ELECTROMAGNETIC WAVES 16

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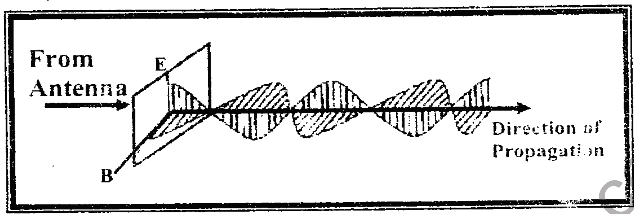
16.1 ELECTROMAGNETIC WAVES:

Faraday discovered that a varying magnetic field can produce varying electric field. Maxwell showed that varying electric field can produce varying magnetic field. ***Such moving electric and magnetic fields which can propagate out in the surrounding space are known as electro-magnetic waves.*** In electromagnetic waves both electric and magnetic fields are perpendicular to each other and their direction reverses together with each cycle. As electric and magnetic fields can exists in vacuum, therefore no medium is required to transmit energy by electromagnetic waves.



The speed of the electro magnetic wave depends upon the permeability and permitivity of the medium through which it propagates.

For Free Space

$$C = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

$$C = 3 \times 10^8 \text{ m/s}$$

Thus the speed of electromagnetic wave is the same as the speed of light in free space. Maxwell therefore proposed that light is a transverse electromagnetic radiation.

16.2 ANTENNA

"An antenna is the device, which can generate or receive electromagnetic waves".

The one which can generate electromagnetic wave is called ***Transmitting Antenna*** and the one which can receive electromagnetic wave is called ***Receiving Antenna.*** However advanced electronics has made it possible to construct such an antenna which can transmit and receive electromagnetic waves simultaneously.

A simple transmitting antenna is formed by two metal rods connected with an alternating source. At any time t=0 charges are located at the midway between the rods. In the first half cycle when current reaches to its peak value, both positive and negative charges are pushed at the opposite ends of the two rods and come back to initial position when current falls to zero, thereby producing varying electric and magnetic fields. In the second half cycle as the cycle of current alters, therefore charges are pushed at the opposite ends of the rod in the opposite directions and hence varying electric and magnetic fields are produced but in opposite direction, which propagate out in space.

16.3 MODULATION

"Modulation is the technique by which some characteristics of carrier wave are varied with time in accordance with the modulation signal."

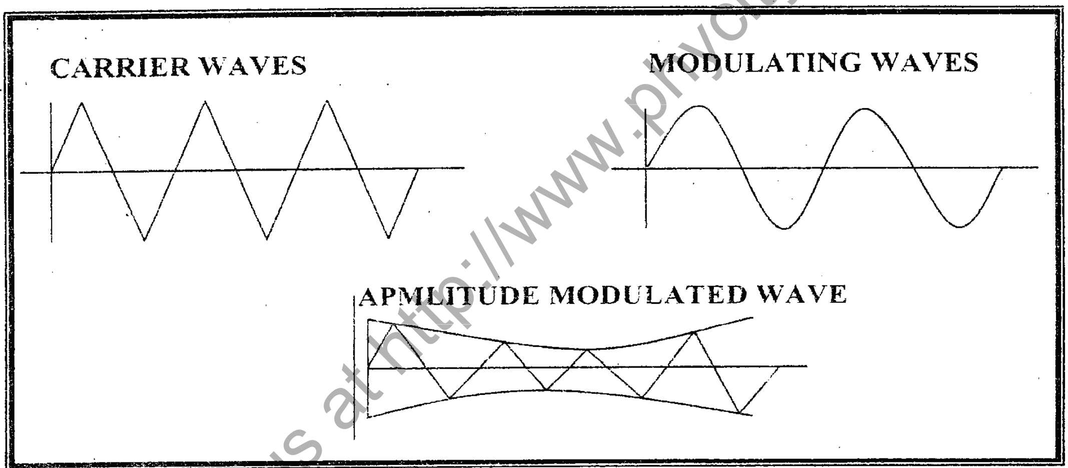
OR

"Process of combining audio frequency (A.F) and radio frequency (R.F) waves to accomplish translation is called Modulation."

There are two types of modulation.

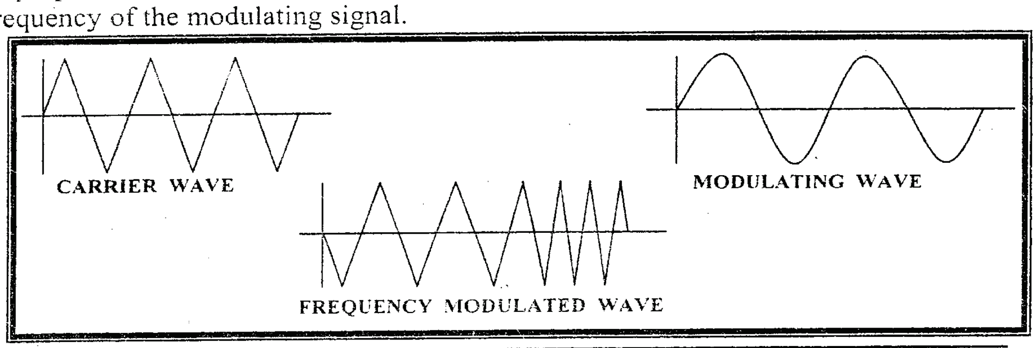
i) AMPLITUDE MODULATION (A.M)

In amplitude modulation the carrier wave amplitude is varied in accordance with the modulating signal. The modulated wave form sketched in the figure shows that the outline of the modulated carrier wave is similar in form to the modulating signal, accordingly this outline is called the ***Modulation Envelope.*** In Amplitude modulation the frequency of modulated carrier wave is maintained at its original strength.



ii) FREQUENCY MODULATION (F.M)

In Frequency modulation the carrier wave frequency is varied in accordance with the modulating signal, whereas the amplitude of the modulated carrier wave is maintained at its original strength. The frequency of the modulated carrier wave varies in proportion to the amplitude of the modulating signal and at a rate determined by the frequency of the modulating signal.



16.4 DE-MODULATION:

"The process by which the original modulation signal or intelligence is recovered in the receiver is called Demodulation."

The carrier wave which has radiated from transmitting antenna in the form of electromagnetic wave, in turn induce small voltage into the receiving antenna. These voltages are fed to a tuned radio frequency (R.F) amplifier, which fed amplified signal to the speaker.

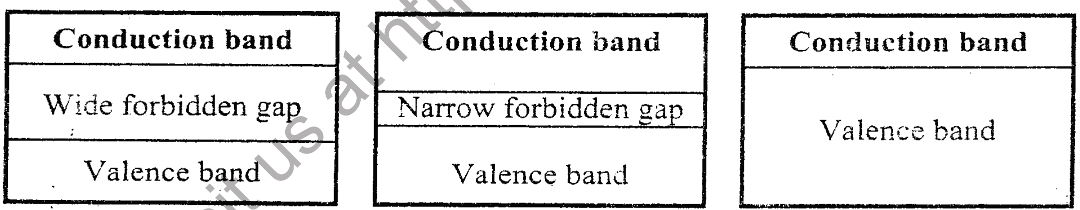
16.5 BAND THEORY OF SOLIDS:

Free electron theory can explain the conductivity of solid metals only. Conductivity of semi conductors could not be explained by free electron theory. To explain the conductivity of semi conductors as well as of solid metals a theory from modern physics is made which is called as ***Band Theory of Solids.***

According to the band theory of solids atoms are said to be initially in the ground state called ***valence band.*** With the gain of energy atoms reach at the higher state called the ***conduction band.*** Between conduction band and valence band, there is a ***forbidden gap.***

Those substances in which there is a wide forbidden gap between valence band and conduction band are called the ***insulators***. In insulator there is an empty conduction band and electrons reside in the valence band only. Those substances in which there is no forbidden gap between valence band and conduction band are called ***conductors.*** In conductors both conduction and valence bands overlap on each other and hence there is an empty valance band, and electrons reside in the conduction band.

Those substances in which there is a medium or narrow forbidden gap between valence band and conduction band are called ***semi-conductors***. In semi-conductors there are partially filled valence band and conduction band.



Insulator **Semi-Conductor** **Conductor**

16.6 SEMI-CONDUCTORS:

"Those substances in which there is a medium or narrow forbidden gap between valence band and conduction band are called semi-conductor substances."

OR

"Those substances, which are insulators at ordinary conditions but by some technique could be changed into conductors are called semi-conductor devices".

In a pure semi-conductor only a few electrons may have enough energy to jump from the valence band to the conduction band. So there will be a small amount of electrical conductivity. If the temperature is raised, more electrons will have enough energy to jump the gap, which decreases the resistivity. In a doped semi-conductor, the impurity provides additional energy states between the bands thus increasing the electrical conductivity.

Elements of group IV of the periodic table are the semi-conductors e.g. Germanium, silicon.

Intrinsic Semi-Conductors:

Pure semi-conductors are also called intrinsic semi-conductors for example Germinium (Ge) and Sillicon (Si).

Extrinsic Semi-Conductors:

Impure or doped semi-conductors are called Extrinsic Semi-Conductors there are following two types on extrinsic semi conductors (i) p-type (ii) n-type semi-conductors.

16.7 DOPING:

"The process of adding an impurity, either of trivalent element of group III e.g., Indium (In) or Gallium (Ga) or of pentavalent element of group V for e.g. Arsenic (As) or Antimony (Sb) into tetravalent element of group IV e.g. Germanium (Ge) or Silicon (Si) is called Doping."

Doped semi-conductor's materials are termed as extrinsic semi-conductors.

DONOR DOPING OR N-TYPE SUBSTANCE:

The process in which an-impurity of pentavalent element of group V [for e.g. As & Sb] is added into tetravalent elements of group IV [for e.g. Ge & Si] is called ***Donor Doping*** & the resultant extrinsics semi-conductor is called ***n-type substance***.

In n-type substances charge carriers are the electrons.

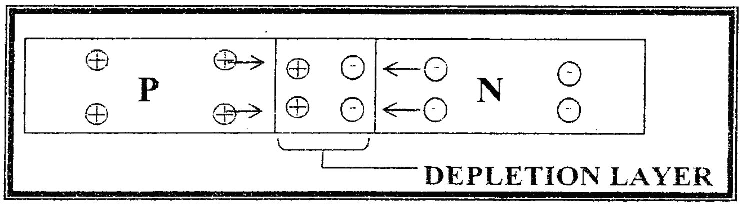
ACCEPTOR DOPING OR P-TYPE SUBSTANCE:

The process in which an impurity of trivalent element of group III [for e.g. In & Ga] is added into tetravalent element of group IV [e.g. Ge & Si] is called ***Acceptor Doping*** and the resultant extrinsic semi-conductor is called p-type substance.

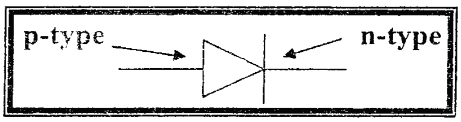
In p-type substance charge carrier are the holes or positive charge.

p-n DIODE OR p-n JUNCTION:

"A p-n diode is a two terminal device formed by joining a p-type and n-type semi-conductors." A junction between p-type and n-type is formed where holes and electrons diffuse into each other thereby forming a ***depletion layer***. The thickness of depletion layer provides a potential barrier which prevent further migration of holes and electrons through depletion layer. Thickness of depletion layer could be increased or decreased by varying the potential of the potential barrier, which increases or decreases the conductivity of diode. A p-n diode could be used in electrical circuits across a battery, as it permits the flow of current in one direction only.



In electronic circuits p-n diode is symbolized as,



16.8 BIASING:

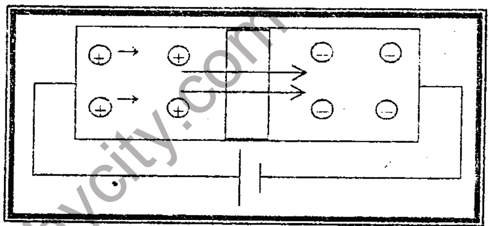
"Biasing is the method of changing the height of potential barrier or the thickness of depletion layer of p-n diode."

Biasing is of two types:

1) Forward Biasing.
2) Reverse Biasing.

1) FORWARD BIASING:

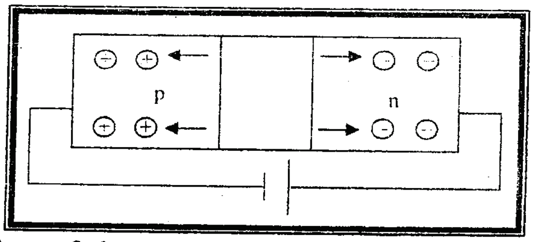
"When external voltage is applied to the p-n junction in such a direction that it cancels the potential barrier, thus permitting the flow of current is called forward biasing."



In forward biasing p-type substance is connected with the positive terminal of source and n-type with negative terminal of source. Due to electrostatic repulsion carrier of n-type cross over the depletion layer, thereby reducing its thickness, as a result of which, height of potential barrier decreases and small forward voltage is sufficient to completing eliminate the barrier. Once the potential barrier is eliminated a low resistance path is established for the entire circuit. Therefore electronic current flow in the circuit.

2) REVERSE BIASING:

"When an external voltage is applied to the p-n Junction in such a direction that potential barrier is increased, thus forbidding the flow of current is called Reverse Biasing."



In reverse biasing p-type substance is connected with negative terminal of source and n-type with positive terminal of source. Due to electrostatic attraction holes and carrier of p-type and n-type move away from depletion layer, thereby, increasing its thickness. As a result of which, height of potential barrier increases, which prevents the flow of charge across the junction. Thus a high resistance path is established for the entire circuit. As p-n diode behaves like a resistor, therefore, no current flows through the circuit.

16.9 RECTIFICATION:

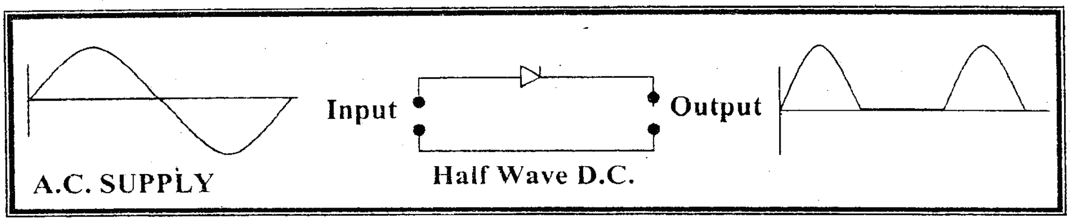
"Rectification is the process of converting alternating current into direct current"

A p-n diode in electronic circuits is used as a rectifier in two ways.

HALF-WAVE REACTION:

"The process of rectifying half-wave of input cycle of alternating current is called Half Wave Rectification."

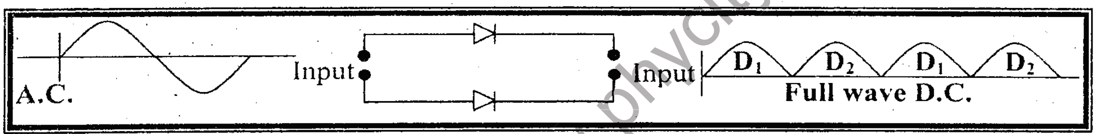
In half wave rectification p-n diode is connected in series with input A.C supply. During the first half cycle, there will be forward biasing of p-n diode due to which diode pass on the input wave of A.C. at the output. During, the second half-cycle there will be reverse biasing of p-n diode due to which diode will not pass on input wave of A.C at the output. Thus, at the output only half-wave of A.C. is rectified.



FULL-WAVE RECTIFICATION:

"The process of rectifying full wave of alternating current into direct current is called full wave rectification."

In full-wave rectification two diodes are employed in electronic circuit at the input. During the first half cycle, the first diode (D_1) is forward biased, whereas the second diode (D_2) is reverse biased. Hence, D_1 pass on the first half of A.C. at the output. During the second half cycle D_1 is reverse biased, whereas D_2 is forward biased. Hence D_2 will pass on the second half wave of A.C. at the output. In this way, full wave of A.C. is rectified.



16.10 PHOTO DIODE:

"A photo diode is the semi-conductor device which converts light energy into electrical energy"

A semi-conductor photo diode is a reverse biased p-n junction which is embedded in a plastic capsule. All the sides of the plastic capsule are painted black except the one which is to be illuminated. When light falls on the reserve biased p-n junction, new electron-hole pairs are formed, the concentration of which is proportional to the incident light flux.

Photo diodes are used in high speed reading computer punched cards and tapes, light detection system, light operating switches, production line counting of objects etc.

16.11 LIGHT EMITTING DIODE (LED):

"The light emitting diode is the device which gives off visible light when it is energized."

"A semi-conductor LED is a forward biased p-n junction". When a forward biased p-n diode is connected across the electrical source, electrons and holes due to electrostatic repulsion jump to conduction band from valence band in the depletion layer, where they collide with each other and loose their energy in the form of photons of visible light.

LED's can be used in battery operated devices because only tiny amount of power is required for light to be emitted. Several everyday products use LED's such as digital clocks, calculators etc.

16.12 SOLAR CELL:

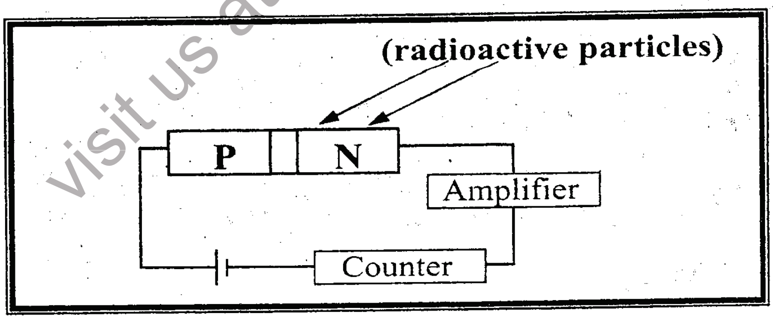
"A solar cell is a photo diode that is used to convert solar light energy into electrical energy"

A solar cell is a reverse biased P-n diode. In a solar cell, every effort is made to ensure that the surface area exposed to the sun is maximum. A photon of light energy in this region may collide with a valence electron and impart to it sufficient energy to leave the parent atom. The result is a generation of free electrons and holes. This phenomena will occur on each side of the junction and result in a generation of current in the solar cell. Solar cells are widely used in space vehicles.

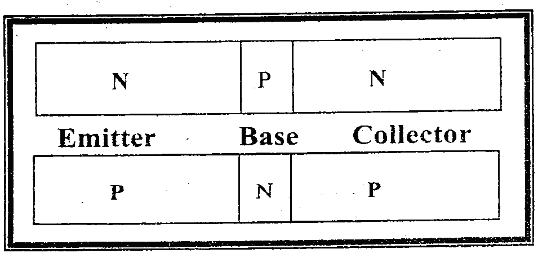
16.13 SOLID STATE DETECTORS:

"Solid state detectors are the semi-conductor devices used to detect radioactive radiations".

These devices basically make use of the solid state semi-conductor p-n diode which is reverse biased. Due to reverse biasing, depletion layer becomes wide and height of potential barrier increases. When a strong ionizing particle (radioactive particle) falls on p-n diode, electrons of n-type get sufficient energy to cross over the depletion layer. The current pulse so produced is then fed into an amplifier, which is then fed to a loud speaker or an electronic counter.



16.14 TRANSISTOR:



"Transistor is the three terminal device formed either by sandwiching n-type semi-conductor between two p-type semiconductors or by sandwiching p-type semi-conductor between two n-type semi-conductors"

The central semi-conductor in transistor is called ***Base.*** Where as, the left and right terminals are called ***Emitter and Collector*** respectively. The junction of base and emitter is called ***Base-Emitter (BE) junction*** whereas the junction of base and collector is called ***Base Collector (BC) junction.***

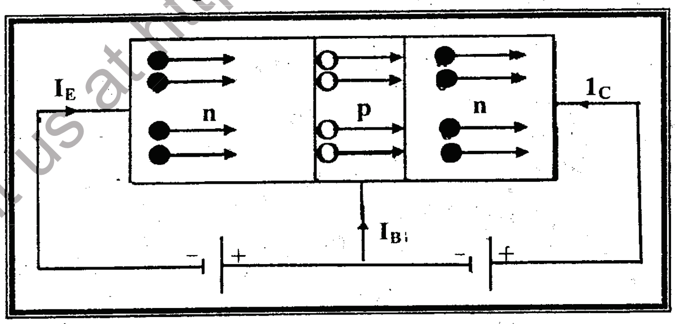
The base emitter junction is forward biased whereas base collector junction is reverse biased.

Charge of emitter migrate towards base emitter junction forming the emitter current (I_E). As base is little doped and thin, therefore only a few charge of emitter current will be neutralized with the charge of base and an equal amount of charge will come from the source forming the base current (I_B). Due to electrostatic repulsion of another source, charge from base will migrate towards the collector and form the collector current (I_C), such that.

$$I_E = I_B + I_C$$

nPn TRANSISTOR:

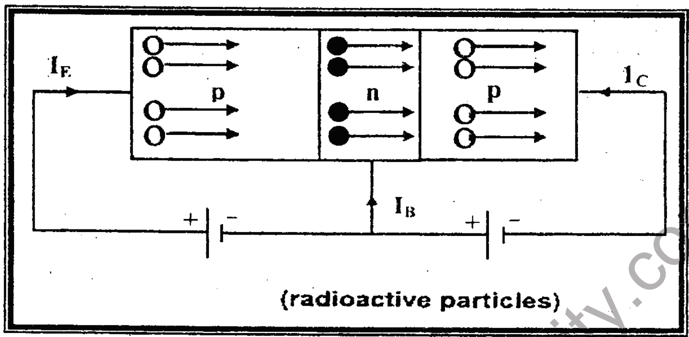
In nPn transistor a P-type substance is sandwiched between two n-type substances, with emitter-base junction forward biased and collector-base junction reverse biased, as shown in the figure.



The forward biasing of emitter base junction causes the electrons in the n-type to flow towards the base. This constitutes the emitter current I_E. As electrons flow through p-type base, they tend to combine with holes, since the base is little doped and is very thin, therefore, only a few electrons combine with holes to constitute base current I_B. Due to electrostatic repulsion of another source, electrons from base migrate to collector, forming collector current I_C. In this way, almost the entire emitter current flows in the collector circuit.

PnP TRANSISTOR:

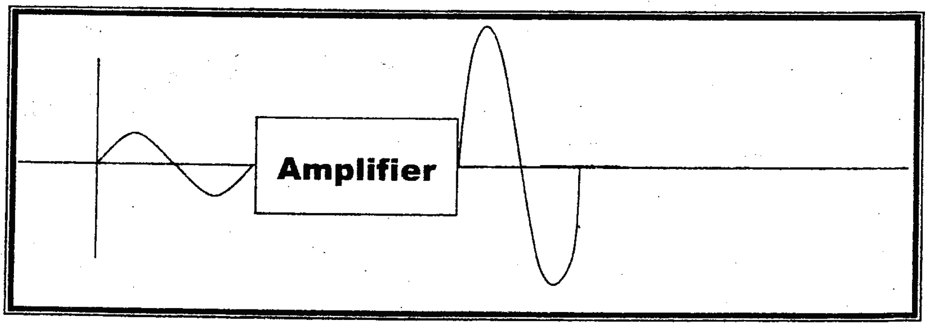
In PnP transistor an n-type substance is sandwiched between two p-type substances, with emitter-base junction forward biased and collector-base junction reserve biased, as shown in the figure.



The forward biasing of base-emitter junction causes the holes in the p-type emitter to flow towards the base which constitutes the emitter current I_E. As these holes cross into the n-type base, they tend to combine with electron, but since the base is little doped and thin, only a few holes combine with electron to constitute base current I_B. Due to electrostatic repulsion of another source, holes from base migrate to collector, forming collector current I_C. In this way, almost the entire emitter current flows in the collector circuit.

TRANSISTOR AS AN AMPLIFIER:

Amplifier is the device, which raises the strength of weak input signal at the output. The weak signal, which is to be amplified, is applied at the base-emitter junction, which is forward biased and the output is taken at base-collector. By increasing the potential V_{BE}, height of potential barrier of base-emitter junction decreases the collector current I_C which increases the strength of weak input signal at the output.

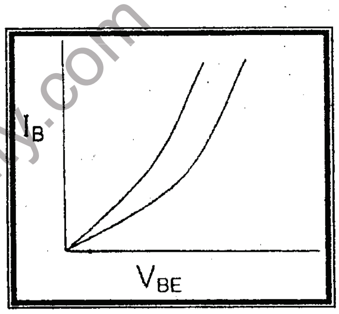


TRANSISTOR CHARACTERISTICS:

Transistor is a three terminal device. It can be used in circuit with its one terminal common between input and output. The three useful configuration are common base (CB), common emitter (CE) and common collector (CC). Common emitter is the most commonly used configuration in electronic devices. The input signal is applied between base and emitter while the output is taken between collector and emitter. The static characteristics of (CE) configuration contains two sets of curves, which are.

i) INPUT CHARACTERISTICS:

This set of curves gives the relationship between input voltage and input current. The output voltage V_{CE} is held constant and for different values of input voltage V_{BE}, the base current I_B is recorded. The curves plotted are called input characteristics curves.



ii) OUTPUT CHARACTERISTICS:

This set of curves gives the relationship between output voltage and output current. The input current I_B is held constant and for different values of V_{CE}, the collector current I_C is recorded. The curves plotted are called output characteristics curves.