signals (b) electrical signals (c) both (a) and (b) (d) none of these

Case Study 10

p-n Junction Diode

A silicon *p-n* junction diode is connected to a resistor *R* and a battery of voltage V_B through milliammeter (mA) as shown in figure. The knee voltage for this junction diode is $V_N = 0.7$ V. The *p-n* junction diode requires a minimum current of 1 mA to attain a value higher than the knee point on the *I-V* characteristics of this junction diode. Assuming that the voltage *V* across the junction is independent of the current above the knee point.

A *p-n* junction is the basic building block of many semiconductor devices like diodes. Important process occurring during the formation of a *p-n* junction are diffusion and drift. In an *n*-type semiconductor concentration of electrons is more as compared to holes. In a *p*-type semiconductor concentration of holes is more as compared to electrons.



(i) If $V_B = 5$ V, the maximum value of R so that the voltage V is above the knee point voltage is

(a) 40 kΩ (b) 4.3 kΩ (c) 5.0 kΩ (d) 5.7 kΩ

(ii) If $V_B = 5$ V, the value of R in order to establish a current to 6 mA in the circuit is

(a) 833 Ω (b) 717 Ω (c) 950 Ω (d) 733 Ω

(iii) If $V_B = 6$ V, the power dissipated in the resistor R, when a current of 6 mA flows in the circuit is

(a) 30.2 mW (b) 30.8 mW (c) 31.2 mW (d) 31.8 mW

(iv) When the diode is reverse biased with a voltage of 6 V and $V_{bi} = 0.63$ V. Calculate the total potential.

(a) 9.27 V (b) 6.63 V (c) 5.27 V (d) 0.63 V

(v) Which of the below mentioned statement is false regarding a *p-n* junction diode?

(a) Diodes are uncontrolled devices. (b) Diodes are rectifying devices.

(c) Diodes are unidirectional devices. (d) Diodes have three terminals.

Case Study 11

Electron Mobility

The electron mobility characterises how quickly an electron can move through a metal of semiconductor when pulled by an electric field. There is an analogous quality for holes, called hole mobility.

A block of pure silicon at 300 K has a length of 10 cm and an area of 1.0 cm^2. A battery of emf 2 V is connected across it. The mobility of electron is 0.14 m^2 V^{-1} s^{-1} and their number density is 1.5×10^{16} m^{-3}. The mobility of holes is 0.05 m^2 V^{-1} s^{-1}.

(i) The electron current is

(a) 6.72×10^{-4} A (b) 6.72×10^{-5} A (c) 6.72×10^{-6} A (d) 6.72×10^{-7} A

(ii) The hole current is

(a) 2.0×10^{-7} A (b) 2.2×10^{-7} A (c) 2.4×10^{-7} A (d) 2.6×10^{-7} A

(iii) The number density of donor atoms which are to be added up to pure silicon semiconductor to produce an *n*-type semiconductor of conductivity 6.4 Ω^{-1} cm^{-1} is approximately (neglect the contribution of holes to conductivity)

(a) 3×10^{22} m^{-3} (b) 3×10^{23} m^{-3} (c) 3×10^{24} m^{-3} (d) 3×10^{21} m^{-3}

(iv) When the given silicon semiconductor is doped with indium, the hole concentration increases to 4.5×10^{23} m^{-3}. The electron concentration in doped silicon is

(a) 3×10^9 m^{-3} (b) 4×10^9 m^{-3} (c) 5×10^9 m^{-3} (d) 6×10^9 m^{-3}

(v) Pick out the statement which is not correct.

(a) At a low temperature, the resistance of a semiconductor is very high.

(b) Movement of holes is restricted to the valence band only.

(c) Width of the depletion region increases as the forward bias voltage increases in case of a *p-n* junction diode.

(d) In a forward bias condition, the diode heavily conducts.

Case Study 12

Doping in Semiconductor

p-n junction is a single crystal of Ge or Si doped in such a manner that one half portion of it acts as *p*-type semiconductor and other half functions as *n*-type semiconductor. As soon as a *p-n* junction is formed, the holes from the p-region diffuse into the n-region and electron from n region diffuse in to p-region. This results in the development of V_B across the junction which opposes the further diffusion of electrons and holes through the junction.

(i) In an unbiased p-n junction electrons diffuse from n-region to p-region because
  (a) holes in p-region attract them
  (b) electrons travel across the junction due to potential difference
  (c) electron concentration in n-region is more as compared to that in p-region
  (d) only electrons move from n to p region and not the *vice-versa*

(ii) Electron hole recombination in p-n junction may lead to emission of
  (a) light (b) ultraviolet rays (c) sound (d) radioactive rays

(iii) In an unbiased p-n junction
  (a) potential at p is equal to that at n
  (b) potential at p is +ve and that at n is –ve
  (c) potential at p is more than that at n
  (d) potential at p is less than that at n.

(iv) The potential of depletion layer is due to
  (a) electrons (b) holes (c) ions (d) forbidden band

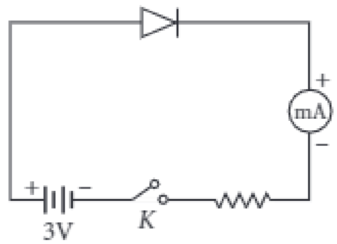
(v) In the depletion layer of unbiased p-n junction,
  (a) it is devoid of charge carriers
  (b) has only electrons
  (c) has only holes
  (d) p-n junction has a weak electric field.

Case Study 13

Potential Barrier

The potential barrier in the p-n junction diode is the barrier in which the charge recquires additional force for crossing the region. In other words, the barrier in which the charge carrier stopped by the obstructive force is known as the potential barrier.

When a p-type semiconductor is brought into a close contact with n-type semiconductor, we get a p-n junction with a barrier potential 0.4 V and width of depletion region is 4.0×10^{-7} m. This p-n junction is forward biased with a battery of voltage 3V and negligible internal resistance, in series with a resistor of resistance R, ideal millimeter and key K as shown in figure. When key is pressed, a current of 20 mA passes through the diode.



(i) The intersity of the electric field in the depletion region when p-n junction is unbiased is
  (a) 0.5×10^6 V m^{-1} (b) 1.0×10^6 V m^{-1} (c) 2.0×10^6 V m^{-1} (d) 1.5×10^6 V m^{-1}

(ii) The resistance of resistor R is
  (a) 150 Ω (b) 300 Ω (c) 130 Ω (d) 180 Ω

(iii) In a p-n junction, the potential barrier is due to the charges on either side of the junction, these charges are
  (a) majority carriers
  (b) minority carriers
  (c) both (a) and (b)
  (d) fixed donor and acceptor ions.

(iv) If the voltage of the potential barrier is V_0. A voltage V is applied to the input, at what moment will the barrier disappear?

(a) $V < V_0$ (b) $V = V_0$ (c) $V > V_0$ (d) $V << V_0$

(v) If an electron with speed 4.0×10^5 m s^{-1} approaches the p-n junction from the n-side, the speed with which it will enter the p-side is

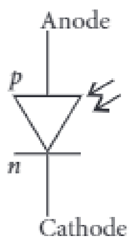
(a) 1.39×10^5 m s^{-1} (b) 2.78×10^5 m s^{-1} (c) 1.39×10^6 m s^{-1} (d) 2.78×10^6 m s^{-1}

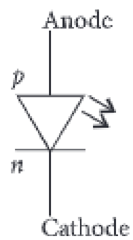
Case Study 14

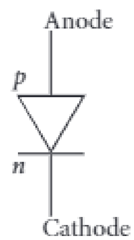
Solar Cell

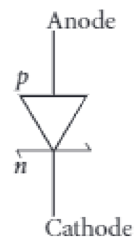
Solar cell is a p-n junction diode which converts solar energy into electric energy. It is basically a solar energy converter. The upper layer of solar cell is of p-type semiconductor and very thin so that the incident light photons may easily reach the p-n junction. On the top face of p-layer, the metal finger electrodes are prepared in order to have enough spacing between the fingers for the lights to reach the p-n junction through p-layer.

(i) The schematic symbol of solar cell is

(a) 

(b) 

(c) 

(d) 

(ii) The p-n junction which generates an emf when solar radiations fall an it, with no external bias applied, is a

(a) light emitting diode (b) photodiode (c) solar cell (d) None of these

(iii) For satellites the source of energy is

(a) Solar cell (b) Fuel cell (c) Edison cell (d) None of these

(iv) Which of the following material is used in solar cell?

(a) Barium (b) Silicon (c) Silver (d) Selenium

(v) The efficiency of a solar cell may be in the range

(a) 2 to 5% (b) 10 to 15% (c) 30 to 40% (d) 70 to 80%

HINTS & EXPLANATIONS

5. **(i) (c)** : The p-n diode is forward biased when p-side is at a higher potential than n-side.

(ii) (c)

(iii) (d) : Forward bias resistance,

$$R_1 = \frac{\Delta V}{\Delta I} = \frac{0.8 - 0.7}{(20-10)\times 10^{-3}} = \frac{0.1}{10 \times 10^{-3}} = 10$$

Reverse bias resistance, $R_2 = \dfrac{10}{1 \times 10^{-6}} = 10^7$

Then, the ratio of forward to reverse bias resistance,

$$\frac{R_1}{R_2} = \frac{10}{10^7} = 10^{-6}$$

(iv) (d) : In p-region the direction of conventional current is same as flow of holes.

In n-region the direction of conventional current is opposite to the flow of electrons.

(v) (c) : In the given circuit the junction diode is forward biased and offers zero resistance.

$\therefore$ The current, $I = \frac{3\text{ V} - 1\text{ V}}{200\ \Omega} = \frac{2\text{ V}}{200\ \Omega} = 0.01\text{ A}$

6. (i) (a) : The rms value of the output voltage at the load resistance, $V_{rms} = \frac{V_0}{\sqrt{2}}$.

(ii) (d)

(iii) (a)

(iv) (c): The given circuit works as a half wave rectifier. In this circuit, we will get current through R when p-n junction is forward biased and no current when p-n junction is reverse biased. Thus the current (I) through resistor (R) will be shown in option (c).

(v) (c)

7. (i) (c) : In insulator, energy band gap is > 3 eV

(ii) (b) : In conductor, separation between conduction and valence bands is zero and in insulator, it is greater than 1 eV. Hence in semiconductor the separation between conduction and valence band is 1 eV.

(iii) (a): According to band theory the forbidden gap in conductors $E_g \approx 0$, in insulators $E_g > 3$ eV and in semiconductors $E_g < 3$ eV.

(iv) (a): The four valence electrons of C, Si and Ge lie respectively in the second, third and fourth orbit. Hence energy required to take out an electron from these atoms (*i.e.* ionisation energy E_g) will be least for Ge, followed by Si and highest for C. Hence, the number of free electrons for conduction in Ge and Si are significant but negligibly small for C.

(v) (b)

8. (i) (b): The I-V characteristics of an LED is similar to that of a Si junction diode. But the threshold voltages are much higher and slightly different for each colour.

(ii) (b)

(iii) (b) : As $E_g = \frac{hc}{\lambda}$ $\therefore \lambda = \frac{hc}{E_g}$

Here, $E_g = 1.9$ eV, $hc = 1240$ eV nm

$\therefore \lambda = \frac{1240\text{ eV nm}}{1.9\text{ eV}} = 652.6\text{ nm}$

Hence, the emitted light is of red colour.

(iv) (c): A light emitting diode is a heavily doped p-n junction diode which emits light only when it is forward biased.

(v) (d)

9. (i) (c) : $\lambda_{max} = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.5 \times 1.6 \times 10^{-19}}$

$= 5000$ Å

$\therefore \lambda = 4000$ Å $< \lambda_{max}$

(ii) (b) : Energy of incident photon, $E = \frac{hc}{\lambda}$

$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{6 \times 10^{-7} \times 1.6 \times 10^{-19}} = 2.06$ eV

The incident radiation can be detected by a photodiode if energy of incident photon is greater than the band gap.

As $D_2 = 2$ eV, therefore D_2 will detect these radiations.

(iii) (a): Photodiode is a device which is always operated in reverse bias.

(iv) (c) : Let E_g be the required bandwidth. Then

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

Here, $hc = 1240$ eV nm, $\lambda = 500$ nm

$\therefore E_g = \frac{1240\text{ eV nm}}{500\text{ nm}} = 2.48\text{ eV}$

(v) (a): A photodiode is a device which is used to detect optical signals.

10. (i) (b) : Voltage drop across R.

$V_R = V_B - V_N = 5 - 0.7 = 4.3$ V

Here, $I_{min} = 1 \times 10^{-3}$ A

$R_{max} = \frac{V_R}{I_{min}} = \frac{4.3}{1 \times 10^{-3}} = 4.3 \times 10^3\ \Omega = 4.3\ \text{k}\Omega$

(ii) (b) : $I = 6$ mA $= 6 \times 10^{-3}$ A;

$V_R = V_B - V_N = 5 - 0.7 = 4.3$ V

$R = \frac{V_R}{I} = \frac{4.3}{6 \times 10^{-3}} = 717\ \Omega$

(iii) (d) : Here, $V_B = 6$ V; $V_N = 0.7$ V,

$V_R = 6 - 0.7 = 5.3$ V

Power dissipated in $R = I \times V_R$

$= (6 \times 10^{-3}) \times 5.3 = 31.8 \times 10^{-3}$ W

$= 31.8$ mW

(iv) (b) : $V_t = V_{bi} + V_R = 0.63 + 6 = 6.63$ V

(v) (d) : Diode is two terminal device, anode and cathode are the two terminals.

11. (i) (d) : $E = \frac{V}{l} = \frac{2}{0.1} = 20$ V/m;

$A = 1.0 \text{ cm}^2 = 1.0 \times 10^{-4} \text{ m}^2$

$v_e = \mu_e E = 0.14 \times 20 = 2.8 \text{ m s}^{-1}$

$I_e = n_e A e v_e$

$= (1.5 \times 10^{16}) \times (1.0 \times 10^{-4}) \times (1.6 \times 10^{-19}) \times 2.8$

$= 6.72 \times 10^{-7}$ A

(ii) (c) : In a pure semiconductor,

$n_e = n_h = 1.5 \times 10^{16} \text{ m}^{-3}$

$v_h = \mu_h \times E = 0.05 \times 20 = 1.0 \text{ ms}^{-1}$

$I_h = n_h A e v_h$

$= (1.5 \times 10^{16}) \times (1.0 \times 10^{-4}) \times (1.6 \times 10^{-19}) \times 1.0$

$= 2.4 \times 10^{-7}$ A

(iii) (a) : $\sigma = e n_e m_e$

or $n_e = \frac{\sigma}{e\mu_e} = \frac{6.4 \times 10^2}{(1.6 \times 10^{-19}) \times 0.14}$

$= 3.14 \times 10^{22} \approx 3 \times 10^{22} \text{ m}^{-3}$

(iv) (c) : $n_e = \frac{n_i^2}{n_h} = \frac{(1.5 \times 10^{16})^2}{4.5 \times 10^{22}} = 5 \times 10^9 \text{ m}^{-3}$

(v) (c) : In case of a *p-n* junction diode, width of the depletion region decreases as the forward bias voltage increases.

12. (i) (c) : Electron concentration in *n*-region is more as compared to that in *p*-region. So electrons diffuse from *n*-side to *p*-side.

(ii) (a) : When an electron and a hole recombine, the energy is released in the form of light.

(iii) (a) : In an unbiased *p-n* junction, potential at *p* is equal to that at *n*.

(iv) (c) : The potential of depletion layer is due to ions.

(v) (a) : In the depletion layer of unbiased *p-n*, junction has no charge carriers.

13. (i) (b) : $E = \frac{V_B}{d} = \frac{0.4}{4.0 \times 10^{-7}} = 1.0 \times 10^6 \text{ V m}^{-1}$

(ii) (c) : Potential difference across $= R = 3 - 0.4 = 2.6$ V

Resistance $R = \frac{\text{Potential difference}}{\text{Current}}$

$= \frac{2.6}{20 \times 10^{-3}} = 130 \ \Omega$

(iii) (d)

(iv) (b) : When the voltage will be the same that of the potential barrier disappears resulting in flow of current.

(v) (a) : $\frac{1}{2} m v_1^2 = e V_B + \frac{1}{2} m v_2^2$

$\Rightarrow \frac{1}{2} \times (9.1 \times 10^{-31}) \times (4 \times 10^5)^2$

$= 1.6 \times 10^{-19} \times (0.4) + \frac{1}{2} \times 9.1 \times 10^{-31} \times v_2^2$

On solving, we get

$v_2 = 1.39 \times 10^5 \text{ m s}^{-1}$

14. (i) (a)

(ii) (c)

(iii) (a) : Solar cells are the source of energy for satellites.

(iv) (b) : Silicon is used in solar cell.

(v) (b) : 10 to 15%.