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The basic building blocks of any electronic circuit are the devices which have controlled flow of electrons. Before the discovery of **semiconductor devices**, such devices were mostly vacuum tubes. The vacuum tubes which have two electrodes : anode and cathode, are called **diode valves** and the tubes which have three electrodes : cathode, anode and grid, are called **triode valves**. Such devices were bulky, consume high power, generally operate at high voltages and have limited life and low reliability.

# SEMICONDUCTOR ELECTRONICS : MATERIALS, DEVICES AND SIMPLE CIRCUITS



**CHAPTER CHECKLIST**
- Semiconductor, Diode and Its Applications

The seed of growth and development of modern solid state semiconductor electronics goes back to 1930, when it was realised that some semiconductors and their junctions have the ability of controlling the number and the direction of flow of charge carriers through them. Simple excitation with the help of light, heat or small applied voltage can change the number of mobile charge carriers in a semiconductor. The supply and flow of charge carriers in these devices are within the solid itself, no vacuum or external heating is required. So, these devices are small in size, consume low power, operate at low voltages and have long life and high reliability.

## CLASSIFICATION OF METALS, CONDUCTORS AND SEMICONDUCTORS ON THE BASIS OF CONDUCTIVITY

On the basis of the relative values of electrical conductivity ($\sigma$) or resistivity ($\rho = 1/\sigma$), the solids are broadly classified as,

(i) **Metals** They possess very low resistivity (or high conductivity).

$$\rho \sim 10^{-2}\text{-}10^{-8}\,\Omega\text{m},\ \sigma \sim 10^{2}\text{-}10^{8}\ \text{Sm}^{-1}$$

(ii) **Semiconductors** They have resistivity or conductivity intermediate to metals and insulators.

$$\rho \sim 10^{-5}\text{-}10^{6}\,\Omega\text{m},\ \sigma \sim 10^{+5}\text{-}10^{-6}\,\text{Sm}^{-1}$$

(iii) **Insulators** They have high resistivity (or low conductivity).

$$\rho \sim 10^{11} - 10^{19}\,\Omega\text{m},\ \sigma \sim 10^{-11} - 10^{-19}\ \text{Sm}^{-1}$$

The values of $\rho$ and $\sigma$ given above are indicative of magnitude and could well go outside the ranges as well.

Our interest in this chapter is in the study of semiconductors, which can be of the following types

(i) **Element semiconductors** These semiconductors are available in natural form.

e.g. Silicon and germanium.

(ii) **Compound semiconductors** These semiconductors are made by compounding the metals. e.g.

(a) Inorganic semiconductors are CdS, GaAs, CdSe, InP, etc.

(b) Organic semiconductors are anthracene, doped pthalocyanines, etc.

(c) Organic polymer semiconductors are polypyrrole, polyaniline, polythiophene, etc.

# ENERGY BANDS IN SOLIDS (CONDUCTOR, INSULATOR AND SEMICONDUCTOR)

## Energy Band

According to Bohr's atomic model and concept of electronic configuration in an isolated atom, the electrons have certain definite discrete amounts of energy corresponding to different shells and subshells, i.e. there are well-defined energy levels of electrons in an isolated atom.

But in a crystal due to interatomic interaction, valence electrons are shared by more than one atom. Due to this, splitting of energy level takes place. The collection of these closely spaced energy levels is called an **energy band**. These bands are formed due to the continuous energy variation in different energy levels.

These different energy levels in different electrons are formed because inside the crystal, each electron has a unique position and no two electrons is exactly at the same pattern of surrounding charges.

## Valence Band

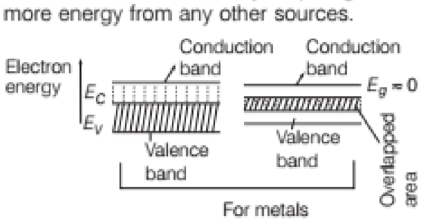
The energy band, which includes the energy levels of the valence electrons is called valence band. This band may be partially or completely filled with electrons but is never empty.

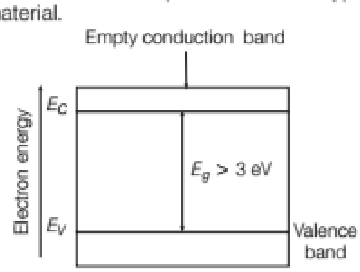
## Conduction Band

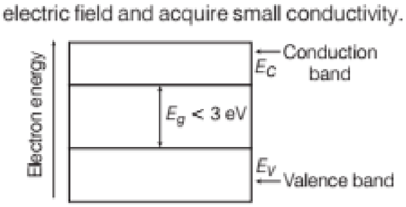
The energy band above the valence band is called conduction band. At room temperature, this band is either empty or partially filled with electrons. Electrons can gain energy from external electric field, then jump from valence to conduction band and contribute to the electric current.

**Difference between Conductor, Insulator and Semiconductor on the basis of Energy Bands**

| Conductor (Metal) | Insulator | Semiconductor |
|---|---|---|
| In conductor, either there is no energy gap between the conduction band which is partially filled with electrons and valence band or the conduction band and valence band overlap each other. | In insulator, the valence band is completely filled, the conduction band is completely empty. In this, energy gap is quite large and even energy from any other source cannot help electrons to overcome it. | In semiconductor, the valence band is totally filled and the conduction band is empty but the energy gap between conduction band and valence band, unlike insulators is very small. |
| Thus, many electrons from below the fermi level can shift to higher energy levels above the fermi level in the conduction band and behave as free electrons by acquiring a little more energy from any other sources. | Thus, electrons are bound to valence band and are not free to move. Hence, electric conduction is not possible in this type of material. | Thus, at room temperature, some electrons in the valence band acquire thermal energy greater than energy band gap and jump over to the conduction band where they are free to move under the influence of even a small electric field and acquire small conductivity. |



## Energy Band Gap

The minimum energy required for shifting electrons from valence band to conduction band is called energy band gap ($E_g$). It is the gap between the top of the valence band and bottom of the conduction band. It can be zero, small or large depending upon the material.

**Note** If $\lambda$ is the wavelength of radiation used in shifting the electron from valence band to conduction band, then energy band gap is

$$\boxed{E_g = h\nu = hc/\lambda}$$

where, $h$ is called Planck's constant and $c$ is the velocity of light.

## Fermi Energy

It is the maximum possible energy possessed by free electrons of a material at absolute zero temperature (i.e. 0 K). The value of fermi energy is different for different materials.

# SEMICONDUCTORS

The materials whose conductivity lie between metals and insulators are known as semiconductors. They are characterised by narrow energy gap (less than 3eV) between the valence band and conduction band. At absolute zero temperature, all states in valence band are filled and all states in conduction band are empty. An applied electric field cannot give so much energy to the valence electrons that they could cross the gap and enter the conduction band. Hence, at low temperatures, pure semiconductors are insulators.

### *Electrons and Holes in Semiconductors*

At room temperature, however some of the valence electrons acquire thermal energy greater than $E_g$ and move into conduction band. A vacancy is created in the valence band at each place where an electron was present before moving into conduction band. This vacancy is called hole. It is a seat of positive charge of magnitude equal to the charge of an electron. Thus, free electrons in the conduction band and the holes are created in the valence band, which can move even under a small applied field. The solid is therefore conducting.

On the basis of purity, semiconductors are of two types

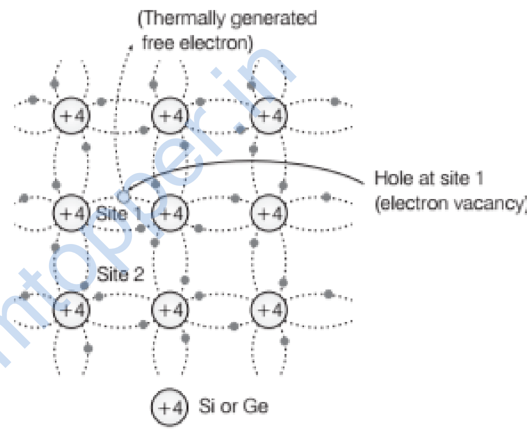
## Intrinsic Semiconductors

This type of semiconductor is also called an **undoped semiconductor** or ***i*-type semiconductor**. It is a pure semiconductor without any significant presence of dopant species. Pure germanium, silicon in their natural state are intrinsic semiconductors.

The number of charge carriers is determined by the properties of the material itself instead of the amount of impurities. In intrinsic semiconductors, the number of excited electrons is equal to number of holes, i.e. $n_h = n_i$ where $n_i$ is called intrinsic carrier concentration. At temperature 0 K, the valence band is filled. The energy gap is 0.72 eV and the conduction band is totally empty.

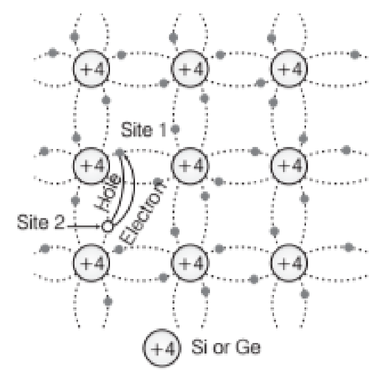
Under the action of an electric field, holes move towards negative potential giving hole current $I_h$. The total current $I$ is the sum of the electron current $I_e$ and the hole current $I_h$, i.e. $I = I_e + I_h$.

It may be noted that apart from the process of generation of conduction in electrons and holes, a simultaneous process of recombination occurs in which the electrons recombine with the holes. At equilibrium, the rate of generation is equal to rate of recombination of charge carriers. The recombination occurs due to an electron colliding with a hole.




(a)

Fig. (a) is representing the generation of hole at site 1 and conduction electron due to thermal energy at moderate temperatures




(b)

Fig. (b) is representing possible thermal motion of a hole. The electron from the lower left hand covalent bond (site 2) goes to the earlier hole site 1, leaving a hole at its site indicating an apparent movement of the hole from site 1 to site 2

An intrinsic semiconductor behaves like an insulator at $T = 0\,\text{K}$. The thermal energy at higher temperature is the only reason which excites some electrons from the valence band to the conduction band.

In Fig. (b) these thermally excited electrons at $T > 0\,\text{K}$, partially occupy the conduction band. They have come from the valence band leaving equal number of holes there.

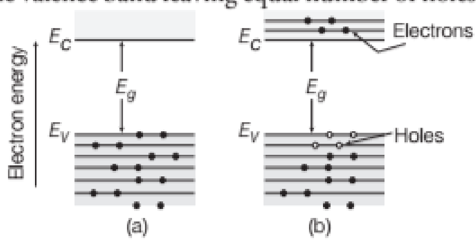



Fig. (a) an intrinsic semiconductor at $T = 0\text{K}$ behaves like insulator. Fig. (b) is representing four thermally generated electron-hole pairs at $T > 0\text{K}$

## Extrinsic Semiconductors

The conductivity of intrinsic semiconductors is very low at room temperature. But, it can be significantly increased, if some pentavalent or trivalent impurity is mixed with it. Hence, those semiconductors in which some impurity atoms are embedded are known as extrinsic or impurity semiconductors.

**NOTE** When some desirable impurity is added to intrinsic semiconductors deliberately then this process is called doping and the impurity are called dopants. The process of adding impurity to an intrinsic semiconductor in a controlled manner is called **doping**.

There are two types of dopants used in doping.

(i) Trivalent (valency 3) atoms: e.g., Indium (In), Boron (B), aluminium (Al), etc.

(ii) Pentavalent (valency 5) atoms: e.g., Arsenic (As), Antimony (Sb), Phosphorous (P), etc.

Extrinsic semiconductors are basically of two types

(i) *n*-type semiconductors (ii) *p*-type semiconductors

### *n*-Type Semiconductors

This type of semiconductor is obtained when pentavalent impurity is added to Si or Ge. During doping, four electrons of pentavalent element bond with the four silicon neighbours while fifth remains very weakly bound to its parent atom. Also the ionisation energy required to set this electron free is very small.

Hence, these electrons are almost free to move. In other words, we can say that these electrons are donated by the impurity atoms. So, these are also known as **donor atoms** and the conduction inside the semiconductor will take place with the help of the negatively charged electrons. Due to this negative charge, these semiconductors are known as ***n*-type semiconductors**. When the semiconductors are placed at room temperature, then the covalent bond breakage takes place. So, more free electrons are generated. As a result, same number of holes generation takes place. But as compared to the free electrons, the number of holes are comparatively less due to the presence of donated electrons, i.e. $n_e >> n_h$.

Therefore, major conduction in *n*-type semiconductors is due to electrons. So, electrons are known as **majority carriers** and the holes are known as the **minority carriers**.

This means, $n_e >> n_h$; $I_e >> I_h$

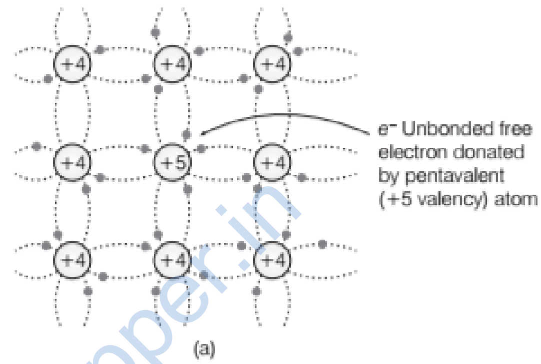



Fig. (a) Pentavalent donor atom (As, Sb, P, etc.) doped for tetravalent Si or Ge giving *n*-type semiconductor

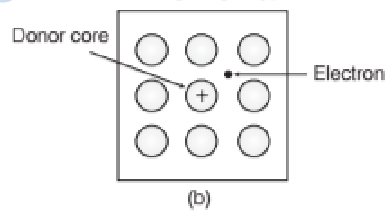



Fig. (b) Commonly used schematic representation for *n*-type material which shows only the fixed cores of the substituent donors with one additional effective positive charge and its associated extra electron.

### *p*-Type Semiconductors

This type of semiconductor is obtained when a trivalent impurity is added to Si or Ge.

So, the three valence electrons of the doped impure atoms will form the covalent bonds with silicon atoms but silicon atoms have four electrons in its valence shell. Hence, one covalent bond will be improper.

This means, one more electron is needed for the proper covalent bonding. This need of one electron is fulfilled from any of the bond between two silicon atoms. So, the bond between the silicon and impurity atoms will be completed. After bond formation, the doped impurity will get ionised. As we know that, ions are negatively charged. So, the impurity will also get negative charge.

As, hole was created when the electron come from silicon-silicon bond moved to complete the bond between the doped impurity and silicon. Due to this, an electron will now move from any one of the covalent bond to fill the empty hole. This will further result in a new hole formation. So, in *p*-type semiconductor, the holes movement results in the formation of the current. This means, in this type of semiconductor majority charge carriere are holes, i.e. positively charged and minority charge carriers are electrons, i.e. $n_h >> n_e$ .; $I_h >> I_e$. Hence, these conductors are known as *p*-type semiconductors or acceptor type semiconductors.

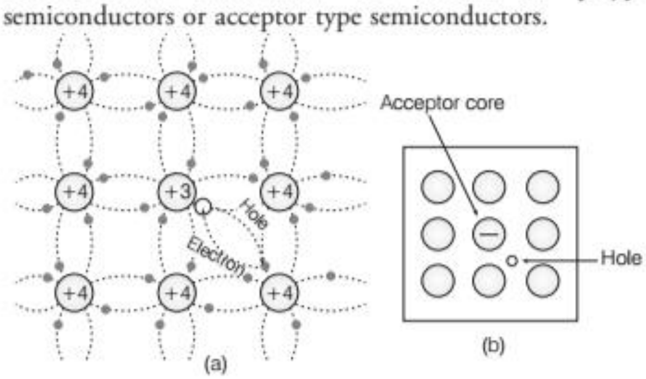



Fig. (a) Trivalent acceptor atom (In, Al, B, etc.) doped in tetravalent Si or Ge lattice giving *p*-type semiconductor. Fig. (b) Commonly used schematic representation of *p*-type material which shows only the fixed core of the substituent acceptor with one effective additional negative charge and its associated hole.

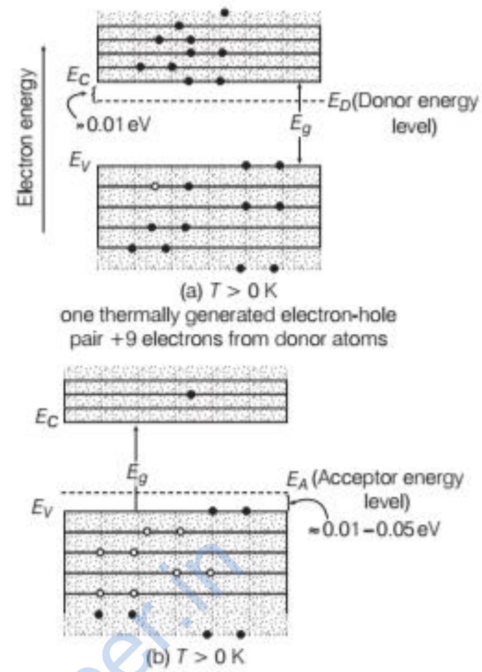
The electron and hole concentration in a semiconductor in thermal equilibrium is given by $n_e n_h = n_i^2$.

**Note** The energy gaps of C,Si and Ge are 5.4 eV, 1.1 eV and 0.7 eV, respectively.
Sn is a group IV element as its energy gaps is zero.

## Energy Band in Extrinsic Semiconductors

In extrinsic semiconductors, additional energy states due to donor impurities ($E_D$) and acceptor impurities ($E_A$) also exist. In the energy band diagram of *n*-type semiconductor, the donor energy level $E_D$ is slightly below the bottom $E_C$ of conduction band and the electrons from this level move into conduction band with very small supply of energy.

In *p*-type semiconductors, the acceptor energy level $E_A$ is slightly above the top energy level $E_V$ of the valence band. With very small supply of energy an electron from the valence band can jump to the level $E_A$ and ionise the acceptor negatively.




Energy bands of (a) *n*-type semiconductor at $T > 0$ K, (b) *p*-type semiconductor at $T > 0$ K

**EXAMPLE |1|** The number of silicon atoms per $m^3$ is $5 \times 10^{28}$. This is doped simultaneously with $5 \times 10^{22}$ atoms per $m^3$ of arsenic and $5 \times 10^{20}$ atoms per $m^3$ of indium. Calculate the number of electrons and holes. Given that, $n_i = 1.5 \times 10^{16} m^{-3}$. Is the material *n*-type or *p*-type?

**NCERT**

**Sol.** For each atom doped with arsenic, one free electron is received. Similarly, for each atom doped of indium, a vacancy is created. So, number of free electrons introduced by pentavalent impurity is

$$N_{As} = 5 \times 10^{22} \ m^{-3}$$

The number of holes introduced by trivalent impurity added is $N_I = 5 \times 10^{20} \ m^{-3}$

So, net number of electrons added is

$$n_e = N_{As} - N_I = 5 \times 10^{22} - 5 \times 10^{20} = 4.95 \times 10^{22} \ m^{-3}$$

We know that,

$$n_e n_h = n_i^2$$

So, $$n_h = \frac{n_i^2}{n_e} = \frac{(1.5 \times 10^{16})^2}{4.95 \times 10^{22}} = 4.54 \times 10^9 \ m^{-3}$$

As, $n_e > n_h$ (number of holes). So, the material is *n*-type semiconductor.

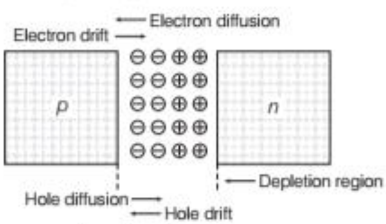
# $p$-$n$ JUNCTION

It 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. In one method, an $n$-type germanium crystal is cut into thin slices called wafers. An aluminium film is laid on an $n$-type wafer, which is then heated in an oven at a temperature of about 600° C. Aluminium then diffuses into the surface of wafer. In this way, a $p$-$n$ junction is formed.

## Formation of Depletion Region in $p$-$n$ Junction

In an $n$-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. 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 ($p \rightarrow n$) 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.

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 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.

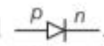
The potential difference developed across the depletion region is called the **potential barrier**. It depends on dopant concentration in the semiconductor and temperature of the junction.

**Note**

- Due to the diffusion of holes from $p$-side to $n$-side and electrons from $n$-side to $p$-side at the junction, a current rises from $p$-side to $n$-side, which is called **diffusion current.**
- If an electron-hole pair is created on the depletion region due to thermal collision, the electrons are pushed by the electric field towards the $n$-side and the holes towards the $p$-side, which gives rise to a current from $n$-side to $p$-side known as **drift current**.
- In steady state, diffusion current = drift current.

# SEMICONDUCTOR DIODE OR $p$-$n$ JUNCTION DIODE

It is basically a $p$-$n$ junction with metallic contacts provided at the ends for the application of an external voltage. It is a two terminal device.

It is represented by the symbol .

The direction of arrow indicates the conventional direction of current.

## Forward Biasing and Reverse Biasing of Junction Diode

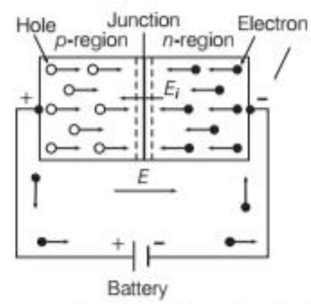
Biasing is the method of connecting external battery or emf source to a $p$-$n$ function diode. The junction diode can be connected to an external battery in two ways, called **forward biasing** and **reverse biasing** of the junction.

### Forward Biasing

A junction diode is said to be forward biased when the positive terminal of the external battery is connected to the $p$-side and negative terminal to the $n$-side of the diode.

### Flow of Current in Forward Biasing

In this situation, the forward voltage opposes the potential barrier, due to which both the potential barrier and width of the depletion layer decreases. Under the effect of external electric field, holes in the $p$-region and electrons in the $n$-region, both move towards the junction. These holes and electrons mutually combine just near the junction and cease to exist. For each electron-hole combination, a covalent bond breaks up in the $p$-region near the positive terminal of the battery. Out of the hole and electron so produced, the hole moves towards the junction, while the electron enters the positive terminal of the battery through the connecting wire.



Forward biasing of junction diode

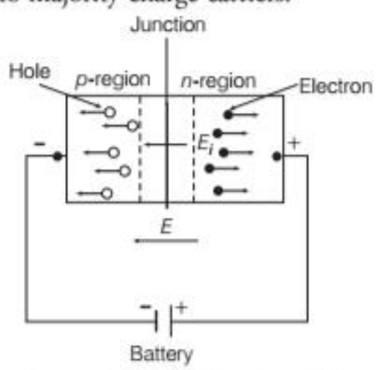
Just at this moment, an electron is released from the negative terminal of the battery which enters the $n$-region to replace the electron lost by combining with a hole at the junction. Thus, a current called **forward current**, is constituted by the motion of majority charge carriers across the junction. In forward bias, the junction diode offers low resistance.

### Reverse Biasing

A junction diode is said to be reverse biased when the positive terminal of the external battery is connected to the *n*-side and negative terminal to the *p*-side of the diode.

### Flow of Current in Reverse Biasing

In this situation, the reverse voltage supports the potential barrier, due to which both the potential barrier and with of the depletion layer increases. Under the effect of external electric field, holes in the *p*-region and electrons in the *n*-region are pushed away from the junction i.e. they cannot be combined at the junction. So, there is almost no flow of current due to majority charge carriers.




Reverse biasing of junction diode

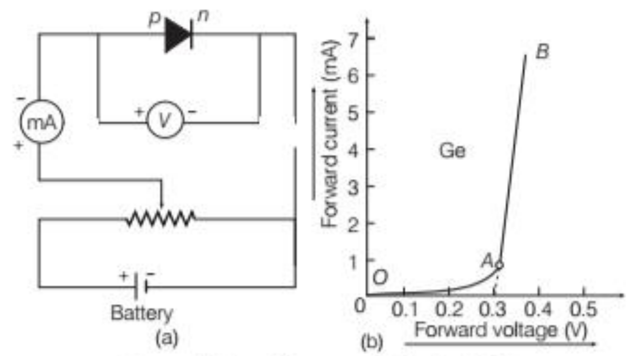
However, a very small current due to minority charge carriers, flows across the junction. This current is called **reverse current**.

## *I-V* (CURRENT-VOLTAGE) CHARACTERISTICS OF *p-n* JUNCTION DIODE

The graphical relations between voltage applied across *p-n* junction and current flowing through the junction are called ***I-V* characteristics of junction diode**.

### Forward Biased Characteristics

The circuit diagram for studying forward biased characteristics is shown in the figure (a). 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 is shown in figure (b).




Forward biased characteristic of a diode

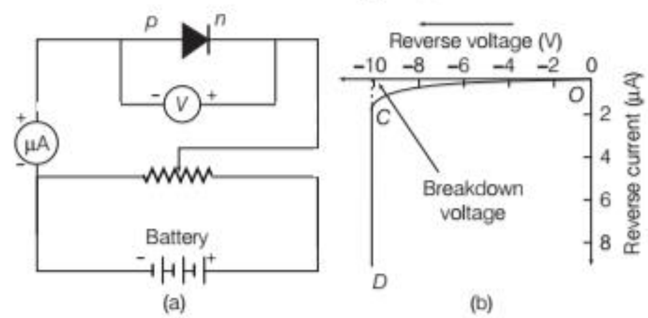
At the start when applied voltage is low, the current through the diode is almost zero. It is because of the potential barrier, which opposes the applied voltage.

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** or **threshold voltage**. If line *AB* is extended back, it cuts the voltage axis at potential barrier voltage.

### Reverse Biased Characteristics

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




Reverse biased characteristic of a diode

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**.

**Note** If the reverse bias is equal to the breakdown voltage, then the reverse current through the junction increases very rapidly ($CD$ portion of the graph), this situation is called **avalanche breakdown** and the junction may get damaged due to excessive heating if this current exceeds the rated value of *p-n* junction.

In diodes, a resistance is offered by the function which depends on the applied voltage, which is called **dynamic resistance.** It is the ratio of small change in voltage to the small change in current produced.

Dynamic resistance, $r_d = \dfrac{\Delta V}{\Delta I}$.

# DIODE AS A RECTIFIER

The process of converting alternating voltage/current into direct voltage/current is called rectification. Diode is used as a rectifier for converting alternating current/voltage into direct current/voltage.

## Principle

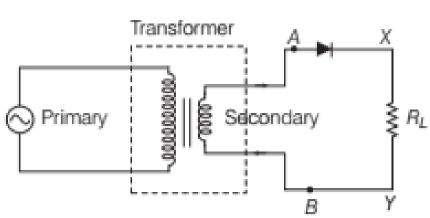
From the $V$-$I$ characteristic of a junction diode, we see that it allows current to pass only when it is forward biased. So, if an alternating voltage is applied across a diode, the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify the current/voltage.

There are two ways of using a diode as a rectifier, i.e.

(i) Diode as a half-wave rectifier
(ii) Diode as a full wave rectifier

## Diode as a Half-Wave Rectifier

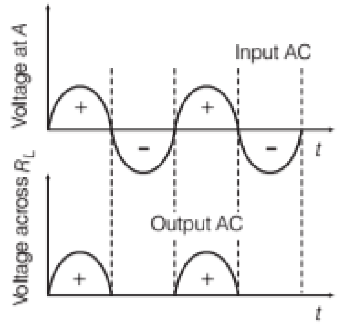
In this, the AC voltage to be rectified is connected to the primary coil of a step-down transformer and secondary coil is connected to the diode through resistor $R_L$ across which, output is obtained.




Circuit diagram of half-wave rectifier

### 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.

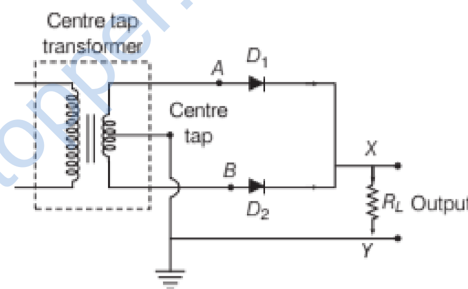



Input and output waveforms

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 is in the load.

## Diode as a Full Wave Rectifier

In the full wave rectifier, two *p-n* junction diodes, $D_1$ and $D_2$ are used. This arrangement is shown in the diagram below.

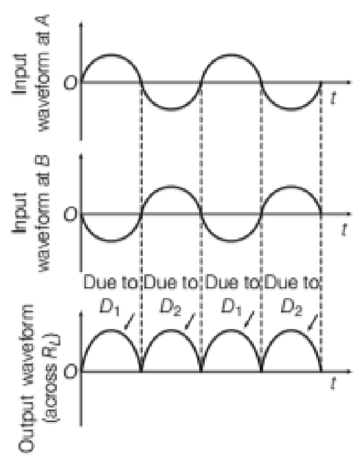



Circuit diagram of full wave rectifier

### 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. Hence, current flows through diode $D_2$. Hence, we find that during both the halves, current flows in the same direction.

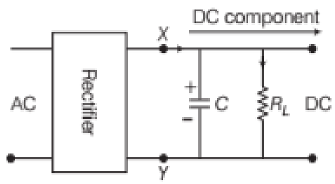



Input and output waveforms

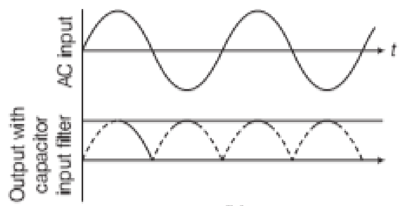
## Role of Filters

In order to get the steady DC output from the pulsating voltage normally, a capacitor is connected across the output terminals (parallel to load $R_L$). An inductor can also be used in series for the same purpose.

As these additional circuits appear to filter out the AC ripple and provide a pure DC voltage, so they are called **filters**.




(a)




(b)

A full wave rectifier with capacitor filter Fig. (a) and input and output voltage of rectifier in Fig. (b).

Let us discuss the role of capacitor in filtering. When the voltage across the capacitor is rising, it gets charged. If there is no external load, it remains charged to the peak voltage of the rectified output. When there is a load, it gets discharged through the load and the voltage across it begins to fall. In the next half cycle of the rectified output, it again gets charged to the peak value (see the above figure). The rate of fall of voltage across the capacitor depends upon the inverse product of capacitor $C$ and the effective resistance $R_L$ used in the circuit and is known as time constant. To make the time constant large value of $C$ should be large. So, capacitor input filters use large capacitors. The output voltage obtained by using capacitor input filter is nearer to the peak voltage of the rectified voltage.

# CHAPTER PRACTICE

(SOLVED)

## OBJECTIVE Type Questions

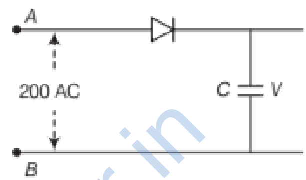
**1.** The conductivity of a semiconductor increases with increase in temperature, because **NCERT Examplar**

(a) number density of free current carriers increases
(b) relaxation time increases
(c) both number density of carriers and relaxation time increase
(d) number density of carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density

**2.** The substance which is doped in an intrinsic semiconductor to make $p$-type semiconductor is

(a) phosphorus (b) antimony
(c) aluminium (d) arsenic

**3.** A 220 V AC supply is connected between points $A$ and $B$ (figure). What will be the potential difference $V$ across the capacitor? **NCERT Examplar**




(a) 220V (b) 110 V (c) 0 V (d) $220\sqrt{2}$V

**4.** The ratio of output frequencies of half wave rectifier and a full-wave rectifier, when an input of frequency 200 Hz is fed at input?

(a) 1 : 2 (b) 2 : 1
(c) 4 : 1 (d) 1 : 4

**Directions** (Q. Nos. 5-7) *In the following questions, two statements are given- one labeled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below*

(a) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
(c) Assertion is true but Reason is false.
(d) Assertion is false but Reason is true.

**5. Assertion** The conductivity of an intrinsic semiconductor depends on its temperature.

**Reason** The conductivity of an intrinsic semiconductor is slightly higher than that of a lightly doped $p$-type semiconductor.

**6.** The ability of a junction diode to ......... an alternating voltage, is based on the fact that it allows current to pass only when it is forward biased. **Delhi 2020**

**7.** The ............, a property of materials C, Si and Ge depends upon the energy gap between their conduction and valence bands.

## VERY SHORT ANSWER Type Questions

**8.** Sn, C and Si, Ge are all group XIV elements. Yet, Sn is a conductor, C is an insulator while Si and Ge are semiconductors. Why? **NCERT Exemplar**

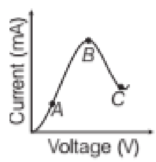
**9.** Show variation of resistivity of Si with temperature in a graph. **Delhi 2014**

**10.** Is the ratio of number of holes and the number of conduction electrons in an $n$-type extrinsic semiconductor more than, less than or equal to 1?

**11.** How does the width of a depletion region of a $p$-$n$ junction vary, if doping concentration is increased? **CBSE SQP (Term-I)**

**12.** What do you mean by reverse current in $p$-$n$ junction diode?

**13.** The graph shown in the figure represents a plot of current *versus* voltage for a given semiconductor. Identify the region, if any, over which the semiconductor has a negative resistance. **All India 2013**




**14.** Can the potential barrier across a $p$-$n$ junction be measured by simply connecting a voltmeter across the junction? **NCERT Exemplar**

**15.** When a voltage drop across a $p$-$n$ junction diode is increased from 0.70 V to 0.71V, the change in the diode current is 10 mA .What is the dynamic resistance of diode?

**16.** In half-wave rectification, what is the output frequency if input frequency is 25 Hz?

**17.** Why are elemental dopants for silicon or germanium usually chosen from group XIII or group XV? **NCERT Exemplar**

## SHORT ANSWER Type Questions

**18.** Write two characteristic features to distinguish between $n$-type and $p$-type semiconductors. **All India 2012**

**19.** Can a slab of $p$-type semiconductor be physically joined to another $n$-type semiconductor slab to form $p$-$n$ junction?

Justify your answer.

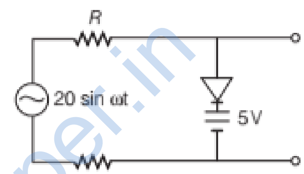
**20.** In a $p$-$n$ junction diode the forward bias resistance is low as compared to the reverse bias resistance. Give reason.

**21.** Briefly explain how a potential barrier is set up across a $p$-$n$ junction as a result of diffusion and drift of the charge carriers. **CBSE 2020 All India**

**22.** Explain with the help of a circuit diagram, the working of a $p$-$n$ junction diode as a half-wave rectifier. **All India 2014**

**23.** Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams. **All India 2014**

**24.** Assuming an ideal diode, draw the output waveform for the circuit given in the figure, explain the waveform. **NCERT Exemplar**




**25.** The ionisation energy of isolated pentavalent phosphorous atom is very large. How is it possible that when it goes into silicon lattice position, it releases its 5th electron at room temperature, so that $n$-type semiconductor is obtained?

**26.** Define the following terms used in electronic devices.

(i) Reverse breakdown voltage

(ii) $V$-$I$ characteristic of forward biased diode

**27.** Write the two processes that take place in the formation of a $p$-$n$ junction. Explain with the help of a diagram, the formation of depletion region and barrier potential in a $p$-$n$ junction. **Delhi 2017**

**28.** (i) In the following diagram, is the junction diode forward biased or reverse biased?

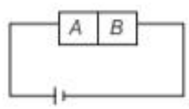

(ii) Draw the circuit diagram of a full wave rectifier and state how it works? **All India 2017 C**

**29.** Draw a labelled diagram of a full wave rectifier circuit. State its working principle. Show the input-output waveforms. **All India 2019, 20**

*Or* Draw the circuit diagram of a full wave rectifier. Explain its working principle. Draw the input and output waveform. **All India 2017C**

**30.** A student wants to use two *p-n* junction diodes to convert alternating current into direct current. Draw the labelled circuit diagram she would use and explain how it works. **CBSE 2018**

**31.** There are two semiconductor materials *A* and *B* which are made by doping germanium crystal with indium and arsenic, respectively. As shown in the figure, the junction of two is biased with a battery. Will the junction be forward bias and reverse bias?




## LONG ANSWER Type I Questions

**32.** Draw the energy band diagram when intrinsic semiconductor (Ge) is doped with impurity atoms of antimony (Sb). Name the extrinsic semiconductor so obtained and majority charge carriers in it. **CBSE SQP (Term-II)**

**33.** (a) Explain the formation of energy bands in crystalline solids.
(b) Draw the energy band diagrams of (i) a metal and (ii) a semiconductor.

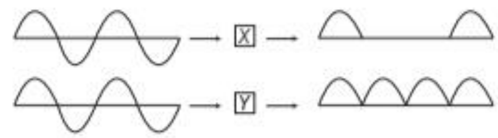
**34.** Explain the formation of potential barrier and depletion region in a *p-n* junction diode. What is effect of applying forward bias on the width of depletion region? **Delhi 2020**

**35.** As we know that an *n*-type semiconductor has large number of electrons but it is still electrically neutral. Why?

## LONG ANSWER Type II Questions

**36.** (i) State briefly the processes involved in the formation of *p-n* junction explaining clearly how the depletion region is formed?
(ii) Using the necessary circuit diagrams, show how the *V-I* characteristics of a *p-n* junction are obtained in
(a) forward biasing (b) reverse biasing
How are these characteristics made use of in rectification? **Delhi 2014**

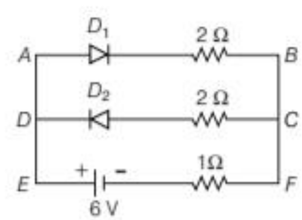
**37.** An AC signal is fed into two circuits *X* and *Y* and the corresponding output in the two cases have the waveforms as shown in below.




(i) Identify the circuits *X* and *Y*. Draw their labelled circuit diagrams.
(ii) Briefly explain the working of circuit *Y*.
(iii) How does the output waveform circuit *Y* get modified when a capacitor is connected across the output terminals parallel to the load resistor?

## NUMERICAL PROBLEMS

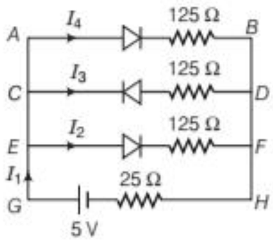
**38.** Assuming that the two diodes $D_1$ and $D_2$ used in the electric circuit as shown in the figure are ideal, find out the value of the current flowing through $1\,\Omega$ resistor. **Delhi 2013, (2 M)**




**39.** The impurity levels of dopped semiconductor are 30 eV below the conduction band. Determine whether the semiconductor is *n*-type or *p*-type. At the room temperature, thermal collisions occur as a result of which, the extra electron loosely bound to the impurity ion gets an amount of energy kT and hence this electron can jump into conduction band. What is the value of *T*? Take, *k* is Boltzmann constant $= 8.62 \times 10^{-5}$ eV/K.

**40.** A potential barrier of 0.4 V exists across *p-n* junction.
(i) If the depletion region is $4.0 \times 10^{-7}$ m wide, what is the intensity of the electric field in this region?
(ii) If an electron with speed $4 \times 10^5$ m/s approaches the *p-n* junction from the *n*-side, find the speed with which it will be *p*-side.

**41.** If each diode in figure has a forward bias resistance of 25 Ω and infinite resistance in reverse bias, what will be the values of the currents $I_1$, $I_2$, $I_3$ and $I_4$?




**42.** 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? **NCERT**

**43.** Predict the effect on the electrical properties of a silicon crystal at room temperature, if every millionth silicon atom is replaced by an atom of indium. Given, concentration of silicon atoms $= 5\times10^{28}\,m^{-3}$, intrinsic carrier concentration $= 1.5\times10^{16}\,m^{-3}$, $H_e = 0.135\,m^3/V\text{-}s$ and $H_h = 0.048 m^3/V\text{-}s$.

## HINTS AND SOLUTIONS

**1.** (d) The conductivity of a semiconductor increases with increase in temperature, because the number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation is much less than increase in number density.

**2.** (c) In an intrinsic semiconductor, when an impurity of trivalent group such as aluminium, boron, etc., mixed in very small quantity, then the resultant crystal will be *p*-type semiconductor.

**3.** (d) As *p-n* junction conducts during positive half cycle only, the diode connected here will work is positive half cycle. Potential difference across $C$ = peak voltage of the given AC voltage $= V_0 = V_{rms}\sqrt{2} = 220\sqrt{2}$ V.

**4.** (a) Output frequency of full wave rectifier is twice the output frequency of half wave rectifier.

$$\therefore \frac{f_{\text{half wave}}}{f_{\text{full wave}}} = \frac{1}{2}$$

**5.** (c) The conductivity of an intrinsic semiconductor is less than that of a lightly doped *p*-type semiconductor.

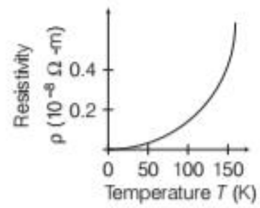
**6.** rectify

**7.** conductivity

**8.** A material is a conductor, if in its energy band diagram, there is no energy gap between conduction band and valence band. For insulator, the energy gap is large and for semiconductor, the energy gap is moderate.

The energy gap for Sn is 0 eV, for C is 5.4 eV, for Si is 1.1 eV and for Ge is 0.7 eV, related to their atomic size. Therefore, Sn is a conductor, C is an insulator and Ge and Si are semiconductors.

**9.** Graph of resistivity of Si as a function of temperature is given alongside (resistivity of metals increases with increase in temperature).




**10.** The ratio of number of holes and the number of conduction electrons in an *n*-type extrinsic semiconductor is less than 1.

**11.** The width of a depletion region of a *p-n* junction of inversely proportional to the concentration of dopants. So, if the doping concentration is increased, then the width of depletion region decreases.

**12.** When a diode is reversed biased, then very small current due to minority charge carries flows across the junction. This current is called reverse current.

**13.** 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 with the increase in current, there is a decrease in voltage.

**14.** We cannot measure the potential barrier across a *p-n* junction by a voltmeter because the resistance of voltmeter is very high as compared to the junction resistance.

**15.** The dynamic resistance of a diode is

$$r_d = \frac{\text{Change in diode voltage } (\Delta V)}{\text{Change in diode current } (\Delta I)}$$

Here, $\Delta V = 0.71 - 0.70 = 0.01$ V and $\Delta I = 10\,\text{mA} = 10\times10^{-3}$ A

$$\therefore \quad r_d = \frac{0.01}{10\times10^{-3}} = 1\,\Omega$$

**16.** The output frequency of a half-wave rectifier is same as that as input frequency, i.e. 25 Hz.

**17.** The size of the dopant atom should be such that their presence in the pure semiconductor does not distort the semiconductor but easily contribute the charge carriers on forming covalent bonds with Si or Ge atoms, which are provided by group XIII or group XV elements.

**18.** Refer to text on page 528.

**19.** No, two different slabs of *p*-type and *n*-type semiconductor cannot be physically joined to form *p-n* junction. It is because, two different slabs have different extent of doping of impurity atom in them. So, the characteristics of a *p-n* junction diode are not met by this process.

**20.** It is because in forward biased condition, the potential barrier is low in $p$-$n$ a junction as compared to that in reverse biased condition. So, the resistance is low in forward biasing as compared to that in reverse biasing.

**21.** Refer to text on page 530.

**22.** Refer to text on page 532.

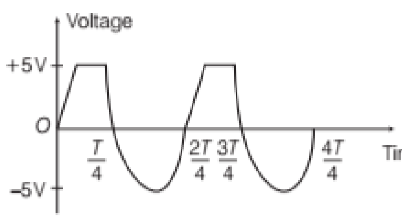
**23.** Refer to text on page 526.

**24.** When the input voltage is equal to or less than 5 V, diode will be reverse biased. It will offer high resistance in comparison to resistance ($R$) in series. Now, diode appears in open circuit. The input waveform is then passed to the output terminals. The result with sine wave input is to dip off all positive going portion above 5 V.

If input voltage is more than + 5 V, diode will be conducting as if forward biased offering low resistance in comparison to $R$. But there will be no voltage in output beyond 5 V as the voltage beyond + 5 V will appear across $R$.

When input voltage is negative, there will be opposition to 5 V battery. In $p$-$n$ junction, input voltage becomes more than − 5 V, the diode will be reverse biased. It will offer high resistance in comparison to resistance $R$ in series. Now, junction diode appears in open circuit. The input waveform is then passed on to the output terminals.

The output waveform is shown here in the figure




**25.** Refer to text on page 529.

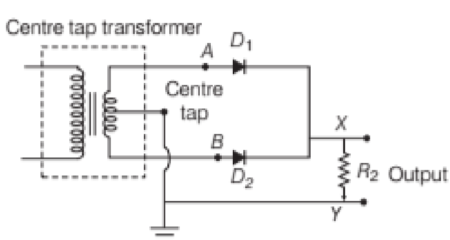
**26.** (i) Refer to text on page 532.
(ii) Refer to text on page 531.

**27.** Refer to text on page 530.

**28.** Refer to text on pages 531 and 532.

**29.** Refer to text on page 532.

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

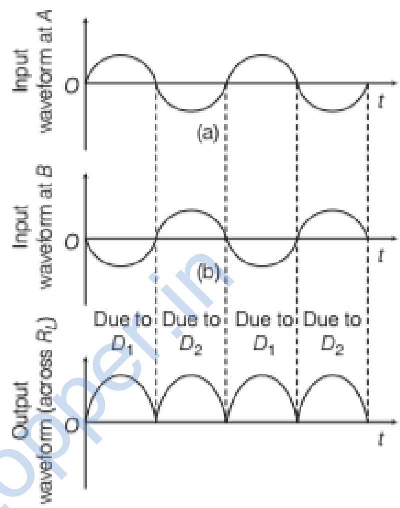



Circuit diagram of full wave rectifier

**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.



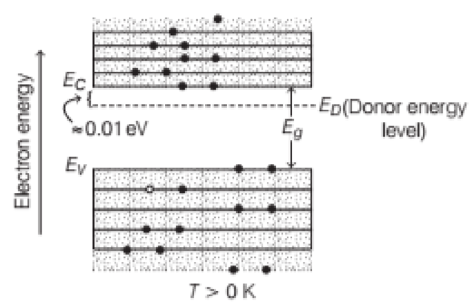



**31.** As, semiconductor $A$ is doped with indium, so it behaves as $p$-type semiconductor and $B$ is doped with arsenic, so it behaves as $n$-type semiconductor. Thus, the figure shows that it is forward bias condition.

**32.** When intrinsic semiconductor (Ge) is doped with impurity atoms of antimony (Sb), which is a pentavalent atom, the extrinsic semiconductor so formed is of $n$-type.

**The energy band diagram for $n$-type semiconductor**

In extrinsic semiconductors, additional energy states due to donor impurities ($E_D$) also exist. In the energy band diagram of $n$-type semiconductor, the donor energy level $E_D$ is slightly below the bottom $E_C$ of conduction band and the electrons from this level move into conduction band with very small supply of energy.




In $n$-type semiconductor, the majority charge carriers are electrons.

**33.** (a) Refer to text on page 526.

(b) Refer to text on page 526.

**34.** Refer to text on page 530.

On applying forward bias, the width of the depletion region decreases.

**35.** $n$-type semiconductor is formed by doping it with pentavalent impurities. These impurities or dopant takes the atoms in the crystal and its four electrons take part in chemical bonding with four electrons of intrinsic semiconductor or pure semiconductor. Whereas the last electrons are left free. Since, as whole atom is electrically neutral, so $n$-type semiconductor is also neutral.

**36.** (i) Refer to text on page 530.

(ii) (a) Refer to text on page 531.

(b) Refer to text on pages 531 and 532.

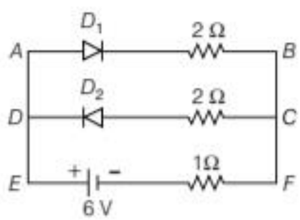
**37.** (i) $X$-Half wave rectifier

$Y$-Full wave rectifier.

(ii) Refer to text on pages 532 and 533.

(iii) Refer to text on pages 532 and 533.

**38.** According to the question,




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

$$\frac{1}{R'} = \frac{1}{2} + \frac{1}{3} = \frac{3+2}{6} = \frac{5}{6}\ \Omega$$

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

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

**39.** The separation of impurity energy level from conduction band is less in case of $n$-type semiconductor and more in case of $p$-type semiconductor. As, energy separation of impurity is $30 \times 10^{-3}$ eV is much smaller than energy gap of pure semiconductor, i.e. $E = 1$ eV. Therefore, the doped semiconductor is $n$-type.

$$E_g = 30 \times 10^{-3}\text{ eV} = kT$$

$$\Rightarrow \quad T = \frac{E_g}{k} = \frac{30 \times 10^{-3}}{8.62 \times 10^{-5}} = 348.02\text{ K}$$

**40.** Given, $V = 0.4$ V

(i) $d = 4 \times 10^{-7}$ m, $E = ?$

Electric field, $E = \frac{V}{d} = \frac{0.4}{4 \times 10^{-7}} = 1 \times 10^6$ V/m

(ii) $v_1 = 4 \times 10^5$ m/s, $v_2 = ?$

Suppose $v_1$ be the speed of electron when it enters the depletion layer and $v_2$ be the speed when it comes out of the depletion layer.

According to principle of conservation of energy,

KE before entering the depletion layer = Gain in PE + KE after crossing the depletion layer

$$\Rightarrow \quad \frac{1}{2}mv_1^2 = e \times V + \frac{1}{2}mv_2^2$$

$$\Rightarrow \quad \frac{1}{2} \times 9.1 \times 10^{-31} \times (4 \times 10^5)^2 = 1.6 \times 10^{-19} \times 0.4 + \frac{1}{2} \times 9.1 \times 10^{-31} \times v_2^2$$

$$\therefore \quad v_2 = 1.39 \times 10^5\text{ m/s}$$

**41.** Given, forward biased resistance = 25 Ω

Reverse biased resistance = ∞

As the diode in branch $CD$ is in reverse biased which having resistance infinite,

So, $I_3 = 0$

Resistance in branch $AB = 25 + 125 = 150\ \Omega$ (say $R_1$)

Resistance in branch $EF = 25 + 125 = 150\ \Omega$ (say $R_2$)

$AB$ is parallel to $EF$.

So, resultant resistance, $\frac{1}{R'} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{150} + \frac{1}{150} = \frac{2}{150}$

$\Rightarrow \quad R' = 75\ \Omega$

Total resistance, $R = R' + 25 = 75 + 25 = 100\ \Omega$

Current, $I_1 = \frac{V}{R} = \frac{5}{100} = 0.05$ A

$I_1 = I_4 + I_2 + I_3$ [here, $I_3 = 0$]

So, $I_1 = I_4 + I_2$

Here, the resistances $R_1$ and $R_2$ are same.

i.e. $I_4 = I_2$

$\therefore \quad I_1 = 2I_2$

$\Rightarrow \quad I_2 = \frac{I_1}{2} = \frac{0.05}{2} = 0.025$ A and $I_4 = 0.025$ A

Thus, $I_1 = 0.05$ A, $I_2 = 0.025$ A, $I_3 = 0$

and $I_4 = 0.025$ A

**42.** Given, 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 = $2 \times 50 = 100$ Hz.

**43.** As, concentration of Si atom $= 5 \times 10^{28}/\text{m}^3$

The doping of indium is 1 atom in $10^6$ atoms of Si. But indium has three valence electrons and each doped indium atom creates one hole in Si crystal. Hence, it acts as an acceptor atom.

$\therefore$ Concentration of acceptor atoms,

$$n_h = 5 \times 10^{28} \times 10^{-6} = 5 \times 10^{22} / \text{m}^3$$

Intrinsic carrier concentration, $n_i = 1.5 \times 10^{16} /\text{m}^3$

$\therefore$ Hole concentration is increased,

$$= \frac{n_h}{n_i} = \frac{5 \times 10^{22}}{1.5 \times 10^{16}} = 3.33 \times 10^6$$

New electron concentration,

$$n_e = \frac{n_i^2}{n_h} = \frac{(1.5 \times 10^{16})^2}{5 \times 10^{22}} = 0.45 \times 10^{10} /\text{m}^3$$

Electron concentration has been reduced

$$= \frac{n_i}{n_e} = \frac{1.5 \times 10^{16}}{0.45 \times 10^{10}} = 3.33 \times 10^6 /\text{m}^3$$

This means that the hole concentration has been increased over its intrinsic concentration by the same amount with which the electron concentration has been decreased.

The conductivity of doped silicon is given by

$$\sigma = e(n_e H_e + n_h H_h)$$
$$= 1.6 \times 10^{-19} (0.45 \times 10^{10} \times 0.135 + 5 \times 10^{22} \times 0.048)$$
$$= 384 \text{ S/m}$$

Resistivity, $\rho = \frac{1}{\sigma} = \frac{1}{384} = 0.0026\ \Omega\text{-m}$

Conductivity of pure Si crystal,

$$\sigma = en_i(H_e + H_h) = 1.6 \times 10^{-19} \times 1.5 \times 10^{16} (0.135 + 0.048)$$
$$= 0.4392 \times 10^{-3} \text{ S/m}$$

Resistivity, $\rho = \frac{1}{\sigma} = \frac{1}{0.4392 \times 10^{-3}} = 2276.8\ \Omega\text{-m}$

Thus, we see that the conductivity of Si doped within become much greater than its intrinsic conductivity and the resistivity has become much smaller than the intrinsic resistivity.

# SUMMARY

- **Semiconductors** are the basic material used in the present solid state electronic devices like diode, transistor, ICs etc.
- Metal have low resistivity ($10^{-2}$ to $10^{-8}$ $\Omega$-m), insulators have very high resistivity ($10^{8}$ $\Omega$-m) while semiconductors have intermediately values of resistivity.
- **Valence Band** is the energy band, which includes the energy levels of the valence electrons. This band may be partially or complete filled with electrons.
- **Conduction Band** is the energy band above the valence band. At room temperature, this band is either empty or partially filled with electrons.
- The minimum energy required for shifting electrons from valence band to conduction band is called energy **band gap.**
- **Fermi Energy** is the maximum possible energy possessed by free electrons of a material at absolute zero temperature.
- An **intrinsic semiconductor** is also called an undoped semiconductor or *i*-type semiconductor.
- **Extrinsic Semiconductor** Those semiconductors in which some impurity atoms are embedded are known as extrinsic semiconductor.
- In *n*-type semiconductors $n_e \geq n_h$ while in *p*-type semiconductors $n_h >> n_e$.
- *n*-type semiconductor Si or Ge is obtained by doping with pentavalent atoms (donors) like As, Sb, P, etc., while *p*-type Si. or Ge can be obtained by doping with trivalent atom like B, Al, In, etc.
- In all cases, $n_e n_h = n_i^2$ further the material possesses an overall charge neutrality.
- A ***p-n* junction** is an arrangement made by a close contact of *n*-type semiconductor and *p*-type semiconductor.
- The region on either side of the junction which becomes depleted (free) from the mobile charge carriers is called **depletion region.**
- The potential difference developed across the depletion region is called the **potential barrier**.
- A **semiconductor diode** is basically a *p-n* junction with metallic contacts provided at the ends for the application of an external voltage.
- In forward bias (*n*-side is connected to negative terminal of the battery and *p*-side is connected to positive), the barrier is decreased while the barrier increases in reverse bias. Hence, forward bias current is more (mA) while it is very small (μA) in a *p-n* junction diode.
- Diodes can be used for rectifying an AC voltage. With the help of a capacitor or a suitable filter, a DC voltage can be obtained.

# CHAPTER **PRACTICE** (UNSOLVED)

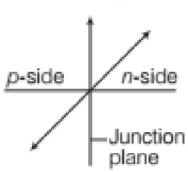
## OBJECTIVE Type Questions

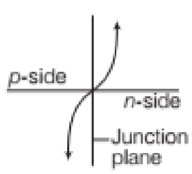
**1.** In an $n$-type silicon, which of the following statements is correct?
(a) Electrons are majority charge carriers and trivalent atoms are the dopants
(b) Electrons are minority charge carriers and pentavalent atoms are the dopants
(c) Holes are minority charge carriers and pentavalent atoms are the dopants
(d) Holes are majority charge carriers and trivalent atoms are the dopants

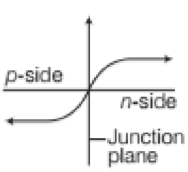
**2.** In an unbiased $p$-$n$ junction, holes diffuse from the $p$-region to $n$-region because
(a) free electrons in the $n$-region attract them
(b) they moves across the junction by the potential difference
(c) hole concentration in $p$-region is more as compared to hole concentration in $n$-region
(d) All of the above

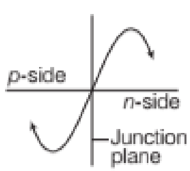
**3.** The potential barrier of germanium diode is
(a) 0.1 V (b) 0.3 V
(c) 0.5 V (d) 0.7 V

**4.** Which of these graphs shows potential difference between $p$-side and $n$-side of a $p$-$n$ junction in equilibrium?

(a) 

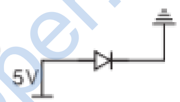

(b) 


(c) 

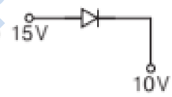

(d) 

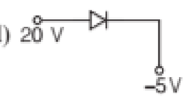

**5.** If reverse biasing potential is increased beyond a certain critical (breakdown) value, then
(a) diode gets destroyed due to overheating
(b) no current flows through the diode
(c) after breakdown a heavy current flows from $p$ to $n$-side
(d) potential barrier becomes zero

**6.** Which is reverse biased diode?

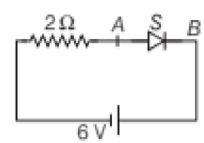
(a) 


(b) 


(c) 

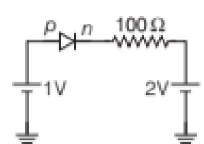

(d) 


**7.** The diode shown in the circuit is a silicon diode. The potential difference between the points $A$ and $B$ will be




(a) 6 V (b) 0.6 V (c) 0.7 V (d) 0 V

**8.** The current through an ideal $p$-$n$ junction shown in the following circuit diagram will be




(a) zero (b) 1 mA
(c) 10 mA (d) 30 mA

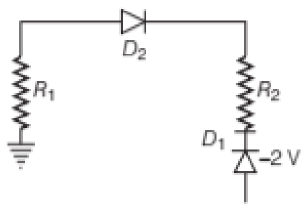
## VERY SHORT ANSWER Type Questions

**9.** At what temperature would an intrinsic semiconductor behave like a perfect insulator?

10. What type of charge carriers are there in an $n$-type semiconductor?

11. What do you mean by dynamic resistance of a $p$-$n$ junction diode?

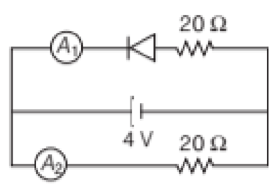
12. Which one of the two diodes $D_1$ and $D_2$ in the given figure is




(i) forward biased? (ii) reverse biased

## SHORT ANSWER Type Question

13. Assuming that the resistances of the meters are negligible, what will be the readings of the ammeters $A_1$ and $A_2$ in the circuit shown in figure?




## LONG ANSWER Type I Question

14. Distinguish between an intrinsic semiconductor and $p$-type semiconductor. Give reason, why a $p$-type semiconductor crystal is electrically neutral, although $n_h >> n_e$?

## LONG ANSWER Type II Question

15. (i) Draw a typical shape of the $V$-$I$ characteristics of a $p$-$n$ junction diode both in (i) forward (b) reverse bias configuration. How do we infer from these characteristics that a diode can be used to rectify alternating voltages.

(ii) Draw the circuit diagram of a full wave rectifier using a centre tap transformer and two $p$-$n$ junction diodes. Give a brief description of the marking of this circuit.

# ANSWERS

1. (*c*) 2. (*c*) 3. (*b*) 4. (*c*) 5. (*c*)

6. (*b*) 7. (*a*) 8. (*a*)

9. At 0K, intrinsic semiconductor behaves like a perfect insulator.

10. Majority charge carriers are electrons and minority charge carriers are holes.

11. It is the ratio of small change in voltage to the small change in current produced, $r_d = \dfrac{\Delta V}{\Delta I}$

12. (i) $D_2$ (ii) $D_1$

13. In the given circuit, the diode is reverse biased . In the upper port of the circuit, no current flows through the upper resistance.

Reading of ammeter, $A_1 = 0$

Reading of ammeter, $A_2 = \dfrac{4}{20} = 0.2\,A$

14. Refer to text on pages 527 and 528.

15. (i) Refer to text on pages 531 and 532.

(ii) Refer to text on page 532.