DCAM classes
Dynamic Classes for Academic Mastery

semiconductor devices (solutions with objectives)

Explanations

1. Refer to graph (Zener Diode). (1)

2. The diode having these type of V-I characteristics is photodiode. (1)

3. Resistance of a material can be found out by the slope of the curve V *versus* I. Part BC of the curve shows the negative resistance as in this region current decreases by increasing the voltage. (1)

4.

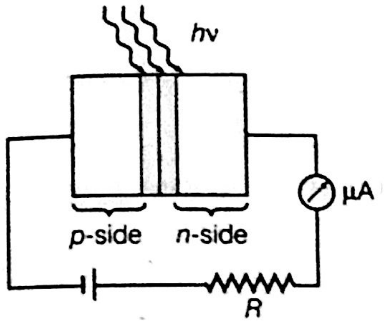
n-type Semiconductor	p-type Semiconductor
It is formed by doping pentavalent impurities with tetravalent atoms.	It is formed by doping trivalent impurities with tetravalent atoms. (1/2)
The electrons are majority carriers and holes are minority carriers. ($n_e >> n_h$)	The holes are majority carriers and electrons are minority carriers ($n_h >> n_e$) (1/20)

5. (i) Width of depletion layer decreases in forward bias. **(1/2)**

(ii) Width of depletion layer increases in reverse bias. **(1/2)**

6. In this way, continuous contact cannot be produced at atomic level and junction will behave as a discontinuity for the flowing charge carrier. **(1)**

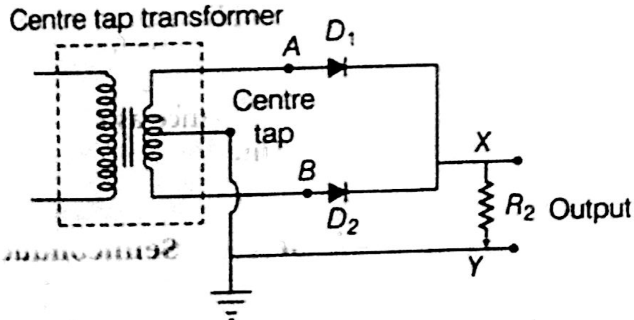
7. **Working of photodiode** A junction diode made from light sensitive semiconductor is called a photodiode. A photodiode is a *p-n* junction diode arranged in reverse biasing.



(1)

The number of charge carriers increases when light of suitable frequency is made to fall on the *p-n* junction, because new electron holes pairs are created by absorbing the photons of suitable frequency. Intensity of light controls the number of charge carriers. Due to this property, photodiodes are used to detect optical signals. **(1)**

8. A rectifier is used to convert alternating current into direct current, whose labelled circuit is given below.

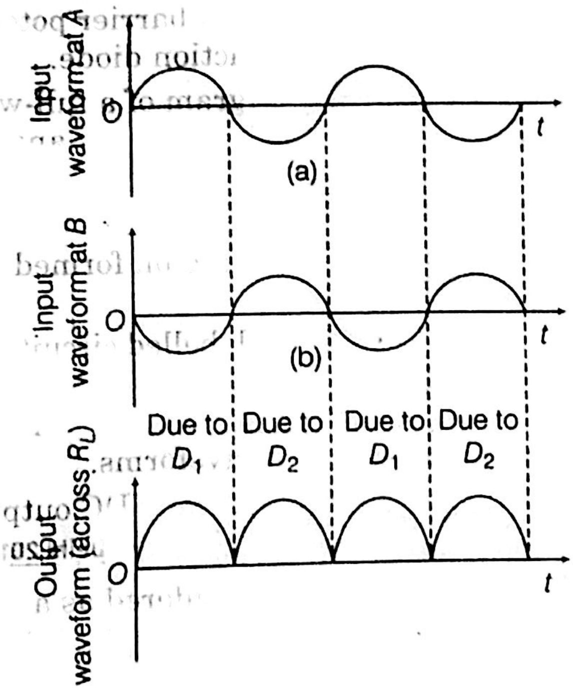


Circuit diagram of full wave rectifier **(1/2)**

Working

During the positive half cycle of the input AC, the diode D_1 is forward biased and the diode D_2 is reverse biased. The forward current flows through diode D_1.

During the negative half cycle of the input AC, the diode D_1 is reverse biased and diode D_2 is forward biased. Thus, current flows through diode D_2. Thus, we find that during both the halves, current flows in the same direction. **(1)**



(1/2)

9. (i) From the given curve, we have

Voltage, $V = 0.7$ volt for current,

$I = 15\,\text{mA}$ for voltage,

$$\therefore \text{Resistance, } \frac{V}{I} = \frac{0.7}{15\times16^{-3}} = 47\Omega$$ **(1)**

(ii) For $V = -10$ V, we have

$$I = -1\,\mu\text{A} = -1\times10^{-6}\text{A}$$

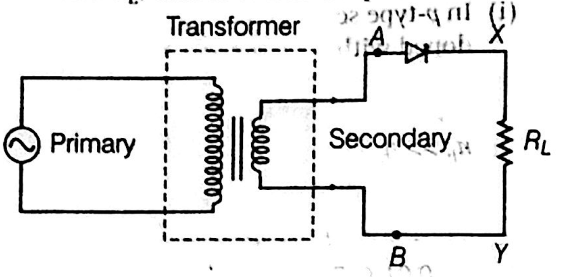
$$\Rightarrow R = \frac{10}{1\times10^{-6}} = 1.0\times10^{7}\Omega$$ **(1)**

10.

Intrinsic semiconductor	Extrinsic semiconductor
It is a pure semiconductor material with no impurity atoms in it.	It is prepared by doping a small quantity of impurity atoms to the pure semiconductor. **(1)**
The number of free electrons in the conduction band and the number of holes in valence band is exactly equal. $n_e = n_h = n_i$	The number of free electrons and holes is never equal. There is an excess of electrons $n_e > n_i$ in *n*-type semiconductors and excess of holes $n_h > n_i$ in *p*-type semiconductors. **(1)**

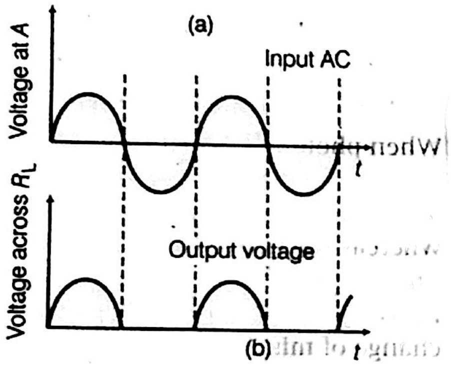
11. ***p-n* Junction Diode as a Half-Wave Rectifier** AC voltage to be rectified is connected to the primary coil of a step-down transformer.

Secondary coil is connected to the diode through resistors R_L, across which output is obtained.



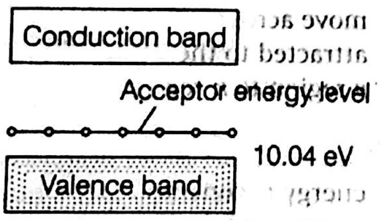
(1)

Working During positive half cycle of the input AC, the *p-n* junction is forward biased. Thus, the resistance in *p-n* junction becomes low and current flows. Hence, we get output in the load. During negative half cycle of the input AC, the *p-n* junction is reverse biased. Thus, the resistance of *p-n* junction is high and current does not flow. Hence, no output in the load. So, for complete cycle of AC, current flows through the load resistance in the same direction.

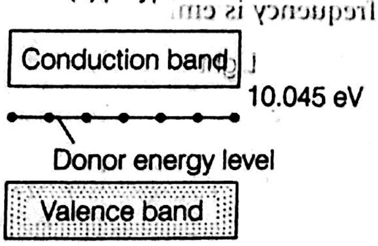


Input and output waveforms (1)

12. The required energy band diagram is shown below (1)

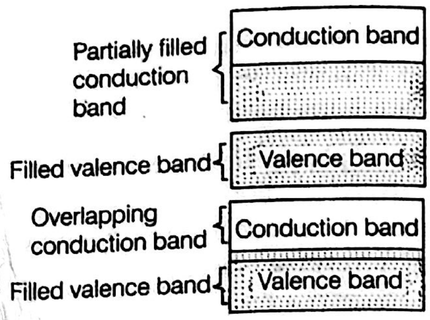


(a) *p*-type



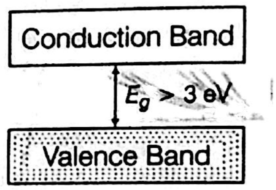
(b) *n*-type (2)

13. **Metal** For metals, the valence band is completely filled and the conduction band can have two possibilities either it is partially filled with an extremely small energy gap between the valence and conduction bands or it is empty, with two bands overlapping each other as shown below:



On applying even small electric field, metals can conduct electricity. (1)

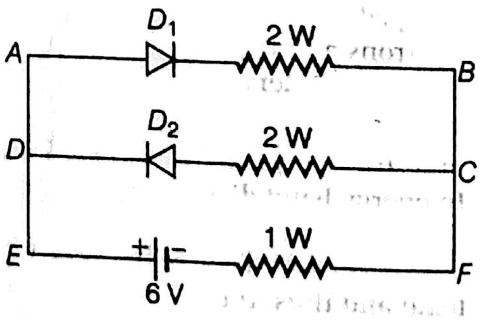
Insulators For insulator, the energy gap between the conduction and valence bands are very large, also the conduction band is practically empty, as shown below:



When an electric field is applied across such a solid, the electrons find it difficult to acquire, so a large amount of energy to reach the conduction band. Thus, the conduction band continues to be empty. That is why no current flows through insulators. (1)

14. Refer to Sol. 7 (2)

15. According to the question,



$$R_{AB} = 2 + 1 = 3\,\Omega$$

$$\frac{1}{R'} = \frac{1}{2} + \frac{1}{3}$$

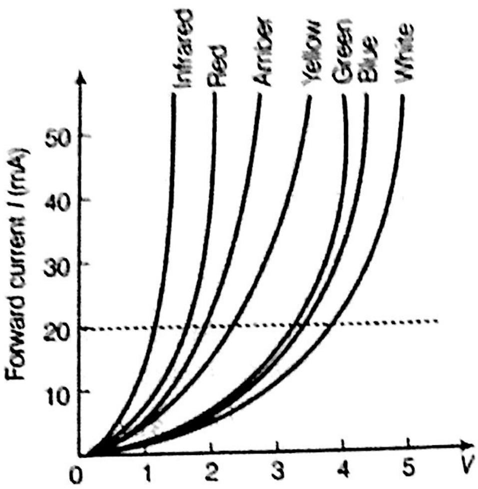
$$= \frac{3+2}{6} = \frac{5}{6}\,\Omega^{-1};$$

$$R' = \frac{6}{5}\,\Omega$$

$$I_{EF} = \frac{V}{R'} = \frac{6}{6/5} = 5\text{A}$$

(2)

16. For LEDs, the threshold voltages are much higher and slightly different for different colours. The reverse breakdown voltages of LEDs are low generally around 5V. It is due to this reason, the care is taken that high reverse voltages do not appear across LEDs. There is very little resistance to limit the current in LED. Therefore, a resistor must be used in series with the LED to avoid any damage to it. **(1)**

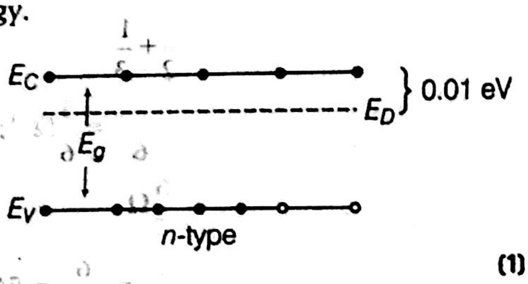


The semiconductor used for fabrication of visible LEDs must at least have a band gap of 1.8eV (spectral range of visible light is from about 0.4 μm to 0.7 μm i.e. from about 3 eV to 1.8 eV). **(1)**

17. Characteristics features of n-type semiconductor

(i) In n-type semiconductor, the semiconductor is doped with pentavalent impurity. In it the electrons are majority carriers and holes are minority carriers or $n_e >> n_h$ (n_e= number density of electrons, n_h= number density of holes).

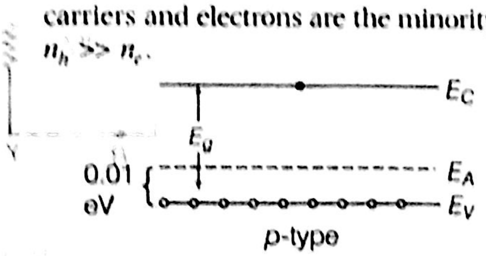
(ii) In energy band diagram of n-type semiconductor, the donor energy level E_D is slightly below the bottom of E_C conduction band and thus, the electron can move to conduction band, even with small supply of energy.



(1)

Characteristics features of p-type semiconductor

(i) In p-type semiconductor, the semiconductor is doped with trivalent impurity. In this semiconductor, the holes are the majority carriers and electrons are the minority carriers i.e. $n_h >> n_e$.



(ii) In energy band diagram of p-type, the acceptor energy level is slightly above the top of valence band E_V. Thus, even with small supply of energy electron from valence band can jump to level, E_A and ionise the acceptor, negatively. **(1)**

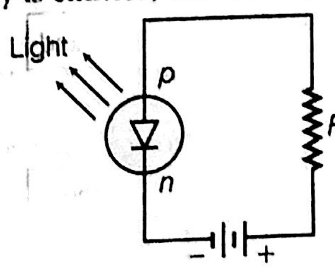
18. Advantages of LEDs over incandescent lamps:

(i) Since, LEDs do not have a filament that can burn out, hence, they last longer. **(1)**

(ii) They do not get hot during use, hence fast action, no warm up time required. **(1)**

19. When photodiode is illuminated with light due to breaking of covalent bonds, equal number of additional electrons and holes come into existence whereas fractional change in minority charge carrier is much higher than fractional change in majority charge carrier. Since, the fractional change of minority carrier current is measurable significantly in reverse bias than that of forward bias. Therefore, photodiodes are connected in reverse bias. **(2)**

20. When we apply sufficient voltage to LED, electron move across the junction into p-region and get attracted to the holes these holes are sent from p region to n region (where they are minority carriers). Thus, electrons and holes recombine. During each recombination, the electric potential energy is converted into the electromagnetic energy and a photon of light with a characteristic frequency is emitted, this is how, LED works.



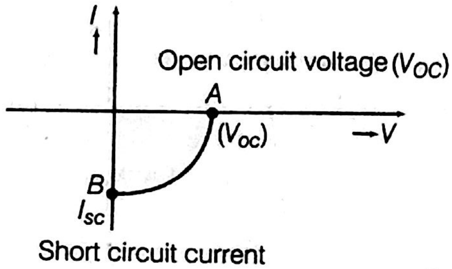
(1)

Advantages of LEDs Refer to Sol. 18 **(1)**

21. (i) The energy for the maximum intensity of the solar radiation is nearly 1.5 eV. In order to have photo excitation, the energy of radiation ($h\nu$) must be greater than energy band gap (E_g), i.e. $h\nu > E_g$. Therefore, the semiconductor with energy band gap about 1.5 eV or lower and with higher absorption coefficient, is likely to give better solar conversion efficiency.

The energy band gap for Si is about 1.1 eV, while for GaAs, it is about 1.43 eV. The gas GaAs is better inspite of its higher band gap than Si because it absorbs relatively more energy from the incident solar radiations being of relatively higher absorption coefficient. **(1)**

(ii)



V-I characteristic of a solar cell

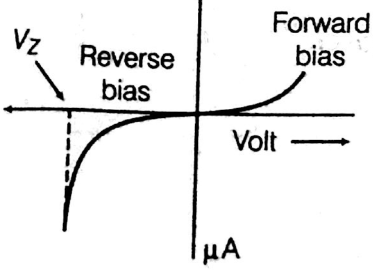
(a) *V-I* curve is drawn in the forth quadrant, because a solar cell does not draw current but supplies current to the load.

(b) In *V-I* curve , the point *A* indicates the maximum voltage V_{OC} which is being supplied by the given solar cell when no current is being drawn from it. V_{OC} is called the open circuit voltage.

(c) In *V-I* curve, the point *B* indicates the maximum current I_{SC} which can be obtained by short circuiting the solar cell without any load resistance. I_{SC} is called the short circuit current. **(1)**

22. Zener diode is used as voltage regulator. **(1/2)**

Principle Zener diode is operated in the reverse breakdown region. The voltage across it remains constant, equal to the breakdown voltage for large change in reverse current. **(1)**



(1/2)

23. Differences between forward and reverse biasing are given below:

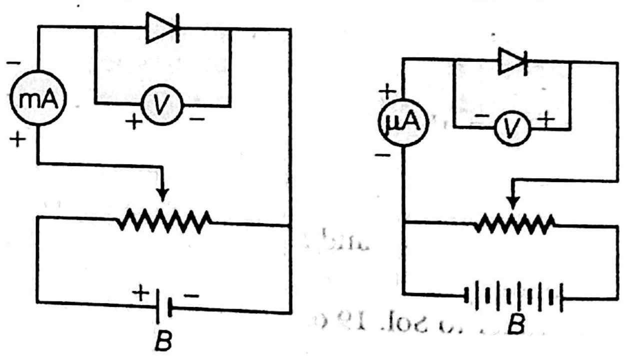
Forward bias	Reverse bias
Positive terminal of battery is connected to *p*-type and negative terminal to *n*-type semiconductor.	Positive terminal of battery is connected to *n*-type and negative terminal to *p*-type semiconductor.
Depletion layer is very thin.	Depletion layer is thick.
p-n junction offers very low resistance.	*p-n* junction offers very high resistance.
An ideal diode have zero resistance.	An ideal diode have infinite resistance.

(1/2 × 4 = 2)

24. With the formation of *p-n* junction, the holes from *p*-region diffuse into the *n*-region and electrons from *n*-region diffuse into *p*-region and electron-hole pair combine and get annihilated.

This in turn, produces potential barrier, V_B across the junction which opposes the further diffusion through the junction. Thus, small region forms in the vicinity of the junction which is depleted of free charge carrier and has only immobile ions is called the depletion region. **(2)**

25. Circuit diagram of forward biased and reverse biased *p-n* junction diode is shown below:



(1)

The width of depletion layer

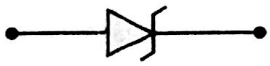
(i) decreases in forward bias.

(ii) increases in reverse bias. **(1/2 × 2 =1)**

26. The four valence electrons of carbon are present in second orbit while that of silicon in third orbit. So, energy required to extricate an electron from silicon is much smaller than carbon. Therefore, the number of free electrons for conduction in silicon is significant on contrary to the carbon. This makes silicon's conductivity much higher than carbon. This is the main distinguishable property. **(2)**

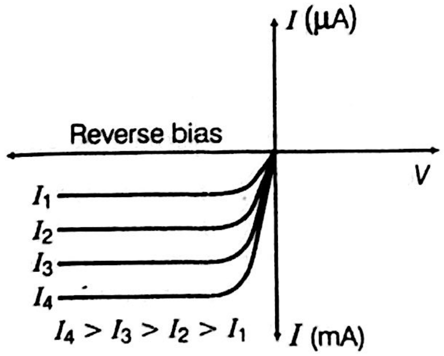
27. Device, D is a Zener diode. **(1)**

Symbol of Zener diode is



(1)

28. Circuit diagram of illuminated photodiode in reverse bias is shown below:



Reverse bias currents through a photodiode **(1)**

Hence, frequency of light ν such that $h\nu > E_g$, where E_g is band gap of increasing intensity I_1, I_2, I_3, etc. The value of reverse saturation current increases with the increase of intensity of light.

Thus, the measurement of change in the reverse saturation current can give the intensity of incident light. **(1)**

29. (i) **Main use of photodiode** In demodulation and detection of optical signals, in light operated switches and in electronic counters. **(1)**

(ii) **Main use of Zener diode** As DC voltage regulator. **(1)**

30. (i) Given, that, $\lambda = 600\,\text{nm}$, so **(1½)**

$$E = \frac{1240}{\lambda} \text{Å} = \frac{1240}{600}\text{ eV} = 2.06\text{ eV}$$

So, diode D_1 and D_3 does not detect light wave of wavelength 600 nm.

(ii) Refer to Sol. 19 **(1½)**

31. Refer to Sol. 8 **(3)**

32. Refer to Sol. 8 **(3)**

33. (i) Refer to Sol. 19 **(1½)**

(ii) $\lambda_1 = \dfrac{hc}{E_1} = \dfrac{6.62 \times 10^{-34} \times 3 \times 10^8}{2.5 \times 1.6 \times 10^{-19}} = 4965\,\text{Å}$

$\lambda_2 = \dfrac{hc}{E_2} = \dfrac{6.62 \times 10^{-34} \times 3 \times 10^8}{2.8 \times 1.6 \times 10^{-19}} = 4433\,\text{Å}$

Range of wavelength = 4433 Å - 4965 Å **(1½)**

34. Zener diode is fabricated by heavily doping both p and n sides of the junction. Due to this, thickness of depletion region is reduced to less than 1 μm which in turn increases the potential gradient of the junction to a very high value.

The current in series resistor is

$$I_S = \frac{V_S - V_Z}{R_S}$$

$$= \frac{20 - 15}{250} = \frac{5}{250} = \frac{1}{50}$$

The current in load resistor across Zener diode is **(1½)**

$$I_L = \frac{V_Z}{R_L} = \frac{15}{1000} = \frac{3}{200}$$

Thus, current across Zener diode is

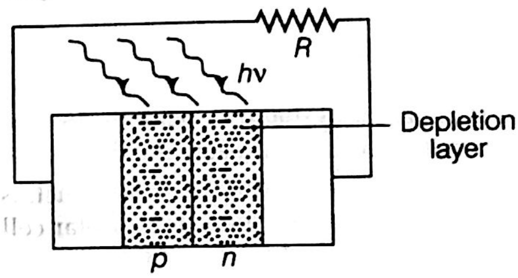
$$I_Z = I_S - I_L$$

$$= \frac{1}{50} - \frac{3}{200} = \frac{1}{200}$$

$$I_Z = 5\,\text{mA}$$ **(1½)**

35. (i) D_1 diode is forward biased, hence current will flow in B_1 bulb and D_2 is reverse biased, so there will be no current in B_2. Hence, B_1 will glow. **(1)**

(ii) The diagram of illuminated p-n junction solar cell is given below



(1)

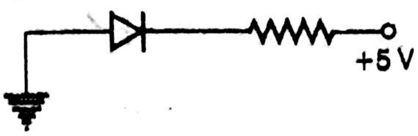
(iii) Processes involved due to generation of emf in a solar cell are given below

(a) When light photon reach the junction, the excited electrons from the valence band to conduction band creating equal number of holes and electrons.

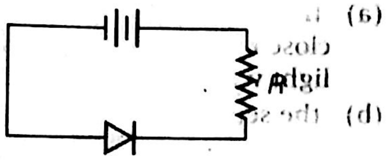
(b) These electron hole pairs move in opposite direction due to junction field. Their movement in opposite direction creates potential difference (photo-voltage).

(c) When load is connected in the external circuit, current starts flowing through it due to photo-voltage. **(1)**

36. (i) The given diagram shown below.



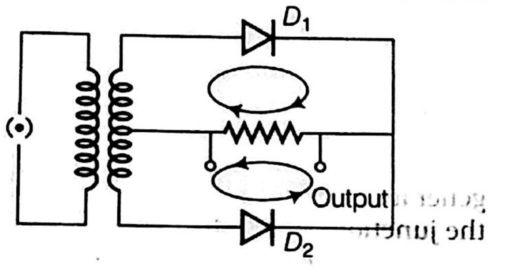
The circuit above can be redrawn as follows



As the p-section is connected to negative terminal of the battery, the diode shown is reverse biased. **(1)**

(ii) **Working of full wave rectifier**

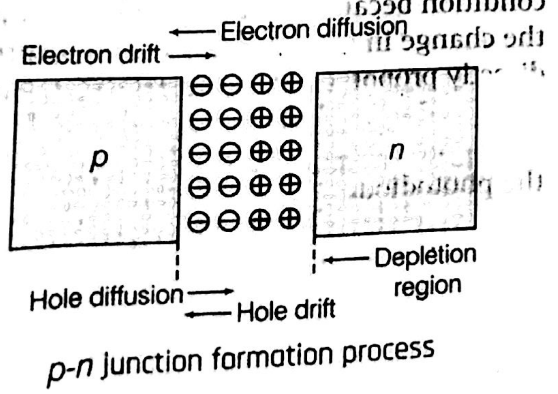
During the first half of input cycle, the upper end of the coil is at positive potential and lower end at negative potential. The function diode D_1 is forward biased and D_2 in reverse biased. Current flows in output load in the direction shown in figure. During the second half of input cycle, D_2 is forward biased. In this way, current flows in the load in the single direction as shown in figure.



Circuit diagram of full wave rectifier **(2)**

37. Two processes that take place during the formation of p-n junction are diffusion and drift of charge carriers. In a n-type semiconductor, the concentration of electrons is more than that of holes. Similarly, in a p-type semiconductor, the concentration of holes is more than that of electrons. Formation of depletion region during formation of p-n junction and due to the concentration gradient across p and n-sides, holes diffuse from p-side to n-side ($p \rightarrow n$) and electrons diffuse from n-side to p-side ($n \rightarrow p$). The diffused charge carriers combine with their counterparts in the immediate vicinity of the junction and neutralise each other. **(1)**

Thus, near the junction, positive charge is built on n-side and negative charge on p-side.



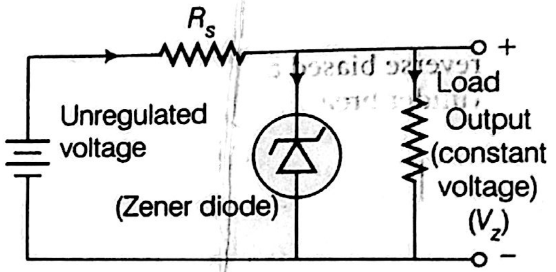
p-n junction formation process

This sets up potential difference across the junction and an internal electric field E_i directed from n-side to p-side. The equilibrium is established when the field E_i becomes strong enough to stop further diffusion of the majority charge carriers (however, it helps the minority charge carriers to drift across the junction). **(1)**

The region on either side of the junction which becomes depleted (free) from the mobile charge carriers is called **depletion region** or depletion layer. The potential difference developed across the depletion region is called the **potential barrier**. **(1)**

38. In Zener diode, both p and n-side of the junctions are heavily doped. Heavy doping ensures high junction field and low breakdown voltage. **(1)**

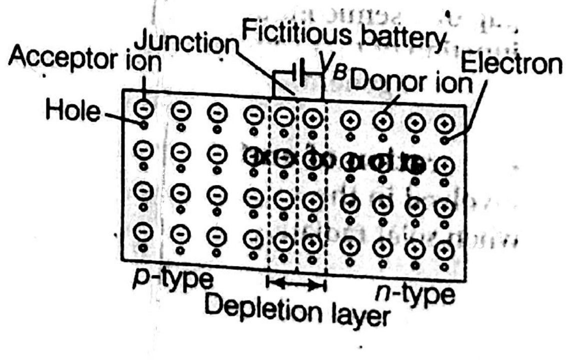
The circuit diagram of a voltage regulator using a Zener diode is shown in figure.



Excess current bypass when $V_{ext} \geq V_z$ **(1)**

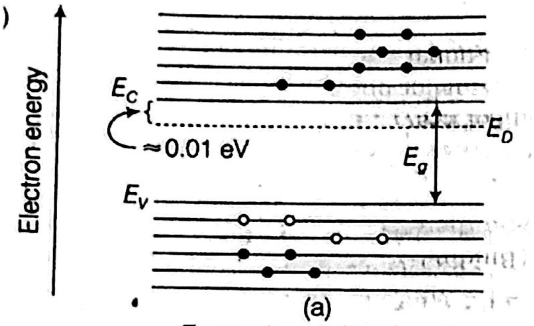
The unregulated DC voltage is connected to the Zener diode through a series resistance R_s in reverse biased. Thus, any change in the input voltage result in change of voltage drop across R_s without any change in voltage across the Zener diode. Therefore, Zener diode acts as a voltage regulator. **(1)**

39. (i) The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called depletion region.

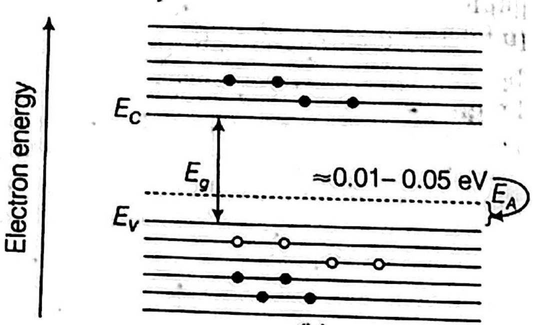


(1)

42. (i)



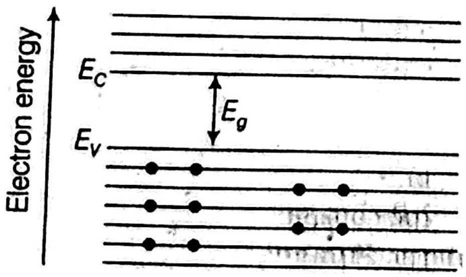
(a)
Energy band diagram of
n-type semiconductor
at $T>0$ K



(b)
Energy band diagram of
p-type semiconductor
at $T>0$ K

In *n*-type extrinsic semiconductors, the number of free electrons in conduction band is much more than the number of holes in valence band. The donor energy level lies just below the conduction band. In *p*-type extrinsic semiconductor, the number of holes in valence band is much more than the number of free electrons in conduction band. The acceptor energy level lies just above the valence band. **(1½)**

(ii)



Energy band diagram of
semiconductor at $T=0$ K

At absolute zero temperature (0 K) conduction band of semiconductor is completely empty, i.e., $\sigma=0$.

Hence, the semiconductor behaves as an insulator. At room temperature, some valence electrons acquire enough thermal energy and jump to the conduction band where they are free to conduct electricity. Thus, the semiconductor acquires a small conductivity at room temperature. **(1½)**

43. The required energy band diagrams are given in Sol. 42(i) **(2)**

The donor energy level E_D is just below the bottom of the conduction band. At room temperature, this small energy gap is easily converted by the thermally excited electrons. The conduction band has more electrons as they have been contributed both by thermal excitation and donor impurities. Whereas the acceptor energy level E_A lies slightly above the top of the valence band.

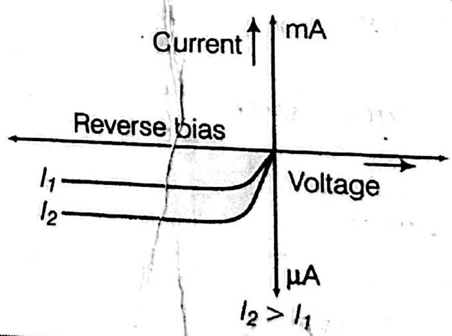
At room temperature, many electrons of the valence band get excited to these acceptor energy levels, leaving behind equal number of holes in the valence band. These holes can conduct current. Thus, the valence band has more holes than the electrons in the conduction band. **(1)**

44. Refer to text **(3)**
(Differences between conductor, insulator and semiconductor on the basis of energy bands).

45. (i) A photodiode is fabricated by allowing light to fall on a diode through a transparent window. It is fabricated such that the generation of *e*-*h* pairs take place near the depletion region. **(1)**

(ii) Refer to Sol. 7

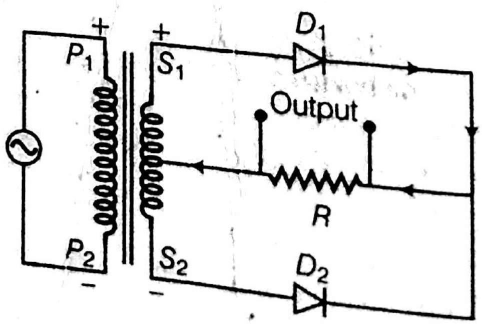
V-*I* **characteristics**

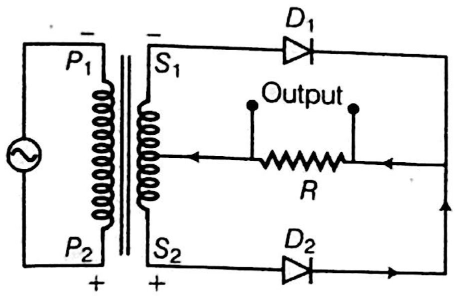


(2)

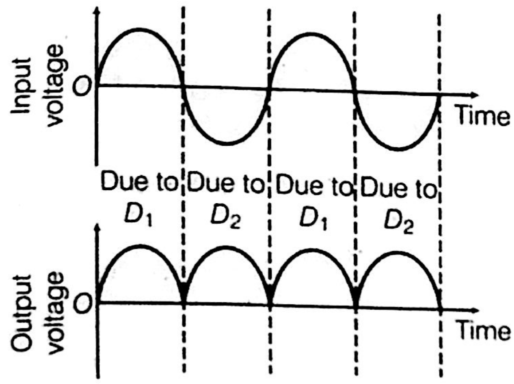
46. In these type of questions, we have to mind that in full-wave rectifier, full cycle of the input will be used.

The circuit diagram of full-wave rectifier is shown below:





The input and output waveforms have been given below:



(2)

Working of full wave rectifier

Refer to Sol 36 (ii) **(1)**

47. ***V-I* characteristic of *p-n* junction diode**

Refer to class notes . **(1)**

(i) Under the reverse bias condition, the holes of *p*-side are attracted towards the negative terminal of the battery and the electrons of the *n*-side are attracted towards the positive terminal of the battery. This increases the depletion layer and the potential barrier. However, the minority charge carriers are drifted across the junction producing a small current.

At any temperature, the number of minority carriers is constant, so there is the small current at any applied potential. This is the reason for the current under reverse bias to be almost independent of applied potential. At the critical voltage, avalanche breakdown takes place which results in a sudden flow of large current. **(1)**

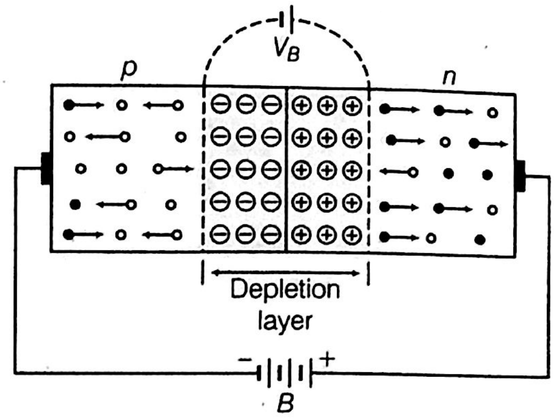
(ii) At the critical voltage, the holes in the *n*-side and conduction electrons in the *p*-side are accelerated due to the reverse bias voltage. These minority carriers acquire sufficient kinetic energy from the electric field and collide with a valence electron.

Thus, the bond is finally broken and the valence electrons move into the conduction band resulting in enormous flow of electrons and thus, formation of hole-electron pairs. Thus, there is a sudden increase in the current at the critical voltage.

Zener diode is a semiconductor device which operates under the reverse bias in the breakdown region. **(1)**

48. Refer to Sol. 46 **(3)**

49.



During the formation of *p-n* junction, diffusion of charge takes place. As, soon as *p*-type semiconductor is joined with *n*-type semiconductor, diffusion of free charges across the junction starts. **(1)**

For explanation of formation of *p-n* junction

Refer to Sol. 24 **(1)**

Potential barrier The accumulation of '–ve' charges in the *p*-region and +ve charges in the *n*-region sets up a potential difference across the junction (*p-n*) is called potential barrier (V_B) which opposes the further diffusion of electrons and holes. **(1)**

50. In these type of questions, we should mind that the diode is connected reverse biased or forward biased.

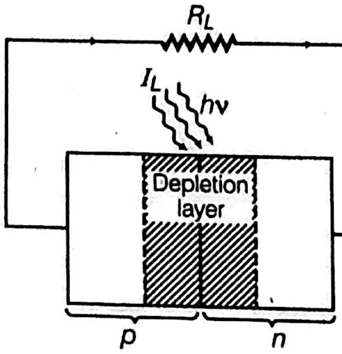
(i) Photodiode is connected in reverse bias and feeble reverse current flows due to thermally generated electron-hole pair, known as **dark current.** When light of suitable frequency (ν) such that $h\nu > E_g$, where E_g is the band gap incident on diode, additional electron-hole pair generated and current grows in the circuit. **(1)**

(ii) Refer to Sol 29(i) **(1)**

(iii) Refer to Sol 28 **(1)**

51. (i) Refer to Sol 21(i) **(1)**

(ii) When light of frequency, ν such that $h\nu > E_g$ (band gap) is incident on junction, then electron-hole pair liberated in the depletion region drifts under the influence of potential barrier. The gathering of these charge carriers make p-type as positive electrode and n-type as negative electrode and hence, generating photo-voltage across solar cell.



(2)

52. (i) **Working of LED** LED is a forward biased p-n junction which converts electrical energy into optical energy of infrared and visible light region. Being in forward bias, thin depletion layer and low potential barrier facilitate diffusion of electron and hole through the junction. When high energy electron of conduction band combines with the low energy holes in valence band, then energy is released in the form of photon, which may be seen in the form of light. **(1)**

(ii) Semiconductors with appropriate band gap (E_g) close to 1.5 eV are preferred to make LED size, e.g. GaAs.

The other reasons to select these materials are high optical absorption, availability of raw material and low cost. **(1)**

(iii) **Uses of LEDs**

(a) LED can operate at very low voltage and consumes less power in comparison to incandescent lamps.

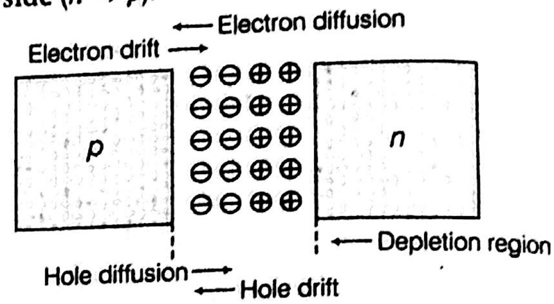
(b) Unlike the lamps, they take very less operational time and have long life. **(1)**

53. (i) Refer to Sol. 37 **($2\frac{1}{2}$)**

(ii) Refer to text (Forward Biased Characteristic) **($2\frac{1}{2}$)**

54. (i) ***p-n* Junction** A p-n junction is an arrangement made by a close contact of n-type semiconductor and p-type semiconductor. There are various methods of forming p-n junction diode. **(1)**

Formation of Depletion Region in *p-n* Junction In an n-type semiconductor, the concentration of electrons is more than concentration of holes. Similarly, in a p-type semiconductor, the concentration of holes is more than that of concentration of electrons. During formation of p-n junction and due to the concentration gradient across p and n-sides, holes diffuse from p-side to n-side ($p \rightarrow n$) and electrons diffuse from n-side to p-side ($n \rightarrow p$).

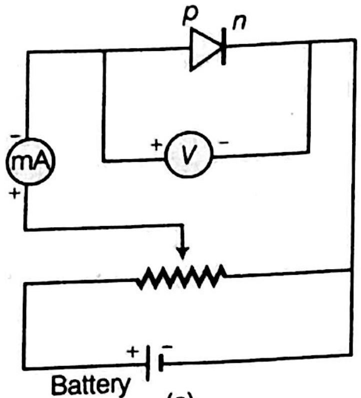


The diffused charge carriers combine with their counterparts in the immediate vicinity of the junction and neutralise each other. **(1)**

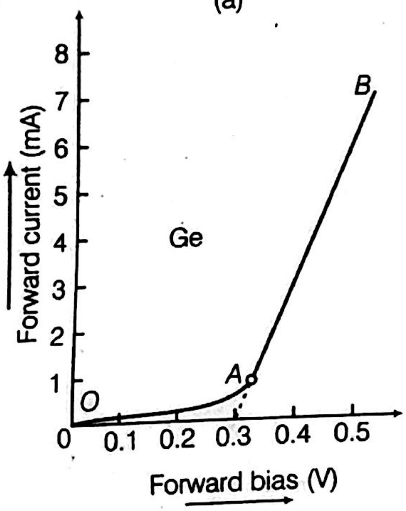
Thus, near the junction, positive charge is built on n-side and negative charge on p-side. This sets up potential difference across the junction and an internal electric field E_i directed from n-side to p-side. The equilibrium is established when the field E_i becomes strong enough to stop further diffusion of the majority charge carriers (however, it helps the minority charge carriers to diffuse across the junction). The region on either side of the junction which becomes depleted (free) from the mobile charge carriers is called depletion region or **depletion layer.** The width of depletion region is of the order of 10^{-6} m. The potential difference developed across the depletion region is called the potential barrier. Potential barrier depends on dopant concentration in the semiconductor and temperature of the junction. **(1)**

(ii) (a) **Forward Biased Characteristics**

The circuit diagram for studying forward biased characteristics is shown in the figure. Starting from a low value, forward bias voltage is increased step by step (measured by voltmeter) and forward current is noted (by ammeter). A graph is plotted between voltage and current. The curve so obtained is the forward biased characteristic of the diode.



(a)

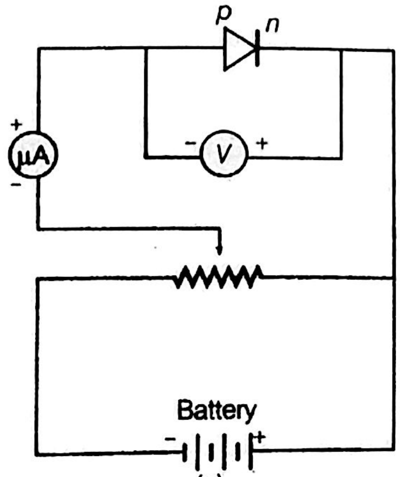


(b)

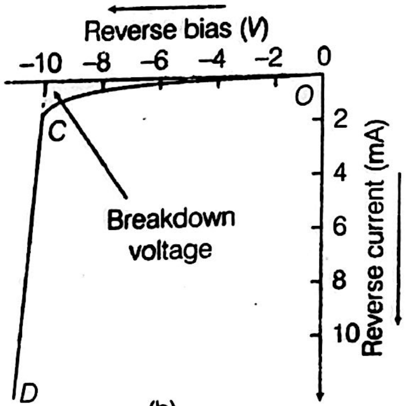
At the beginning, when applied voltage is low, the current through the diode is almost zero. It is because of the potential barrier, which opposes the applied voltage. Till the applied voltage exceeds the potential barrier, the current increases very slowly with increase in applied voltage (*OA* portion of the graph). With further increase in applied voltage, the current increases very rapidly (*AB* portion of the graph), in this situation, the diode behaves like a conductor. The forward voltage beyond which the current through the junction starts increasing rapidly with voltage is called **knee voltage**. If line *AB* is extended back, it cuts the voltage axis at potential barrier voltage. **(1)**

(b) Reverse Biased Characteristics

The circuit diagram for studying reverse biased characteristics is shown in the figure.



(a)



(b)

In reverse biased, the applied voltage supports the flow of minority charge carriers across the junction. So, a very small current flows across the junction due to minority charge carriers.

Motion of minority charge carriers is also supported by internal potential barrier, so all the minority carriers cross over the junction.

Therefore, the small reverse current remains almost constant over a sufficiently long range of reverse bias, increasing very little with increasing voltage (*OC* portion of the graph). This reverse current is voltage independent upto certain voltage known as **breakdown voltage** and this voltage independent current is called **reverse saturation current**.

Use of *p-n* Junction Characteristics in Rectification

From forward and reverse characteristics, it is clear that current flows through the junction diode only in forward bias not in reverse bias i.e. current flows only in one direction. **(1)**

(3)

55. (i) Refer to Sol. 54(ii) **(2)**

(ii) Refer to Sol. 28 **(3)**

56. (i) Refer to Sol. 54 (i) **(2)**

(ii) Refer to Sol. 46

57. (i) Refer to Sol. 54(i) **(1)**

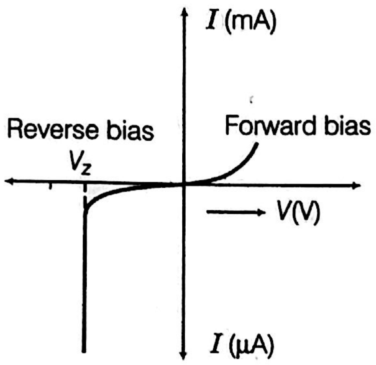
(ii) Refer to Sol. 46 **(1)**

(iii) A full-wave bridge rectifier using four diodes (full-wave bridge rectifier) gives a continuous, unidirectional but pulsating output voltage or current. **(1)**

The rectified output is passed through a filter circuit which removes the ripple and an almost steady DC voltage (or current) is obtained. **(2)**

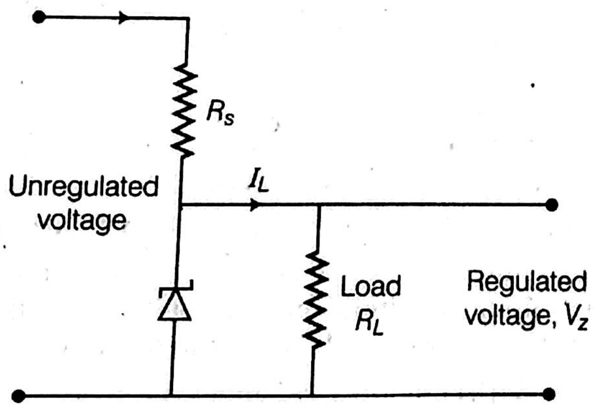
58. Zener diode works only in reverse breakdown region that is why it is considered as a special purpose semiconductor. **(1)**

I-V characteristics of Zener diode is given below **(1)**



Reverse current is due to the flow of electrons from $n \rightarrow p$ and holes from $p \rightarrow n$. As, the reverse biased voltage increase the electric field across the junction, increases significantly and when reverse bias voltage $V = V_z$, then the electric field strength is high enough to pull the electrons from *p*-side and accelerated it to *n*-side. **(1)**

These electrons are responsible for the high current at the breakdown.



Voltage regulator converts an unregulated DC output of rectifier into a constant regulated DC voltage, using Zener diode.

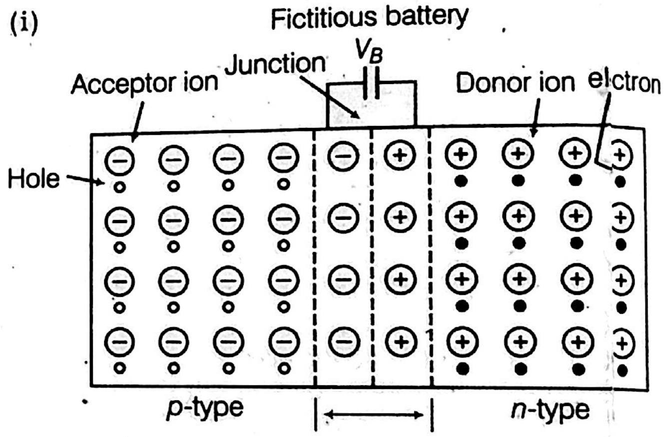
The unregulated voltage is connected to the Zener diode through a series resistance R_S such that the Zener diode is reverse biased. If the input voltage increases, then current through R_S and Zener diode increases. Thus, the voltage drop across R_S increases without any change in the voltagedrop across Zener diode. This is because of the breakdown region, Zener voltage remain constant even though the current through Zener diode changes. Similarly, if the input voltage decrases, the current through R_S and Zener diode decreases. The voltage drop across R_S, decreses without any change in the voltage across the Zener diode. **(1)**

Now, any change in input voltage results th change in voltage drop across R_S, without any change in voltage across the Zener diode.Thus, Zener diode acts as a voltage regulator. **(1)**

59.

> When we are dealing with depletion layer formation we have to keep in mind the majority charge carriers, diffusion will always happen from high concentration to low concentration.

(i)



The two process involved in the formation of *p-n* junction.

(a) Diffusion (b) Drift. **(1/2 × 2 = 1)**

Holes and electrons diffuse from *p* to *n* and *n* to *p* respectively.

The majority charge carrier drifts under the influence of applied electric field such that

(a) holes along applied **E** and

(b) electron opposite to **E** **(1/2 × 2 = 1)**

(ii) Zener diode is used as a voltage regulator. For explanation Refer to Sol. 22 and 58 **(3)**

60. (i) Refer to Sol. 54 (ii) **(2)**

(ii) Refer to Sol. 52(i) and (iii) **(3)**

61. (i) Refer characteristics curve of Sol. 22 **(1)**

(ii) **Circuit diagram** Refer to Sol. 38 **(1)**

Zener diode connected with unregulated DC voltage in reverse bias. When the input voltage increases, then current through R_s increase and hence, voltage drop across R_s, increases while voltage across the Zener diode remains constant. The voltage across Zener diode remains constant beyond Zener voltage and hence, same/constant regulated voltage is obtained across R_L. **(1)**

(iii) In n-type semiconductor, $n_e \gg n_h$ ...(1)

On incidence of light of suitable frequency, there is equal rise in number of electrons and holes [i.e. Δn (say)]

$$\Rightarrow \quad \frac{1}{n_e} < \frac{1}{n_h} \text{ or } \frac{\Delta n}{n_e} < \frac{\Delta n}{n_h}$$

where, Δn = change in electron or hole charge carrier. Thus, fractional change in minority charge carrier (hole) is much higher than fraction change in majority charge carrier (electron). Also, minority charge carrier contribute in drift current in reverse bias.

Thus, with incidence of light, fractional change in minority charge carrier is significant. Therefore, photodiode should be connected in reverse bias for measuring light intensity. **(2)**

62. (i) Refer to Sol. 54 (ii) **(3)**

(ii) Refer to Sol. 52 **(2)**

Objective Questions

1 Mark Questions

1. In insulators (CB is Conduction Band and VB is Valence Band)

(a) VB is partially filled with electrons
(b) CB is partially filled with electrons
(c) CB is empty and VB is filled with electrons
(d) CB is filled with electrons and VB is empty

2. Identify the wrong statement.

(a) In conductors, the valence and conduction bands overlap.
(b) Substances with energy gap of the order of 10 eV are insulators.
(c) The resistivity of semiconductors is lower than metals.
(d) The conductivity of metals is high.

3. In the band gap between valence band and conduction band in a material is 5.0 eV, then the material is

(a) semiconductor (b) good conductor
(c) superconductor (d) insulator

4. In n-type semiconductor, electrons are majority charge carriers but it does not show any negative charge. The reason is

(a) electrons are stationary
(b) electrons neutralise with holes
(c) mobility of electrons is extremely small
(d) atom is electrically neutral

5. In a n-type semiconductor, which of the following statement is true?

(a) Electrons are majority carriers and trivalent atoms are dopants
(b) Electrons are minority carriers and pentavalent atoms are dopants
(c) Holes are minority carriers and pentavalent atoms are dopants
(d) Holes are majority carriers and trivalent atom are dopants

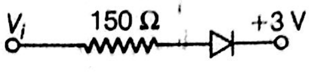
6. If a small amount of antimony is added to germanium crystal

(a) the antimony becomes an acceptor atom
(b) there will be more free electrons than holes in the semiconductor
(c) its resistance is increased
(d) it becomes a p-type semiconductor

7. Identify the wrong statement with reference to solar cell.

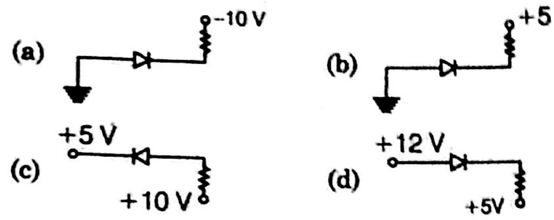
(a) It is a p-n junction diode with no external bias.
(b) It uses materials of high optical absorption.
(c) It uses materials with band gap of 5 eV.
(d) It converts light energy into electrical energy.

8. In the circuit shown below, assume the diode to be ideal. When V_i increases from 2 V to 6 V, the change in the current is (in mA)



(a) zero (b) 20
(c) 80/3 (d) 40

9. In the following figures, which one of the diode is reverse biased?



10. Zener diode is used for
(a) amplification
(b) rectification
(c) voltage regulation
(d) produce oscillation in an oscillator

11. When two semiconductors of p-type and n-type are brought into contact, they form a p - n junction which acts like a
(a) conductor (b) oscillator
(c) amplifier (d) rectifier

12. For detecting intensity of light, we use
(a) photodiode in forward bias
(b) photodiode in reverse bias
(c) LED in forward bias
(d) LED in reverse bias

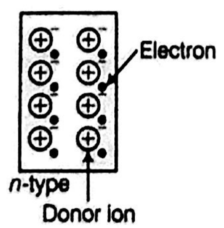
Explanations

1. *(c)* In insulators conduction band is empty and valence band is filled with electrons.

2. *(c)* The resistivity of semiconductors is lower than metals,this is not correct.

3. *(d)* The band gap of 5 eV corresponds to that of an insulator.

4. *(d)* The n-type semiconductor region has (negative) electrons as majority charge carriers and an equal number of fixed positively charged donor ions. Again, the material as a whole is neutral. That is a reason that atom is electrically neutral.

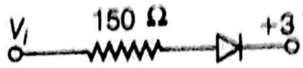


5. *(c)* The n-type semiconductor can by produced by doping an impurity atom of valency 5, i.e. pentavalent atoms such as phosphorus and electrons are as majority charge carrier and holes are minority charge carrier.

6. *(b)* When a small amount of antimony is added to germanium crystal, the crystal becomes n-type semiconductor, because antimony is a pentavalent substrate. It has excess free electrons.

7. *(c)* The wrong statement with reference to a solar cell is that, it uses materials with band gap of 5 eV. Because for solar cell, band gap < 3 eV.

8. *(b)* The initial current, $I_{in} = 0$

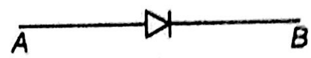


and the final current, $I_f = \frac{3}{150} = 0.02$ A

So, change in current, ΔI

$= I_f - I_{in} = 0.02$ A $= 20$ mA

9. *(b)* A diode is symbolically shown in the adjacent diagram.

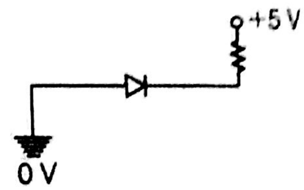


The diode is said to be forward biased when, $V_A > V_B$.

The diode is said to be reverse biased when, $V_A < V_B$

In the option (b),

5 V > 0 V



Hence, $V_B > V_A$

So, the diode is reverse biased.

10. *(c)* A zener voltage remains constant even though the current through the zener diode varies over a wide range, hence it is used to obtain regulated voltage output as shown in the above diagram.

11. *(d)* An p-n junction acts as a rectifier.

12. *(b)* To detect the intensity of light photodiode is used in reverse bias.