BASIC ELECTRONICS

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BASIC ELECTRONICS ENGINEERING / DIPLOMA

Introduction :

In this fast developing society, electronics has come to stay as the most important branch of engineering. Electronics devices are being used in almost all the industries for quality control and automation and they are fast replacing the present vast army of workers engaged in processing and assembling in the factories. Great strides taken in the industrial applications of electronics during recent years have demonstrated that this versatile tool can be of great importance in increasing production, efficiency and control.

CHAPTER – 1

ELECTRONIC DEVICES

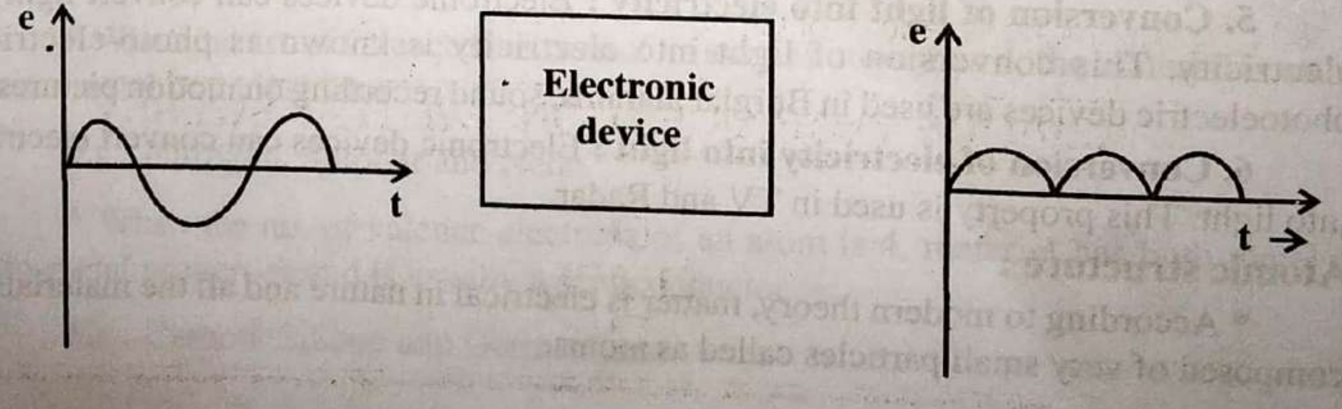
Electronics :

The branch of engineering which deals with current conduction through a vacuum or gas or semiconductor is known as electronics.

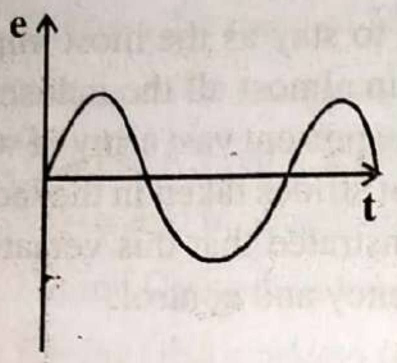
Importance of Electronics :

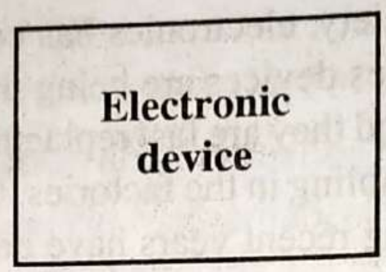
Electronics has gained much more importance due to its numerous application in industry. The electronic devices are capable of performing the following functions.

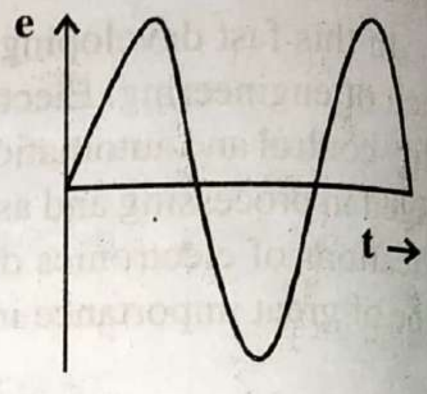
1. Rectification : The conversion of a.c. into d.c. is called as rectification. Electronics devices can convert a.c. power into d.c. power, with very high efficiency. This d.c. supply can be used for charging storage batteries, field supply of d.c. generators, electroplating etc.



2. Amplification : The process of raising the strength of a weak signal is known as amplification. Electronic devices can accomplish the job of amplification and thus act as amplifier.



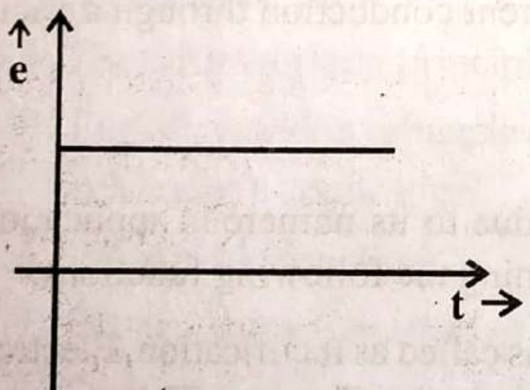


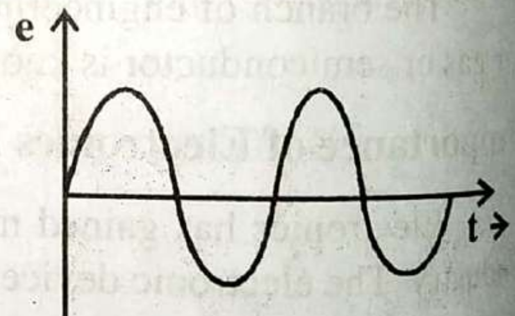


3. Control : Electronic devices find wide applications in automatic control.

Ex : Speed motor, voltage across a refrigerator can be automatically controlled with the help of such devices.

4. Generation : Electronic devices can convert d.c. power into a.c. power of any frequency. The devices performing this function is called as oscillators.





5. Conversion of light into electricity : Electronic devices can convert light into electricity. This conversion of light into electricity is known as photo-electricity, photoelectric devices are used in Burglar alarams, sound recording on motion pictures etc.

6. Conversion of electricity into light : Electronic devices can convert electricity into light. This property is used in TV and Radar.

Atomic structure :

* According to modern theory, matter is electrical in nature and all the materials are composed of very small particles called as atoms.

* The atoms are the building bricks of all matter.

* An atom consists of a central nucleus of positive charge around which small negatively charged particles called electrons revolve in different paths or orbits.

Nucleus :

* It is the central part of an atom and contains protons and neutrons.

* A proton is a positively charged particle, while neutron has the same mass as the proton, but has no charge. Therefore, the nucleus of an atom is positively charged.

* The sum of protons and neutrons constitutes the entire weight of an atom and is called atomic weight.

i.e., Atomic Weight = No. of protons + No. of neutrons.

Extra Nucleus :

* It is the outer part of an atom and contains only electrons.

* Under ordinary condition in an atom no. of electrons is equal to no. of protons.

* Atomic no. = No. of protons or electrons in an atom.

Valence Electrons :

* The electrons in the outermost orbit of an atom are known as valence electrons.

The valence electrons determine the physical and chemical properties of the material.

The valence electrons determine whether or not the material is chemically active; metal or non-metal or a gas or solid.

Note : When the no. of valence electrons of an atom is less than 4, the material is usually a metal or conductor.

Ex : Sodium, Magnesium and Aluminium.

* When the no. of valence electrons of an atom is more than 4, the material is usually a non-metal or an insulator.

Ex : Nitrogen, Sulphur and Neon.

* When the no. of valence electrons of an atom is 4, material has both metal and non-metal properties and is usually a semiconductor.

Ex : Carbon, Silicon and Germanium.

Free electron :

The valence electron which are very loosely attached to the nucleus are known as free electrons.

* A conductor contains large no. of free electrons.

* An insulator contains practically no electrons,

* A semiconductor is a substance which has very few free electrons at room temperature.

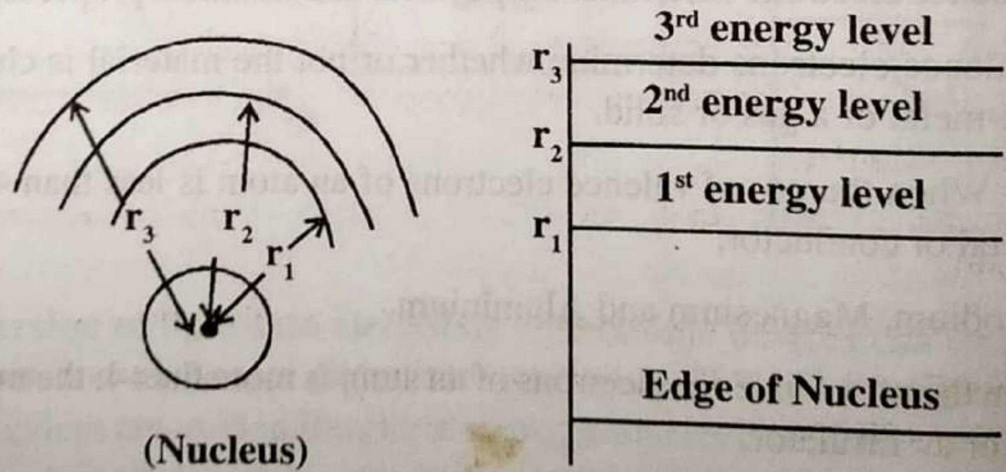
Energy levels :

We now that each orbit has a fixed amount of energy associated with it. The electrons moving in a particular orbit possess the energy of that orbit. The larger the orbit, the greater is its energy. The outer orbit electrons possess more energy than the inner orbit electrons.

A convenient way of representing the energy of different orbits is as shown in figure below. This is known as energy level diagram.

The first orbit represents the first energy level, the second orbit indicates the second energy level and so on.

The larger the orbit of an electron, the greater is its energy and higher is the energy level.



Energy Band :

(i) The range of energies possessed by an electron in a solid is known as energy band.

(ii) In a single isolated atom, the electron in any orbit possesses definite energy.

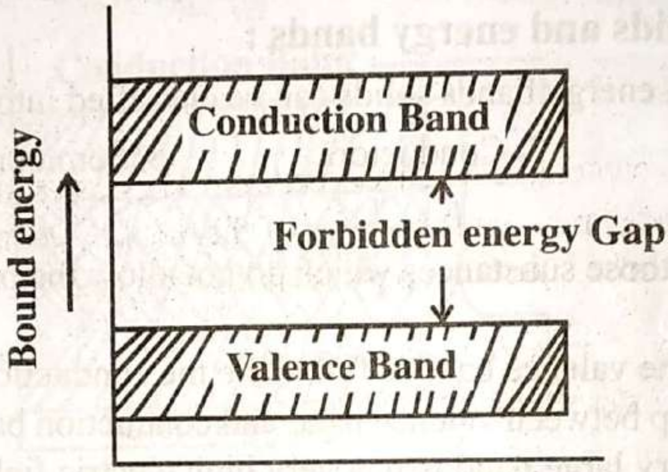
(iii) However, an atom in a solid is greatly influenced by the closely packed neighbouring atoms.

(iv) Thus, the electron in any orbit of such an atom can have a range of energies which is called as energy band.

Important Energy Bands in solids :

Though there are a no. of energy bands in solids, the following are of particular importance.

(1) Valence Band (2) Conduction Band (3) Forbidden energy gap.



1. Valence Band :

* The range of energies possessed by valence electrons is known as valence band.

* In a normal atom, valence band has the electrons of highest energy.

* This band may be completely or partially filled.

Example : In case of Inert gases, the valence band is full whereas for other materials, it is only partially filled. The partially filled band can accommodate more electrons.

2. Conduction Band :

* The range of energies possessed by conduction band electrons is known as conduction band.

* All the electrons in the conduction band are free electrons.

* If a substance has empty conduction band, it means current conduction is not possible in that substance.

* Generally, insulator have empty conduction band and for conductors, it is partially filled.

3. Forbidden energy gap :

* The separation between conduction band and valence band on the energy level diagram is known as forbidden energy gap.

* No electron of a solid can stay in a forbidden energy gap as there is no allowed energy state in this region.

* The width of forbidden energy gap is a measure of the bondage of valence electrons to the atom.

* The greater the energy gap more tightly the valence electrons are bound to the nucleus.

* In order to push an electron from valence band to the conduction band, external energy equal to the forbidden energy gap must be supplied.

Classification of solids and energy bands :

Depending upon energy bands solids can be classified into three categories, such as

1. Insulators 2. Conductors 3. Semiconductors

1. Insulators :

* Insulators are those substances which do not allow the passage of electric current through them.

* In insulators the valence band is full while the conduction band is empty.

* The energy gap between valence band and conduction band is very large (15 eV).

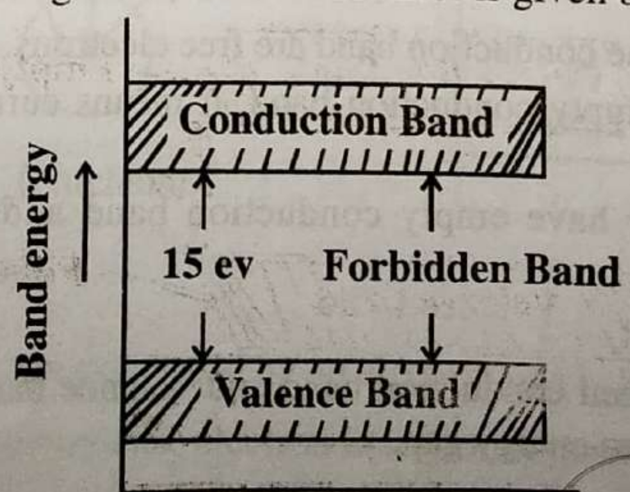
* Because of very large band gap, a very high electric field is required to push the valence electrons to the conduction band.

* Therefore the electrical conductivity of such materials is extremely small and may be regarded as nil under ordinary condition.

* At room temperature, the valence electrons of the insulators do not have enough energy to cross over to the conduction band. When the temperature is raised, some of the valence electrons may acquire enough energy to cross over to the conduction band. Hence, the resistance of an insulator decreases with the increase in temp. i.e., an insulator has negative temp. coefficient of resistance.

Example : Wood, Glass etc.

* Energy band diagram in case of insulator is given below.



2. Conductors :

* Conductors are those substances which easily allow the passage of electric current through them.

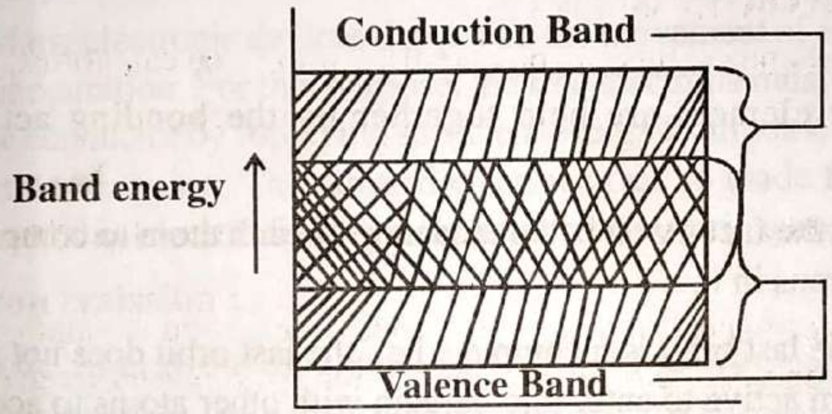
* There are a large no. of electrons available in a conductor.

* In conductor, valence and conduction bands overlap with each other.

* Due to the overlapping of conduction band and valence band a small potential difference across a conductor causes the free electrons to constitute electric current.

Example : Copper, Aluminium etc.

* The energy band diagram in case of conductors is given below.



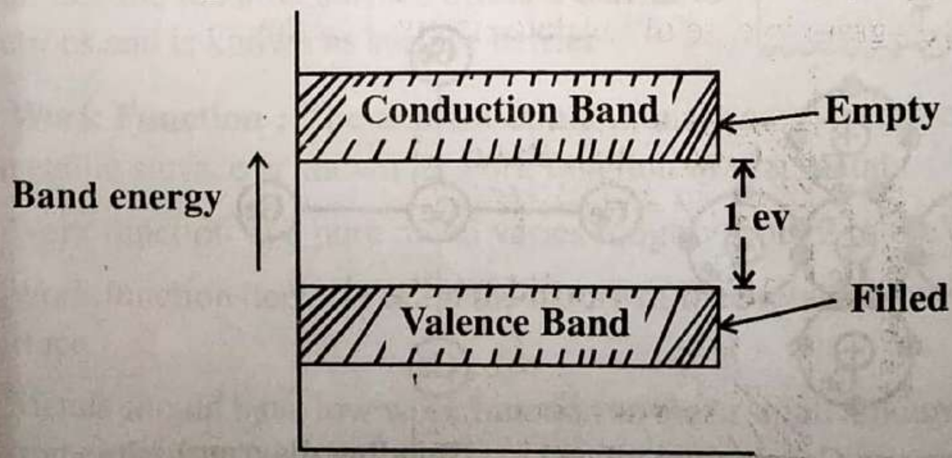
Semiconductor :

* Semiconductors are those substances whose electrical conductivity lies in between conductors and insulators.

* In semiconductors the valence band is almost filled while the conduction band is almost empty.

* The energy gap between valence and conduction band is very small (≃ 1 eV). Therefore, comparatively small electric field is required to push the electrons from the valence band to the conduction band.

* The band diagram of semiconductor is given below.



* At low temp. a semiconductor virtually behaves as an insulator because, at low temp., the valence band is completely filled and conduction band is completely empty.

* However, even at room temp. some electrons (about one electron for 10^{10} atoms) cross over to the conduction band, imparting little conductivity to the semiconductor.

As the temp. increased, more valence electrons cross over to the conduction band and the conductivity increases i.e., the electrical conductivity of a semiconductor increases with the rise in temp. i.e., A semiconductor has negative temp. coefficient of resistance.

Example : Germanium, Nichrome, Silicon, Selenium.

Bands in Semiconductor :

* The atoms of every element are held together by the bonding action of valence electrons.

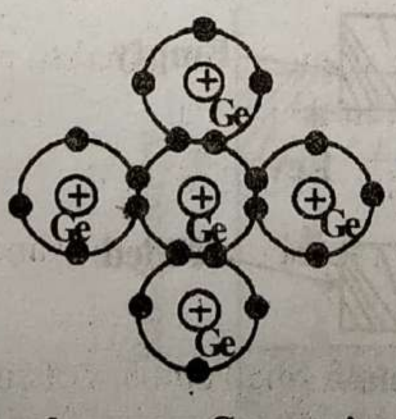
* The bonding is due to the fact that it is the tendency of each atom to complete its last orbit by acquiring 8 electrons in it.

* In most substances, the last orbit is incomplete i.e., the last orbit does not have 8 electrons. This makes the atom active to enter into bargain with other atoms to acquire 8 electrons in the last orbit. To do so, the atom may lose, gain or share valence electrons with other atoms.

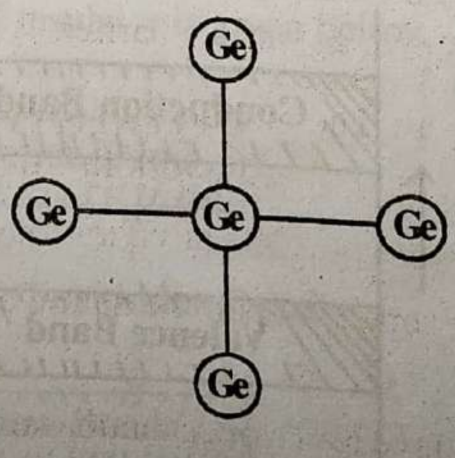
* In semiconductors, bonds are formed by sharing valence electrons. Such bonds are called as covalent bonds.

* In the formation of a covalent bond, each atom contributes equal no. of valence electrons and the contributed electrons are shared by the atoms engaged in the formation of the bond.

* The figure given below shows the covalent bonds among germanium atoms.



(Covalent bonds among Germanium atoms)



(Bonding diagram)

ELECTRON EMISSION

Introduction :

The valence electrons of the conductor atoms are loosely bound to the atomic nuclei. At room temp., the thermal energy in the conductor is adequate to break the bonds of the valence electrons and leave them attached to any one nucleus. These bound electrons move at random within the conductor and are known as free electrons. If an electric field is applied across the conductor, these free electrons move through the conductor in an ordinary manner, thus constituting electric current.

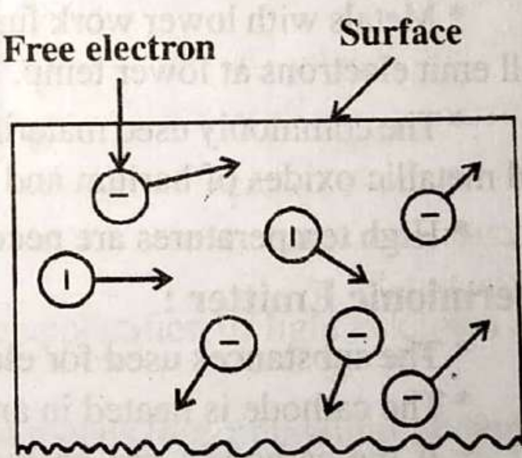
Many electronic devices depend on the movement of electrons in an evacuated space for their operation. For this purpose, the free electrons must be ejected from the surface of metallic conductor by supplying sufficient energy from some external source. This is known as electron emission. The emitted electrons can be made to move in vacuum under the influence of an electric field, thus constituting electric current in vacuum.

Electron emission :

The liberation of electrons from the surface of a substance is known as electron emission.

* For electron emission, metals are used as they have many free electrons.

* If we investigate a piece of metal at room temp. the random motion of free electrons is as shown below. But these electrons can only transfer from one atom to another within the metal but can not leave the metal surface to provide electron emission, because of positive nuclei pulling. Thus at the surface of a metal, a free electron encounters forces that prevent it to leave the metal. i.e., the metallic surface offers a barrier to free electrons and is known as surface barrier.



* **Work Function :** The amount of additional energy required to emit an electron from a metallic surface is known as work function of that metal.

* Work function of a pure metal varies roughly from 2 to 6 eV.

* Work function depends upon the nature of the metal, its purity and the conditions of its surface.

* Metals should have low work function so that a small amount of energy is required for electron emission.

Types of Electron Emission :

The electron emission from the surface of a metal is possible only if sufficient additional energy is supplied from some external source. This external energy may come from a variety of sources such as heat energy, energy stored in electric field, light energy or kinetic energy of the electric charges bombarding the metal surface. Accordingly, there are four methods of obtaining electron emission from the metal surface. They are -

(1) Thermionic emission
(2) Field emission
(3) Photo-electric emission
(4) Secondary emission

(1) Thermionic Emission :

The process of electron emission from a metal surface by supplying thermal energy to it is known as thermionic emission.

At ordinary temp., the energy possessed by free electrons in the metal is inadequate to cause them to escape from the surface. When heat is applied to the metal, some of heat energy is converted into kinetic energy causing accelerated motion of free electrons. When the temp. rises sufficiently, these electrons acquire additional energy equal to the work function of the metal. Consequently, they overcome the restraining surface barrier and leave the metal surface.

* Metals with lower work function will require less additional energy and therefore, will emit electrons at lower temp.

* The commonly used materials for electron emission are tungsten, thoriated tungsten and metallic oxides of barium and strontium.

* High temperatures are necessary to cause thermionic emission.

Thermionic Emitter :

* The substances used for electron emission is known as an emitter or cathode.
* The cathode is heated in an evaluated space to emit electrons.
* If the cathode were heated to the required temp. in open air, it would burn up because of the presence of oxygen in the air.
* The substance selected as cathode should have low work function so that electron emission takes place by applying small amount of heat energy, i.e., at low temp.
* The substance used as a cathode should have high melting point. But for materials such as copper, which has the advantage of a low work function, it is seen that it cannot be used as a cathode because it melts at 810^{0}C.
* The emitter should have high mechanical strength to withstand bombardment of positive ions.

2. Field Emission :

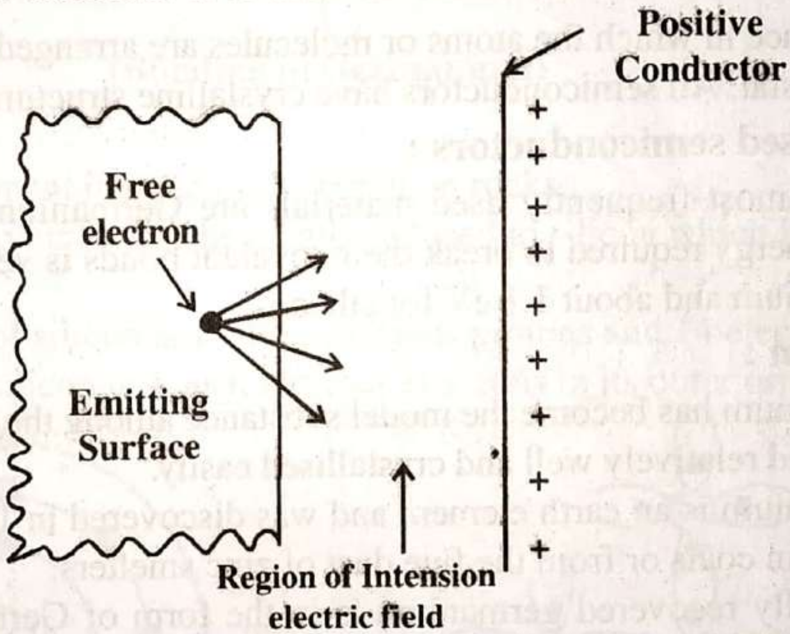
* The process of electron emission by the application of strong electric field at the surface of a metal is known as field emission.

* When a metal surface is placed close to a high voltage conductor which is positive w.r.t. the metal surface, the electric field experts attractive force on the free electrons in the metal. If the positive potential is great enough, it succeeds in overcoming the restraining forces of the metal surface and the free electrons will be emitted from the metal surface.

* Very intense electric field is required to produce field emission.

* Usually a voltage of the order of a million volts per centimetre distance between the emitting surface and the positive conductor is necessary to cause field emission.

* Field emission can be obtained at temperatures much lower than required for thermionic emission and therefore it is also called as cold cathode emission or auto electric emission.



3. Photo-electric Emission :

* Electron emission from a metallic surface by the application of light is known as photo-electric emission.

* When a beam of light strikes the surface of certain metals (e.g. potassium, sodium, cesium), the energy of photons of light is transferred to the electrons within the metal. If the energy of the striking photons is greater than the work function of the metal then free electrons will be knocked out from the surface of the metal. The emitted electrons are known as photo electrons and the phenomenon is called as photoelectric emission.

* The amount of photoelectric emission depends upon the intensity of light falling upon emitter and frequency of radiations.

* Photo-electric emission is utilised in photo tubes which form the basis of television and sound films.

4. Secondary Emission :

* Electron emission from a metallic surface by the bombardment of high speed electrons or other particles is known as secondary emission.

* When high speed electrons suddenly strike a metallic surface they may give some or all of their kinetic energy to the free electrons in the metal. If the energy of the striking electrons is sufficient, it may cause free electrons to escape from the metal surface. This phenomenon is called as secondary emission.

* The electrons that strike the metal are called primary electrons and the emitted electrons are known as secondary electrons.

* The intensity of secondary emission depends upon the emitter material, mass and energy of the bombarding particles.

Crystals :

A substance in which the atoms or molecules are arranged in an ordinary pattern is known as a crystal. All semiconductors have crystalline structure.

Commonly used semiconductors :

The two most frequently used materials are Germanium (Ge) and Silicon (Si). Because, the energy required to break their covalent bonds is very small being about 0.7 eV for Germanium and about 1.1 eV for silicon.

1. Germanium :

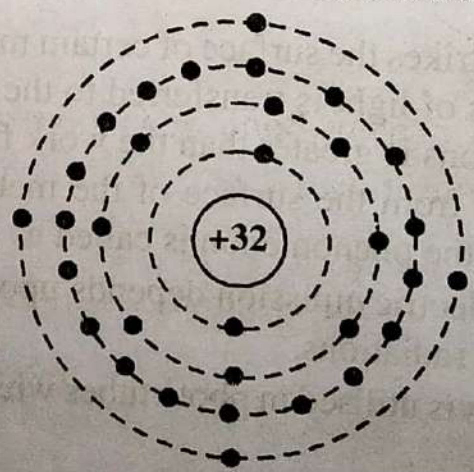
* Germanium has become the model substance among the semiconductors because it can be purified relatively well and crystallised easily.

* Germanium is an earth element and was discovered in 1886 and recovered from the ash of certain coals or from the flue dust of zinc smelters.

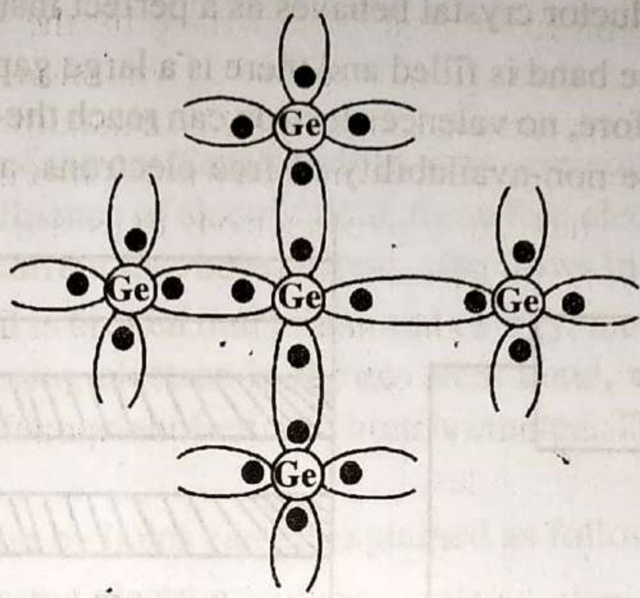
* Generally recovered germanium is in the form of Germanium dioxide powder which is then reduced to pure Germanium.

* The atomic no. of Germanium is 32 i.e., it has 32 protons and 32 electrons.

* Germanium has four valence electrons i.e., it is a tetravalent element.



* In Germanium as the atoms are arranged in an orderly pattern, therefore Germanium has crystalline structure.



(Bonding in Germanium)

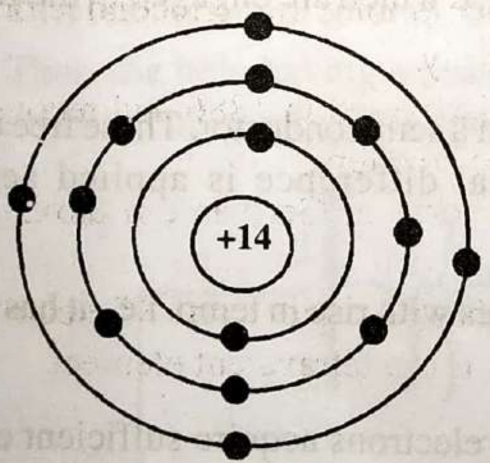
Silicon :

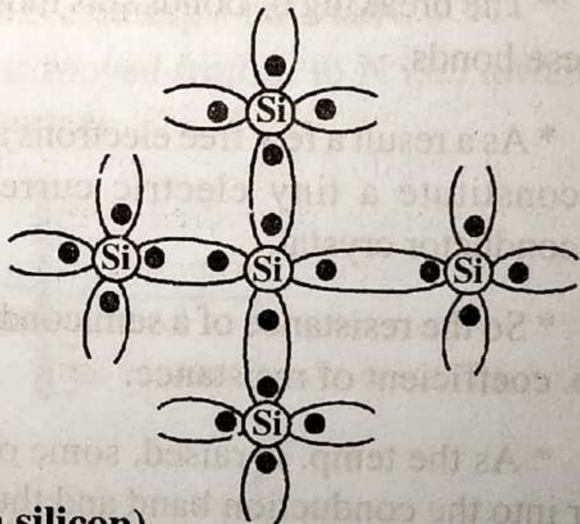
* Silicon is an element in most of the common rocks.

* The silicon compounds are chemically reduced to silicon which is 100% pure for use as a semiconductor.

* The atomic no. of silicon is 14, i.e., 14 has is protons and 14 electrons.

* The valency of silicon is 4, as it has four electrons in its outer orbit.





(Covalent Bonding in silicon)

Effect of temp. on semiconductors :

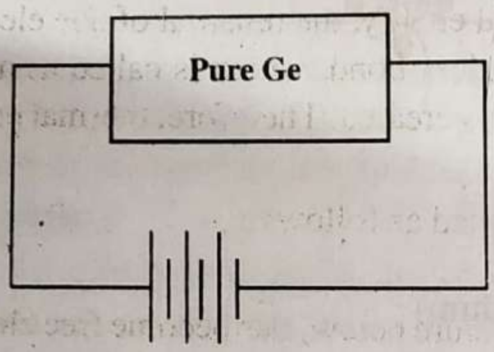
1. At Absolute zero temp :

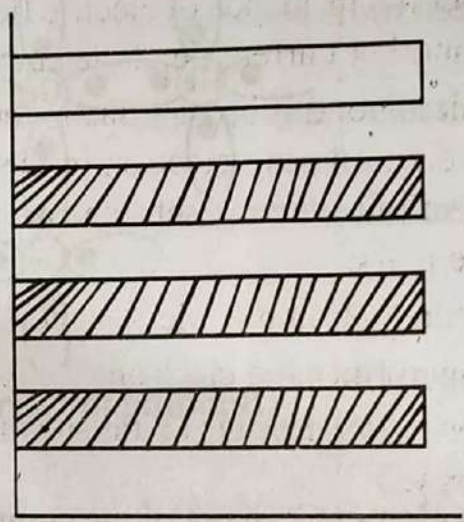
* At absolute zero temp., all the electrons are tightly held by the semiconductor atoms.

* The inner orbit electrons are bound whereas the valence electrons are engaged in covalent bonding.

* At this temp, the covalent bonds are very strong and there are no free electrons. Therefore, the semiconductor crystal behaves as a perfect insulator.

* Here, the valence band is filled and there is a large gap between valence band and conduction band. Therefore, no valence electron can reach the conduction band to become free electron. Due to the non-availability of free electrons, a semiconductor behaves as an insulator.





2. Above absolute zero :

* When the temp. is raised above absolute zero, some of the covalent bonds in the semiconductor break due to the thermal energy supplied.

* The breaking of bonds sets those electrons free which are engaged in the formation of these bonds.

* As a result a few free electrons are available in a semiconductor. These free electrons can constitute a tiny electric current if potential difference is applied across the semiconductor crystal.

* So the resistance of a semiconductor decreases with rise in temp. i.e., it has negative temp. coefficient of resistance.

* As the temp. is raised, some of the valence electrons acquire sufficient energy to enter into the conduction band and thus become free electrons.

* Under the influence of electric field, these free electrons will constitute electric current.

* A hole is created in the valence band, when a valence electron enters into the conduction band.

* The holes also contribute to current.

Note :

Hole current :

At room temp. some of the covalent bonds in pure semiconductor break, setting up free electrons. Under the influence of electric field, these free electrons constitute current. At the same time, another current i.e., hole current, also flows in semiconductor.

When a covalent bond is broken due to thermal energy, the removal of one electron leaves a vacancy i.e., a missing electron in the covalent bond, which is called as a hole (positive charge). For one electron set free, one hole is created. Therefore, thermal energy creats electron-hole pairs.

The current conduction by holes can be explained as follows :

The hole shows a missing electron.

* Let the valence electron be at L (as shown in figure below) has become free electron due to thermal energy.

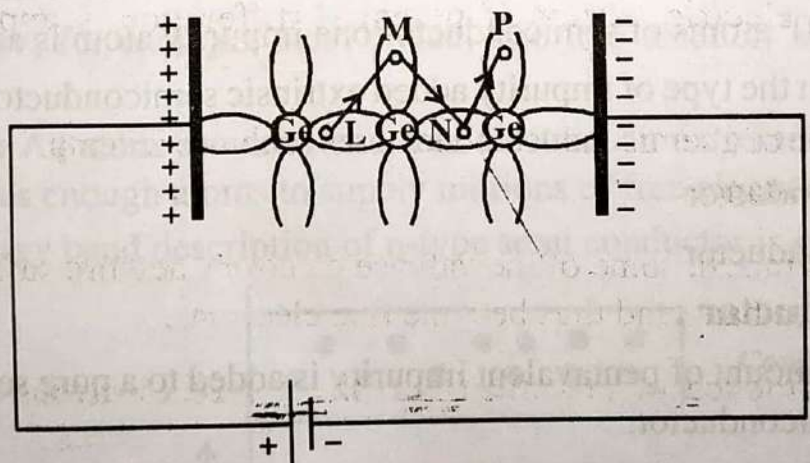
* This creates a hole in the covalent bond at L.

* The hole is a strong centre of attraction for the electron.

* A valence electron (say at M) from nearby covalent bond comes to fill in the hole at L.

* This results in the création of hole at M, thus creating a hole at N.

* Thus, the hole having a positive charge has moved from L to N i.e., towards the negative thermal of supply. This constitutes hole current.



* The hole current is due to the movement of valence electrons from one covalent bond to another bond.

* Even if the conduction is by electrons it is called as hole current because the basic reason for current flow is the presence of holes in the covalent bonds.

Types of Semiconductors :

Semiconductors are of two types :

1. Intrinsic semiconductor
2. Extrinsic semiconductor

1. Intrinsic semiconductor :

* A semiconductor in an extremely pure form is known as an intrinsic semiconductor.

* In an intrinsic semiconductor even at room temp. electron hole pairs are created.

* When electric field is applied across an intrinsic semiconductor, the current conduction takes place by two processes namely by free electrons and by holes. Therefore, the total current inside the semiconductor is the sum of currents due to free electrons and holes.

* The current in the external wires is fully by electrons.

* Intrinsic semiconductor has little current conduction capability at room temp.

2. Extrinsic semiconductor :

* Since the intrinsic semiconductor has little current conduction capability at room temp. to be useful in electronic devices, it is needed that the semiconductor has more conduction capability.

* This is achieved by adding a small amount of suitable impurity to a semiconductor.

* When impurity is added to a semiconductor it is called as extrinsic semiconductor.

* The process of adding impurity to a semiconductor is called as doping.

* Generally for 10^8 atoms of semiconductor one impurity atom is added.

* Depending upon the type of impurity added extrinsic semiconductors are classified into two types.

(a) n-type semiconductor

(b) p-type semiconductor

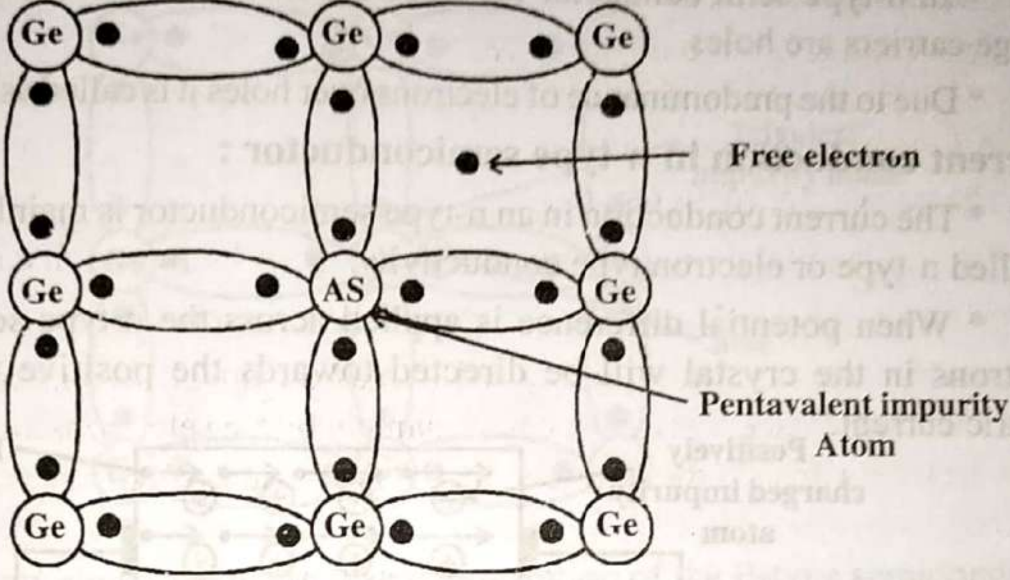
(a) n - type semiconductor :

* When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as n-type semiconductor.

* The addition of pentavalent impurity provides a large no. of free electrons in the semiconductor crystal.

* Example of pentavalent impurity : Arsenic and Antimony.

* Such impurities which produce n-type semiconductor are known as donor impurities because they donate or provide free electrons to the semiconductor crystal.



The formation of n-type semiconductor can be explained as follows :

* Let's consider a pure germanium crystal.

* Ge has four valence electrons.

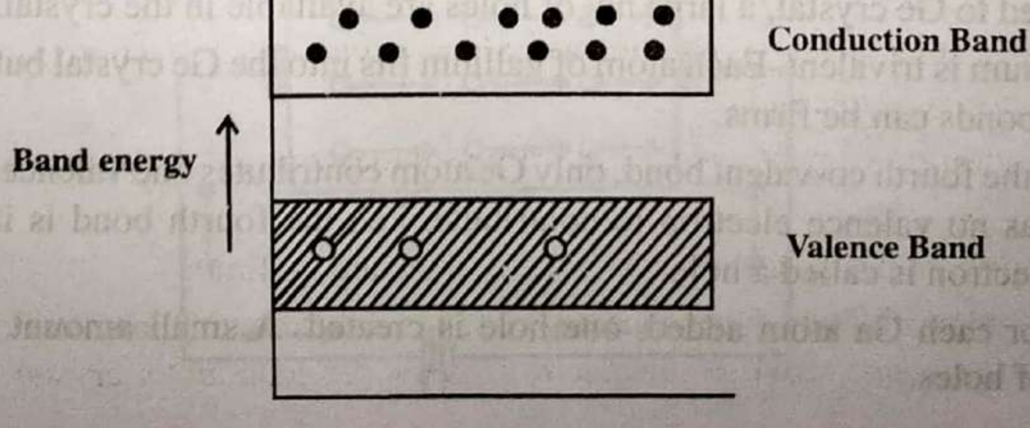
* When a small amount of pentavalent impurity like As or Sb is added to germanium crystal a large no. of free electrons become available in the crystal.

* As is pentavalent *i.e.*, its atom has five valence electrons. An 'As' atom fits in the Germanium crystal in such a way that its four valance electrons form covalent bonds with four Ge atoms. The fifth valence electron of As atom finds no place in covalent bonds and thus becomes free.

* Therefore, for each As atom added, one free election will be available in the Ge crystal.

* As each As atom provides one free electron an extremely small amount of As impurity provides enough atoms to supply millions of free electrons.

* The energy band description of n-type semi conductor is given below.



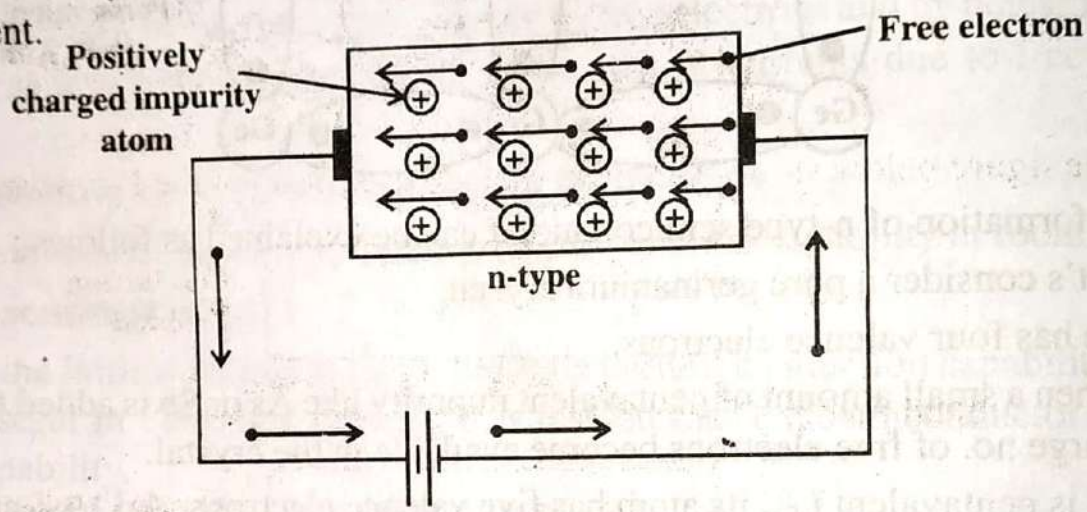
* In n-type semi conductor the majority charge carries are electrons and minority charge carriers are holes.

* Due to the predominance of electrons over holes it is called as n-type semi conductor.

Current conduction in n-type semiconductor :

* The current conduction in an n-type semiconductor is mainly by free electrons and is called n-type or electron type conductivity.

* When potentiãl difference is applied across the n-type semiconductor, the free electrons in the crystal will be directed towards the positive terminal, constituting electric current.



P-type semiconductor :

* When a small amount of trivalent impurity is added to a pure semiconductor, it is called n-type semiconductor.

* The addition of trivalent impurity provides a large no. of holes in the semiconductor.

* Example of trivalent impurity are Gallium and Indium.

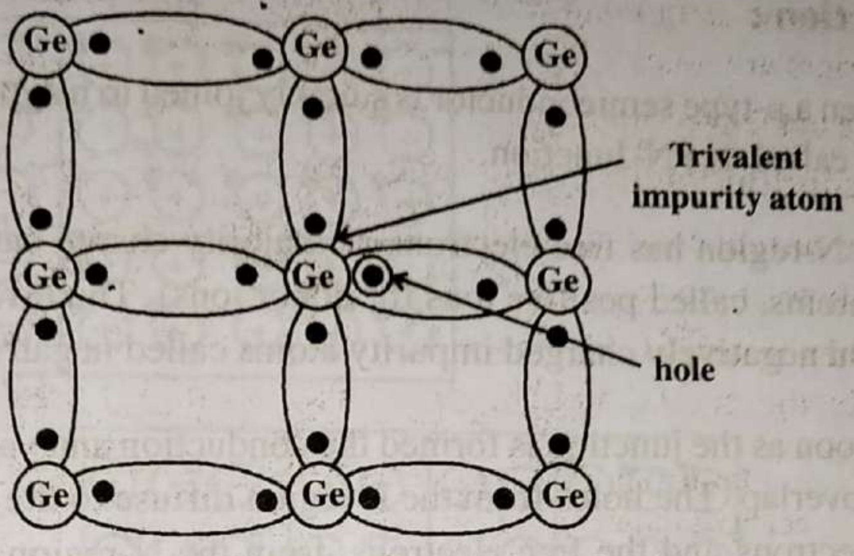
* Such impurities are known as acceptor impurities, because the holes created can accept the electrons.

* Let's consider a pure Ge crystal. When a small amount of trivalent impurity like Ga, is added to Ge crystal, a large no. of holes are available in the crystal.

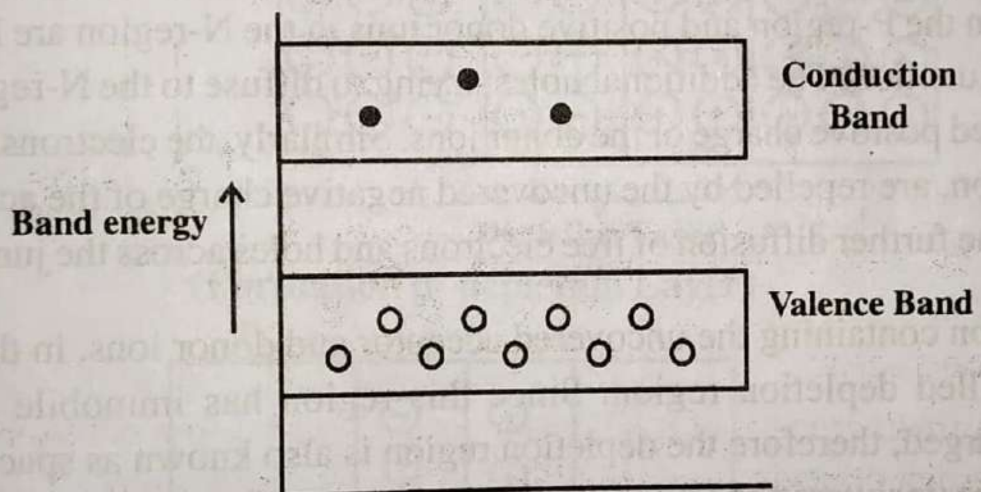
Gallium is trivalent. Each atom of gallium fits into the Ge crystal but now only three co-valent bonds can be firms.

* In the fourth co-valent bond, only Ge atom contributes one valence electron. While gallium has no valence electron to contribute. i.e., the fourth bond is incomplete. The missing electron is called a hole.

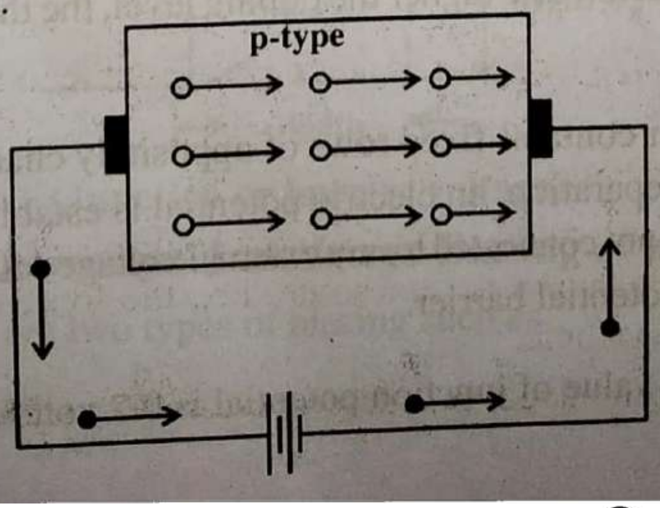
* For each Ga atom added, one hole is created. A small amount of Ga provides millions of holes.



* The figure below shows the energy band description of the P-type semiconductor.



* Due to predominance of holes over free electrons it is called p-type semiconductor.
* When potential difference is applied to the p-type semiconductor the holes are shifted from one co-valent bond to another.
* As the holes are positively charged, they are directed towards the negative terminal, constituting hole current.



PN-Junction :

When a p-type semiconductor is suitably joined to n-type semiconductor, the contact surface is called as PN-Junction.

The N-region has free electrons as majority charge carries and positively charged impurity atoms, called positive ions (or donor ions). The P-region has holes (as majority carries) and negatively charged impurity atoms called negative ions (or acceptor ions).

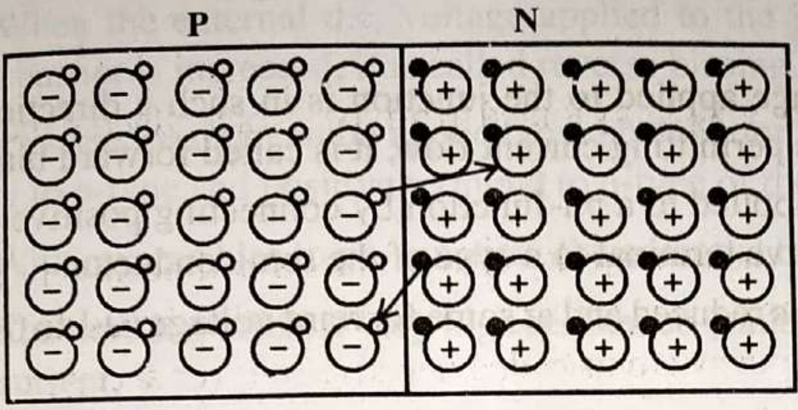
As soon as the junction is formed the conduction and valence bands of P and N-type materials overlap. The holes from the P-region diffuse to the N-region and combine with the free electrons and the free electrons, from the N-region diffuse to the P-region and combine with the holes and disappears due to recombination. In this process the negative acceptor ions in the P-region and positive donor ions in the N-region are left uncovered in the vicinity of junction. The additional holes, trying to diffuse to the N-region, are repelled by the uncovered positive charge of the donor ions. Similarly, the electrons, trying to diffuse into the F-region, are repelled by the uncovered negative charge of the accepter ions. As a result of this, the further diffusion of free electrons and holes across the junction is stopped.

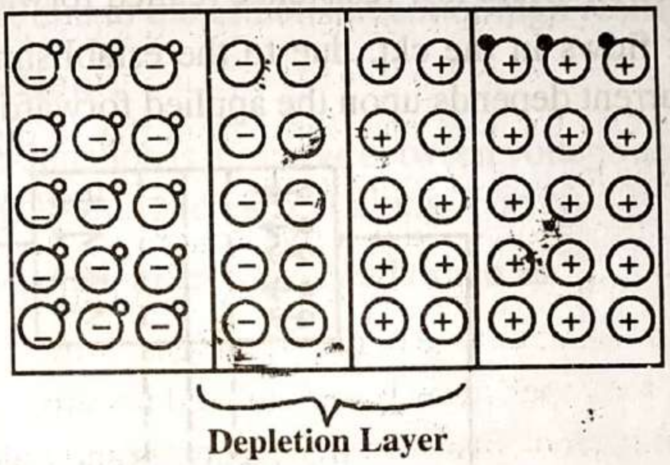
The region containing the uncovered acceptor and donor ions, in the vicinity of the junction, is called depletion region. Since this region has immobile ions, which are electrically charged, therefore the depletion region is also known as space-charge region. Moreover, as the uncovered charges with the depletion region exists in the form of parallel rows or plates of opposite charges, therefore it is known as depletion layer. The depletion layer behaves like an insulator.

The width of depletion layer depends upon the doping level of the impurity in N-type or P-type semiconductor. The higher the doping level, the thinner will be the depletion layer and vice-versa.

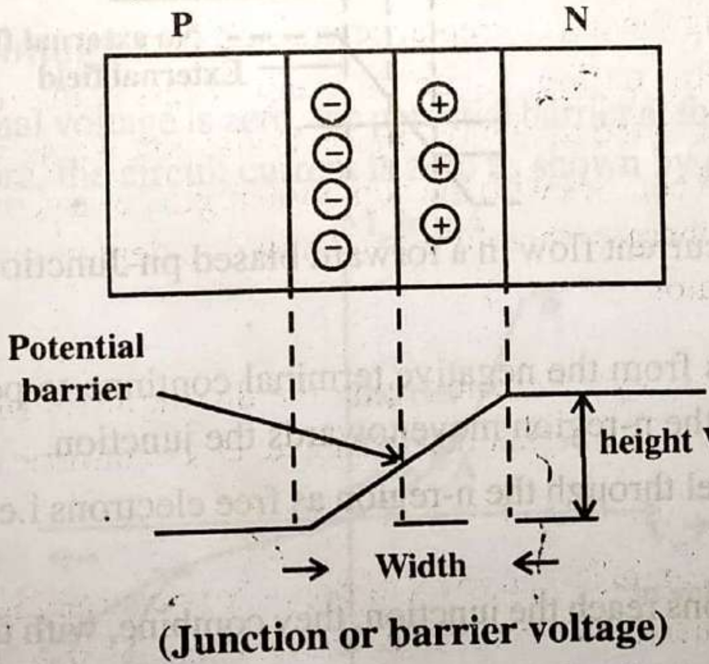
The depletion layer contains fixed rows of oppositely charged ions on its two sides. Because of this charge separation, an electric potential is established across the junction, even when the junction is not connected to any external voltage source. This electric potential is called as junction or potential barrier.

At room temp. the value of junction potential is 0·7 volt for silicon and 0·3 volt for Germanium.





(Formation of depletion Layer)



(Junction or barrier voltage)

Applying D.C. voltage across pn-Junction or Biasing of a pn Junction :

In pn Junction there are two types of biasing such as

1. Forward Biasing
2. Reverse Biasing

1. Forward Biasing :

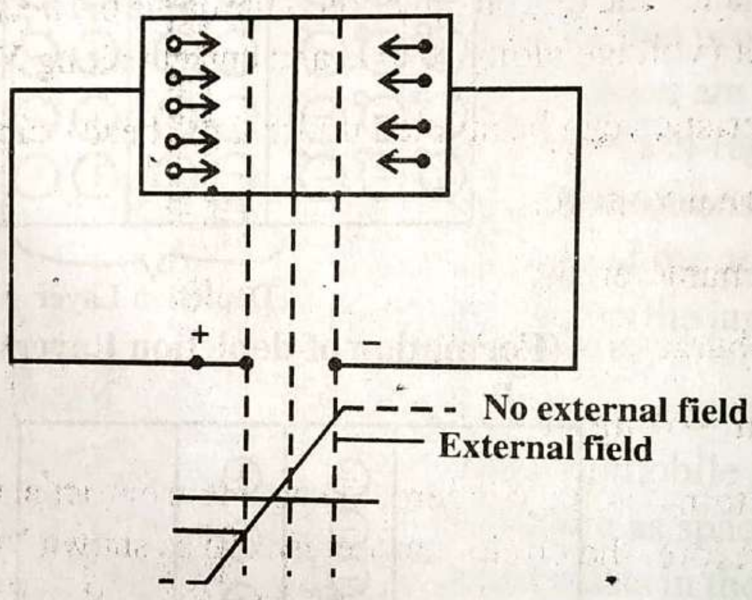
* When external d.c. voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting current flow, it is called forward biasing.

* Forward biasing can be applied to a pn-Junction by connecting positive terminal of the battery to p-type and negative terminal to n-type of the semiconductor.

* Here the potential barrier is reduced and at some forward voltage (0·1 to 0·30), it is eliminated altogether.

* The junction offers low resistance (called forward resistance, R_f) to current flow.

* Current flows in the ckt. due to the establishment of low resistance path. The magnitude of current depends upon the applied forward voltage.



The mechanism of current flow in a forward biased pn-Junction can be described as follows :

* The free electrons from the negative terminal continue to pour into the n-region while the free electron in the n-region move towards the junction.

* The electrons travel through the n-region as free electrons i.e., current in n-region is by free electrons.

* When these electrons reach the junction, they combine, with the holes and become valence electrons.

* The electrons travel through p-region as valence electrons i.e., current in the p-region by holes.

* When these valence electrons reach the left of the crystal, they flow into the positive terminal of the battery.

2-Reverse Biasing :

* When the external d.c. voltage applied to the junction in such a direction that potential barrier is increased, it is called reverse biasing.

* Reverse biasing can be applied to a pn-Junction by connecting negative terminal of battery to p-type and positive terminal to n-type of the pn-Junction.

* With reverse bias to pn-Junction, the potential barrier is increased.

* The junction offers a very high resistance (called as reverse resistance, R_r) to the flow of current.

* No current flows in the ckt due to the establishment of high resistance path.

V-I characteristics of pn-Junction :

The V-I characteristic of a pn-Junction is the curve between voltage across the junction and the ckt. current (voltage along X-axis and current along Y-axis).

The characteristics can be studied under three heads such as

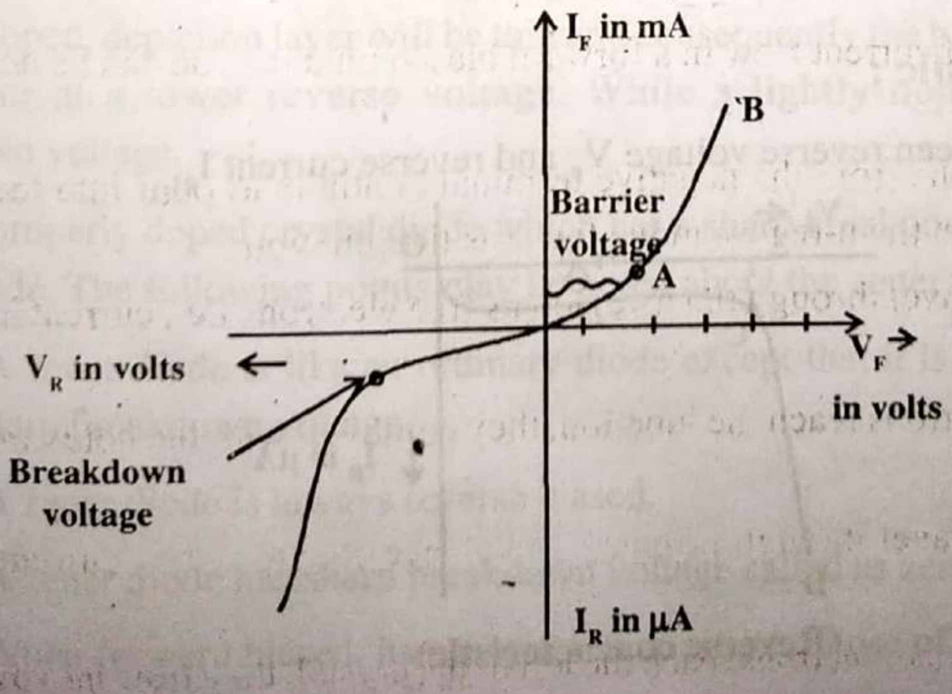
1. Zero external voltage.

2. Forward characteristics.

3. Reverse characteristics.

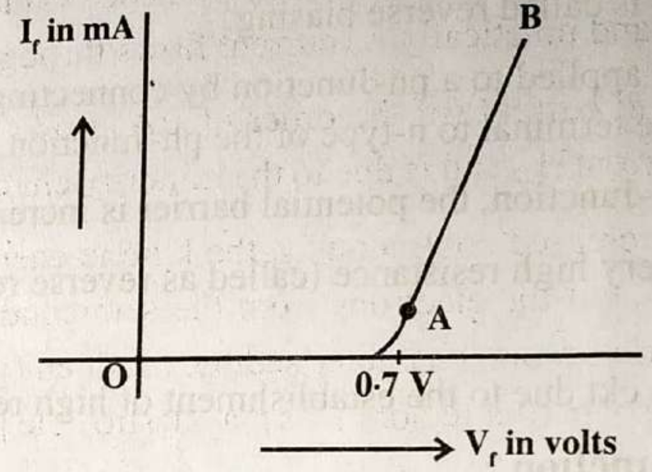
1. Zero External Voltage :

When the external voltage is zero, the potential barrier at the junction does not permit current flow. Therefore, the circuit current is zero as shown by point 0.



2. Forward characteristic :

It is the curve between forward voltage V_f and forward current I_f.



* Here the curve OAB represents the forward characteristic of a silicon pn-Junction diode.

* It is clear from the forward characteristic that there is no diode current till the point A is reached, because the external applied voltage is opposed by the junction voltage, whose value is 0·7 V for silicon and 0·3 V for Ge.

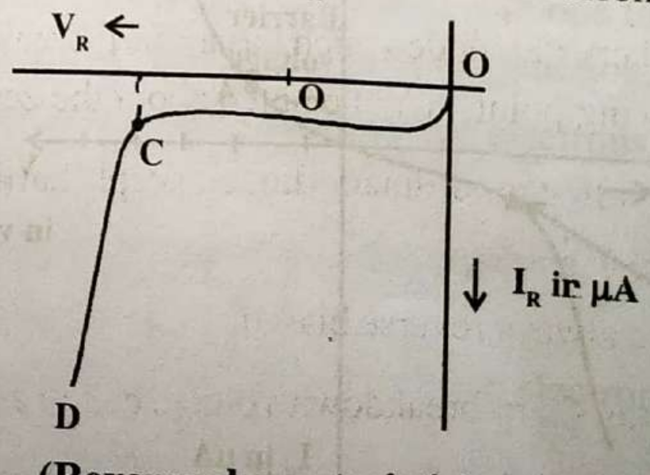
* As the voltage is increased above that point A, the diode current increases rapidly.

* The voltage at which the diode starts conducting, is called as knee voltage or barrier voltage or cent-in voltage or threshold voltage.

Note : *It has been observed that a voltage of about 1 volt produces a forward current of about 20 to 50 mA.*

3. Reverse characteristic :

It is the curve between reverse voltage V_R and reverse current I_R.



(Reverse characteristic)

* The curve OCD represents the reverse characteristic of the diode.

* While forward biasing, the potential barrier at the junction is increased, the junction resistance becomes very high and practically no current flows through the circuit.

* Practically a very small current (of the order of μA) flows in the ckt. which is called as reverse saturation current (I_s) and is due to the minority charge carries i.e., holes.

* If reverse voltage is increased continuously, the kinetic energy of electrons may become high enough to knock out the electrons from the semiconductor atoms. At this stage breakdown of the junction occurs, characterised by a sudden rise of reverse current and sudden fall of the resistance of barrier region. This may destroy the junction permanently.

* The voltage at which breakdown of the junction occurs, is called as breakdown voltage.

Zener diode :

We know that when the reverse bias on a crystal diode is increased, a critical voltage called breakdown voltage is reached where the reverse current increases rapidly to a high value.

The satisfactory explanation of the junction was first given by American scientist C. Zener. Therefore, the breakdown voltage is sometimes called as zener voltage and the sudden increase in current is known as Zener current.

The breakdown or zener voltage depends upon the amount of doping. If the diode is heavily doped, depletion layer will be thin and consequently the breakdown of the junction will occur at a lower reverse voltage. While a lightly doped diode has a higher breakdown voltage.

A properly doped crystal diode which has a sharp breakdown voltage is known as a zener diode. The following points may be noted about the zener diode.

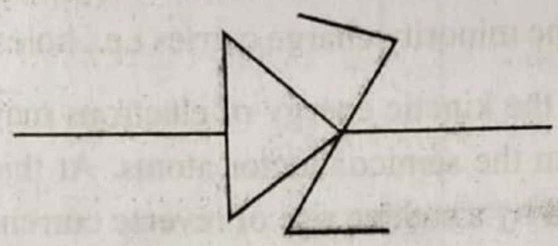
* A zener diode is like an ordinary diode except that it is properly doped so as to have a sharp breakdown voltage.

* A zener diode is always reverse biased.

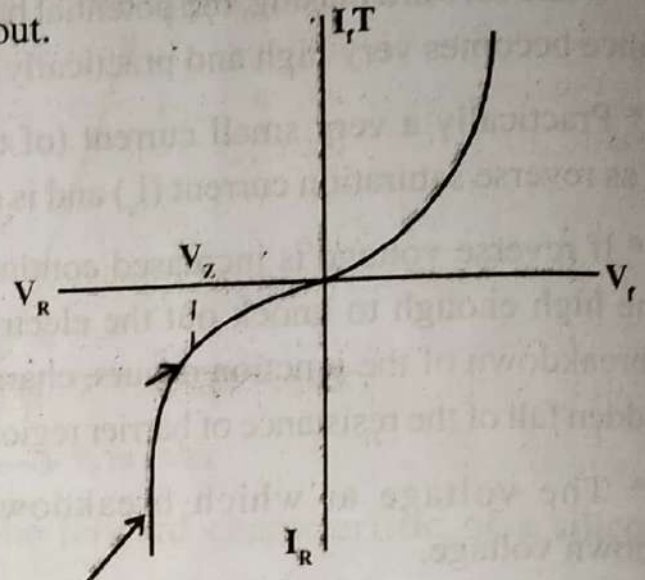
* A zener diode has sharp breakdown voltage called as zener voltage V_Z.

* When forward biased, its characteristics are just those of ordinary diode.

* The zener diode is not immediately burnt just because it has entered the breakdown region. As long as the external ckt. connected to the diode limits the diode were to less than burn out value, the diode will not burn out.



(Symbol of Zenerdiode)



Reverse characteristic of zener diode

Application of Zener diode :

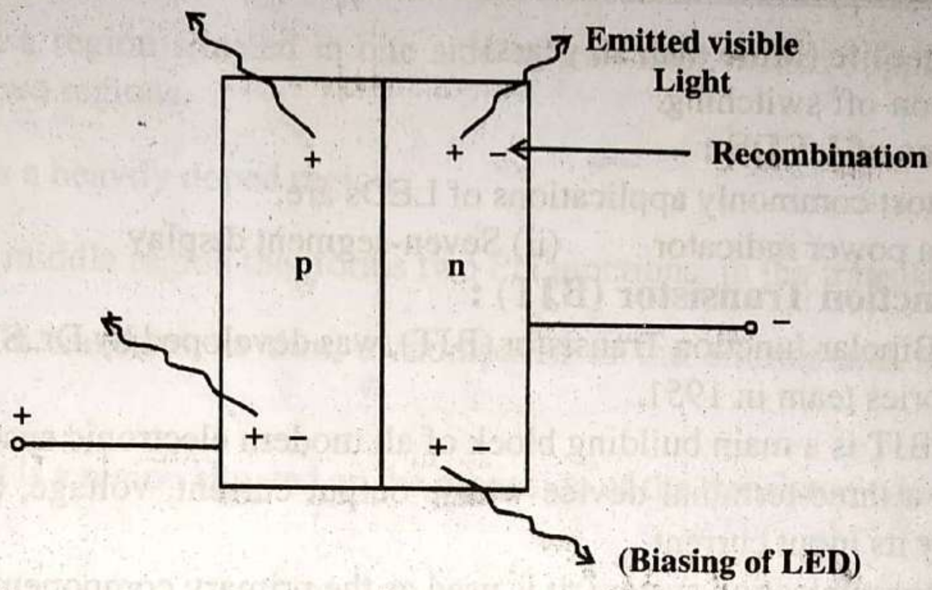
* It can be used as a voltage regulator.
* It can be used as a fixed reference voltage in transistor biasing ckt.
* It can be used as peak clippers or limiters in waveshaping ckts.
* Used for meter protection against damage from accidental applications etc.

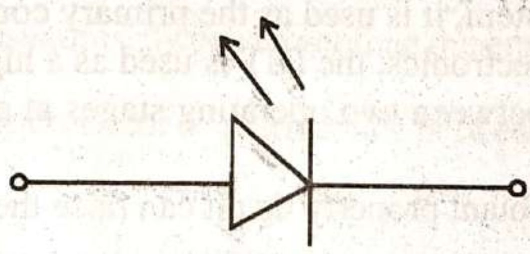
Light emitting diode (LED) :

A light-emitting diode is a diode that gives off visible light when forward biased.

Light-emitting diodes are not made from silicon or germanium but are made by using elements like galium, phosphorus and Arsenic. By varying the quantities of these elements, it is possible to produce light of different wavelengths with colours that include Red, Green, Blue and Yellow.

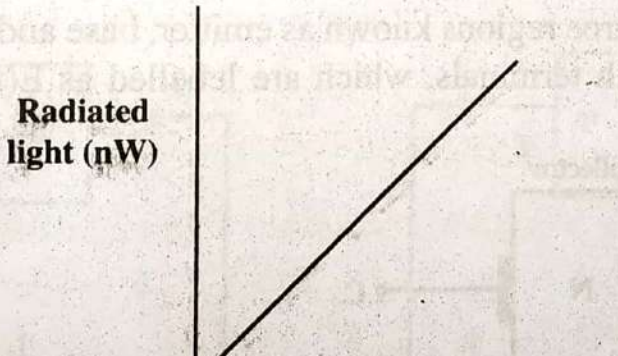
When LED is forward biased, the electrons from the n-type material cross the pn-Junction and recombine with holes in the p-type material. When recombination occurs, the recombining electrons release energy in the from of heat and light. In Ge and Si, diodes, almost the entire energy is given up in the form of heat and emitted light is insignificant. But in materials like Gallium Arsenide, the no. of photons of light energy is sufficient to produce quite intense visible light.





(Schematic symbol of LED)

→ Although LEDs are available in several colours the schematic symbol is same for all LEDs.



The above figure shows the graph between radiated light and the forward current of the LED. From the graph it can be studied that the intensity of radiated light is directly proportional to the forward current of LED.

Advantages of LED :

* The LED is a solid-state light source. LEDs have replaced incandescent lamps in many applications because they have the following advantages.

* Low voltage.

* Longer life (More than 20 years)
* Fast on-off switching.

Applications of LEDS :

Two most commonly applications of LEDs are;

(i) As a power indicator (ii) Seven-segment display

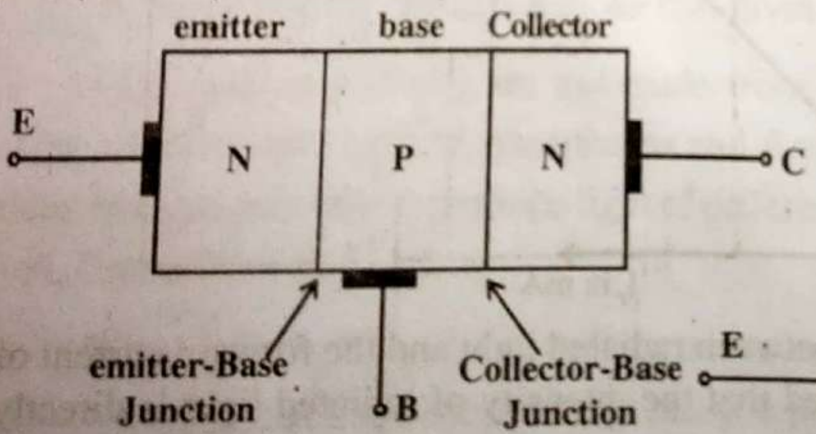
Bipolar Junction Transistor (BJT) :

* The Bipolar Junction Transistor (BJT), was developed by Dr. Shockley along with Bell laboratories team in 1951.
* The BJT is a main building block of all modern electronic systems.
* It is a three-terminal device whose output current, voltage, and / or power are controlled by its input current.
* In communication system, it is used as the primary component in the amplifier.
* In digital computer electronics, the BJT is used as a high-speed electronic switch that is capable of switching between two operating stages at a rate of several billions of times per second.
* A BJT has a very impotant property that it can raise the strength of a weak signal.

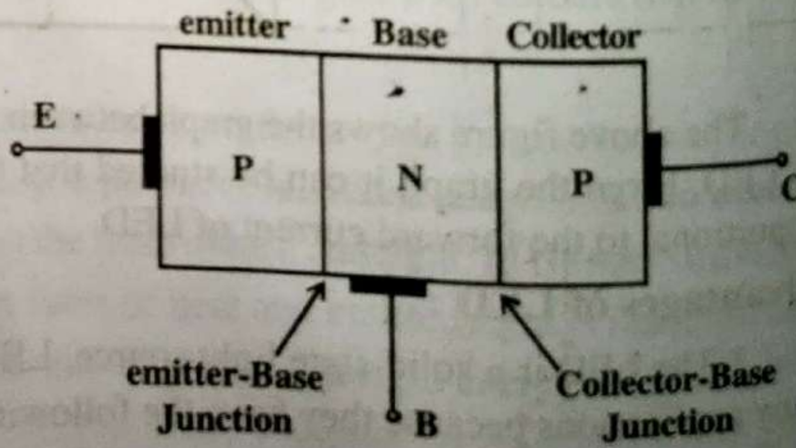
BJT Construction :

A Bipolar Junction Transistor consists of two PN Junctions. The junctions are formed by sandwitching either P-type or N-type semiconductor layers between a pair of opposite types.

A BJT has, essentially, three regions known as emitter, base and collector. All these three regions are provided with terminals, which are lebelled as E(for Emitter), B (for Base) and C(for Collector).



(NPN Transistor)



(PNP Transistor)

Emitter : It is a region situated in one side of transistor, which supplies charge carriers to the other two regions.

* The emitter is a heavily doped region.

Base : It is the middle region that forms two PN junctions, in the transistor.

* The base of a transistor is thin, as compared to the emitter and is a lightly doped region.

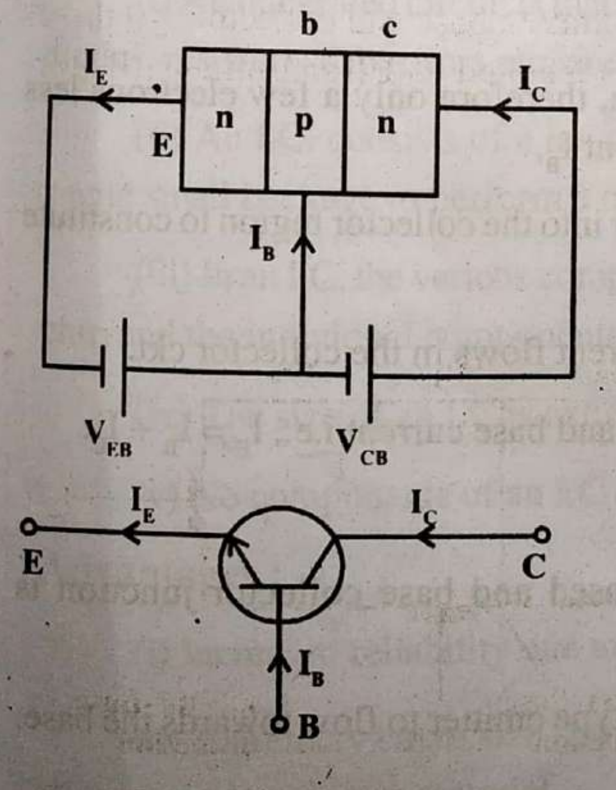
Collector : * It is a region situated on the other side of the transistor, which collects charge carriers.

* The collector of a transistor is always larger than the emitter and base of a transistor.

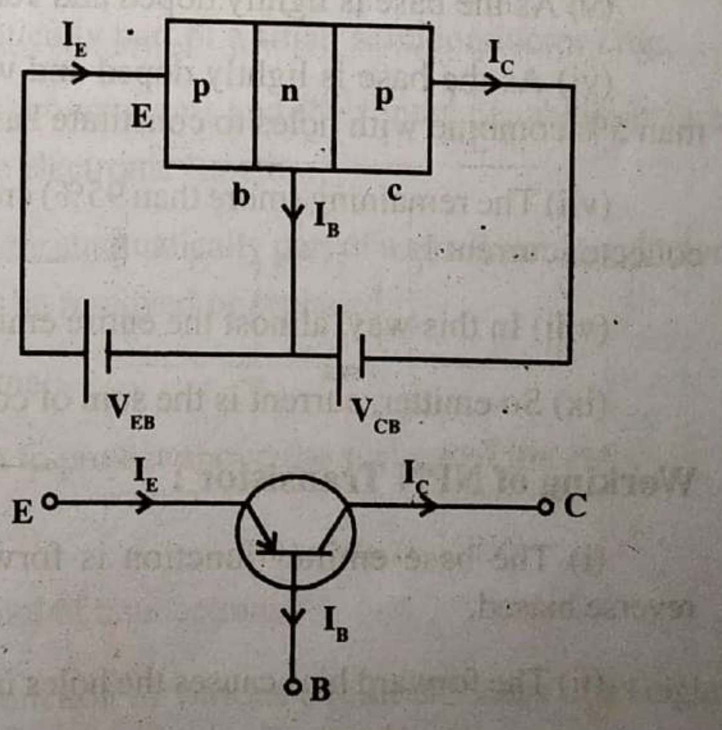
* The doping level of the collector is intermediate between the doping lebel of emitter and base.

BJT has two PN junctions such as emitter base junction and collector base junction.

Bipolar Junction Transistor Symbols :



(NPN)

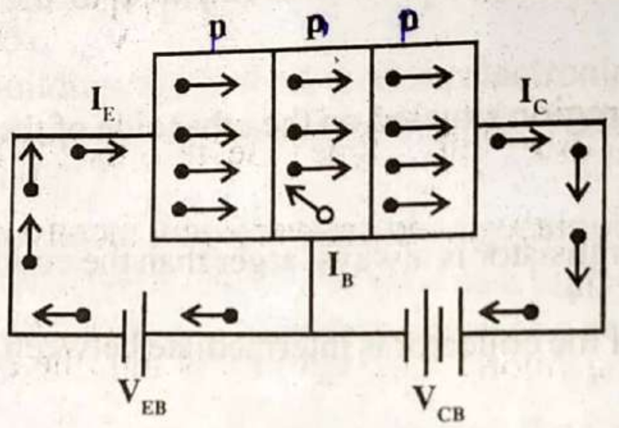


(PNP)

Working of PNP Transistor :

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

(ii) The forward bias causes the electrons in the n-type emitter to flow towards the base.



(iii) This constitues the emitter current I_E.

(iv) As these electrons flow through the p-type base, they tend to combine with holes.

(v) As the base is lightly doped and very thin.

(vi) As the base is lightly doped and very thin, therefore only a few electrons less than 5% combine with holes to constitute base current I_B.

(vii) The remaining (more than 95%) cross over into the collector region to constitute collector current I_C.

(viii) In this way, almost the entire emitter current flows in the collector ckt.

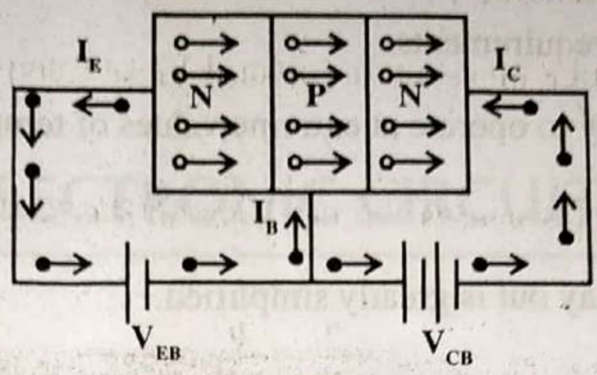
(ix) So emitter, current is the sum of collector and base current i.e., $I_E = I_B + I_C$.

Working of NPN Transistor :

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

(ii) The forward bias causes the holes in the p-type emitter to flow towards the base.

(iii) This constitutes emitter current I_E.



(iv) As these holes cross into n-type base, they tend to combine with the electrons.

(v) As the base is lightly doped and very thin, therefore, a few holes (less than 5%) combine with the electrons.

(vi) The remaining (more than 95%) cross into the collector region to constitute collector current I_c.

(vii) In this way, almost the entire emitter current flows in the collector circuit.

Integrated circuits :

(i) An integrated circuit is that circuit in which circuit components such as transistors, diodes, resistors, capacitors etc. are automatically part of a small semiconductor chip.

(ii) An I.C. consists of a no. of circuit components and their inter-connections in a single small package to perform a complete electronic function.

(iii) In an I.C, the various components are automatically part of a small semiconductor chip and the individual components cannot be removed or replaced.

(iv) The size of an I.C is extremely small.

(v) No components of an I.C are seen to project above the surface of the chip.

Advantages :

(i) Increased reliability due to lesser no. of connections.

(ii) Extremely small size due to the function of various circuit elements in a single chip of semiconductor material.

(iii) Lesser weight and space requirement.

(iv) Low power requirements.

(v) Greater ability to operate at extreme values of temp.

(vi) Low cost

(vii) The circuit lay out is greatly simplified.

Disadvantages :

(i) If any component in an I.C goes out of order, the whole I.C has to be replaced by the new one.

(ii) In I.C it is neither convenient nor economical to fabricate capacitances exceeding 30 PF, therefore for high values of capacitance, discrete components exterior to IC chip are connected.

(iii) It is not possible to fabricate inductors and transformers on the surface of semiconductor chip. Therefore, these components are connected exterior to the semi-conductor chip.

(iv) It is not possible to produce high power Ics.

Difference between Vacuum tube and Semiconductor :

Semiconductor	Vacuum Tube
(i) Small in size	(i) Big in size
(ii) Light in weight	(ii) Heavy in weight
(iii) Have longer life	(iii) Have less life
(iv) Easy operation	(iv) Complex operations
(v) No filament is present	(v) Filament is required. So heating power is required.
(vi) Very low operating voltage is required	(vi) Very high operating voltage is required.
(vii) Consumes less power and produces high efficiency	(vii) Consumes high power and produces low efficiency.

■