# BASIC ELECTRONICS ENGINEERING

## OF 1ST & 2ND SEMESTER

### For

DIPLOMA IN ALL ENGINEERING COURSE
**Government Polytechnic Nayagarh**

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# Contents

# CHAPTER-1

## 1. ELECTRONIC DEVICE

### Basic Concept of Electronics and its application.

**Defination:**

The branch of engineering which deals with current conduction through a vacuum or gas or semiconductor is known as electronics. An electronic device is that in which current flows through a vacuum or gas or semiconductor.

(Or)

Electronics is the branch of science that deals with the study of the flow of electrons and their effects in a vacuum, gases, and semiconductor materials.

**Applications:**

Electronics has gained much importance due to its numerous applications in our daily life starting from home to any industry. For simplification we categorise them in some area such as

- **Consumer Electronics.**

  Electronics devices which make our life easy and better such as air conditioner, cooking appliances, dryer, personal computer, mobile phones, etc.

- **Commercial applications.**

  Electronic devices and gadgets are widely used for the commercial purpose such as Telephone, Airconditioning, heating, Digital Advertising, power supplies, Personal computer, MP3s, office equipment, light dimmer, uninterruptible power supplies (UPS), etc.

- **Medical applications.**

  With the advancement of the electronics field, and particularly that of computer technology has made possible many of the application which made possible for nurses and doctors to examine his patient. Many machines like NMR, ECE, x-ray, etc use electronics. There is noticeable advancement of electronics in the field of medical sciences. There are a

few mindblowing innovations which prove how important is electronics – Robotic Arm, Robotic Check-Ups, Bionic Eye, Needle-Free Diabetes Care, etc.

- **Agriculture application.**

  Electronics has proved to be the biggest problem solver in the agriculture field. Today number of electronics devices and sensors are used to monitor a crop or enhance the production of Agriculture. Like e-Agri Sensors and other electronic gadgets which are used for measuring the salinity of soil, moisture level, and nutrition level in the soil.

- **Industrial automation.**

  Electronics applications are widely utilized in Arc and Industrial furnaces such as blowers, fans, pumps and compressors, industrial lasers, transformer tap changers, rolling mills, textile mills, excavators, cement mills, welding. Nowadays most of the firms use robotics technology Such as in the manufacturing of cars.

- **Communication.**

  In order to communicate for far distance, Electronic devices and systems are used such as Am Radio, FM Radio, Television, processing, Memory storage, display, analysis, protection, etc.

- **Military &defence applications.**

  Electronics devices and machinery are also widely used in the military such as UAV and drones which are used in the military for aerial attack as well as for monitoring. Magnetic anomaly detector, People sniffer, Night vision device, infrared detector, RADAR, PNS Hameed, and night vision camera etc. are some gadgets used by the military.

- **Automobiles.**

  Electronics are used in road vehicles, such as Lighting system of the car, telematics, in-car sound systems, etc. Initially, electronics were used to in cars to control engines. Nowadays almost every things are controlled using electronics whether it"s a chair in car or speed limitation in car, or Gas management in the car. Now electronic with its advancement.

- **Aerospace.**

  Today with advancement in electronics engineering application in the field of aerospace has open many impossible ways to humans. Most of the parts used in the Space shuttle, Satellite power supplies, aircraft power management, and other communication instruments

are electronics devices. Even in commercial airlines, there are numerous electronic devices which are used to measure different physical parameters like humidity, temperature, pressure, elevation, etc.

**Basic Concept of Electron Emission & its types.**

**Electron emission** is defined as the liberation of electrons from any surface of a substance.

Any metal consists of plenty of free electrons. Even at room temperature, these free electrons moves randomly inside the metal from one atom to another but can not leave the surface of the metal to provide electron emission.

This is because the free electrons reach the extreme boundary of the metal are pulled back by the positive nuclei behind them & their kinetic energy decreases.

Thus at the surface of a metal, a free electron encounters forces that prevent it to leave the metal. In other words, the metallic surface offers a barrier to free electrons and isknown as surface barrier.

However, if sufficient external energy is given to the free electron, its kinetic energy is increasedand thus electron will cross over the surface barrier to leave the metal. This additional energy requiredby an electron to overcome the surface barrier of the metal is called work function of the metal.

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

**Types of Electron Emission.**

The process of emission happens by supplying Energy equal to or greater than the work function to the metal & the electron absorbs the energy, thus able toovercome the surface barrier and leaves the metal surface. Depending on the process of supplying external energy to the metal surface, the emission is of different types.

**(i) Thermionic Emission.**
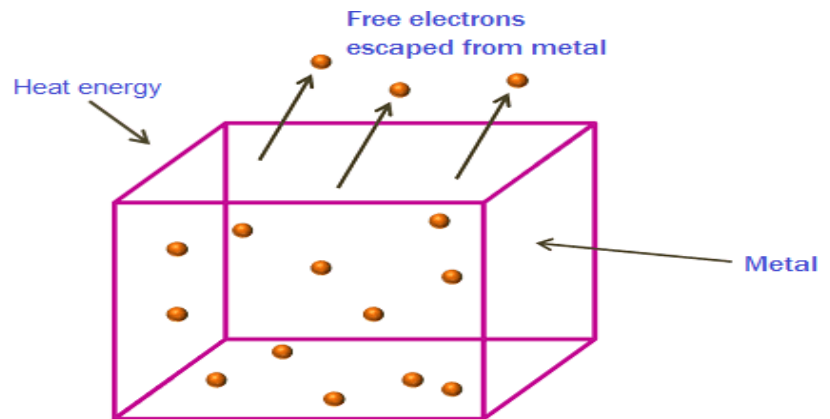
The process of electron emission from a metal surface by supplying thermal energy to it is known asthermionic emission.

In this method, the metal is heated to sufficient temperature (about2500°C) to enable the free electrons to leave the metal surface. The number of electrons emitteddepends upon the temperature. The higher the temperature, the greater is the emission of electrons.This type of emission is employed in vacuum tubes.

### (ii) 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.

In this method, when a sufficiently high positive charge is placed in front of the emitter surface, due to the strong electrostatic force of the created electric field, the free electron can get sufficient energy to overcome the surface barrier and can get emitted from the surface of the emitter body. As this type of electron emission is caused by the electric field present in the space, it is called field emission. The stronger the electric field, the greater is the electron emission.
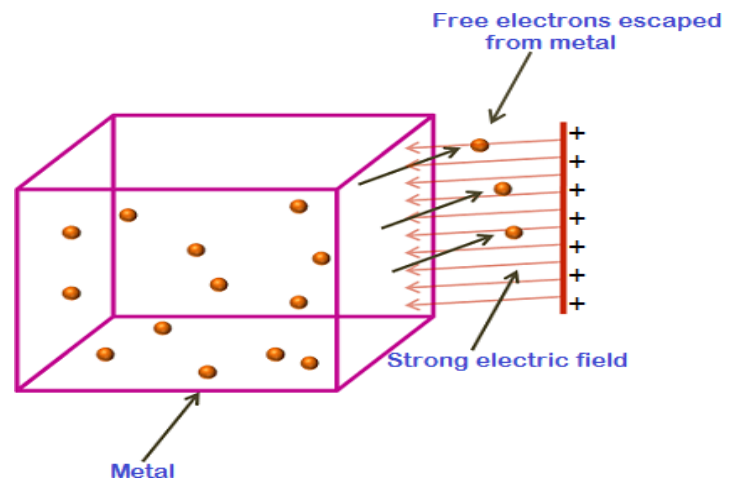
### (iii) Secondary emission.

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

In this method, When a beam of high-velocity electrons stricks on the metal surface, the kinetic energy of high
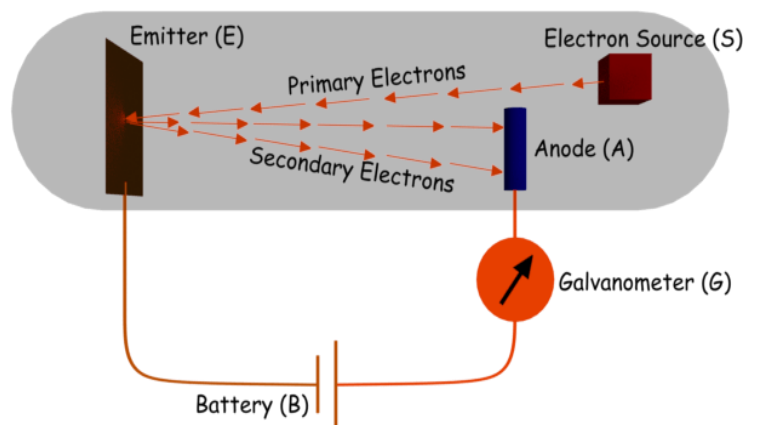
velocity striking electrons, transferred to the free electrons on the metal surface. Thus the free electrons may get sufficient kinetic energy to overcome the surface barrier and knocked out from the surface &start electron emission.

This type of emission is known as secondary electron emission.The electrons that strike the metal are called primary electrons while the emitted electrons are known as secondary electrons.

**(iv) Photo-electric emission.**

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

In this method, the energy of light falling upon the metal surfaceis transferred to the free electrons within the metal to enable them to leave the surface. The greater theintensity (i.e. brightness) of light beam falling on the metal surface, the greater is the photo-electricemission.
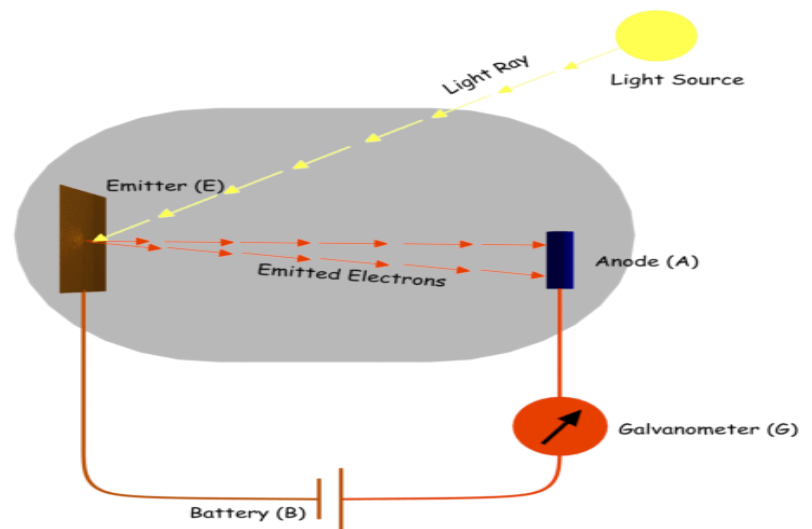
## Classification of material according to electrical conductivity (Conductor, Semiconductor & Insulator) with respect to energy band diagram only.

For better understanding of classification we have to understand what is energy band and different types of bands present in a metal.

**Energy Band:**The range of energies possessed by an electron in a solid is known as **energy band.**

**Valence band:**The range of energies (i.e. band) possessed by valence electrons is known as **valenceband.**

**Conduction band:**The range of energies (i.e. band) possessed by conduction band electrons is known as **conduction band.**

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

**(i) Insulators.**Insulators (*e.g.* wood, glass etc.) are those substances which do not allow the passage of electric current through them. In terms of energy band, the valence band is full while the conduction band is empty. Further, the energy gap between valence and conduction bands is very large (15 eV). Therefore, a very high electric field is required to push the valence electrons to the conduction band.

However, 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 temperature *i.e.* an insulator has negative temperature coefficient of resistance.

**(ii) Conductors.**Conductors (*e.g.* copper, aluminium) are those substances which easily allow the passage of electric current through them. It is because there are a large number of free electrons available in a conductor. In terms of energy band, the valence and conduction bands overlap each other. Due to this overlapping, a slight potential difference across a conductor causes the free electrons to constitute electric current.
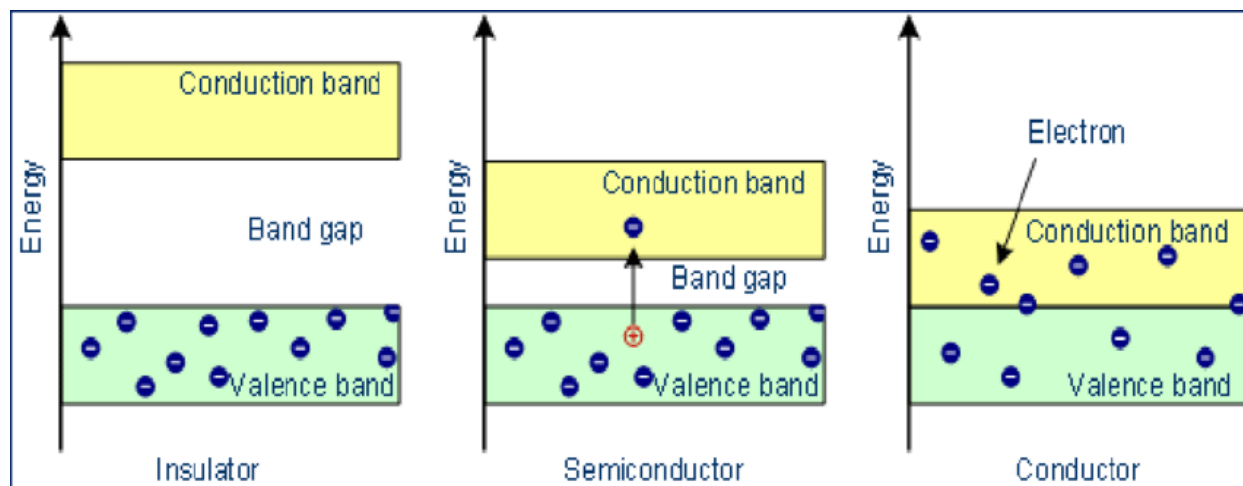


**(iii) Semicondutors.**Semiconductors (*e.g.* germanium, silicon etc.) are those substances whoseelectrical conductivity lies inbetween conductors andinsulators. In terms of energy band, the valence band isalmost filled and conduction band is almost empty.Further, the energy gap between valence and conductionbands is very small. Therefore,comparatively smaller electric field(smaller than insulators but much greater than conductors) isrequired to push the electrons from the valence band to the conduction band. In short, a semiconductorhas :

**(a)** almost full valence band

**(b)** almost empty conduction band

(c) small energy gap (1 eV) between valence and conduction bands.

At low temperature, the valence band is completely full and conduction band is completely empty. Therefore, a semiconductor virtually behaves as an insulator at low temperatures. However, even at room temperature, some electrons (about one electron for 1010 atoms) cross over to the conduction band, imparting little conductivity to the semiconductor.

## Difference between Intrinsic & Extrinsic Semiconductor.
**Intrinsic Semiconductor:**

A semiconductor in an extremely pure form is known as an **intrinsic semiconductor**.
In an intrinsic semiconductor, even at room temperature, hole-electron pairs are created. Whenelectric field is applied across an intrinsic semiconductor, the current conduction takes place by twoprocesses, namely; by *free electrons* and *holes*. The free electrons are produceddue to the breaking up of some covalent bonds by thermal energy. At the same time, holes arecreated in the covalent bonds. Under the influence of electric field, conduction through the semiconductoris by both free electrons and holes. Therefore, the total current inside the semiconductor is thesum of currents due to free electrons and holes.
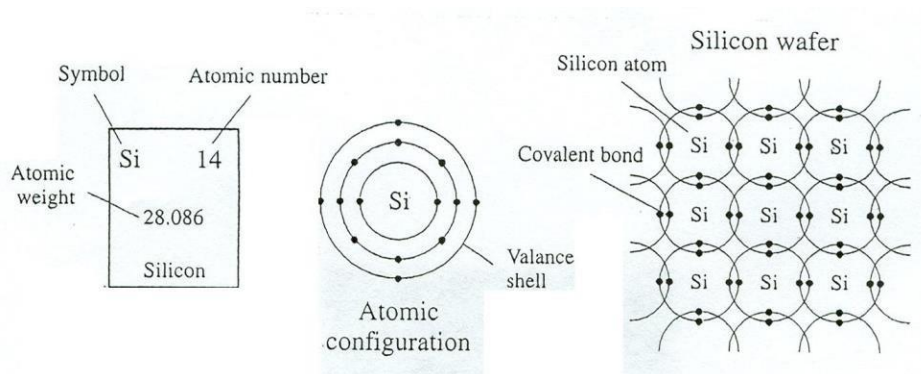


**Extrinsic Semiconductor:**

When a small amount of impurity is added to a pure semiconductor it becomes**extrinsic semiconductor.**

The intrinsic semiconductor has little current conductivity at room temperature, to make it suitable for electronic applications we must change its conducting properties. This is achieved

by adding a small amount of suitable impurity to a semiconductor. It is then called impurity or extrinsic semiconductor. The process of adding impurities to a semiconductor is known as doping.

The purpose of adding impurity is to increase either the number of free electrons or holes in the semiconductor crystal. If a pentavalent impurity (having 5 valence electrons) is added to the semiconductor, a large number of free electrons are produced in the semiconductor. If a trivalent impurity (having 3 valence electrons) is added to the semiconductor, large number of holes are produced in the semiconductor crystal. Depending upon the type of impurity added, extrinsic semiconductors are classified into:

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

### (i) 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 pro-vides a large number of free electrons in the semiconductor crystal. Typical examples of pentavalent impurities are arsenic, antimony,Bismuth and Phosphorous etc. Such impurities which produce n-type semiconductor are known as donor impurities because they donate or provide free electrons to the semiconductor crystal.In n-type semiconductor electrons are said to be the majority carriers whereas holes are the minority carriers.
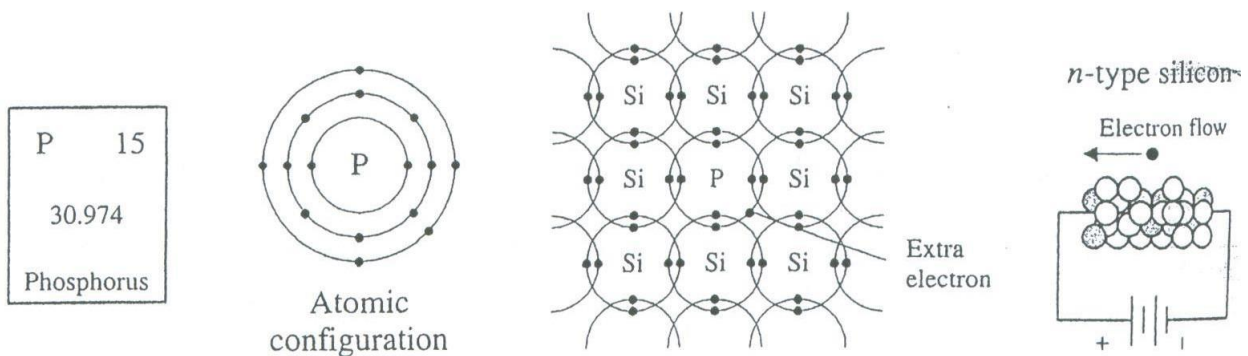


### (ii) p-type Semiconductor

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

The addition of trivalent impurity provides a large number of holes in the semiconductor. Typical examples of trivalent impurities are gallium, indium, boron etc. Such impurities which produce p-type semiconductor are kno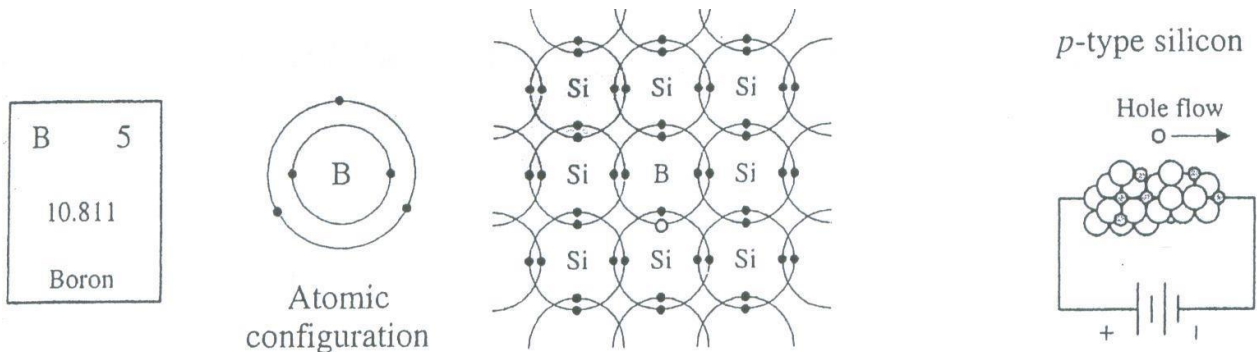wn as acceptor impurities because the holes created can accept the electrons. In p-type semiconductor holes are the majority carriers whereas electrons are said to be the minority carriers.



**Difference between Intrinsic & Extrinsic Semiconductor.**

| S.No | Intrinsic Semiconductor | Extrinsic Semiconductor |
|---|---|---|
| 1. | Semiconductor in a pure form is called intrinsic semiconductor. | Semiconductor which are doped with impurity is called extrinsic semiconductor |
| 2. | Here the change carriers are produced only due to thermal agitation. | Here the change carriers are produced due to impurities and may also be produced due to thermal agitation. |
| 3. | They have low electrical conductivity. | They have high electrical conductivity. |
| 4. | They have low operating temperature. | They have high operating temperature. |
| 5. | At 0K, Fermi level exactly lies between conduction band and valence band. | At 0K, Fermi level exactly lies closer to conduction band in "n" type semiconductor and lies near valence band in "p" type semiconductor. |
| | **Examples:** Si,Ge,etc. | **Examples:** Si and Ge doped with Al, In,P,As etc |

**Difference between vacuum tube & semiconductor.**

| Vacuum tube | Semiconductor |
|---|---|
| • Power consumption is high and heat wastage is comparatively high | • Lower power consumption, less wastage of heat |
| • Large size than transistor | • Size is so small as compared to vacuum tubes. |
| • High cost. | • Low cost. |
| • Less suitable for portable products. | • Suitable for portable device. |
| • It requires the high voltage power supply, not suitable for smaller voltage devices. | • It requires a lower power supply, suitable for smaller voltage devices |
| • Low voltage gain | • High voltage gain |
| • There is glass tube in a vacuum tube so not that much physical strength. | • Physical strength is high |
| • Not that much depend upon temperature | • Depend upon Temperature |
| • High input impedance | • Low input impedance |
| • Made up of wires. | • Made up of PN junction. |
| • Vacuum tubes can easily be replaced by a user | • Relatively maintenance more difficult, cannot easily be replaced by a user. |

**Principle of working and use of PN junction diode, Zener diode and Light Emitting Diode (LED)**

**PN Junction:**

When a p-type & n-type semiconductor properly join together it forms pn junction. It is the basic building block for many semiconductor devices. After the formation of junction a large difference in carrier density exists which results holes in the p-side tends to diffuse into n-side leaving behind trivalent ion and electrons in the n-side are tends to diffuse into p-side leaving behind pentavalent ion. Due to this charg separation a layer of negative charges (trivalent ions) in p-type & positive charges (pentavalent ions) in n-type near the junction created.These two layers of positive and negative charges form the **depletion region**(or **depletion layer**).
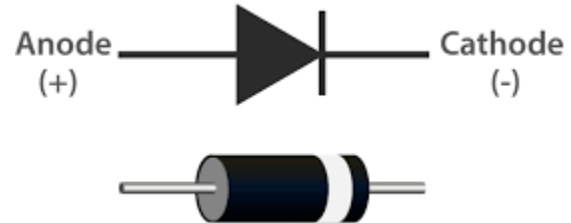
Once pnjunction is formed and depletion layer created, the diffusion of free electrons stops. Inother words, the depletion region acts as a barrier to the further movement of free electrons across thejunction. Since the holes in p-side encounters a positive charge in n-side near the junction similarly electrons in n-side encounters a negative charge in p-side near the junction. The positive and negative charges set up an electric field. The electric field is a barrier to the free electrons in the n-region. There exists a potential difference across the depletion layer and is called **barrier potential** (V0).

**Pn- junction Diode:**

*A pn junction is known as a* semi-conductor *or*crystal diode. It is a two terminal unidirectional (allows current only in single direction) semiconductor device. The lead connected to p-side called **anode** and the lead connected to n-side called **cathode** of the diode. The circuit symbol of diode is shown in figure.

Depletion width during unbiased condition

P-type    N-type

Negative ion    Positive ion
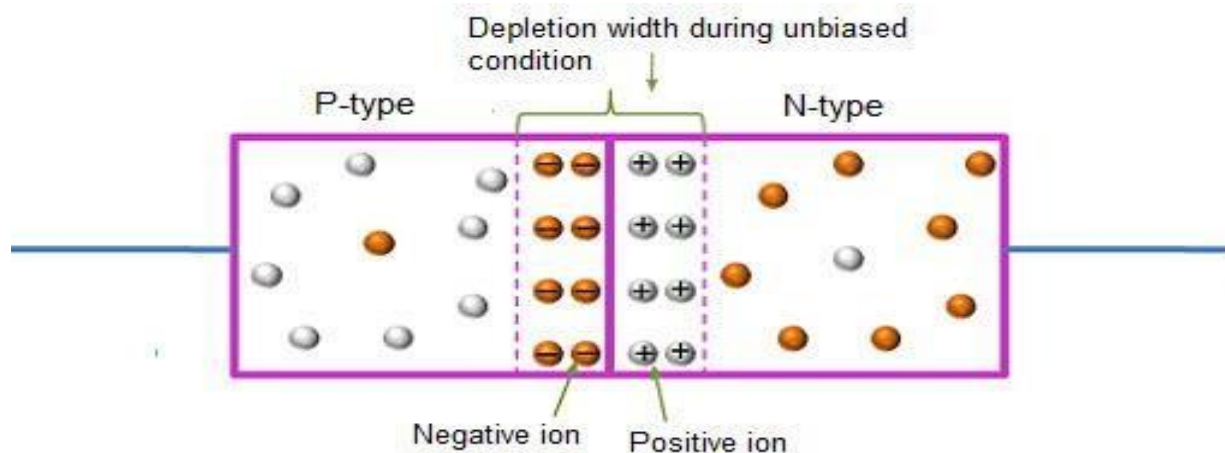
This pn junction does not allow flow of current. To make it suitable for electronics circuits we need to biasing (applying external voltage) pn-diode. There are two ways of biasing pn-diode (i) Forward biasing

(ii) Reverse biasing

**(i) Forward biasing**

When a diode is connected in a **Forward Bias** condition, a negative voltage is applied to the N-type material and a positive voltage is applied to the P-type material.

Like charges repel, so the free electrons are pushed toward the PN junction. Similarly, the holes are repelled by the positive terminal of the battery toward the PN junction. If the voltage pushing the electrons and holes has sufficient strength to overcome the depletion zone (approximately 0.7 V for typical silicon diode) the electrons and holes combine at the junction and current passes through the diode.

The forward voltage at which the deplation region vanishes and the current in diode raises rapidly is called „**Knee voltage**".

Forward bias



Forward Biased
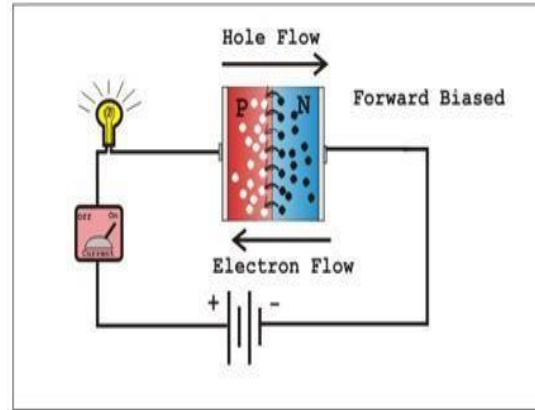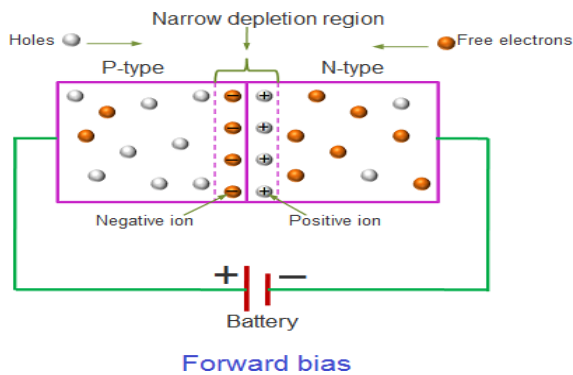
**(ii) Reverse biasing**

When a diode is connected in a **Reverse Bias** condition, a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material.

The negative terminal attracts the positive holes in the P-type silicon and the positive terminal of the battery attracts the free electrons in the N-type silicon. All the charge carriers are pulled away from the PN junction which essentially creates a larger depletion region. In reverse bias condition there is a small reverse leakage current because of minority carriers which is independent of reverse supply voltage called „**Reverse saturation current'**.

The minimum reverse voltage at which pn junction breaks down with sudden rise in reverse current is called „**Breakdown voltage'**.



Reverse bias



Reversed Biased
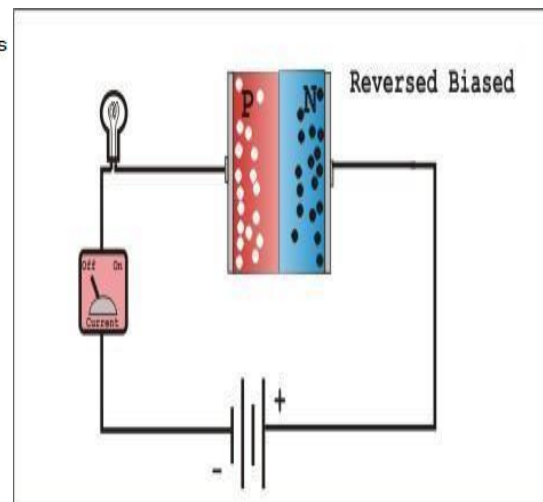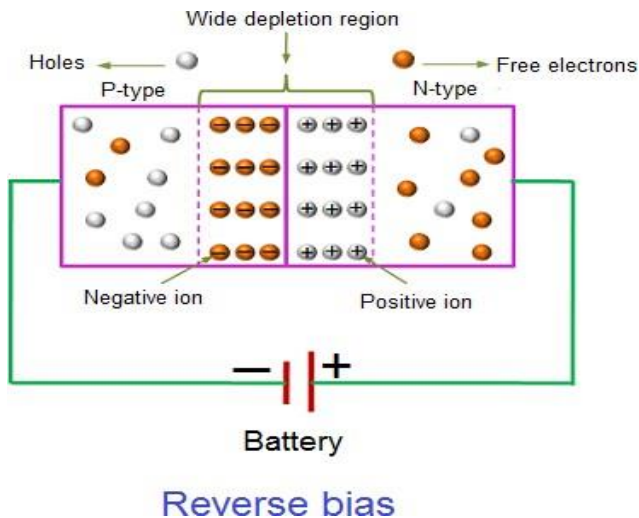
**VI characteristics of pn-diode**

Volt-ampere (V-I) characteristics of a pn-diode is the graphical representation of the curve between voltage across the junction and the current through the circuit.Normally the voltage is taken along the x-axis and current along y-axis.

**Applications of Diode**

In forward bias condition, the diode allows electric current whereas in reverse bias condition, the diode does not allow electric current. Due to this characteristic, the diode finds number of applications as given below:

      i.      Rectificatioe

      ii.     Clipper & Clamping circuits

      iii.    Voltage regulating circuits

      iv.    Light emitting diodes(LED) & Laser diodes

      v.     Switching Circuits

**Note:-**

The breakdown occurs In reverse bias condition is two types as described below

**i. Avalanche Breakdown**

When the electric field is applied across the diode, the velocity of the charge carrier increases. This charge carrier collides with the other atoms and creates the pairs of hole and electrons. The free charge carrier further collides with other atoms and creates more pairs of electron and hole. These free electrons start moving across the junction and develop the reverse bias current. The reverse bias current completely destroys the junction. And once the junction breakdown occurs, it cannot regain its original position. It occurs in the lightly doped pn junction having thick depletion region.
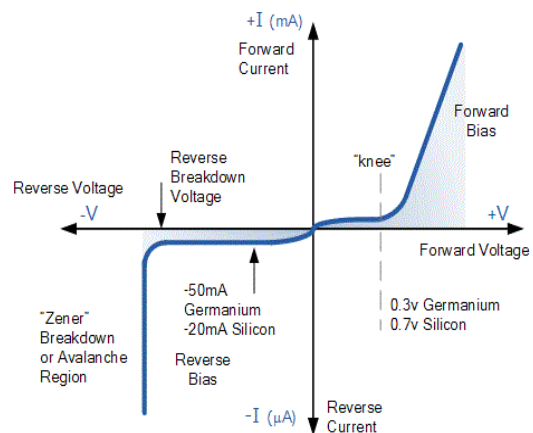
**ii. Zener Breakdown.**

When the high electric field is applied across the junction, the charge carrier starts jumping across the junction. These electrons constitute the heavy current in the reversed direction. In Zener breakdown, the temporary breakdown of junction occurs. The junction regains its original position when the reverse voltage removes. It occurs in the heavily doped pn junction having thin deplation region.

**Difference between avalanche breakdown and zener breakdown**

| Avalanche Breakdown | Zener Breakdown |
| --- | --- |
| The process of applying high voltage and increasing the free electrons or electric current in semiconductors and insulating materials is called an avalanche breakdown. | The process in which the electrons move across the barrier from the valence band of p-type material to the conduction band of n-type material is known as Zener breakdown. |
| It occurs in diodes that are lightly doped. | It occurs in diodes that are highly doped. |
| The valence electrons are pushed to conduction due to the energy imparted by accelerated electrons, which gain their velocity due to their collision with other atoms. | The valence electrons are pulled into conduction due to the high electric field in the narrow depletion region. |
| The increase in temperature increases the breakdown voltage. | The increase in temperature decreases the breakdown voltage. |
| The VI characteristic curve of the avalanche breakdown is not as sharp as the Zener breakdown. | The VI characteristics of a Zener breakdown has a sharp curve. |
| This is observed in Zener diode having a Zener breakdown voltage Vz greater than 8 volts. | This is observed in Zener diodes having a Zener breakdown voltage Vz of 5 to 8 volts. |

**Zener Diode**

Zener diode is an ordinary diode which is properly doped so that it has a sharp breakdown voltage. Unlike normal pn junction diode it allows current in forward bias as well as reverse bias condition. It starts conducting in reverse direction when reverse voltage reaches a predetermined value. Zener diode is mostly used in reverse bias condition only. The circuit symbol is shown in figure.
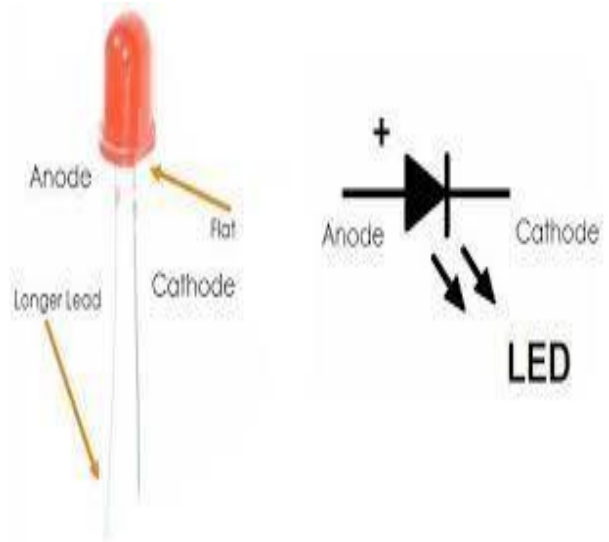
**Working principle**

When zener diode connected in the reverse mode, which is usual in most of its applications, a small leakage current may flow. As the reverse voltage increases to the predetermined breakdown voltage ($V_z$), a current starts flowing through the diode. The current increases to a maximum, which is determined by the series resistor, after which it stabilizes and remains constant over a wide range of applied voltage.
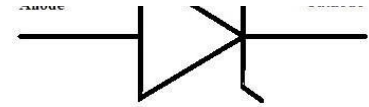
**VI charecterstic of Zener diode**

The graph between voltage and current of zener diode in forward bias is same as normal pn diode but in reverse bias it has sharp breakdown region at zener voltage Vz.

**Applications**

Zener diodes are mostly used in voltage regulator, overvoltage protection & clipper circuits.

**Light Emitting diode (LED)**

A **light-emitting diode (LED)** is a special purpose diode that gives off fairly narrow bandwidth
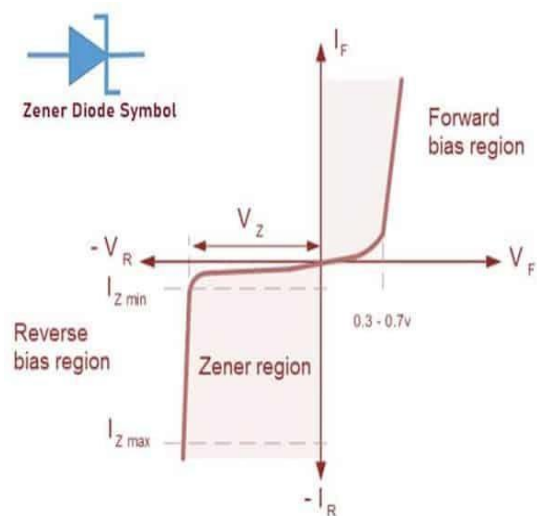
of visible or invisible light when forward biased.The circuit symbol is shown in figure.

These are made by using elements like gallium, phosphorus and arsenic instead of normal Silicon and Germanium materials.

When light-emitting diode (LED) is forward biasedthe electrons from the *n*-type material cross the *pn*junction and recombine with holes in the *p*-type material. These free electrons are in the conduction band and at a higher energy level than the holes in the valence band. When recombination takes place, the recombining electrons release some part of energy in the form of heat and light. In Si &Ge diodes these energy dissipate in the form of heat but in Galium-Arsenide-phosphorous (GaAsP) and Galium-phosphorous (GaP) semiconductors, the electrons dissipate energy in the form of photons.

Light Emitting Diodes are made from exotic semiconductor compounds such as Gallium, Arsenide, Phosphorus all mixed together at different ratios to produce a distinct wavelength of colour given in the table.

| Semi conductor | abbr, | Colour(s) |
|---|---|---|
| Aluminium-gallium-arsenide | AlGaAs | red |
| Aluminium-indium-gallium-phosphide | AlInGaP | red, yellow |
| Gallium-arsenide-phosphide | GaAsP | red, orange, yellow |
| Indium-gallium-nitride | InGaN | green, blue |

**Applications**

LEDs are mostly used in power indicator, TVs and seven segment displays.

**Integrated circuits (I.C) & its advantages.**

An **integrated circuit** sometimes called **Chip** or **Microchip**is one in which thousand no of circuit components like transistors, diodes, resistors, capacitors etc. arefabricated on a small semiconductor chip.

It consist of a number of circuit components (*e.g.* transistors, diodes, resistors etc.) and their inter connections in a single small package to perform a complete electronic function and the individual components cannot be removed or replaced.

The size of this is so small that we need microscope to see the inter connections.

**Advantages of IC**

Integrated Circuits has many advantages over discrete circuits such as:

(i) Extremely small in size,

(ii)  Low power consumption,

(iii) Reliability,

(iv) Reduced cost,

(v) Very small weight

(vi) Easy replacement.


## Chapter Review Questions:

1. Define Electronics & its application.

2. Define work function.

3. Define Electronic Emission & different types of Emission.

4. Explain Conductor, Semiconductor & Insulator with respect to energy band diagram only.

5. Define doping.

6. Define energy gap & valence electrons.

7. Discuss Intrinsic Semiconductor.

8. Discuss Extrinsic Semiconductor.

9. Define accepter & donor atom.

10. List different types of Impurity.

11. Explain the difference between vacuum tube & semiconductor.

12. State basic concept of integrated circuits (I.C) & its use.

13. Explain P-type and N-type semiconductor junction.

14. Define PN junction Barrier voltage, depletion region, Junction Capacitance.

15. Draw Forward biased & reversed biased junction Diode.

16. Draw symbol, circuit diagram for characteristics (Forward & reversed) Characteristics PN junction diode.

17. Explain Construction (reference to doping level),Symbol ,circuit diagram for characteristics (forwarded & reversed) of Zener Diode.

18.  Explain Avalanche &Zener breakdown and its comparison.

19. Explain Construction ,Symbol ,circuit diagram for characteristics of LED.

# CHAPTER-2

## 2. ELECTRONIC CIRCUITS

**Rectifier & its uses.**
### Rectifier

A rectifier is an electrical device that converts an Alternating Current (AC) into a Direct Current (DC) by using one or more P-N junction diodes.

When AC voltage or AC current is applied across the P-N junction diode, during the positive half cycle the diode is forward biased and allows electric current through it. However, when the AC current reverses its direction to negative half cycle, the diode is reverse biased and does not allow electric current through it. Thus, electric current flows through the diode only during the positive half cycle of the AC current.

This current which flows across the diode is nothing but a DC current. Thus, the P-N junction diode acts like a rectifier by converting the AC current into DC current.

Rectifiers are mostly used to provide continuous voltage (DC Voltage) required to run almost all electronic devices & circuits.

## Principles of working of different types of Rectifiers with their merits and demerits

**Types of Rectifier:** The rectifiers are mainly classified into two types:

(i)    Half wave rectifier
(ii)   Full wave rectifier

### Half Wave Rectifier

As the name suggests, the half wave rectifier is a type of rectifier which converts half of the AC input signal (positive half cycle) into pulsating DC output signal and the remaining half signal (negative half cycle) is blocked or lost. A half-wave rectifier is the simplest of them all as it is composed of only a single diode.

**Operation**

During the positive half cycle, the diode terminal anode will become positive and the cathode will become negative known as forward bias. And it will allow the positive cycle to flow through the diode.



AC Input Waveform

Resultant Output Waveform
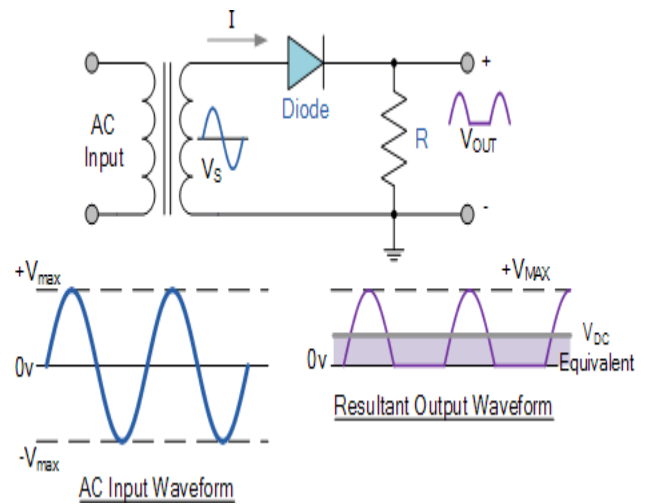
During the negative half cycle, the anode will become negative and the cathode will become positive, which is known as reverse bias. So the diode will block the negative cycle.

In this way rectifier allows only the positive half cycle of the input AC voltage supply. It uses only half of the input voltage the other hafe is wasted.

**Merits**

o   Simple circuit as it uses less no of components.

o   Low cost

**Demerits**

o   It only allow +ve half-cycle and wasted the -ve half-cycle which leads to power loss.

o   Produce low output voltage

o   Output is not purely DC, it has high ripple factor.

**Full wave rectifier**

The full wave rectifier is a type of rectifier which converts the full AC input signal (positive half cycle and negative half cycle) to pulsating DC output signal. Unlike the half wave rectifier, the input signal is not wasted in full wave rectifier. The efficiency of full wave rectifier is high as compared to the half wave rectifier. A full wave rectifier is made up of more than one diode.

There are two types of full wave rectifier.

1. Center-Tap Rectifier

2. Bridge Rectifier

**Center-Tap  Full Wave Rectifier**

This type of rectifier circuit uses a transformer with secondary winding tapped at the center point & two diodes as shown in figure.

**Operation**

The full wave rectifier circuit consists of two *power diodes* connected to a single load resistance (RL) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode D1 conducts in the forward direction as indicated by the arrows.When point B is positive (in the negative half of the cycle) with respect to point C, diode D2 conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles.

**Merits**

o   Low ripples in the output DC signal
o   Rrectifier efficiency is doubled as compare to half wave rectifier.
o   Low power loss

**Demerits**

o   It is expensive as it uses center tapped transformer.
o   The output voltage is half of the secondary voltage, as each diode utilizes only one half of the transformer secondary voltage.

**Bridge Type Full Wave Rectifier**

This type of single phase rectifier uses four individual rectifying diodes connected in a "bridge" configuration as shown in figure. The main advantage of this bridge circuit is that it does not require a special centre tapped transformer, thereby reducing its size and cost.

**Operation**

The four diodes labelled D1 to D4 are arranged in "series pairs" with only two diodes conducting current during each half cycle.

During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load as shown in figure.

During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2switch "OFF" as they are now reverse biased. The current flowing through the load is the same direction as during the positive half cycle as shown in figure.



Input Voltage Waveform
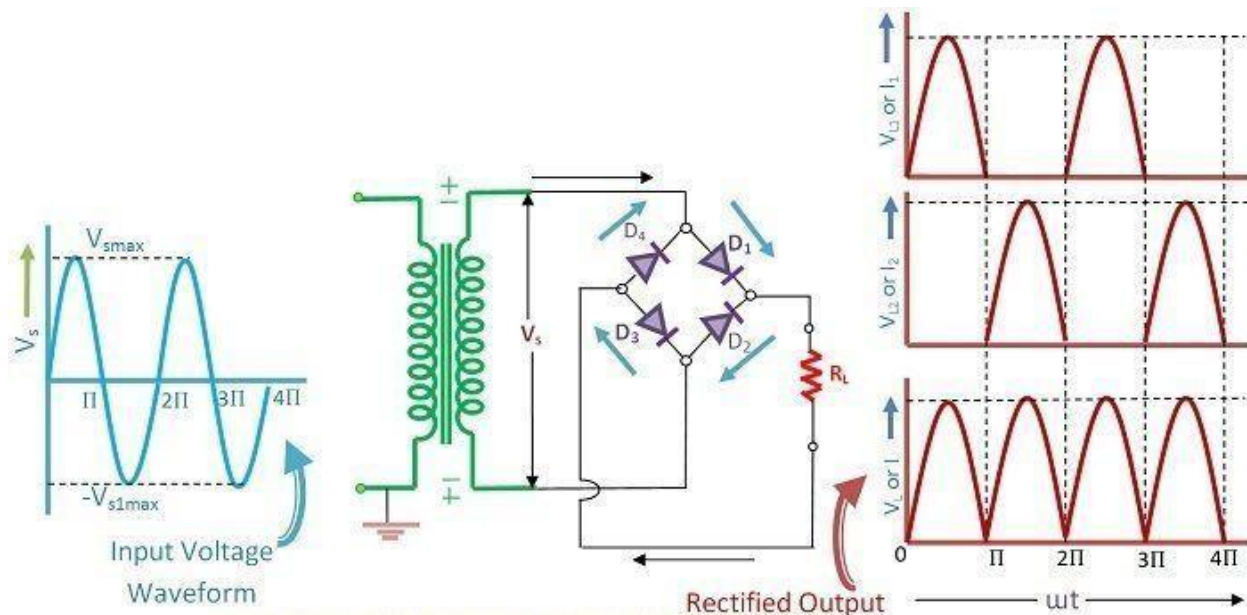
Rectified Output

**Merits**

- o   High rectifier efficiency.
- o   Low power loss as compared to half wave rectifier.

**Demerits**

- o   Since four diodes are used , cost is high.
- o   The output is not a proper DC quantity. It has ripples in its output.
- o   More power loss compared to centre tapped full wave rectifier.

## Functions of filters and classification of simple Filter circuit (Capacitor, Choke inputand $\pi$)
### Filters

A **filter circuit** is a device which removes the a.c. component of rectifier output but allows thed.c. component to reach the load.

It is connected between rectifier and load because the output of a rectifier has pulsating character i.e. it contains a.c. and d.c. components. The a.c. component is undesirable and must be kept away from the load. To do so, a filter circuit is used which removes (or filters out) the a.c. component and allows only the d.c. component to reach the load.

A filter circuit is generally a combination of inductors (L) and capacitors (C). A capacitor passes a.c. readily but does not pass d.c. at all. On the other hand, an inductor opposes a.c. but allows d.c. to pass through it. It then becomes clear that suitable network of L and C can effectively remove the a.c.component & allowing the d.c. component to reach the load.

**Classification of Filters**

**i. Shunt Capacitor:**

It is also called Capacitor Filter. It offers low reactance to ac &a very high reactance to the dc component. The capacitive reactance is $X_C=1/2\pi fc$ ,ford.c , f=0 Then, $X_C=\infty$

Hence a capacitor does not allow the d.c to pass through it. When th pulsating output is applied the ac component expeience a resistive path so bypass through the capacitor but the dc component is blocked by capacitor and appears at load. In this way the the undesired ac component is emoved.

**ii.Choke input filter:**

It consists of a choke L connected in series with the rectifier output and a filter capacitor C across the load.The inductive reactance is $X_L=2\pi fL$ , for d.c , f(frequency)=0 Then, $X_L=0$

Hence inductor allows the d.c to pass through it& blocks ac. When the pulsating output is applied the ac component is blocked by the series Inductor L, only dc component passes through it. If the resultant output have any ac component it bypass through the parallel capacitor C and the pure dc component will appear across load.

**iii. Capacitor input filter:**

It consists of a filter capacitor $C_1$ connected across the rectifier output, a choke L
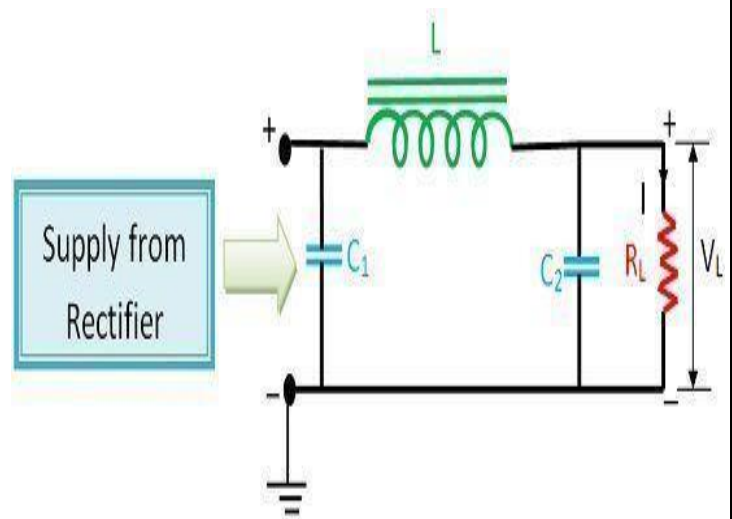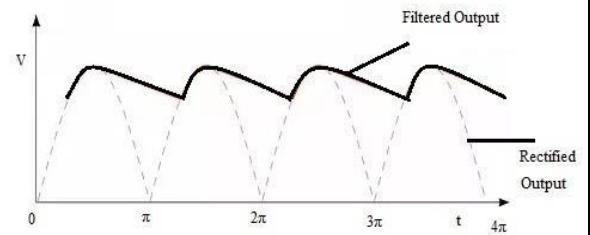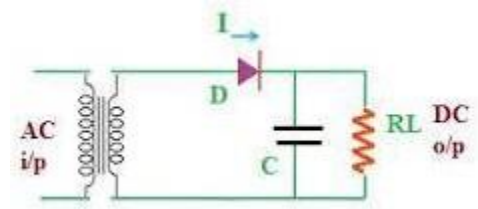
in series and another filter capacitor $C_2$ connected across the load.The shape of the circuit diagram of this filter circuit appears like Greek letter $\pi$ (pi) and hence the name $\pi$-filter.

Here pulsating output from rectifier is applied across 1st capacitor $C_1$which offers zero reactance to a.c& infinite reactance to d.c. Hence d.c component continues to reach across (Choke Filter)L . The filter choke then allows the d.c component easily by blocking a.c component if any. Finally the 2nd capacitor $C_2$across load bypasses the a.c component if any which the choke(L) failed to block by making d.c component to reach across load.

## Working of D.C power supply system (unregulated) with help of block diagrams only

Almost all household electronic circuits need an unregulated AC to be converted to constant DC in order to operate. All devices will have certain power supply
Limit and the inside circuit must be able to supply dc voltage within this limit. This DC supply is regulated & limited interms of voltage and current but the mains supply may be fluctuating may cause damage to the electronic circuit. This job is done by a unregulated power supply.

The DC power supply is practically converted to each & every stage in the system. All low power system can be run with a battery but batteries are expensive & frequently replaced. So the best method is a unregulated power supply.

A unregulated power supply is a combination of 3 parts namely atransformer, a rectifier & a filter circuit. The Block diagram of a unregulated power supply is shown in figure.



Unregulated Power Supply - Block Diagram
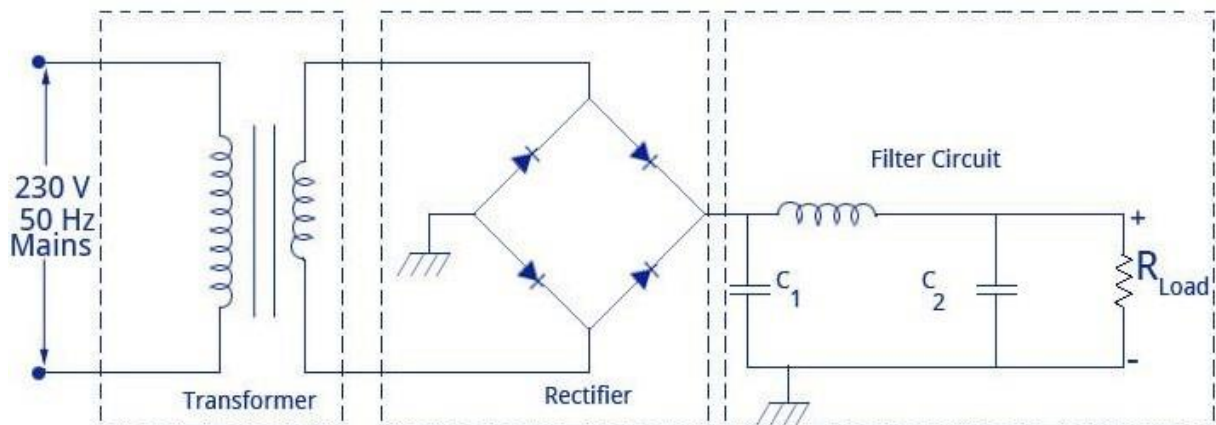
A small step down transformer is used o reduce the voltage level as the device needed. The output of the transformer is a pulsating AC voltage which is feed into rectifier circuit. The rectifier convert it and it"s output is pulsating DC. Again this output is feed to filter circuit as input. This filter circuit then removes the ac components present if any and gives a DC voltage as required by the electronic circuit.

## Transistor, Different types of Transistor Configuration and state output and inputcurrent gain relationship in CE,CB and CC configuration( No mathematical derivation)

**Transistor**

The transistoris a three terminal semiconductor device that regulates current or voltage flow and acts as a switch or gate for signals.The transistor is a semiconductor device which



NPN Transistor     PNP Transistor
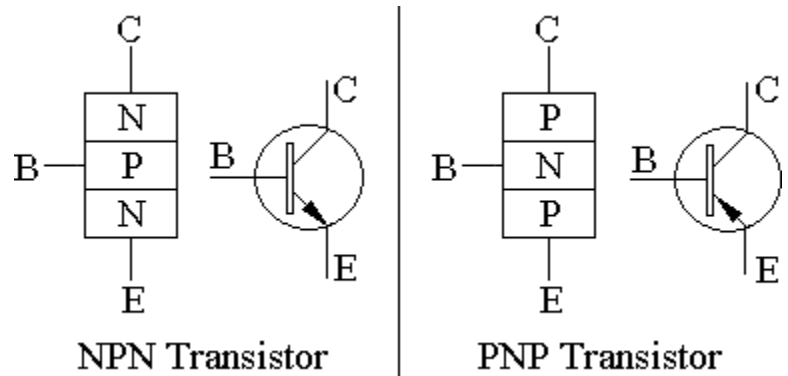
transfers a weak signal from low resistance circuit to high resistance circuit. The words **trans** mean **transfer property** and **istor** mean **resistance property** offered to the junctions**.**

**Construction**

A transistor consists of two pn junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types. Also we can say The transistor consists two PN diode connected back to back.Hence it has got two PN junctions.

Accordingly there are two types of transistors namely ;

(i)n-p-n transistor

(ii)p-n-p transistor

An *n-p-n* transistor is composed of two *n*-type semiconductors separated by a thin section of *p*type and a *p-n-p* transistor is formed by two *p*-sections separated by athin section of *n*-type as shown in Figure.

The three terminals drawn from the transistor indicate Emitter (E)**,** Base (B) and Collector (C) terminals. They have their functionality as discussed below.

**Emitter**

- The left-hand side of the above shown structure can be understood as Emitter.
- This has a moderate size and is heavilydoped as its main function is to supply a number of majority carriers, i.e. either electrons or holes.
- As this emits electrons, it is called as an Emitter.
- This is simply indicated with the letter **E**.

**Base**

- The middle material in the above figure is the Base.
- This is thin and lightlydoped.
- Its main function is to pass the majority carriers from the emitter to the collector.
- This is indicated by the letter **B**.

**Collector**

- The right side material in the above figure can be understood as a Collector.
- Its name implies its function of collecting the carriers.
- This is a bit larger in size than emitter and base. It is moderately doped.
- This is indicated by the letter **C**.

The emitter-basa junction is always forward bias whereas the collector-base junction is always reverse bias.The arrow in the symbol indicates the direction of flow of conventional current in the emitter with forward biasing applied to the emitter-base junction. The only difference between the NPN and PNP transistor is in the direction of the current.

**Working of NPN Transistor**

- Here emitter-base junction is forward biased and collector-base junction is reverse biased.
- The voltage $V_{EE}$ provides a negative potential at the emitter which repels the electrons in the N-type material and these electrons cross the emitter-base junction, to reach the base region.
- There, a very low percent of electrons re-combine with free holes of P-region. This provides very low current which constitutes the base current $I_B$.
- The remaining holes cross the collector-base junction, to constitute the collector current $I_C$.

- As an electron reaches out of the collector terminal, and enters the positive terminal of the battery, an electron from the negative terminal of the battery $V_{EE}$ enters the emitter
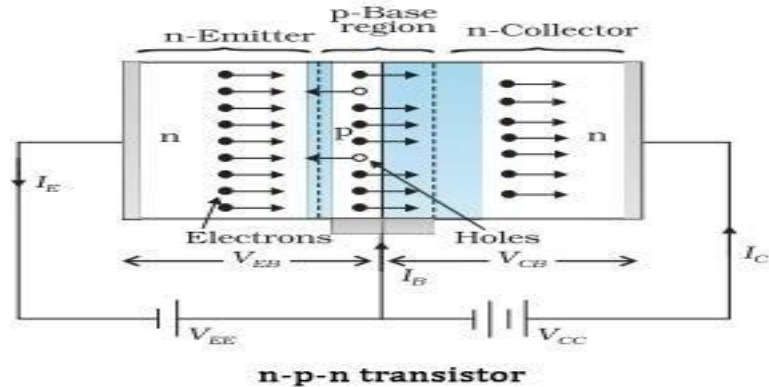


increases and the electron current flows through the transistor.

- Using Kirchhoff''s Current Law we get$I_E = I_B + I_C$

**Working of PNP Transistor**

- Here emitter-base junction is forward biased and collector-base junction is reverse biased.

- The voltage $V_{EE}$ provides a positive potential at the emitter which repels the holes in the P-type material and these holes cross the emitter-base junction, to reach the base region.

- There a very low percent of holes re-combine with free electrons of N-region. This provides very low current which constitutes the base current $I_B$.

- The remaining holes cross the collector-base junction, to constitute collector current $I_C$, which is the hole current.

- As a hole reaches the collector terminal, an electron from the battery negative terminal fills the space in the collector. This flow slowly increases and the electron minority current flows through the emitter, where each electron entering the positive terminal of $V_{EE}$, is replaced by a hole by moving towards the emitter junction. This constitutes emitter current $I_E$.

- Here also if we applyingKirchhoff''s Current Law we get$I_E = I_B + I_C$

- 

**Different Transistor Configurations**

There are three leads in a transistor named as Emitter, Base and Collector terminals. However, when atransistor is to be connected in a circuit, we require four terminals, two for the input and two for theoutput. This difficulty is overcome by making one terminal of the transistor common to both inputand output. The input is fed between this common terminal and one of the other twoterminals. The output is obtained between the common terminal and the remaining terminal.

Accordingly, There are three different configurations of Transistors.

- **Common Base (CB) Configuration**: no current gain but voltage gain
- **Common Emitter (CE) Configuration**: current gain and voltage gain
- **Common Collector (CC) Configuration**: current gain but no voltage gain

**Common Base (CB) Configuration**

As its name suggests, in the Common Base or grounded base configuration, the BASE connection is common to both the input signal AND the output signal with the input signal being applied between the base and the emitter terminals. The corresponding output signal is taken from between the base and the collector terminals as shown with the base terminal grounded or connected to a fixed reference voltage point.



p-n-p transistor
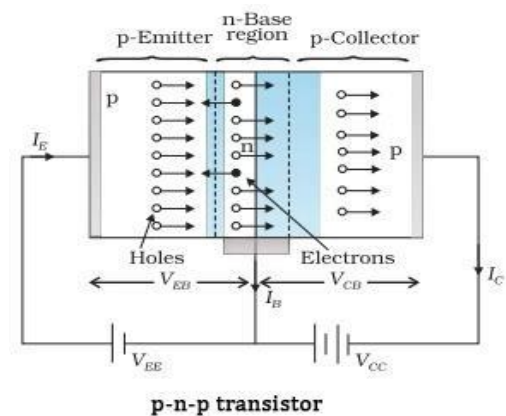
The ratio of change in collector current ($\Delta I_C$)to the change in emitter current ($\Delta I_E$)at constant collector-basevoltage ($V_{CB}$) is known as **current amplification factor**in common base (CB) arrangementi.e.$\alpha = \Delta I_C/ \Delta I_E$

**Common Emitter (CE) Configuration**

In the Common Emitter or grounded emitter configuration, the input signal is applied between the base and the emitter, while the output is taken from between the collector and the emitter as shown. This type of configuration is the most commonly used circuit for transistor based amplifiers and which represents the "normal" method of bipolar transistor connection.

The ratio of change in collector current ($\Delta I_C$) to the change in base current ($\Delta I_B$) is known as **base current amplification factor** i.e. $\boldsymbol{\beta = \Delta I_C / \Delta I_B}$
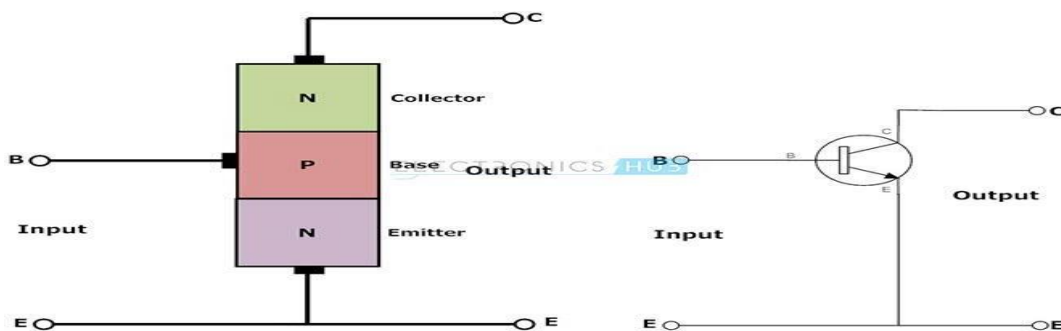


**Common Collector (CC) Configuration**

In the Common Collector or grounded collector configuration, the collector is now common through the supply. The input signal is connected directly to the base, while the output is taken from the emitter load as shown. This type of configuration is commonly known as a Voltage Follower or Emitter Follower circuit: The emitter follower is a current amplifier that has no voltage gain.
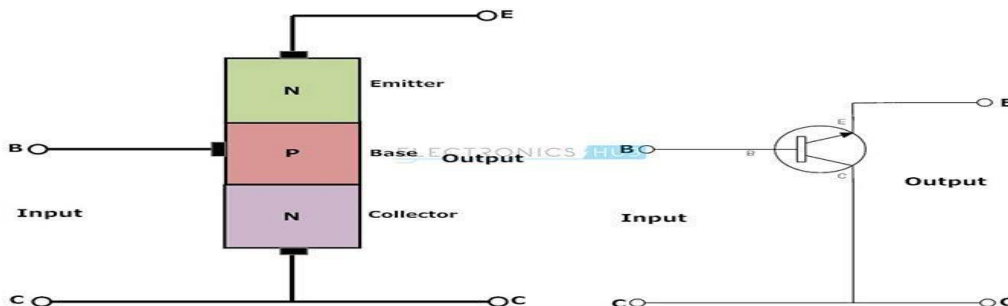
The ratio of change in emitter current ($\Delta I_E$) to the change in base current ($\Delta I_B$) is known as **current amplification factor** in common collector (CC) arrangement i.e.$\boldsymbol{\gamma = \Delta I_E / \Delta I_B}$

**Relation between α, β and γ**

Relation between α and β: $\beta = \dfrac{\alpha}{1-\alpha}$ also $\alpha = \dfrac{\beta}{1+\beta}$

Relation between α and γ: $\gamma = \dfrac{1}{1-\alpha}$ also $\alpha = \dfrac{\gamma-1}{\gamma}$

Relation between β and γ: $\gamma = 1 + \beta$ also $\beta = \gamma - 1$

Relation between α,β and γ: $\alpha = \dfrac{\beta}{1+\beta}$ , $\beta = \dfrac{\alpha}{1-\alpha}$ , $\gamma = \dfrac{1}{1-\alpha}$ , $\beta = \alpha \times \gamma$ , $\gamma = 1 + \beta$ , $\beta = \gamma - 1$

## Need of biasing and explain different types of biasing with circuit diagram. (only CEconfiguration)

**Biasing**

**Biasing** is the application of external dc supply to establish a fixed level of current and voltage. Transistor operates only at a particular point of the characteristics called operating point or Q-point/ Quiescent point. The circuit which provides transistor biasing is called as **Biasing Circuit**.

**Need for DC biasing**

If a signal of very small voltage is given to the input of a ransistor, it cannot be amplified. Because, to amplify a signal a transistor must satisfy these two conditions.

- The input voltage should exceed **cut-in voltage** for the transistor to be **ON**.

- The BJT should be in the **active region**, to be operated as an **amplifier**.

If appropriate DC voltages and currents are given through BJT by external sources, so that BJT operates in active region and superimpose the AC signals to be amplified, then this problem can be avoided. The given DC voltage and currents are so chosen that the transistor remains in active region for entire input AC cycle. Hence DC biasing is needed.

The below figure shows a transistor amplifier that is provided with DC biasing on both input and output circuits.
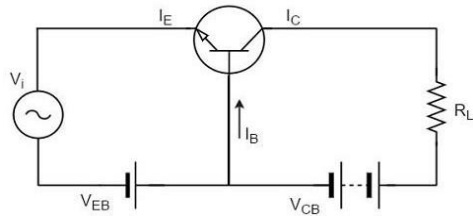
For a transistor to be operated as a faithful amplifier, the operating point should be stabilized.

**Types of Biasing**

Transistor biasing was done with the aid of a battery $V_{BB}$which was separate from the battery $V_{CC}$used in the output circuit. However, in the interest of simplicity and economy, it is desirable that transistor circuit should have a single source of supply. The following are the most commonly used methods of obtaining transistor biasing from one source of supply (*i.e.* $V_{CC}$)

     i.      Base resistor method

     ii.     Emitter bias method

     iii.    Biasing with collector-feedback resistor method

     iv.    Voltage-divider bias method

**Base Resistor Method**

In this method, a high resistance $R_B$ isconnected between the base and +ve end of supply for *npn*transistor and between base and negative end of supply for *pnp*transistor. Here, the required zero signalbase current is provided by $V_{CC}$and it flows through $R_B$. Itis because now base is positive *w.r.t.* emitter *i.e.* base-emitterjunction is forward biased. The required value of zerosignal base current $I_B$(and hence $I_C = \beta I_B$) can be made toflow by selecting the proper value of base resistor $R_B$.

**Base Emitter Loop:**

Applying KVL wehave

$V_{CC} - I_B R_B - V_{BE} = 0$
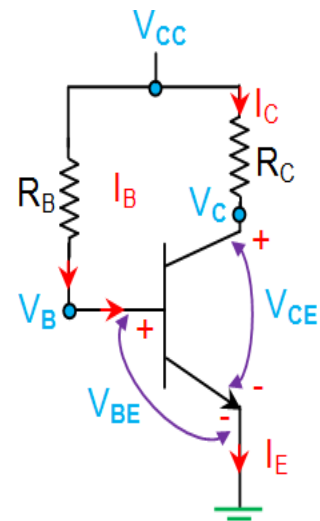
$I_B = \dfrac{Vcc - Vbe}{Rb}$

Since $V_{BE}$ and $V_{CC}$ are constant, the selection of a base resistor $R_B$ sets the level of base current for the operating point.

**Collector Emitter Loop:**

$I_C = \beta\ I_B$

$V_{CC} - I_C R_C - V_{CE} = 0$

$V_{CE} = V_{CC} - I_C R_C$

So $R_B$ controls $I_B$ and $I_C$, and the level of $R_C$ determines the magnitude of $V_{CE}$.

$V_{CE} = V_C - V_E$, $V_{BE} = V_B - V_E$

**Emitter Bias Method**

This circuit differs from base-bias circuit in two important respects. First, it uses two separate d.c. voltage sources; one positive $(+\ V_{CC})$ and the other negative $(-\ V_{EE})$. Normally, the two supply voltages will be equal. For example, if $V_{CC} = +\ 20V$ (d.c.), then $V_{EE} = -\ 20V$ (d.c.). Secondly, there is a resistor $R_E$ in the emitter circuit.

**Base Emitter Loop:**

Applying KVL we have

$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$

**Collector Emitter Loop:**

$I_C = \beta\ I_B$

$V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$

$V_{CE} = V_{CC} - I_C\ (R_C + R_E)$

**Collector feedback Resistor Method**

In this method, one end of $R_B$ is connected to the base and the other end to the collector as shown in Figure. Here, the required zero signal base current is determined *not* by $V_{CC}$ but by the collectorbase voltage $V_{CB}$. It is clear that $V_{CB}$ forward biases the base-emitter junction and hence base current $I_B$ flows through $R_B$. This causes the zero signal collector current to flow in the circuit.

**Base Emitter Loop:**

Applying KVL and solving we have

$$I_B = \frac{Vcc - Vbe}{Rf + \beta(Rc + Re)}$$

**Collector Emitter Loop:**

Applying KVL and solving we have

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

**Voltage divider Method**

This is the most widely used method of providing biasing and stabilisation to a transistor. In this method, two resistances $R_1$ and $R_2$ are connected across the supply voltage $VCC$ and provide biasing. The emitter resistance $R_E$ provides stabilisation. The name „„voltage divider‟‟ comes from the voltage divider formed by $R_2$ and $R_2$. The voltage drop across $R_2$ forward biases the base-emitter junction. This causes the base current and hence collector current flow in the zero signal conditions.
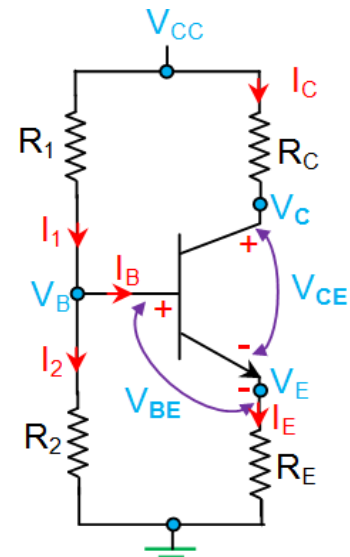


The Thevenin equivalent circuit is redrawn and the $I_{BQ}$ can be found by applying KVL in output loop

$$V_{TH} - I_B R_{TH} - V_{BE} - I_E R_E = 0$$

By solving the output collector emitter loop by KVL

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

**Amplifiers(concept) , working principles of single phase CE amplifier**

**Amplifier**

The device which increase the strength of a weak signal is known as amplifier. This can achieve by use of transistor. It may be classified based on the no of stage of amplification.

1. Single stage amplifier
2. Multi stage amplifier

**Working principles of single stage CE amplifier**

When in an amplifier circuit only one transistor is used for amplifying a weak signal, the circuit is known as single stage amplifier. A single stage CE amplifier has one common emitter transistor, bias circuit & other auxiliary components as shown in figure.
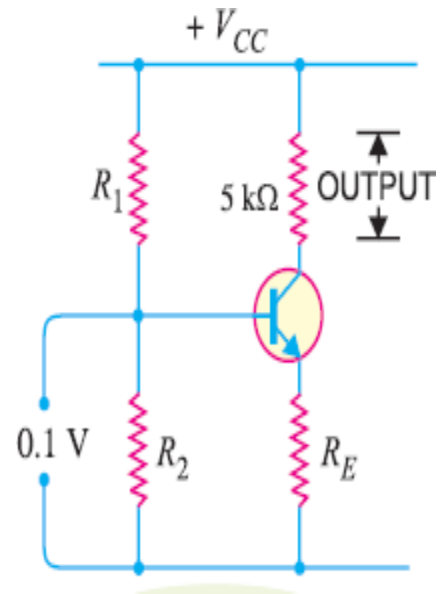
When a weak a.c. signal is applied to the base of the transistor, a small base current starts flowing in the input circuit.

Due to transistor action, a much larger ($\beta$ times the base current) a.c. current flows through the the load $R_c$ in the output circuit. Since the value of load resistance $R_c$ is very high, a large voltage will drop across it.

Thus, a weak signal applied in the base circuit appears in amplified form in the collector circuit. In this way the transistor acts as an amplifier.

The resistances $R_1$ , $R_2$ and $R_E$ provide biasing and stabilisation.

An electrolytic capacitor of value 10 µF is used to couple the signal to the base of the transistor.

An emitter bypass capacitor of value 100 µF is used in parallel with $R_E$ to provide a low reactance path to the amplified a.c. signal.

The coupling capacitor of value 10 µF is used to couple one stage of amplification to the next stage.

The voltage gain of a single stage transistor amplifier is the ratio of a.c. output voltage to a.c. input signal voltage.

**Electronic Oscillator and its classification**
**Defination**

An **oscillator** is a circuit which produces a continuous, repeated, alternating waveform without any input. Oscillators basically convert unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components.

The basic principle behind the working of oscillators can be understood by analyzing the behavior of an LC tank circuit shown in Figure, which employs an inductor L and a completely pre-charged capacitor C as its components.

**Classification of Oscillator**

The oscillators are classified based on the nature of the output waveforms, the parameters used, the range of frequency etc. The various ways in which oscillators are classified as :

**Based on the Output Waveform**

Under this, the oscillators are classified as sinusoidal and non sinusoidal oscillators. The sinusoidal oscillator generate purely sinusoidal waveform at the output. While non sinusoidal oscillators generate an output waveform as triangular, square, saw tooth etc.

**Based on the circuit components**

The oscillator using the components resistance and capacitor are called RC oscillators. While the oscillators using the components inductance and capacitor are called LC oscillators. In some oscillators, crystal is used, are called crystal oscillators.

**Based on the range of Operating Frequency**

If the oscillators are used to generate the oscillations at audio frequency range which is 20 Hz to 100 – 200 KHz, then the oscillators are classified as low frequency or audio frequency oscillators. While the oscillators used at the frequency range more than 200 – 300 KHz upto GHz

are classified as high frequency or radio frequency oscillators. The RC oscillators are used at low frequency while the LC oscillators are used at high frequency range.

**Based on type of Feedback used**

The oscillators in which the feedback is used, which satisfies the required conditions, are classified as feedback type of oscillators. The oscillators in which the feedback is not used to generate the oscillations, are classified as non feedback oscillators.

**Working of Basic Oscillator with different elements through simple Block Diagram**

**Working of Oscillator**

The **oscillators** are nothing but the amplifier circuits which are provided with a positive or regenerative feedback wherein a part of the output signal is fed back to the input as shown in the figure. Here the amplifier consists of an amplifying active element which can be a transistor or an Op-Amp and the back-fed in-phase signal is held resonsible to keep-up (sustain) the oscillations by making-up for the losses in the circuit

Once the power supply is switched ON, the oscillations will be initiated in the system due to the electronic noise present in it. This noise signal travels around the loop, gets amplified and converges to a single frequency sine wave very quickly.

The amplifier produce total hase shift of $360^o$ hence the feedback becomes a positive feedback and produce oscillations.

**BLOCK DIAGRAM OF AN OSCILLATOR**



**Chapter Review Questions:**

1. Define rectifier.

2. Draw the circuit of centre tap FWR & Bridge FWR.
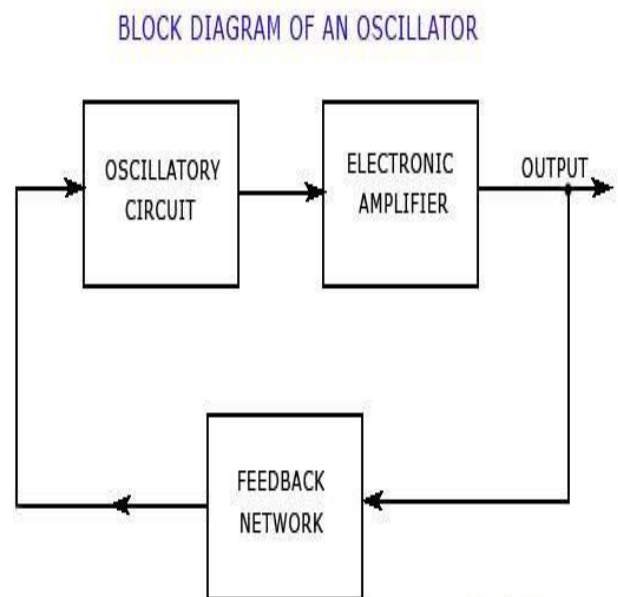
3. State different types of filters .

4. Define ripple & ripple factor.

5. Define rectifier efficiency.

6. What is a transistor ?

7. State different types of transistor configurations.

8. State relation between α & β and β & γ.

9. State the need of biasing & name different types of biasing.

10. What is DCregulator ?Explain need of regulators.

11. Define Concept of amplification

12. Explain Single stage CE amplifier with voltage divider biases its explanation.

13. Define oscillator.

14. Explain working of basic Oscillator with simple block diagram.

# CHAPTER-3

## 3.COMMUNICATION SYSTEM

### Basic communication system (concept & explanation with help of Block diagram)

The communication system is a system which describes the information exchange between two points. The process of transmission and reception of information is called communication. The major elements of communication are the **Transmitter** of information, **Channel or medium** of communication and the **Receiver** of information.

**Block Diagram of Communication Systems**

The block diagram given below represents the flow of the signal from the source to the destination.
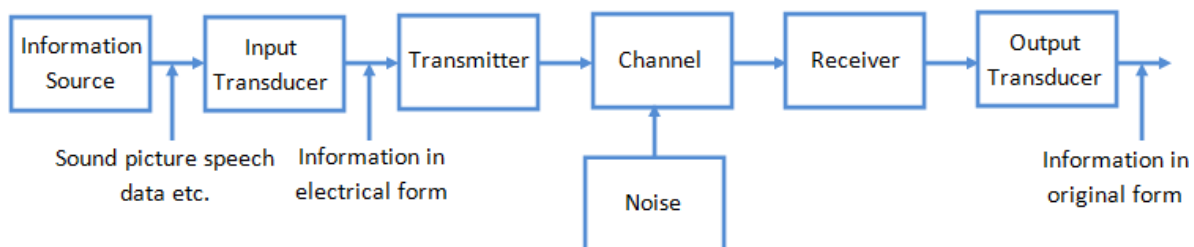


The essential components of a communication system are information source, input transducer, transmitter, communication channel, receiver and destination.

**Information Source**

➢ Message or information is the entity that is to be transmitted. It can be in the form of audio, video, temperature, picture, pressure, etc.

**Input Transducer**

➢ A transducer is a device which converts one form of energy into another form.
➢ The message from the information source may or may not be electrical in nature. In a case when the message produced by the information source is not electrical in nature, an input transducer is used to convert it into a time-varying electrical signal.

- Example: microphone converts the information or massage which is in the form of sound waves into corresponding electrical signal.

**Transmitter**

- It is the arrangement that processes the message signal into a suitable form for transmission and subsequently reception.
- Modulation is the main function of the transmitter. In modulation, the message signal is superimposed upon the high-frequency carrier signal.

**Channel**

- A channel refers to a physical medium such as wire, cables, space through which the signal is passed from transmitter to the receiver.
- There are many channel impairments that affect the channel performance to a pronounced level. Noise, Attenuation and distortion to mention the major impairments.

**Noise**

- Noise is an unwanted signal which tend to interfere with the required signal. Noise signal is always random in character. Noise may interfere with signal at any point in a communication system.

**Receiver**

- An arrangement that extracts the message or information from the transmitted signal at the output end of the channel and reproduces it in a suitable form as the original message signal is a receiver.
- The main function of the receiver is to reproduce the message signal in electrical form from the distorted received signal. This reproduction of the original signal is accomplished by a process known as the demodulation or detection. Demodulation is the reverse process of modulation carried out in transmitter.

**Output transducer**

- Output transducer convert an electrical message signal into its original form.

➢ Example- loudspeaker which works as a transducer i.e. converts the electrical signal in the form of original sound signal.

## Concept of Modulation and Demodulation, Difference between them

➢ Modulation is the process by which some characteristics or parameters of the carrier wave is changed according to the signal containing information. These characteristics can be amplitude, frequency or phase. Basically, it is assumed that the information signal is a low-frequency one and thus needs conversion from low to high in order to have a better transmission.

➢ Demodulation is defined as extracting the original information-carrying signal from a modulated carrier wave. A demodulator is an electronic circuit that is mainly used to recover the information content from the modulated carrier wave.

**Need for modulation:**

- The baseband signals can be transmitted directly, but the baseband transmission has many limitations which can be overcome using modulation.

- In the process of modulation, the baseband signal is translated i.e. shifted from low frequency to high frequency.

- This frequency shift is proportional to the frequency of carrier.

- The modulation process has the following advantages:

**Advantages of modulation:**

**- Reduction in the height of antenna:**

- When the transmission occurs over free pace, the antennae radiate the signal out and receiver receives it. In order to operate efficiently, antennae need to be in order of the magnitude of wavelength of the transmitted signal.

- For the transmission of radio signals, the antenna height must be a multiple of $(\lambda/4)$. Here $\lambda$ is the wavelength. $\Lambda = c/f$ where c is velocity of light and f is the frequency of the signal to be transmitted.

- The minimum antenna height required to transmit a baseband signal of f=10 kHz is calculated as follows:

Minimum antenna height= $\lambda/4$ = c/4f=$(3x10^8)/(4x10x10^3)$=7500meters i.e. 7.5 km
It is impossible to build antennae this big.

- Now consider a modulated signal at f= 1MHz.The minimum antenna height is given by,

    Minimum antenna height= $\lambda/4$ = c/4f=$(3x10^8)/(4x1x10^6)$=75 meter
- This length of the antenna can be b uilt easily and this example clearly shows us how hugely the process of modulation is enabling communication systems.

-**Avoids mixing of signals:**

- If the baseband sound signals are transmitted without using the modulation by more than one transmitter, then all the signals will be in the same frequency range i.e 0 to 20Khz. Therefore, all the signals get mixed together and a receiver cannot separate them from each other.

- Hence, if each baseband sound signal is used to modulate a different carrier then they will occupy different slots in the frequency domain (different channels). Thus, modulation avoids mixing of signals.

-**Increase the range of communication:**

- By using modulation to transmit the signals through space to long distances, it removed the need for wires in the communication systems.

- The technique of modulation helped to use wireless equipment in a bug way in their lives.

-**Multiplexing is possible:**

- Multiplexing is a process in which two or more signals can be transmitted over the same communication channel simultaneously. This is possible only with modulation.

- The Multiplexing allows the same channel to be used by many signals.

-**Improves quality of reception:**

- With frequency modulation (FM), and the digital communication techniques like PCM, the effect of noise is reduced to a great extent. This improves quality of reception.

**Differences between Modulation and Demodulation**

1. The key difference between modulation and demodulation is that modulation is done at the transmitter side while demodulation is done at the receiver side of a communication system.

2. Both modulation and demodulation occur during data transmission but the two processes are exactly reverse of each other. In modulation original message signal is mixed with the carrier wave whose parameters are required to be changed. As against, in demodulation the combination of carrier and message signal are separated from each other, to have original information signal.

3. Modulation requires a modulator section for mixing of the two signals whereas demodulation requires demodulator to recover the original signal. However, combined equipment is used for the two known as Modem.

4. Modulation is done to convert the low-frequency signal into a high-frequency signal. While at the time of demodulation, the low-frequency signal is achieved form high-frequency signal.

5. Modulation is basically done to transmit data to longer distance whereas demodulation is done to regain the original message signal.

6. Demodulation is somewhat a complex process when compared with modulation.

## Different types of Modulation (AM, FM & PM) based on signal, carrier wave and modulated wave (only concept, No mathematical Derivation)

There are three types of modulation, namely:

**1.Amplitude modulation (AM)**

In **amplitude modulation**, the amplitude of the carrier wave is varied in proportion to the message signal, and the other factors like frequency and phase remain constant.
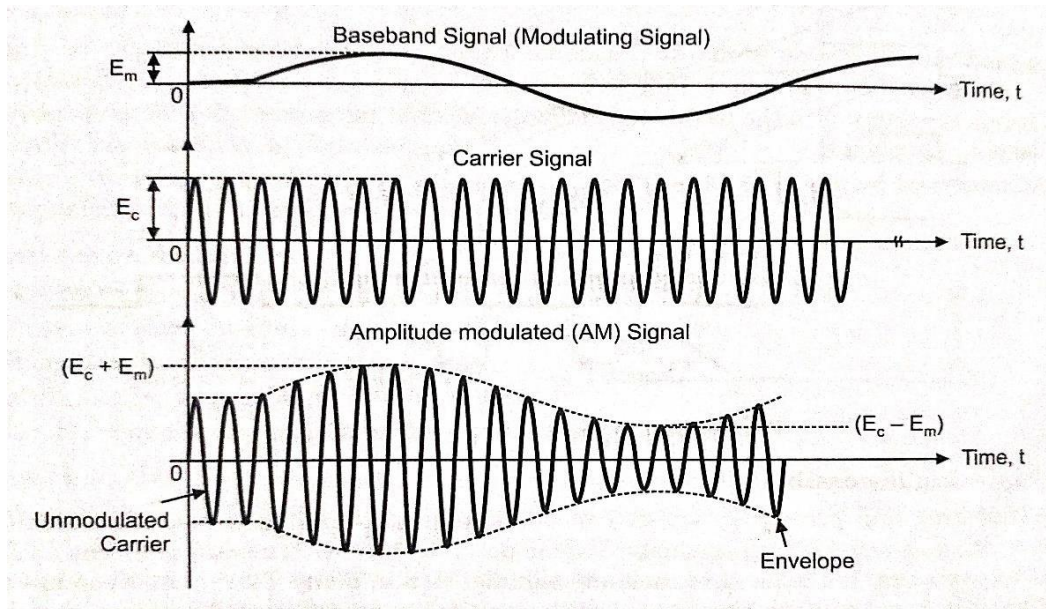
## 2. Frequency modulation (FM)

**Frequency modulation** (FM) varies the frequency of the carrier in proportion to the message or data signal while maintaining other parameters constant.
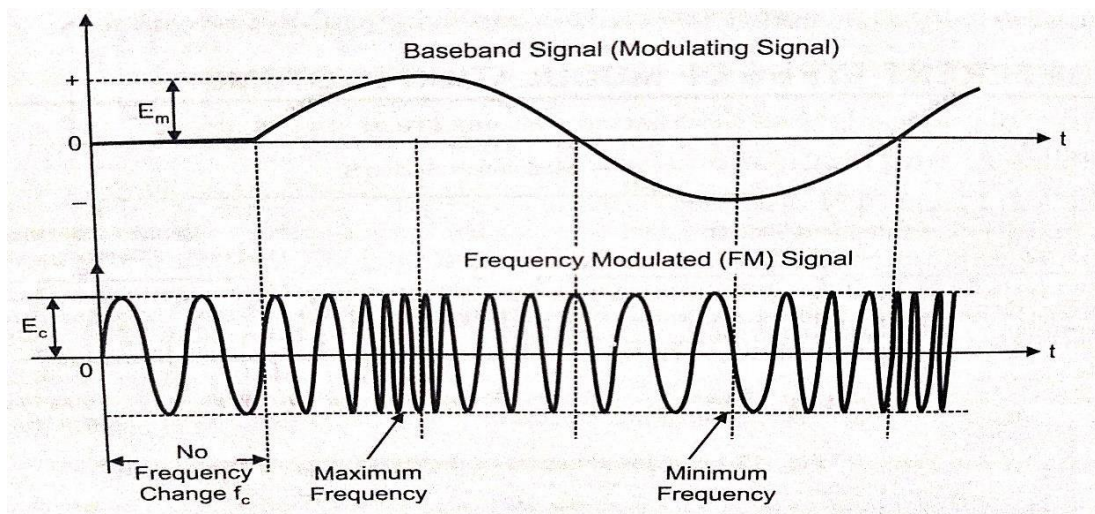


## 3. Phase modulation (PM)

In **phase modulation**, the carrier phase is varied in accordance with the data signal while maintaining other parameters constant.

Baseband Signal (Modulating Signal)

Modulating voltage

$E_m$

Unmodulated Carrier

Phase Modulated (PM) Signal

No Phase Change

Carrier Stretching (Phase Lag)

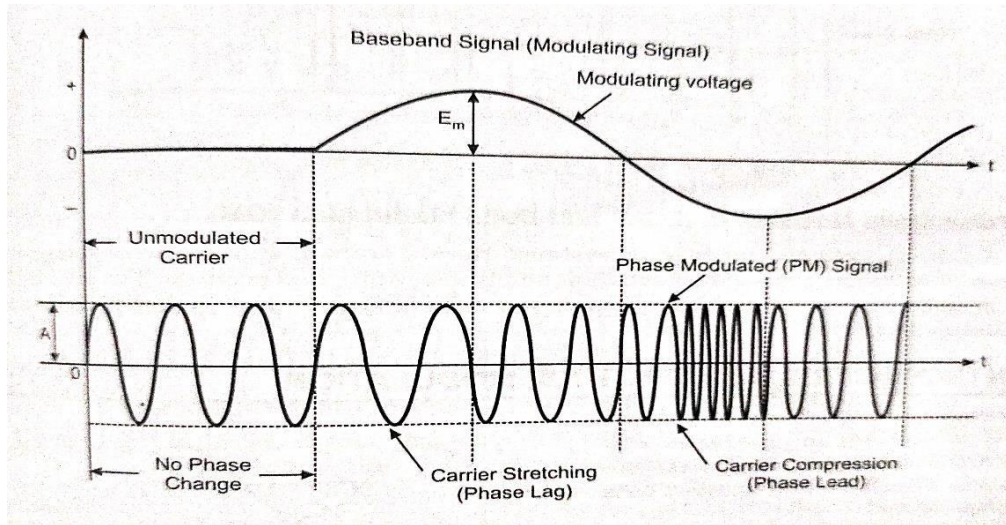Carrier Compression (Phase Lead)

**Chapter Review Questions:**

1. Define communication system?
2. Define Transducer?
3. What are the basic constituents of a communication system?
4. What is meant by the term Channel as applied to a communication system?
5. What is Modulation?
6. Explain different type of modulation?
7. Explain the difference between modulation and demodulation?
8. Draw the block diagram of a communication system and explain the function of each block?

# CHAPTER-4

## 4. TRANSDUCERS AND MEASURING INSTRUMENTS

### Concept of Transducer and sensor with their differences

**Transducer**

➢ The transducer is a device that changes the physical attributes of the non-electrical signal into an electrical signal which is easily measurable.

➢ The process of energy conversion in the transducer is known as the transduction.

➢ The transduction is completed into two steps. First by sensing the signal and then strengthening it for further processing.
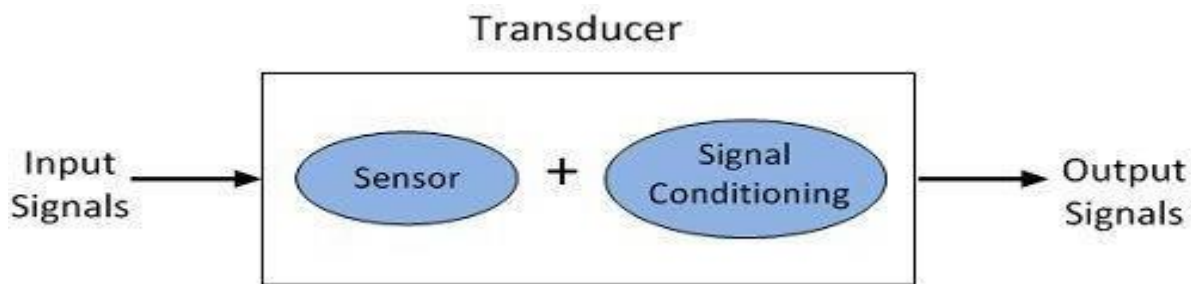


Transducer

➢ The transducer has three major components; they are the input device, signal conditioning or processing device and an output device.

➢ The input devices receive the measurand quantity and transfer the proportional analogue signal to the conditioning device. The conditioning device modified, filtered, or attenuates the signal which is easily acceptable by the output devices.

**Sensor**

➢ The sensor is a device that measures the physical quantity (i.e. Heat, light, sound, etc.) into an easily readable signal (voltage, current etc.). It gives accurate readings after calibration.

➢ **Ex** – The mercury used in the thermometer converts the measured temperature into an expansion and contraction of the liquid which is easily measured with the help of a

calibrated                                      glass                                      tube.
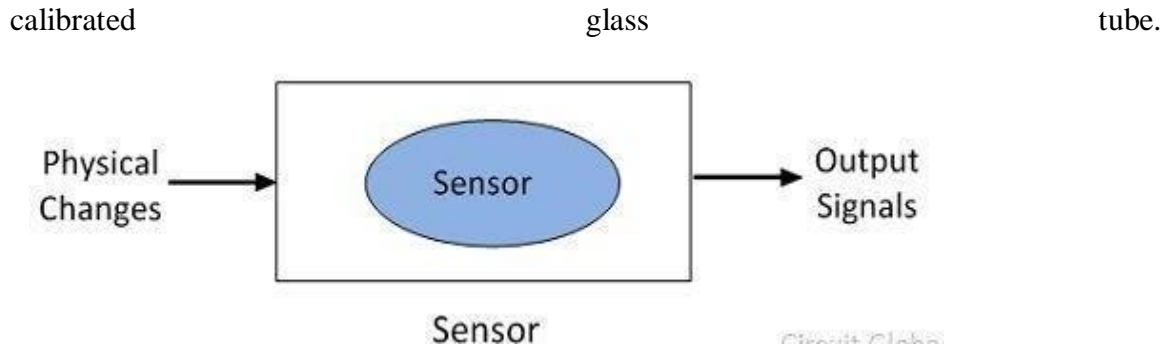


Sensor

## Differences between Sensor and Transducer

The following are the key differences between the sensor and transducer.

1. The sensor senses the physical change across the surrounding whereas the transducer transforms the one form of energy into another.
2. The sensor itself is the major component of the sensor, whereas the sensor and the signal conditioning are the major elements of the transducer.
3. The primary function of the sensor is to sense the physical changes, whereas the transducer converts the physical quantities into an electrical signal.
4. The accelerometer, barometer, gyroscope are the examples of the sensors whereas the thermistor, and thermocouple is the examples of the transducer.

## Different type of Transducers & concept of active and passive transducer.
## Classification of Transducers

The classification of transducers is made from the following basis:

1. Based on the physical phenomenon

   - Primary transducer
   - Secondary transducer

2. Based on the power type Classification

   - Active transducer
   - Passive transducer

3. Based on the type of output the classification of transducers are made

- Analog transducer
- Digital transducer

4. Based on the electrical phenomenon is a best Classification of Trasnducer

- Resistive transducer
- Capacitive transducer
- Inductive transducer
- Photoelectric transducer
- Photovoltaic transducer

5. Based on the non-electrical phenomenon Classification of transducer

- Linear displacement
- Rotary displacement

6. Based on the transduction phenomenon

- Transducer
- Inverse transducer.

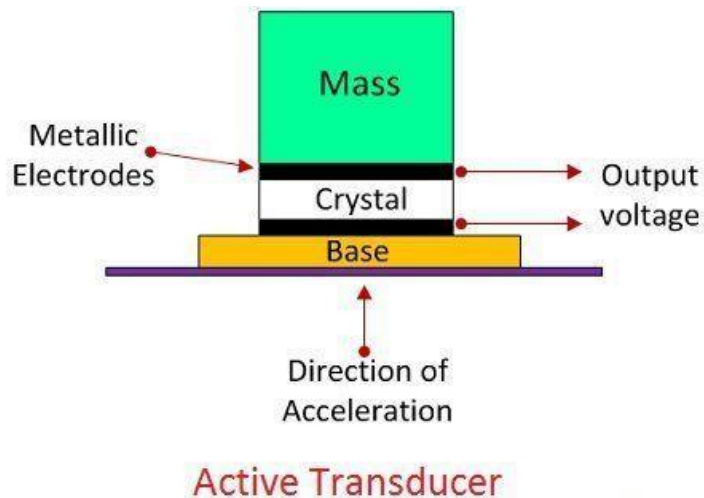**concept of active and passive transducer.**

**Active Transducer**

➢ The transducer which does not require the external power source is known as the active transducer.

➢ Such type of transducer develops theirs owns voltage or current, hence known as a self-generating transducer.

➢ The energy requires for generating the output signals are obtained from the physical quantity which is to be measured.

**Example:**

The Piezo electrical crystal is the example of the natural active transducer. The crystal has the property of producing the output voltage when the external force applied to them. The piezoelectric crystal is placed between the two metallic electrodes. When the force applied to the crystal, the voltage induces across it.



Active Transducer

**Passive Transducer**

➤ The transducer which requires the power from an external supply source is known as the passive transducer.

➤ They are also known as the external power transducer. The capacitive, resistive and inductive transducers are the example of the passive transducer.

➤ **The passive transducer takes power from the external energy source for transduction.** The word transduction means conversion of energy from one form to another.

**Example**:

The linear potentiometer is the examples of the passive transducer. It is used for measuring the displacement. The POT requires the external power source $e_i$ for work. It measures the linear displacement $x_i$.
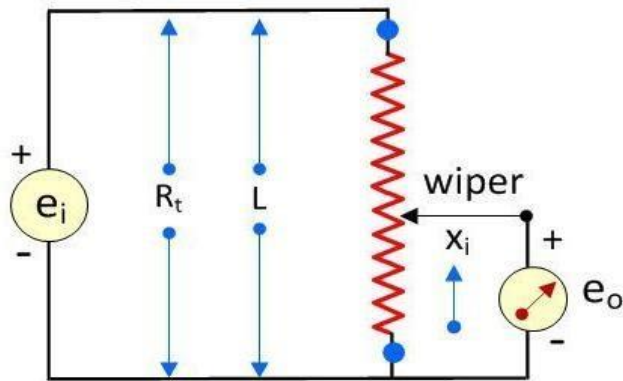


Linear Potentiometer (Pot), a passive transducer

Consider the L is the length of the potentiometer. $R_i$ is their total internal resistance and $x_i$ is their input displacement. The output voltage is calculated by the formula shown below.

$$e_o = \frac{x_i}{L} e_i$$

Or

$$x_i = \left(\frac{e_o}{e_i}\right) L$$

## Working principle of photo emissive, photoconductive, photovoltaic transducer and its application

The photoelectric transducer converts the light energy into electrical energy. It is made of semiconductor material. The photoelectric transducer uses a photosensitive element, which ejects the electrons when the beam of light absorbs through it.

Thesephotoelectric transducers are classified into five types which include the following

- Photo emissive Cell
- Photodiode

- Phototransistor
- Photo-voltaic cell
- Photoconductive Cell

**Photo-emissive Cell**

> ➢ The Photo-emissive cell converts thephotons into electric energy. It consists the anode rode and the cathode plate. The anode and cathode are coated with Photo-emissive material called caesium antimony.



Photoemissive Cell
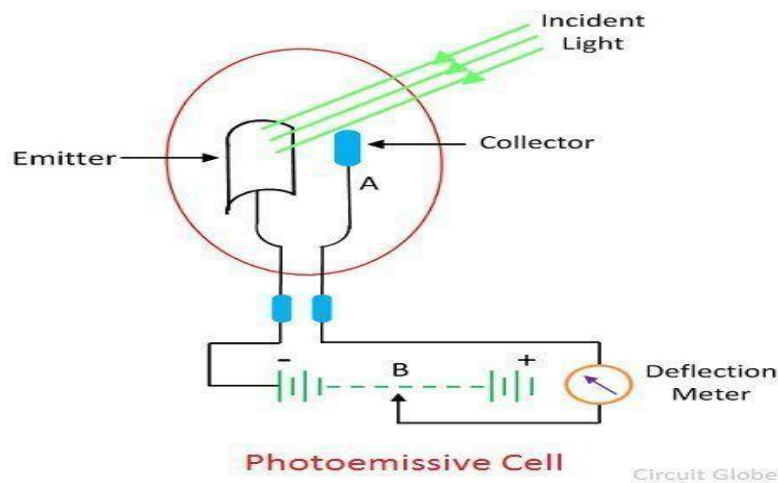
> ➢ When the radiation of light fall on cathode plates the electrons starts flowing from anode to cathode. Both the anode and the cathode are sealed in a closed, opaque evacuated tube. When the radiation of light falls on the sealed tube, the electrons starts emitting from the cathode and moves towards the anode.

> ➢ The anode is kept to the positive potential. Thus, the photoelectric current starts flowing through the anode. The magnitude of the current is directly proportional to the intensity of light passes through it.

**Photoconductive Cell**

> ➢ The photoconductive cell converts the light energy into an electric current. It uses the semiconductor material like cadmium selenide, Ge, Se, as a photo sensing element.

Photoconductive Cell
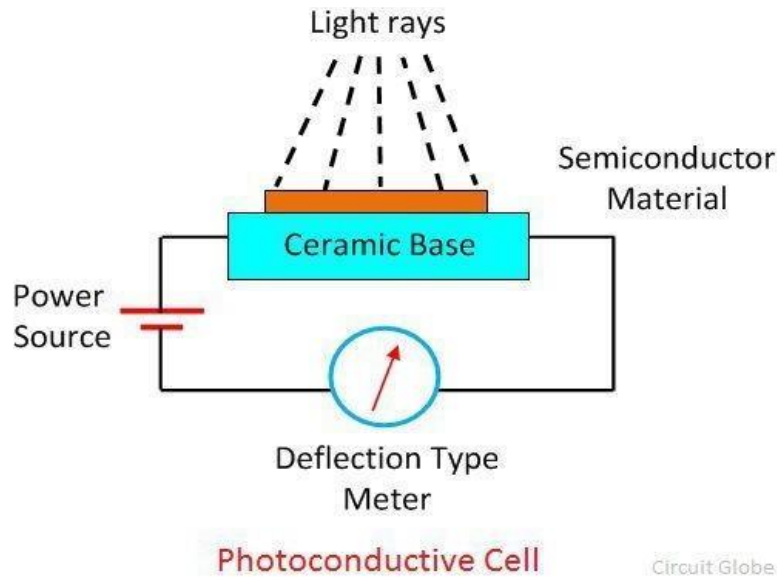
➢ When the beam of light falls on the semiconductor material, their conductivity increases and the material works like a closed switch. The current starts flowing into the material and deflects the pointer of the meter.

**Photo-voltaic cell**

➢ The photovoltaic cell is the type of activetransducer. The current starts flowing into the photovoltaic cell when the load is connected to it. The silicon and selenium are used as a semiconductor material. When the semiconductor material absorbs heat, the free electrons of the material starts moving. This phenomenon is known as the photovoltaic effect.

➢ The movements of electrons develop the current in the cell, and the current is known as the photoelectric current.

Photovoltaic Cell

Circuit Globe
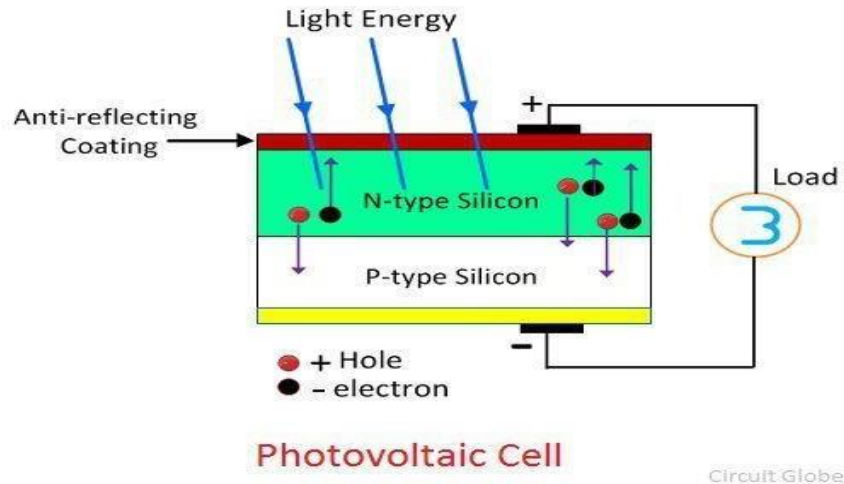
**Applications of Photoelectric Transducer**

The applications of this transducer mainly include the following.

- These transducers are used in biomedical applications
- Pickups of pulse
- Pneumograph respiration
- Measure blood pulsatile volume changes
- Records Body movements.

## Multimeter and its applications

> A multimeter is an electronic measuring instrument that combines several measurement functions in one unit.

> A typical multimeter can measure voltage, current, and resistance. It is an indispensable instrument and can be used for measuring d.c as well as a.c voltages and currents.

> Multimeter is the most inexpensive equipment and can make various electrical measurement with reasonable accuracy.

**Applications**

- For checking the circuit continuity.

- For measuring d.c current flowing through the cathode, plate,screen and other vacuum tube circuits.

- For measuring d.c voltages across various resistors in electric circuits.

- For measuring a.c voltages across power supply transformers.

- For ascertaining whether or not open or short circuit exits in the circuit under study.

## Analog and Digital Multimeter and their differences

### Analog Multimeter

➢ Analog Multimeter is basically a moving coil instrument. A rectifier unit is also provided with the instrument. It is a multirange instrument and various ranges are obtained by different resistance elements in series or in parallel with the movement of the instrument. With the help of a rotary selector switch the various ranges are used.

### Digital Multimeter

➢ The digital multimeter is an instrument capable of measuring dc voltage, ac voltage, dc current, ac current, resistance, conductance and decibles. Thus DMM offers increased versatility. Some DMMs can measure the temperature, frequency etc.

➢ A DMM has a digital display and a function selector switch. The range selection takes place automatically. There are four input terminals, out of which two terminals are used for measurement of all the general purpose quantities such as ac/dc voltage, resistance, capacitance and diode, transistor testing.

### Difference between Analog and Digital Multimeter

| Analog Multimeter | Digital Multimeter |
|---|---|
| Power supply is not required | Power supply is required |

| | |
|---|---|
| Visual indication of changes in the reading is not that much better | Better visual indication of changes in the reading is obtained |
| Less suffered from electrical noise | More suffered from electrical noise |
| Less isolation problems. | More isolation problems. |
| Accuracy is less | High accuracy is obtained. |
| The output cannot be interfaced with external equipment | The output can be interfaced with external equipment |
| Construction is simple | Construction is complicate |
| Bigger in size | Smaller in size |
| Many times output is ambiguous | An unambiguous reading is obtained |
| Less expensive | More expensive |

## Working principle of Multimeter with Basic Block diagram

➢ All digital multimeters make use of some type of analog to digital converter (ADC). Generally dual slope integration type AD is used for this purpose. The block diagram of basic digital multimeter is as shown in figure below
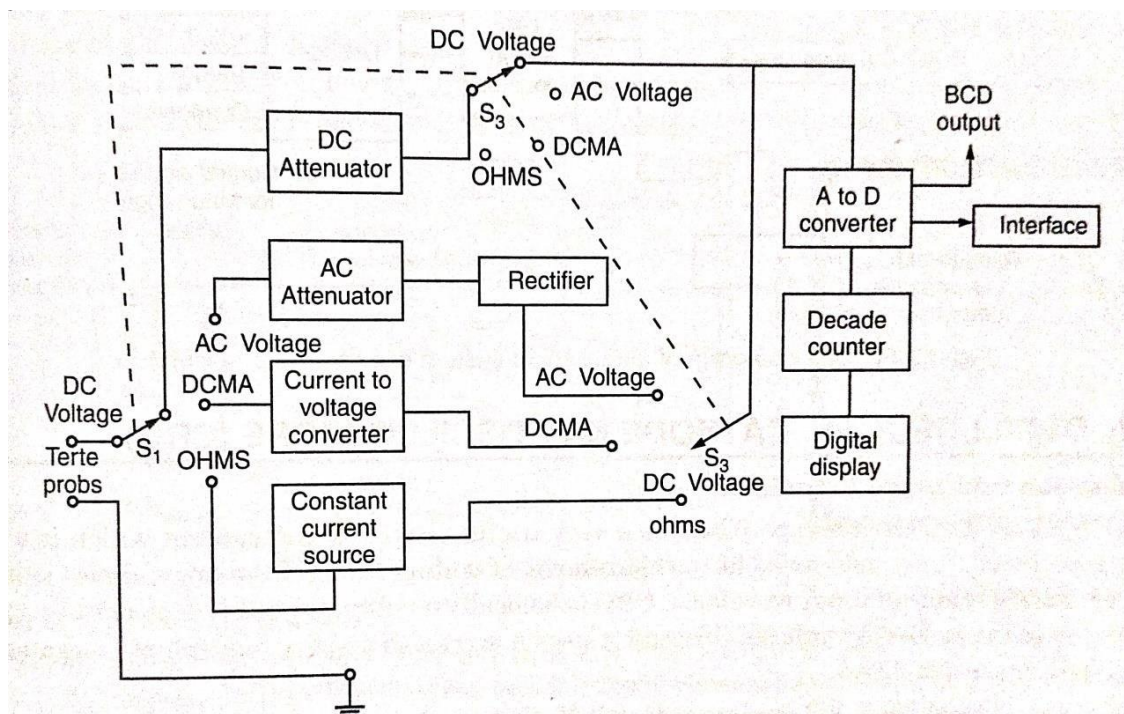


➢ A commercial digital multimeter consist of several A to D converters, decade counters and display. It is basically dc voltmeter. In order to measure unknown current; current to

voltage converter is used. An unknown current to be measured is applied to one of the input terminals of op-amp. Since input impedance of op-amp is very high; very small current can pass through it. This current passing into the op-amp can be neglected.

➢ Thus $I_{in}= I_{fb}$, Here $I_{fb}$ = feedback current

➢ This feedback current is allowed to pass through one of the known resistances. This current will cause a voltage drop across the resistance. This voltage is applied to analog to digital converter and finally digital display is obtained. Thus, output displayed on the digital display is directly proportional to unknown current.

➢ In order to measure an unknown resistance; a constant current source is used. The current from this constant current source is allowed to pass through unknown resistance. Thus the proportional voltage is obtained. The output disply is directly proportional to unknown resistance.

➢ To measure the ac voltage; a rectifier and filter is used. This rectifier converts ac signal into dc signal. Now, this dc signal is applied to A to D converter to the digital display. The BCD output can be obtained from A to D converter. Similarly, the output from digital multimeter can be used to interface with other equipments.

## CRO, working principle of CRO with simple Block diagram

➢ Oscilloscope is electronic equipment, which displays a voltage waveform. Among the oscilloscopes, Cathode Ray Oscilloscope (CRO) is the basic one and it displays a time varying signal or waveform.

### Block Diagram of CRO

➢ Cathode Ray Oscilloscope (CRO) consists a set of blocks. Those are vertical amplifier, delay line, trigger circuit, time base generator, horizontal amplifier, Cathode Ray Tube (CRT) & power supply. The block diagram of CRO is shown in below figure.
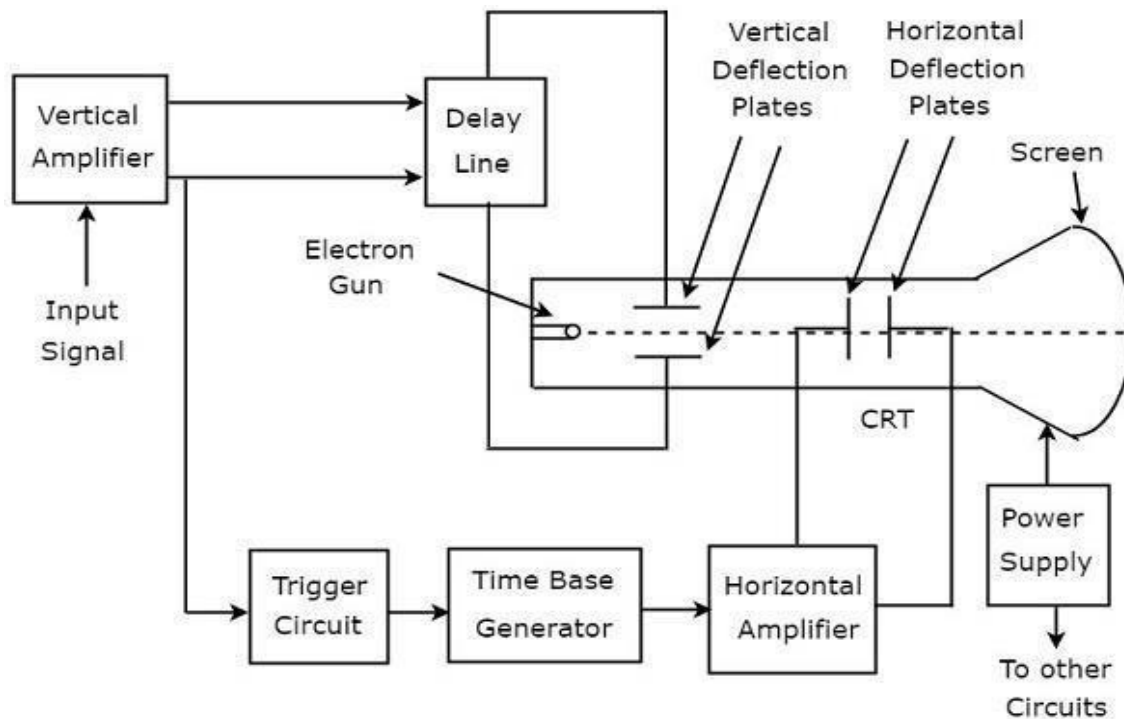
The function of each block of CRO is mentioned below.

- **Vertical Amplifier** − It amplifies the input signal, which is to be displayed on the screen of CRT.

- **Delay Line** − It provides some amount of delay to the signal, which is obtained at the output of vertical amplifier. This delayed signal is then applied to vertical deflection plates of CRT.

- **Trigger Circuit** − It produces a triggering signal in order to synchronize both horizontal and vertical deflections of electron beam.

- **Time base Generator** − It produces a sawtooth signal, which is useful for horizontal deflection of electron beam.

- **Horizontal Amplifier** − It amplifies the sawtooth signal and then connects it to the horizontal deflection plates of CRT.

- **Power supply** − It produces both high and low voltages. The negative high voltage and positive low voltage are applied to CRT and other circuits respectively.

- **Cathode Ray Tube (CRT)** − It is the major important block of CRO and mainly consists of four parts. Those are electron gun, vertical deflection plates, horizontal deflection plates and fluorescent screen.The electron beam, which is produced by an electron gun gets deflected in both vertical and horizontal directions by a pair of vertical deflection plates and a pair of horizontal deflection plates respectively. Finally, the deflected beam will appear as a spot on the fluorescent screen.

In this way, CRO will display the applied input signal on the screen of CRT. So, we can analyse the signals in time domain by using CRO.

**Chapter Review Questions:**

1. Define Transducer?
2. What are the type of Transducer?
3. Write difference between Transducer and Sensor?
4. Write difference between Active and Passive Transducer?
5. What is Multimeter?
6. Write two application of Multimeter?
7. Write short notes on Photo-Emission transducer?
8. Write difference between Analog and Digital Multimeter?
9. Explain working principle of photo emissive, photoconductive, photovoltaic transducer?
10. Explain working principle of Multimeter with Basic Block diagram?
11. What is CRO? Explain working principle of CRO with simple Block diagram?

# Government Polytechnic Naygarh
# Electrical Department

# BASIC ELECTRICAL ENGINEERING

## OF 1ST & 2ND SEMESTER

## For

## DIPLOMA IN ALL ENGINEERING COURSE

# Basic electrical engineering (Th.4 (a))

## of 1st & 2nd semester

### for

## Diploma in all engineering course of SCTE&VT,Odisha
Lecture Name: Samir Kumar Sethi

# SYLLABUS

## Th.4(a). BASIC ELECTRICAL ENGINEERING
### (1st sem Common)

Theory: 2 Periods per Week

Total Periods: 30 Periods

Examination: 1.5 Hours

I.A : 10 Marks

End Sem Exam : 40 Marks

TOTAL MARKS : 50 Marks

### Topic wise Distribution of Periods and Marks

| Sl.No. | Topics | Periods |
|--------|--------|---------|
| 1 | Fundamentals | 05 |
| 2 | A C Theory | 08 |
| 3 | Generation of Elect. Power | 03 |
| 4 | Conversion of Electrical Energy | 07 |
| 5 | Wiring and Power Billing | 04 |
| 6 | Measuring Instrument | 03 |
| | **Total** | **30** |

Objective

1.    To be familiar with A.C Fundamental and circuits
2.    To be familiar with basic principle and application of energy conversion devices
3.    To be familiar with generation of Electrical power
4.    To be familiar with wiring and protective device
5.    To be familiar with calculation and commercial Billing of electrical power & energy
6.    To have basic knowledge of various electrical measuring instruments & conservation of electrical energy

### 1. FUNDAMENTALS

Concept of current flow.

Concept of source and load.

State Ohm"s law and concept of resistance.

Relation of V, I & R in series circuit.

Relation of V, I & R in parallel circuit.

Division of current in parallel circuit.

Effect of power in series & parallel circuit.

Kirchhoff"s Law.

   Simple problems on Kirchhoff"s law.

### 2. A.C. THEORY

   Generation of alternating emf.

Difference between D.C. & A.C.

   Define Amplitude, instantaneous value, cycle, Time period, frequency, phase angle, phase difference.

   State & Explain RMS value, Average value, Amplitude factor & Form factor with Simple problems.

Represent AC values in phasor diagrams.

AC through pure resistance, inductance & capacitance

AC though RL, RC, RLC series circuits.

   Simple problems on RL, RC & RLC series circuits.

   Concept of Power and Power factor

   Impedance triangle and power triangle.

### 3. GENERATION OF ELECTRICAL POWER

Give elementary idea on generation of electricity from thermal , hydro & nuclear power station with block diagram

### 4. CONVERSION OF ELECTRICAL ENERGY

(No operation, Derivation, numerical problems)

Introduction of DC machines.

Main parts of DC machines.

Classification of DC generator

Classification of DC motor.

Uses of different types of DC generators & motors.

Types and uses of single phase induction motors.

Concept of Lumen

Different types of Lamps (Filament, Fluorescent, LED bulb) its Construction and Principle.

Star rating of home appliances (Terminology, Energy efficiency, Star rating Concept)

### 5. WIRING AND POWER BILLING

Types of wiring for domestic installations.

Layout of household electrical wiring (single line diagram showing all the important component in the system).

List out the basic protective devices used in house hold wiring.

Calculate energy consumed in a small electrical installation

### 6. MEASURING INSTRUMENTS

Introduction to measuring instruments.

Torques in instruments.

Different uses of PMMC type of instruments (Ammeter & Voltmeter).

Different uses of MI type of instruments (Ammeter & Voltmeter).

Draw the connection diagram of A.C/ D.C Ammeter, voltmeter, energy meter and wattmeter. (Single phase only).

# CONTENTS

# CHAPTER-1
# FUNDAMENTALS

## CHARGE:-

- The most basic quantity in an electric circuit is the electric charge.
- Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C). Charge, positive or negative, is denoted by the letter q or Q.
- All matter is made of fundamental building blocks known as atoms and that each atom consists of electrons, protons, and neutrons. We also know that the charge „e" on an electron is negative and equal in magnitude to $1.602 \times 10^{-19}$ C, while a proton carries a positive charge of the same magnitude as the electron and the neutron has no charge. The presence of equal numbers of protons and electrons leaves an atom neutrally charged.

## CURRENT:-

- Current can be defined as the motion of charge through a conducting material, measured in Ampere (A). Electric current, is denoted by the letter i or I.
- The unit of current is the ampere abbreviated as (A) and corresponds to the quantity of total charge that passes through an arbitrary cross section of a conducting material per unit second.

   Mathematically,

   $$I = \frac{Q}{t} \quad \text{or} \quad Q = It \qquad \qquad .........(1.1)$$

   Where Q is the symbol of charge measured in Coulombs (C), I is the current in amperes (A) and t is the time in second (s).

- The current can also be defined as the rate of charge passing through a point in an electric circuit. Mathematically,

   $$i = \frac{dq}{dt} ....................................................(1.2)$$

- The charge transferred between time $t_1$ and $t_2$ is obtained as

   $$q = \int_{t1}^{t2} i \, dt \qquad \qquad ........... (1.3)$$

- A constant current (also known as a direct current or DC) is denoted by symbol I whereas a time-varying current (also known as alternating current or AC) is represented by the symbol i or i (t).
- Current is always measured through a circuit element in ammeter as shown in Fig.1.1

1
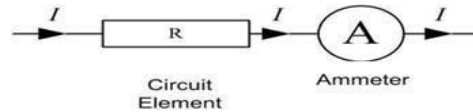
(**Fig. 1.1.** Current through Resistor (R))

- Two types of currents:
  1) A direct current (DC) is a current that remains constant with time.
  2) An alternating current (AC) is a current that varies with time.



(a)                                             (b)
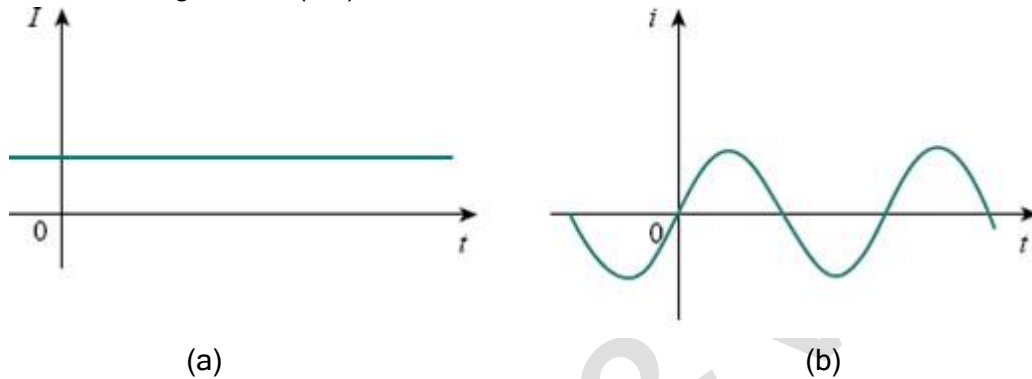
(**Fig.1.2.** Two common types of current: (a) Direct Current (b) Alternating Current)

## VOLTAGE (OR) POTENTIAL DIFFERENCE:-

- To move the electron in a conductor in a particular direction requires some work or energy transfer. This work is performed by an external electromotive force (emf), typically represented by the battery in Fig 1.3(a). This emf is also known as voltage or potential difference. The voltage $V_{ab}$ between two points a and b in an electric circuit is the energy (or work) needed to move a unit charge from a to b.



(a)                                             (b)
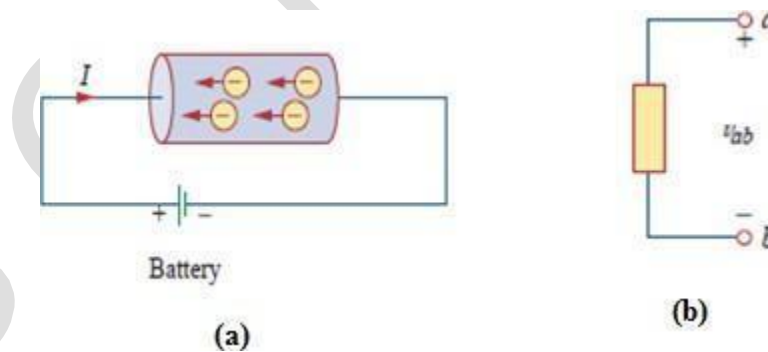
(**Fig. 1.3**.(a) Electric Current in a conductor, (b) Polarity of voltage $V_{ab}$)

- Voltage (or potential difference) is the energy required to move charge from one point to the other, measured in volts (V). Voltage is denoted by the letter v or V.

  Mathematically,

$$V_{ab} = \frac{dw}{dt}$$

..........(1.4)

2

where w is energy in joules (J) and q is charge in coulombs (C). The voltage Vab or simply V is measured in volts (V).

1 volt = 1 joule/coulomb = 1 newton-meter/coulomb

Fig1.3(b). shows the voltage across an element (represented by a rectangular block) connected to points a and b. The plus (+) and minus (-) signs are used to define reference direction or voltage polarity.

- The $V_{ab}$ can be interpreted in two ways: (1) point a is at a potential of $V_{ab}$ volts higher than point b, or (2) the potential at point a with respect to point b is $V_{ab}$. It follows logically that in general

$$V_{ab} = -V_{ba}$$  ..........(1.5)

- Voltage is always measured across a circuit element in Voltmeter as shown in Fig.1.4
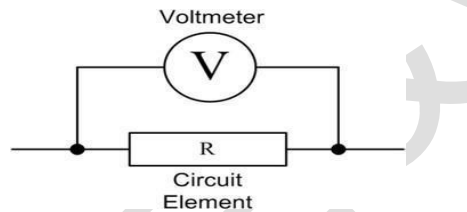


(**Fig.1.4.** Measurement of voltage through voltmeter across circuit element)

## POWER:-

- Power is the time rate of expending or absorbing energy, measured in watts (W). Power, is denoted by the letter p or P.
Mathematically,

$$P = \frac{dw}{dt}$$  ..........(1.6)

Where P is power in watts (W), w is energy in joules (J), and t is time in seconds (s). From voltage and current equations, it follows that;

$$P = \frac{dw}{dt} = \frac{dw}{dq} \times \frac{dq}{dt} = V \times I$$  ..........(1.7)

Thus, if the magnitude of current I and voltage are given, then power can be evaluated as the product of the two quantities and is measured in watts (W).
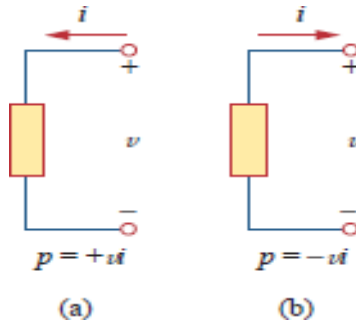
- **Sign of power:**

**Plus sign:** Power is absorbed by the element. (Resistor, Inductor)
**Minus sign:** Power is supplied by the element. (Battery, Generator)

3

● **Passive sign convention:**
   If the current enters through the positive polarity of the voltage, P = +VI
   If the current enters through the negative polarity of the voltage, P = – VI



(**Fig.1.5.** Polarities for Power using passive sign convention
(a) Absorbing Power (b) Supplying Power)

## ENERGY:-

● Energy is the capacity to do work, and is measured in joules (J).
● The energy absorbed or supplied by an element from time 0 to t is given by,

$$W = \int_0^t P\,dt = \int_0^t VI\,dt$$

..........(1.8)

● The electric power utility companies measure energy in watt-hours (WH) or Kilo watt-hours (KWH).

1 WH = 3600 J.............................................. (1.9)

## ENERGY SOURCES:-

● The energy sources which are having the capacity of generating the energy. The most important energy sources are voltage or current sources that generally deliver power/energy to the circuit connected to them.

   There are two kinds of sources
   a) Independent sources
   b) Dependent sources

### a) Independent Sources:

An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements.

**Ideal Independent Voltage Source:**

An ideal independent voltage source is an active element that gives a constant voltage across its terminals irrespective of the current drawn through its terminals.

**Ideal Independent Current Source:**

An ideal independent Current source is an active element that gives a constant current through its terminals irrespective of the voltage appearing across its terminals.

**b) Dependent (Controlled) Sources:**

● An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.
● Dependent sources are usually designated by diamond-shaped symbols, as shown in Fig.1.6 Since the control of the dependent source is achieved by a voltage or current of some other element in the circuit, and the source can be voltage or current, it follows that there are four possible types of dependent sources, namely:

1. A voltage-controlled voltage source (VCVS)
2. A current-controlled voltage source (CCVS)
3. A voltage-controlled current source (VCCS)
4. A current-controlled current source (CCCS)



(a) VCVS      (b) CCVS      (c) VCCS      (d) CCCS
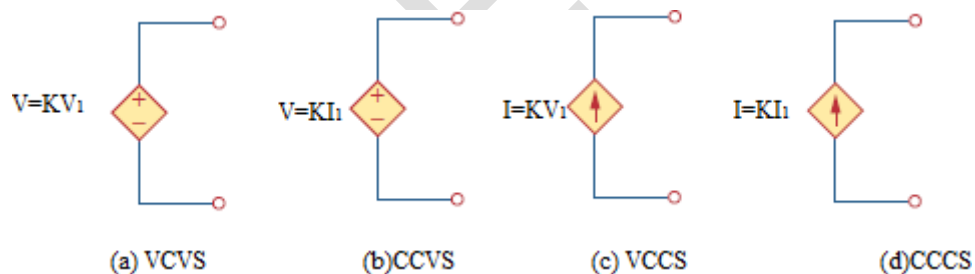
(**Fig.1.6.** (a) voltage-controlled voltage source (b) current-controlled voltage source (c) voltage-controlled current source (d) current-controlled current source)

## ELECTRICAL LOAD:-

● The electrical load is a device that consumes electrical energy in the form of the current and transforms it into other forms like heat, light, work etc.
● The electrical load are (a) Resistive (b) Inductive (c) Capacitive
● **Resistive Load** – The resistive load obstructs the flow of electrical energy in the circuit and converts it into thermal energy.
  Ex- Lamp, Heater
● **Inductive Load-** The inductive load has a coil which stores magnetic energy when the current pass through it.
  Ex- Generator, motor, transformer
● **Capacitive Load-** The capacitive load include energy stored in materials and device.
  Ex- capacitor bank and synchronous condenser

## OHM'S LAW:-

- Georg Simon Ohm (1787-1854), a German physicist, is credited with finding the relationship between current and voltage for a resistor. This relationship is known as Ohm‟s law.
- Ohm‟s law states that at constant temperature, the voltage (V) across a conducting material is directly proportional to the current (I) flowing through the material. Mathematically,

$$V \propto I$$

$$V = RI \qquad \qquad .........(1.10)$$

Where the constant of proportionality R is called the resistance of the material. The V-I relation for resistor according to Ohm‟s law is depicted in Fig.1.7
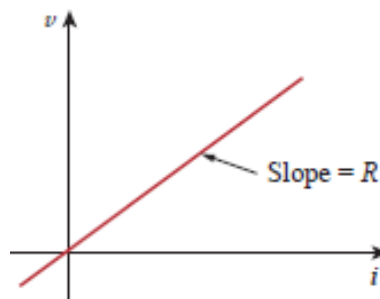


(**Fig.1.7.** V-I Characteristics for resistor)

Limitations of Ohm‟s Law:
1. Ohm‟s law is not applicable to non-linear elements like diode, transistor etc.
2. Ohm‟s law is not applicable for non-metallic conductors like silicon carbide.

**Example-1.1**. An electrical iron carrying 2A at 120V. Find resistance of the device?

**Solution:**

$$R = \frac{V}{I} = \frac{120}{2} = 60\Omega$$

**Example-1.2.**The essential component of a toaster is an electrical element (a resistor) that converts electrical energy to heat energy. How much current is drawn by a toaster with resistance 12Ω at 110V?

**Solution:**

$$I = \frac{V}{R} = \frac{110}{12} = 9.167\, Amp$$

## RESISTOR:-

Materials in general have a characteristic behavior of resisting the flow of electric charge. This physical property, or ability to resist the flow of current, is known as resistance and is represented by the symbol R. The Resistance is measured in ohms ($\Omega$).

## RELATION OF V,I &R IN SERIES CIRCUIT: -

Two or more resistors are said to be in series if the same current flows through all of them. The process of combining the resistors is facilitated by combining two of them at a time. With this in
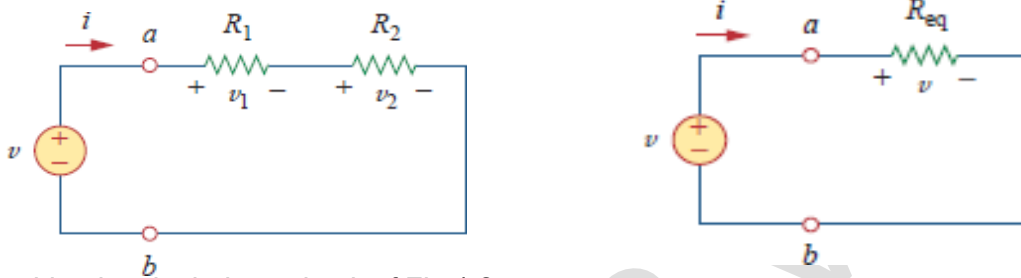


mind, consider the single-loop circuit of Fig.1.8

(a)                                          (b)

(**Fig.1.8.** (a) A single loop circuit with two resistors in series, (b) Equivalent Circuit of series resistors)

The two resistors are in series, since the same current i flow in both of them. Applying Ohm"s law to each of the resistors, we obtain

$$V_1 = iR_1, V_2 = iR_2 \qquad \qquad ........(1.11)$$

If we apply KVL in the loop (moving in the clockwise direction), we have

$$V - V_1 - V_2 = 0 \qquad \qquad .........(1.12)$$

Combining equation (1.11) &(1.12), we get

$$V = V_1 + V_2 = iR_1 + iR_2 = i(R_1 + R_2) \qquad \qquad ..........(1.13)$$

Equation (1.13) can be written as $\qquad V = iR_{eq} \qquad \qquad ..........(1.14)$

Where $R_{eq} = R_1 + R_2$ i.e. the summation of two resistors.

From Eq.(1.13) we get,

$$i = \frac{V}{R_1 + R_2} \qquad \qquad .........(1.15)$$

In general, the equivalent resistance of any number of resistors connected in series is the sum of the individual resistances.

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For N resistors in series then,

$$R_{eq} = R_1 + R_2 + ..... + R_N = \sum_{n=1}^{N} R_n$$

..........(1.16)

## Voltage Division:

To determine the voltage across each resistor in Fig.1.8, we substitute Eq. (1.15) into Eq. (1.11) and obtain

$$V_1 = \frac{V}{R_1 + R_2} R_1, V_2 = \frac{V}{R_1 + R_2} R_2$$

.........(1.17)

Note that the source voltage is divided among the resistors in direct proportion to their resistances; the larger the resistance, the larger the voltage drop. This is called the principle of voltage division.

**Example.1.3**. Find the current I passing through and the voltage across each of the resistors in the circuit.
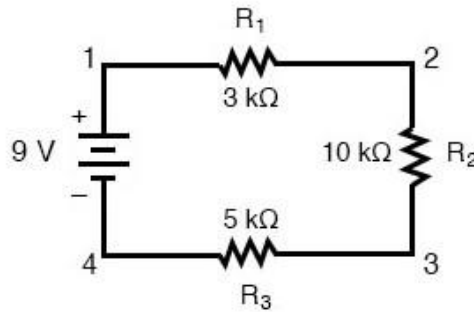


**Solution:** $R_{total} = R_1 + R_2 + R_3 = 3K\Omega + 10K\Omega + 5K\Omega = 18K\Omega$

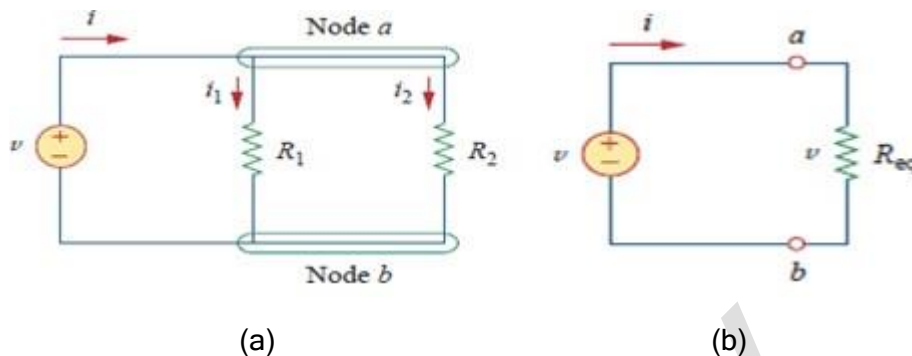$$I = \frac{V}{R_{total}} = \frac{9}{18 \times 10^3} = 0.5 \text{ mA}$$

$$V_{R1} = \frac{VR1}{R_1 + R_2 + R_3} = \frac{9}{18 \times 10^3} \times 3 \times 10^3 = 1.5V$$

$$V_{R2} = \frac{V}{R_1 + R_2 + R_3} R_2 = \frac{9}{18 \times 10^3} \times 10 \times 10^3 = 5V$$

$$V_{R3} = \frac{V}{R_1 + R_2 + R_3} R3 = = 2.5V$$

## RELATION OF V,I &R IN PARALLEL CIRCUIT:-

Two or more resistors are said to be in parallel if the same voltage appears across each element. Consider the circuit in Fig.1.9(a) , where two resistors are connected in parallel and therefore have the same voltage across them.



(a)                                   (b)

(**Fig: 1.9.** (a) Two resistors in parallel (b) Equivalent circuit)

$$v = i_1 R_1 = i_2 R_2 \qquad\qquad \text{..... (1.18)}$$

$$i_1 = \frac{v}{R_1}, \; i_2 = \frac{v}{R_2} \qquad\qquad \text{...... (1.19)}$$

Applying KCL at node a gives the total current i is

$$i = i_1 + i_2 \qquad\qquad \text{.....(1.20)}$$

Substituting Equation 1.19 into 1.20, we get

$$i = \frac{v}{R_1} + \frac{v}{R_2} = v\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{v}{R_{eq}} \qquad\qquad \text{......(1.21)}$$

Where $R_{eq}$ is the equivalent resistance of the resistors in parallel.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \qquad\qquad \text{......(1.22)}$$

Thus, The equivalent Resistance of parallel-connected resistors is the reciprocal of the sum of the reciprocals of the individual resistances.

If a circuit with N resistors in parallel then the equivalent resistance is

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots\ldots + \frac{1}{R_N} = \sum_{n=1}^{N} \frac{1}{R_n} \qquad\qquad \text{.........(1.23)}$$

## DIVISION OF CURRENT IN PARALLEL CIRCUIT:-

We know that the equivalent resistor has the same voltage, or

$$v = iR_{eq} = \frac{iR_1R_2}{R_1 + R_2}$$

......(1.24)

Substituting eq (1.24) into (1.19)

$$i_1 = \frac{iR_2}{R_1 + R_2}$$

$$i_2 = \frac{iR_1}{R_1 + R_2}$$

.......(1.25)

This shows that the total current is shared by the resistors in inverse proportion to their resistances. This is known as the principle of current division, and the circuit is known as a current divider.

**Example.1.4.** Find the current I passing through and the current passing through each of the resistors in the circuit below.
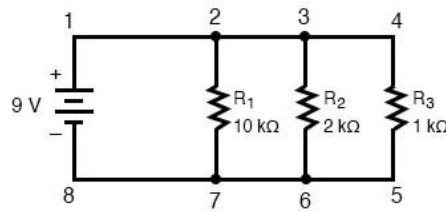


**Solution:**

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{10 \times 10^3} + \frac{1}{2 \times 10^3} + \frac{1}{1 \times 10^3} = 0.0016$$

$$R_{total} = 625\Omega$$

$$I = \frac{V}{R_{total}} = \frac{9}{625} = 0.0144 Amp = 14.4 mA$$

$$I_{R1} = \frac{V}{R_1} = \frac{9}{10 \times 10^3} = 0.9 mA$$

$$I_{R2} = \frac{V}{R_2} = \frac{9}{2 \times 10^3} = 4.5 mA$$

$$I_{R3} = \frac{V}{R_3} = \frac{9}{1 \times 10^3} = 9 mA$$

## POWER IN SERIES & PARALLEL CIRCUIT:-

(a) Series Combinations:- If the electrical appliances of power $P_1$ & $P_2$ are connected in series with main voltage V having resistance $R_1$ & $R_2$, then

$$R_1 = \frac{V^2}{P_1}; R_2 = \frac{V^2}{P_2} \qquad\qquad \left( \because P = \frac{V^2}{R} \right) \quad \text{.....(1.26)}$$

When connected in series, then their effective resistance is $R = R_1 + R_2$

$$\frac{V^2}{P} = \frac{V^2}{P_1} + \frac{V^2}{P_2} \Rightarrow \frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} \qquad \text{......(1.27)}$$

(b) Parallel Combinations:- If the electrical appliances of power P₁& P₂ are connected in parallel with main voltage V having resistance R₁& R₂, then

$$R_1 = \frac{V^2}{P_1}; R_2 = \frac{V^2}{P_2} \qquad\qquad \left( \because P = \frac{V^2}{R} \right) \quad \text{........(1.28)}$$

When connected in parallel, then their effective resistance is

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{P}{V^2} = \frac{P_1}{V^2} + \frac{P_2}{V^2} \Rightarrow P = P_1 + P_2 \qquad \text{...........(1.29)}$$

## KIRCHHOFF'S LAWS:-

The most common and useful set of laws for solving electric circuits are the Kirchhoff"s voltage and current laws. Several other useful relationships can be derived based on these laws. These laws are formally known as Kirchhoff"s current law (KCL) and Kirchhoff"s voltage law (KVL).

## KIRCHHOFF'S CURRENT LAW (KCL)

This is also called as Kirchhoff's first law or Kirchhoff"s nodal law. Kirchhoff"s first law is based on the law of conservation of charge, which requires that the algebraic sum of charges within a system cannot change.
**Statement:** Algebraic sum of the currents meeting at any junction or node is zero. The term „algebraic" means the value of the quantity along with its sign, positive or negative.

Mathematically, KCL implies that

$$\sum_{n=1}^{N} i_n = 0 \qquad \text{........(1.30)}$$

Where N is the number of branches connected to the node and is the nth current entering (or leaving) the node. By this law, currents entering a node may be regarded as positive, while

currents leaving the node may be taken as negative or vice versa.

**Alternate Statement:** Sum of the currents flowing towards a junction is equal to the sum of the currents flowing away from the junction
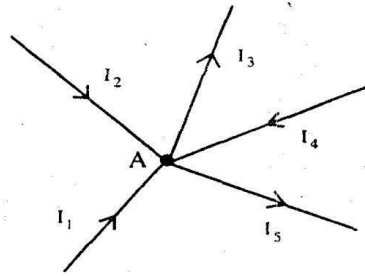


(**Fig.1.10.** Currents meeting in a junction)

Explanation:-

Consider Fig.1.10. where five branches of a circuit are connected together at the junction or node A. Currents $I_1$, $I_2$ and $I_4$ are flowing towards the junction whereas currents $I_3$ and $I_5$ are flowing away from junction A. If a positive sign is assigned to the currents $I_2$ and $I_4$ that are flowing into the junction then the currents $I_3$ and $I_4$ flowing away from the junction should be assigned with the opposite sign i.e. the negative sign.

Applying Kirchhoff"s current law to the junction A

$$I_1 + I_2 - I_3 + I_4 - I_5 = 0 \text{ (algebraic sum is zero)}$$

The above equation can be modified as $I_1 + I_2 + I_4 = I_3 + I_5$ (sum of currents towards the junction = sum of currents flowing away from the junction).


## KIRCHHOFF'S VOLTAGE LAW (KVL):-

This is also called as Kirchhoff's second law or Kirchhoff's loop or mesh law. Kirchhoff"s second law is based on the principle of conservation of energy.

**Statement:** Algebraic sum of all the voltages around a closed path or closed loop at any instant is zero. Algebraic sum of the voltages means the magnitude and direction of the voltages; care should be taken in assigning proper signs or polarities for voltages in different sections of the circuit.
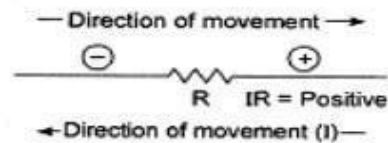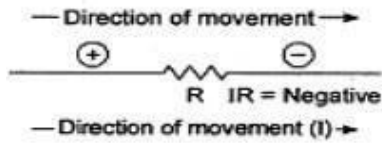
Mathematically, KVL implies that

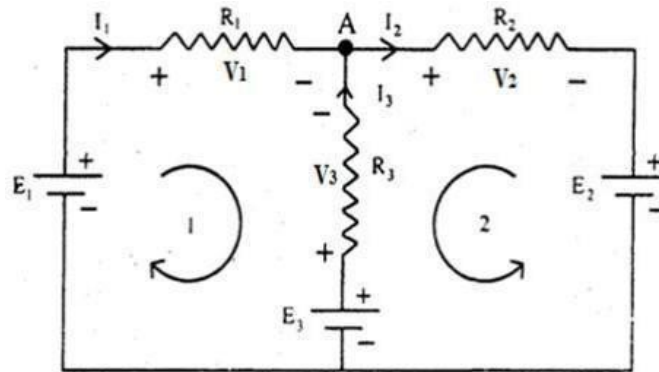$$\sum_{n=1}^{N} V_n = 0$$

...........(1.31)

Where N is the number of voltages in the loop (or the number of branches in the loop) and is the n voltage in a loop.

Sign Rules of KVL : If we give positive sign to all rise in potential then we must give Negative sign for all fall in potential and vice versa.



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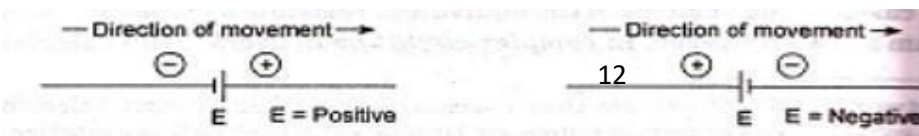
Explanation:-



*The circuit has three active elements with voltages $E_1$, $E_2$ and $E_3$. The polarity of each* of them is fixed. $R_1$, $R_2$, $R_3$ are three passive elements present in the circuit. Currents $I_1$ and $I_3$ are marked flowing into the junction A and current $I_2$ marked away from the junction A with known information or assumed directions. With reference to the direction of these currents, the polarity of voltage drops $V_1$, $V_2$ and $V_3$ are marked.

*For loop1 it is considered around clockwise*

$+ E_1 - V_1 + V_3 - E_3 = 0$

$+ E_1 - I_1 R_1 + I_3 R_3 - E_3 = 0$

$E_1 - E_3 = I_1 R_1 - I_3 R_3$

*For loop2 it is considered anticlockwise*

$+ E_2 + V_2 + V_3 - E_3 = 0$

$+ E_2 + I_2 R_2 + I_3 R_3 - E_3 = 0$

$E_2 - E_3 = - I_2 R_2 - I_3 R_3$

*Two equations are obtained following Kirchhoff's voltage law. The third equation can be* written based on Kirchhoff"s current law as

$I_1 - I_2 + I_3 = 0$

*With the three equations, one can solve for the three currents $I_1$, $I_2$, and $I_3$.*

*If the results obtained for $I_1$, $I_2$, and $I_3$ are all positive, then the assumed direction of the* currents are said to be along the actual directions. A negative result for one or more currents will indicate that the assumed direction of the respective current is opposite to the actual direction.

**Example.1.5**. Calculate the current supplied by two batteries in the circuit given below
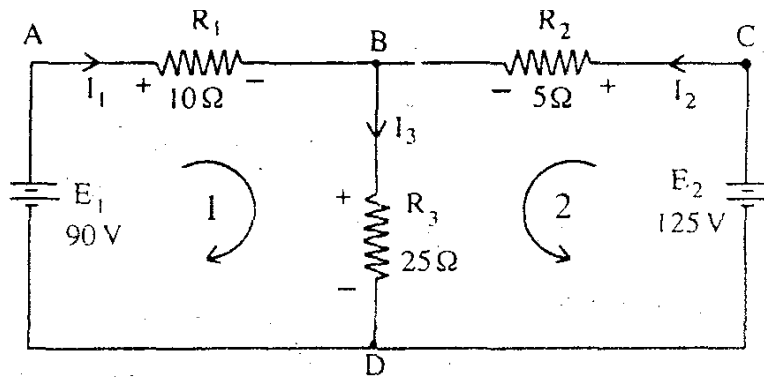
### Solution:

The four junctions are marked as A, B, C and D. The current through $R_1$ is assumed to flow from A to B and through $R_2$, from C to B and finally through $R_3$ from B to D. With reference to current directions, polarities of the voltage drop in $R_1$, $R_2$ and $R_3$ are then marked as shown in the figure. Applying KCL to junction B

$$I_3 = I_1 + I_2 \dots (1)$$

Applying KVL to loop 1

$$E_1 - I_1 R_1 - I_3 R_3 = 0 \Rightarrow E_1 = I_1 R_1 + I_3 R_3$$
$$\Rightarrow 90 = 10 I_1 + 25 I_3 \qquad \dots (2)$$

Substituting Eq. (1) in Eq. (2)

$$90 = 10 I_1 + 25 (I_1 + I_2) \Rightarrow 90 = 35 I_1 + 25 I_2 \qquad \text{--------(3)}$$

Applying KVL to loop 2

$$E_2 - I_2 R_2 - I_3 R_3 = 0 \Rightarrow E_2 = I_2 R_2 + I_3 R_3$$
$$\Rightarrow 125 = 5 I_2 + 25 I_3 \qquad \dots (4)$$

Substituting Eq. (1) in Eq. (4)

$$125 = 5 I_2 + 25 (I_1 + I_2)$$
$$\Rightarrow 125 = 25 I_1 + 30 I_2 \qquad \dots (5)$$

After solving Eq. (3) & (5) we get

$$I_1 = -1 A$$

$$I_2 = 5 A$$

As the sign of the current $I_1$ is found to be negative from the solution, the actual direction of $I_1$ is from B to A to D i.e. 90 V battery gets a charging current of 1 A.

## QUESTIONS FOR PRACTICE

### Short Answer Questions

1. Define electric current.
2. State and explain Ohm's Law.
3. Define One Ohm.
4. What is meant by source in electricity?
5. State and explain Kirchoff's Voltage Law.

6.  State and explain Kirchoff's Current Law.
7.  Derive the expression of resistance in (i) series circuit (ii) Parallel circuit

## Long Answer Questions

1. A 10v battery is connected to parallel combination of two resistors $10\Omega$ and $5\Omega$. Calculate the current through in each resistor and power consumed by them.

2. The resistance of two wires is $15\Omega$ when connected in series and $7\Omega$ when connected in parallel, find the resistances of each one.
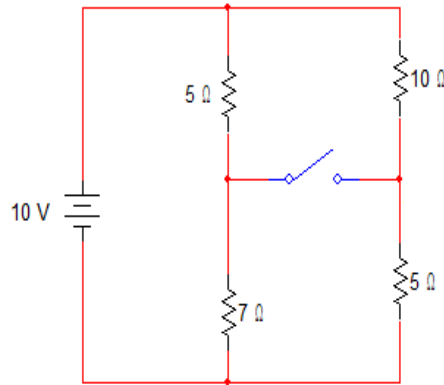


3. A resistance R is connected in series with a parallel circuit comprising of resistances of $4\Omega$ and $6\Omega$ respectively. When the applied voltage is 15V, the power dissipated in $4\Omega$ resistor is 36W, Calculate R.

4. Determine the electric current that flows in the circuit as shown in the figure below.
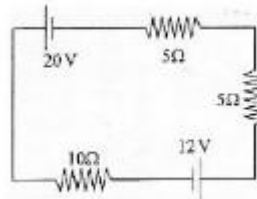


5. Determine the equivalent resistance and electric current that flows in circuit as shown in figure below.
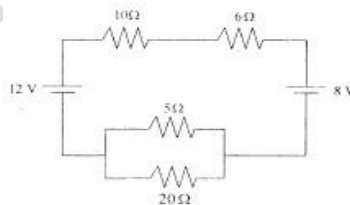
# CHAPTER- 2

## A.C. THEORY

An electrical quantity is said to be "alternating" if it changes in magnitude & direction continuously with time. The term AC is nothing but the alternating current & the circuit that carries the AC is called as AC circuit. This alternating quantity may be periodic and non-periodic. Periodic quantity is one whose value will be repeated for every specified interval. Generally to represent alternating voltage or current we prefer sinusoidal wave form

## GENERATION OF ALTERNATING EMF:-

AC generator generates A.C. voltage based on the faraday"s law of electromagnetic induction.
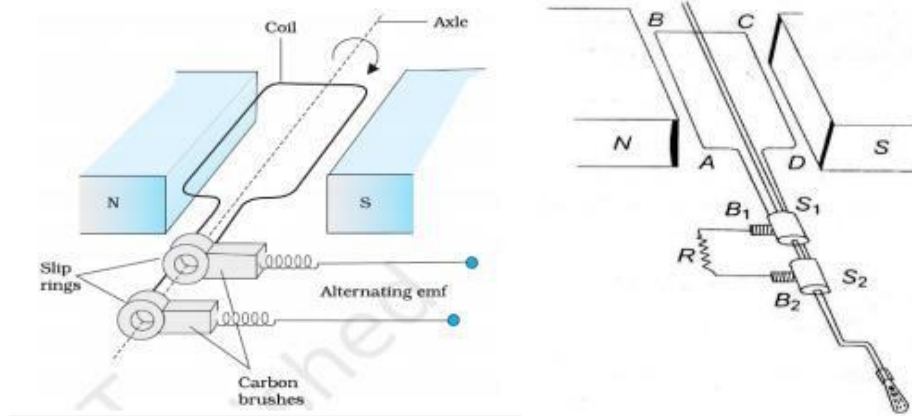
(**Fig.2.1.** Schematic Diagram of AC generator)

- The armature coil is rotated as shown in the fig.2.1, about an axis perpendicular to the magnetic field lines. As the angle between the area vector of the coil and the magnetic field changes, the magnetic flux linked with the coil changes and an e.m.f. is induced in the coil.

(a)    (b)
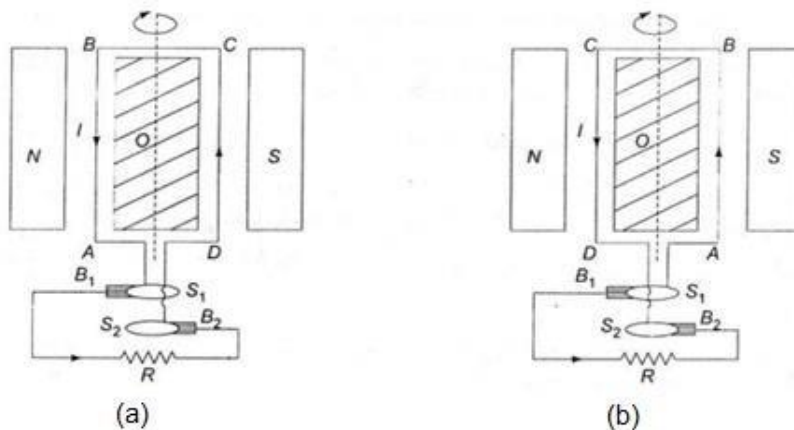
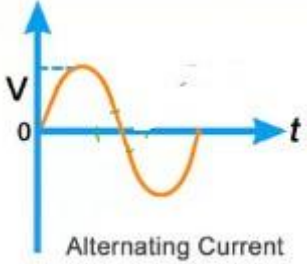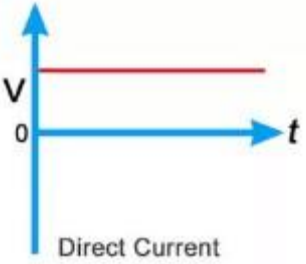(**Fig.2.2.** Rotation of armature in AC generator)

- When the plane of the coil is parallel to the plane of the paper, the flux linked with the coil is zero. As the coil is rotated as shown in fig. 2.2(a), AB moves in and CD moves out of the screen, causing current I to be induced in the coil in the direction DCBAD, through the resistance R in the external circuit as shown.
- After half a rotation of the coil. AB moves out and CD moves into the plane of the screen, causing current I to be induced in the coil in the direction ABCDA, through resistance R in the external circuit in the opposite direction as in fig.2.2 (b).
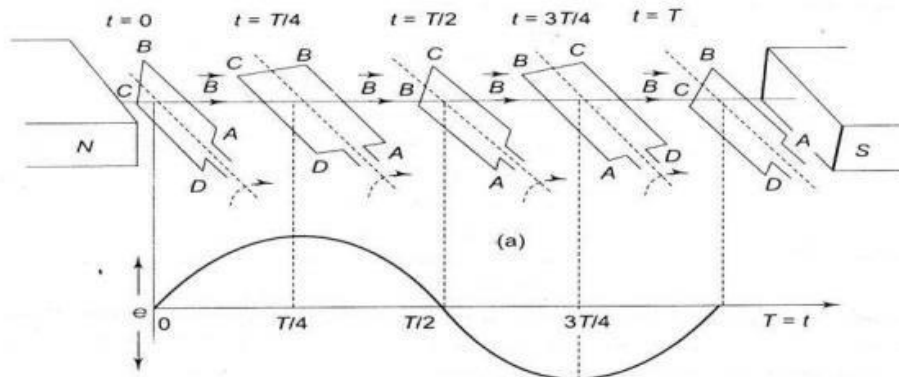


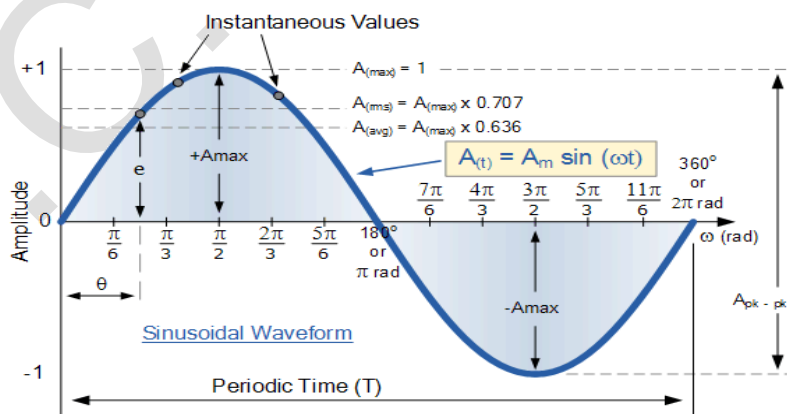(**Fig.2.3.** Rotation of armature in different instant of time & induced emf in AC generator)

- In five different position of the armature coil ABCD at time t = 0, T/4, T/2, 3T/4 t =T, the induced emf will change w.r.t time.
- The coil is rotated in uniform magnetic field B with constant angular velocity ω .*where m* = $2\pi T$ . T is the periodic time or time for one complete rotation of the coil.
- The change in direction of induced current due to induced emf. The graph of emf vs time shows the variation in voltage as a consequence of rotation of the coil.
- When we get maximum emf and when its value becomes zero. For one complete rotation there are two instants when emf is max at T/4 and at 3T/4. The same would be repeated for the next rotation.

## DIFFERENCE BETWEEN AC & DC:-

| AC | DC |
|---|---|
|  <br> Alternating Current |  <br> Direct Current |
| 1. The current which change its | 1. The current which does not change its |

| | |
|---|---|
| magnitude & direction periodically (or at regular interval) is called alternating current. | magnitude & direction periodically is called alternating current. i.e the direction of current remains same. |
| 2. The direction of flow of electron is bidirectional | 2. The direction of flow of electron is unidirectional |
| 3. It has frequency, like Indian standard frequency is 50Hz. | 3. It has zero frequency. |
| 4. It"s power factor lies between 0 & 1. | 4. It"s power factor is always 1 |
| 5. It"s passive parameter is impedance Combination of Reactance and Resistance. | 5. It"s passive parameter is resistance. |
| 6. AC generate from AC generator. | 6. DC generate from DC generator, battery, solar cell etc. |
| 7. It is represented by sine wave, square wave, triangular wave etc. | 7. It is represented by straight line i.e it may be 2 types Pure DC and Pulsating DC |
| 8. Can be transmitted over long distance with some losses. | 8. It can be transmitted over very long distance with negligible losses. |
| 9. Their load is resistive, inductive or capacitive. | 9. Their load is usually resistive in nature. |
| 10. Dangerous | 10. Very Dangerous |
| 11. Easily convert into direct current by rectifier. | 11. Easily convert into alternating current by inverter. |
| 12. Application- Factories, Industries and for the domestic purposes. | 12. Application- Electroplating, Electrolysis, Electronic Equipment etc. |

## DEFINITIONS RELATED TO AN ALTERNATING VOLTAGE OR CURRENT: -



(**Fig.2.4.** An alternating sin wave)

**1) Periodic waveform**
If the same set of variations is repeated indefinitely after a certain interval of time then the waveform is known as periodic waveform.

### 2) Peak Amplitude
It is the maximum value reached by the alternating quantity in a cycle either in positive or negative half cycle. It. is also known as crest value. It is denoted by $A_m$

### 3) Cycle
The interval of time during which a complete set of non-repeating waveform variation occurs is called cycle. It may be positive or negative cycle.

### 4) Frequency
It is defined as the number of cycles completed by an alternating quantity in one second. Its SI unit is Hertz (Hz). 1 Hz = 1 cycle/second

### 5) Angular frequency

It is the angular distance (angle) covered by alternating quantity in one second. It is also known as angular velocity. $\omega = 2\pi f$

### 6) Time Period
It is defined as the time required for an alternating quantity to complete one cycle. It is denoted by T.

### 7) Phase
Phase of an alternating quantity is the angular displacement of the phasor representing that alternating quantity up to the instance of consideration measured from a mean or reference value.
In other word it is the angular measurement of alternating quantity which specifies the position of wave. Phase of the sine indicates staring phase of the sine wave.
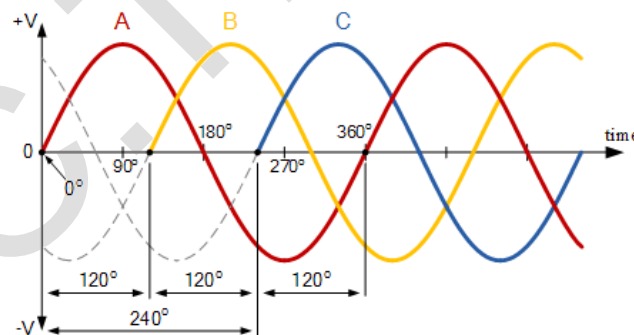


(**Fig.2.5.** Phasor Representation of Alternating emf)

In the above figure,**A** waveform being a reference wave at Ø = 0°,**B** waveform being 120° time delayed or lag behind A,**C** waveform being 120° time advanced or lead behind A.

### 8) Phase difference

The difference between the phases of the two alternating quantities is called as phase difference.

Let, V(t) = Vm sin wt, here we can say that phase is zero as function starts from origin.

V(t)= Vm sin(wt-θ), here we can say that phase of function is θ degrees to right shift.

V(t)= Vm sin(wt+θ), here we can say that phase of the function is θ degrees to the left shift.

In the above fig the phase difference between A &B is120°.

## DIFFERENT TYPES OF VALUES OF ALTERNATING VOLTAGE & CURRENT:-

1. **Instantaneous Value:-**

   It is defined as the value of alternating quantity at any instant of time. It is represented by i(t) or v(t).

   Ex: v(t)= $V_m$sin($\omega t$ +Θ)

2. **Average value:-**
   For an alternating current, the average value is defined as that value of DC current which transfers across any circuit the same charge as is transferred by the alternating current during the same time under the same conditions. It is represented by $V_{avg}$ or $I_{avg}$.
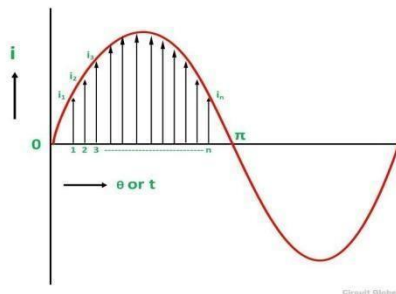   - There are two methods to calculate average value
     i. **Mid ordinate method/ graphical method**
        The average value is defined as the arithmetic average or mean value of all the values of an alternating quantity over one cycle
        Let $i_1$, $i_2$, $i_3$..........$i_n$ be the mid ordinates
        The Average value of current $I_{av}$ = mean of the mid ordinates



(**Fig.2.6.** Average Value of a positive half-cycle)

$$I_{av} = \frac{i_1 + i_2 + i_3 + .....+ i_n}{n} = \frac{Area of alternation}{Base}$$

If we consider symmetrical waves like sinusoidal current or voltage waveform, the positive half cycle will be exactly equal to the negative half cycle. Therefore, the average value over a complete cycle will be **zero**.

So the average value is taken for only the positive half cycle.

     ii. **Analytical method**

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Consider a sinusoidal waveform, the average value of alternating current is

$$I_{avg} = \frac{Area\ under\ the\ half\ cycle}{Length\ of\ base\ of\ half\ cycle}$$

$$Iavg = \frac{\int_0^\pi i\, d\theta}{\pi}$$

$$Iavg = \frac{\int_0^\pi I_m\ Sin\theta\, d\theta}{\pi}$$

$$Iavg = \frac{Im}{\pi} \int_0^\pi \sin\theta\, d\theta$$

$$Iavg = \frac{Im}{\pi} [-cos\ \theta]_0^\pi$$

$$Iavg = \frac{2Im}{\pi}$$

**Hence average value of current = 0.637× maximum value of current (for half cycle)**

### 3. RMS value (root-mean-square)/ effective value:-

The RMS value of an alternating current is given by that value of DC current which when flowing through a given circuit for a given time, produces the same amount of heat as produced by the alternating current, which when flowing through the same circuit for the same time.

 In other words, the R.M.S value is defined as the square root of means of squares of instantaneous values. It is represented by $V_{rms}$ or $I_{rms}$.

There are two methods calculate RMS value.

#### i. Mid ordinate method/ graphical method

Let I be the alternating current flowing through a resistor R for time t seconds, which produces the same amount of heat as produced by the direct current ($I_{eff}$). The base of one alteration is divided into n equal parts so that each interval is of t/n seconds as shown in the figure below

Let i₁, i₂, i₃, ...............iₙ be the mid ordinates. Then the heat produced in

First interval = $\frac{i_1^2 Rt}{Jn}$ calories

$$\text{Second interval} = \frac{i_2^2 Rt}{Jn} \text{ calories}$$

$$n^{th} \text{ interval} = \frac{i_n^2 Rt}{Jn} \text{ calories}$$

$$\text{Total Heat produced} = \frac{Rt}{J}\left(\frac{i_1^2 + i_2^2 + \dots + i_n^2}{n}\right) calories \dots \dots (2.1)$$

Since $I_{eff}$ is considered as the effective value of this current, then the total heat produced by this current will be

$$\frac{I_{eff}^2 Rt}{J} calories \dots \dots (2.2)$$

Now, equating equation (2.1) and (2.2) we will get

$$\frac{I_{eff}^2 Rt}{J} = \frac{Rt}{J}\left(\frac{i_1^2 + i_2^2 + \dots + i_n^2}{n}\right)$$

$$I_{eff} = \sqrt{\frac{i_1^2 + i_2^2 + \dots + i_n^2}{n}}$$

## ii. Analytical method

RMS value of sinusoidal current $i = i_m \sin \omega t$

$$i_{rms} = \sqrt{\frac{1}{2\Pi}\int_0^{2\Pi} i^2 \, d(\omega t)}$$

$$i_{rms} = \sqrt{\frac{1}{2\Pi}\int_0^{2\Pi} i_m^2 \sin^2 \omega t \, d(\omega t)}$$

$$i_{rms} = \frac{I_m}{\sqrt{2}} = 0.707 I_m$$

## 4. Form Factor

The form factor is the ratio of RMS value of an alternating quantity to the average value of the same quantity

$$form\ factor = \frac{RMS\ Value}{Average\ Value} = \frac{0.707 \times maximum\ Value}{0.637 \times maximum\ Value} = 1.11$$

F.F=1.11 for sinusoidal alternating quantity only

## 5. Peak factor/ crest/ amplitude factor

Hence RMS value of current =0.707×maximum value of current

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Peak factor or crest factor of an alternating quantity is the ratio of maximum value (peak value) to RMS value

$$\text{Peak factor} = \frac{maximum\,Value}{RMS\,Value} = \frac{maximum\,Value}{0.707 \times maximum\,Value} = 1.414$$

**Example 2.1:-** Write down the equation for a sinusoidal voltage of 50 Hz and its peak value is 20 V. Draw the corresponding voltage versus time graph.
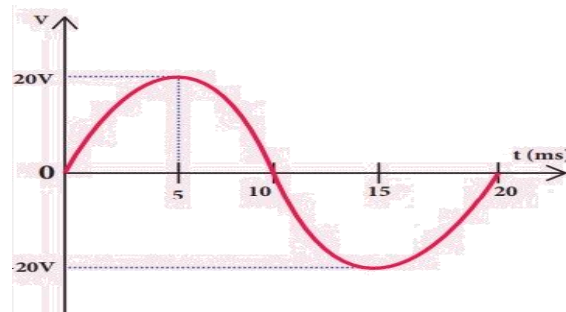
**Solution**

$$f = 50Hz \quad ; \quad V_m = 20V$$

Instantaneous Voltage =

$$
\begin{aligned}
v &= V_m \sin \omega t \\
&= V_m \sin 2\prod ft \\
&= 20 \sin(2\prod \times 50)t \\
&= 20 \sin(2 \times 3.141 \times 50)t \\
&= 20 \sin 314t
\end{aligned}
$$

Time for one cycle = $T = \dfrac{1}{f} = \dfrac{1}{50} = 0.02\text{sec}$

The waveform is:



**Example 2.2:-**

The equation for an alternating current is given by $i = 77 \sin 314t$. Find the peak value, frequency, time period and instantaneous value at t = 2 ms.

**Solution**

i = 77 sin 314t ; t = 2 ms = 2×10$^{-3}$ s
The general equation of an alternating current is i = I$_m$ sin ωt . On comparison,
(i) Peak value, I$_m$ = 77 A
(ii) Frequency, $f$ = ω/2π = 314 / 2 ×3.14 = 50 Hz

Time period, T = 1/$f$ = 150 = 0 .02 $s$
(iv) At t = 2 m s,
Instantaneous value,
$i$ = 77 sin(314×2×10⁻³ )
 i = 45.24 A

## **REPRESENT AC VALUES IN PHASOR DIAGRAMS:-**

An alternating quantity can be represented using
i) Waveform
ii) Equations
iii) Phasor

A sinusoidal alternating quantity can be represented by a rotating line called a **Phasor.** A phasor is a line of definite length rotating in anticlockwise direction at a constant angular velocity

The waveform and equation representation of an alternating current is as shown. This Sinusoidal quantity can also be represented using phasors.



$$i = I_m \sin \omega t$$
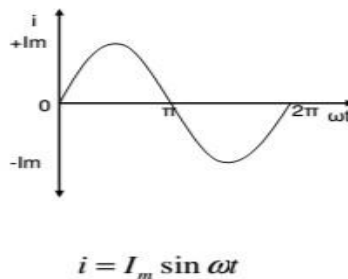
(**Fig.2.7.** Waveform of alternating quantity)

In phasor form the above wave  is written as $\overline{I} = I_m \angle 0°$

Draw a line OP of length equal to I$_m$. This line OP rotates in the anticlockwise direction with a uniform angular velocity ω rad/sec and follows the circular trajectory shown in figure. At any instant, the projection of OP on the y-axis is given by OM=OPsinθ = I$_m$sinωt. Hence the line OP is the phasor representation of the sinusoidal current.
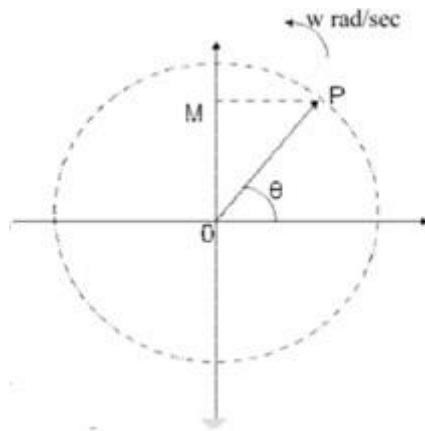
(**Fig.2.8.** Phasor representation of alternating wave)

## AC THROUGH PURE RESISTANCE, INDUCTANCE & CAPACITANCE:-

### AC Circuit with A Pure Resistance
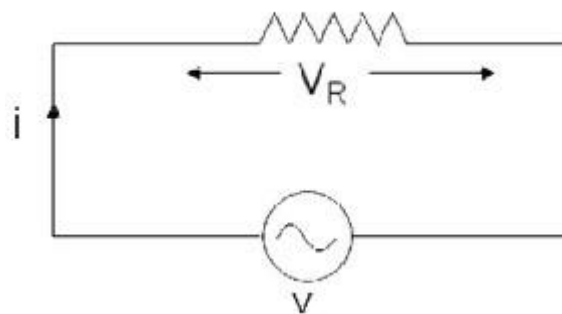


(**Fig.2.9.** AC circuit with a pure resistance R)

Consider an AC circuit with a pure resistance R as shown in the figure 2.9.
The alternating voltage v is given by

$$v = Vm \sin(\omega t) \qquad \text{..........(2.3)}$$

The current flowing in the circuit is i. The voltage across the resistor is given as $V_R$ which is the same as v.
Using ohm's law, we can write the following relations

$$i = \frac{v}{R} = \frac{Vm \sin(\omega t)}{R}$$
$$i = Im \sin(\omega t)$$

Where, $\qquad\qquad\qquad\qquad\qquad\qquad Im = \frac{Vm}{R} \qquad \text{.......(2.4)}$

From equation (2.3) and (2.4) we conclude that in a pure resistive circuit, the voltage and current are in phase. Hence the voltage and current waveforms and phasors can be drawn as below.

25
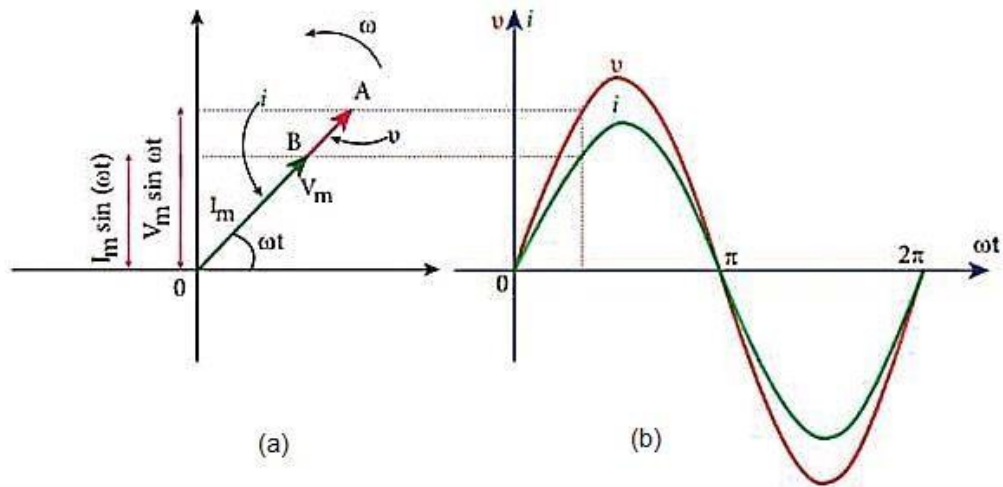
**(Fig.2.10**.(a) Phasor representation of voltage and current in pure resistive circuit (b) Wave representation of voltage and current in pure resistive circuit)

**AC Circuit with A Pure Inductance**
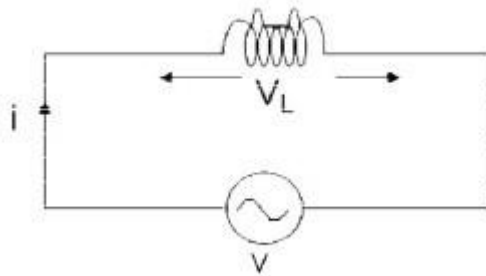


**(Fig.2.11.** AC circuit containing pure inductor)

Consider an AC circuit with a pure inductance L as shown in the figure 2.11. The alternating voltage V is given by

$$v = V_m \sin (\omega t) ....(2.5)$$

The current flowing in the circuit is i. The voltage across the inductor is given as $V_L$ which is the same as v.

The voltage $v = L \dfrac{di}{dt}$

$$V_m \sin (\omega t) = L \frac{di}{dt}$$

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$$\Rightarrow di = \frac{V_m}{L}\sin \omega t$$
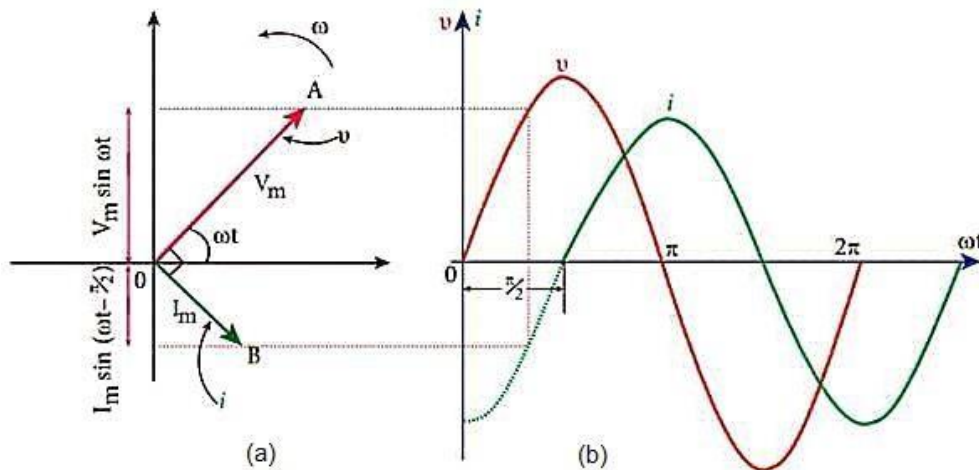
$$\Rightarrow i = \frac{V_m}{L}\int \sin(\omega t)dt$$

$$\Rightarrow i = \frac{V_m}{\omega L}(-)\cos(\omega t)$$

$$\Rightarrow i = \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\Pi}{2}\right)$$

$$\Rightarrow i = I_m \sin\left(\omega t - \frac{\Pi}{2}\right)$$

Where $I_m = \dfrac{V_m}{\omega L}$ .................... (2.6)

From equation (2.5) and (2.6) we observe that in a pure inductive circuit, the current lags behind the voltage by 90°. Hence the voltage and current waveforms and phasors can be drawn as below.
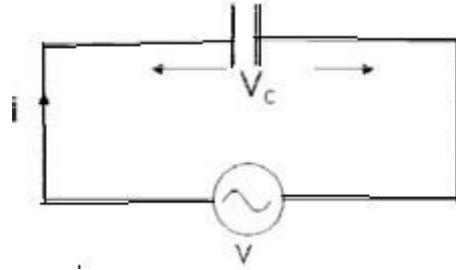


**(Fig.2.12.(**a) Phasor representation of voltage and current in pure inductive circuit (b) Wave representation of voltage and current in pure inductive circuit)

Inductive reactance:-

The inductive reactance $X_L$ is given as $X_L = 2\pi fL$
It is equivalent to resistance in a resistive circuit. The unit is ohms (Ω).

**AC Circuit with A Pure Capacitance**

**(Fig.2.13.** AC circuit containing pure inductor)

Consider an AC circuit with a pure capacitance C as shown in the figure 2.13. The alternating voltage v is given by

$$v = V_m \, sin\,(\omega t).......(2.7)$$

The current flowing in the circuit is i. The voltage across the capacitor is given as $V_C$ which is the same as V .

Current through the capacitor is $v = \dfrac{1}{c}\int i dt$

$$i = c\frac{dv}{dt}$$

$$= c\frac{d(V_m Sin\omega t)}{dt}$$

$$= cV_m(\omega Cos\omega t)$$

$$= \omega C V_m Cos\omega t$$

$$= \omega C V_m Sin(\omega t + \frac{\Pi}{2})$$

$$= i_m Sin(\omega t + \frac{\Pi}{2})......(2.8)$$

Where $i_m = \omega C V_m = X_c V_m$

From equation (2.7) and (2.8) we observe that in a pure capacitive circuit, the current leads the voltage by 90°. Hence the voltage and current waveforms and phasors can be drawn as below.

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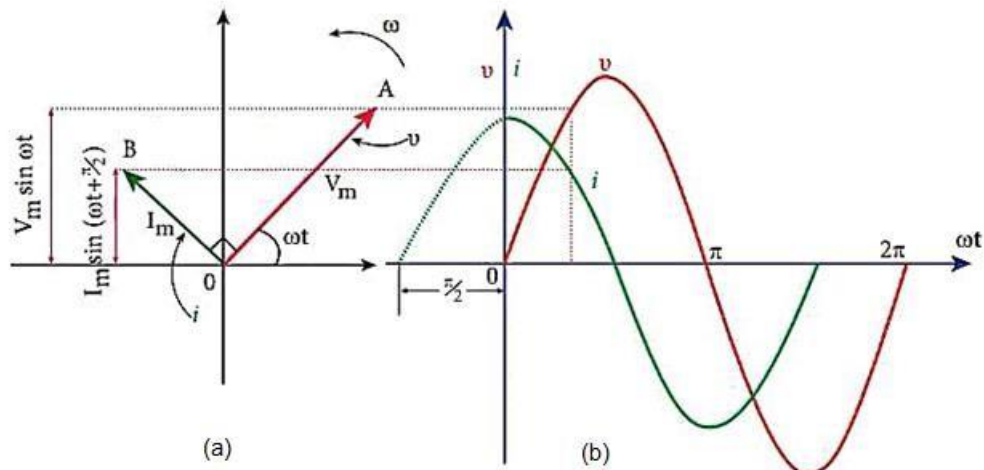
**(Fig.2.14.(**a) Phasor representation of voltage and current in pure capacitive circuit (b) Wave representation of voltage and current in pure capacitive circuit)

Capacitive reactance:-

The capacitive reactance $X_c$ is given as

$$X_c = \frac{1}{2\pi f C}$$

$$Im = \frac{V_m}{X_c}$$

It is equivalent to resistance in a resistive circuit. The unit is ohms (Ω)

## AC THROUGH RL, RC, RLC SERIES CIRCUITS

In actual practice, AC circuits contain two or more than two components connected in series. In a series circuit, each component carries the same current. An AC series circuit may be classified as under:
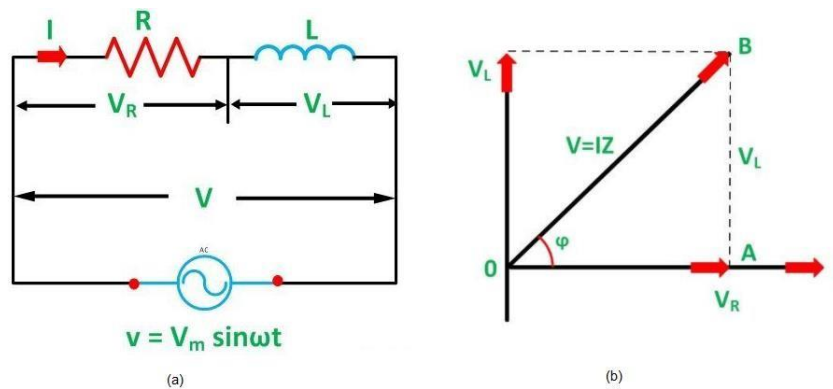
- R-L series circuit
- R-C series circuit
- R-L-C series circuit

## RL Series Circuit

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**(Fig.2.15.(**a) Circuit diagram of RL series circuit (b) Phasor diagram of RL series circuit)

In right angle triangle OAB        $V_R = IR$,        $V_L = IX_L$

So supply voltage $V = \sqrt{(IR)^2 + (IX_L)^2}$

$$= I\sqrt{(R)^2 + (X_L)^2}$$

$$= IZ \quad .....(2.9)$$

Where Z = Impedance = $\sqrt{(R)^2 + (X_L)^2}$

So $I = \dfrac{V}{Z}$

Where Z in ohm($\Omega$).

Phase angle: - In RL Series circuit the current lags the voltage by 90 degrees angle known as phase angle. It is given by the equation:

$$\tan\phi = \frac{V_L}{V_R} = \frac{IX_L}{IR} = \frac{X_L}{R}$$

$$\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$$

Voltage drop $V_R$ is in phase with current vector, whereas, the voltage drop in inductive reactance $V_L$ leads the current vector by 90° since current lags behind the voltage by 90° in the purely inductive circuit. The vector sum of these two voltage drops is equal to the applied voltage V (RMS value).

The power waveform for RL series circuit is shown in the figure. In this figure, voltage wave is considered as a reference. The points for the power waveform are obtained from the product of the corresponding instantaneous values of voltage and current.

It is clear from the power waveform that power is negative between 0 and φ and between 180° and (180° + φ). The power is positive during rest of the cycle. Since the area under the positive loops is greater than that under the negative loops, the net power over a complete cycle is positive. Hence a definite quantity of power is consumed by the RL series circuit. But power is consumed in resistance only; inductance does not consume any power.

(**Fig.2.16.** waveform representation of R-L circuit)

## RC Series Circuit



(a)

(b)
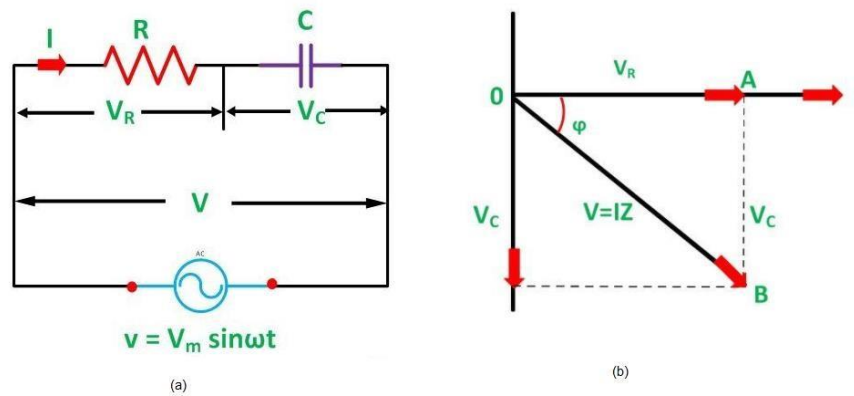
**(Fig.2.17.(**a) Circuit diagram of RC series circuit (b) Phasor diagram of RC series circuit)

In right angle triangle OAB    $V_R = IR$,    $V_C = IX_C$

So supply voltage V = $\sqrt{(IR)^2 + (IX_C)^2}$

$= I\sqrt{(R)^2 + (X_C)^2}$

$= IZ$ .....(2.10)

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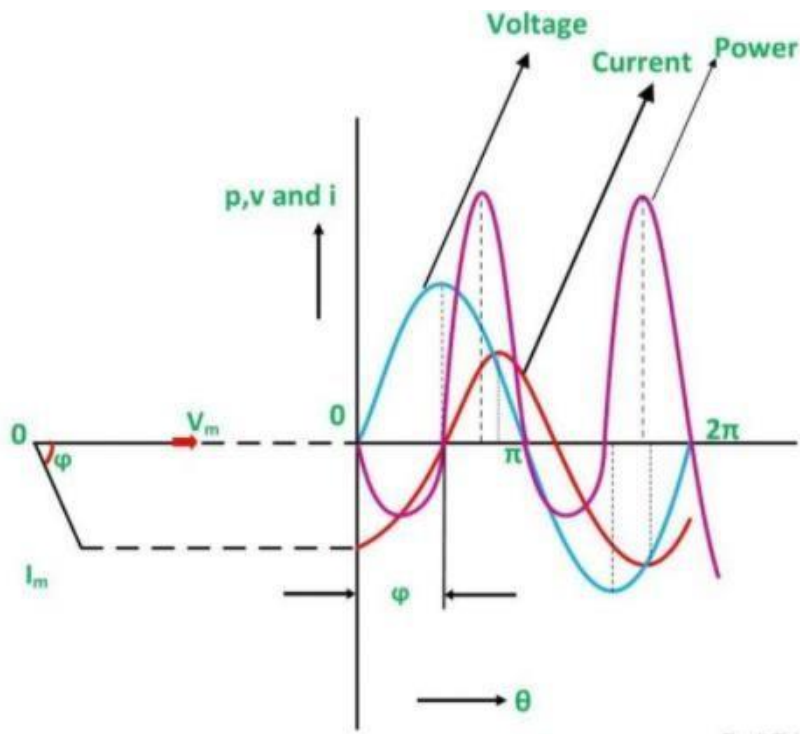Where Z = Impedance = $\sqrt{(R)^2 + (X_C)^2}$

So $I = \dfrac{V}{Z}$

Phase angle: - In RC Series circuit the current leads the voltage by 90 degrees angle known as phase angle. It is given by the equation:

$$\tan\phi = \frac{V_C}{V_R} = \frac{IX_C}{IR} = \frac{X_C}{R}$$

$$\phi = \tan^{-1}\left(\frac{X_C}{R}\right)$$

Voltage drop $V_R$ is in phase with current vector, whereas, the voltage drop in capacitive reactance $V_C$ lags behind the current vector by 90°, since current leads the voltage by 90° in the pure capacitive circuit. The vector sum of these two voltage drops is equal to the applied voltage V (RMS value).
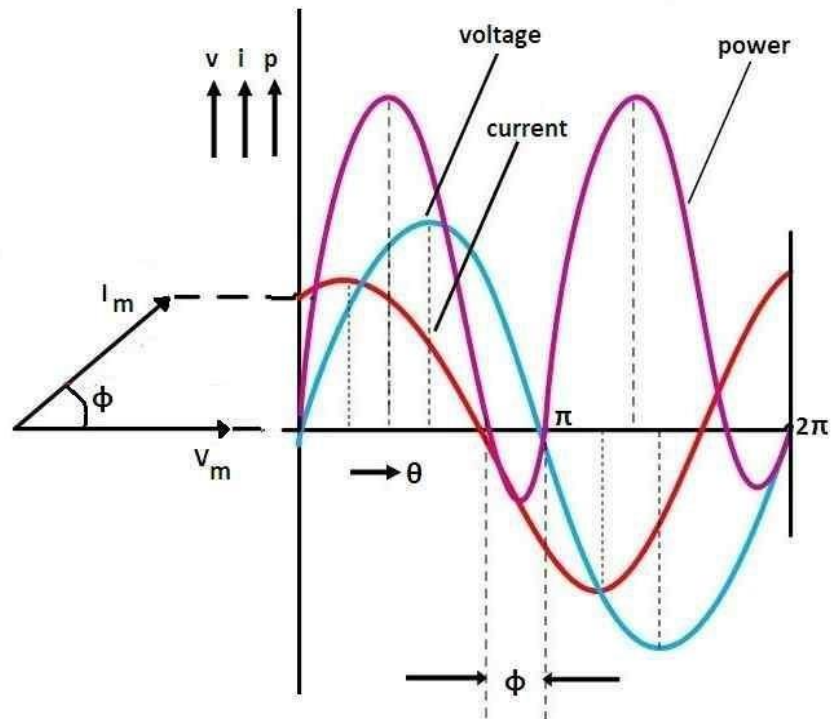


(**Fig.2.18.** Waveform representation of R-C circuit)

The power waveform for RC series circuit is shown in the figure. In this figure, voltage wave is considered as a reference. The points for the power waveform are obtained from the product of the corresponding instantaneous values of voltage and current. It is clear from the power waveform that power is negative between (180° – φ) and 180° and between (360° – φ) and 360°. The power is positive during rest of the cycle.

Since the area under the positive loops is greater than that under the negative loops, the net power over a complete cycle is positive. Hence a definite quantity of power is consumed by the

RC series circuit. But power is consumed in resistance only; capacitor does not consume any power.

**RLC Series Circuit**
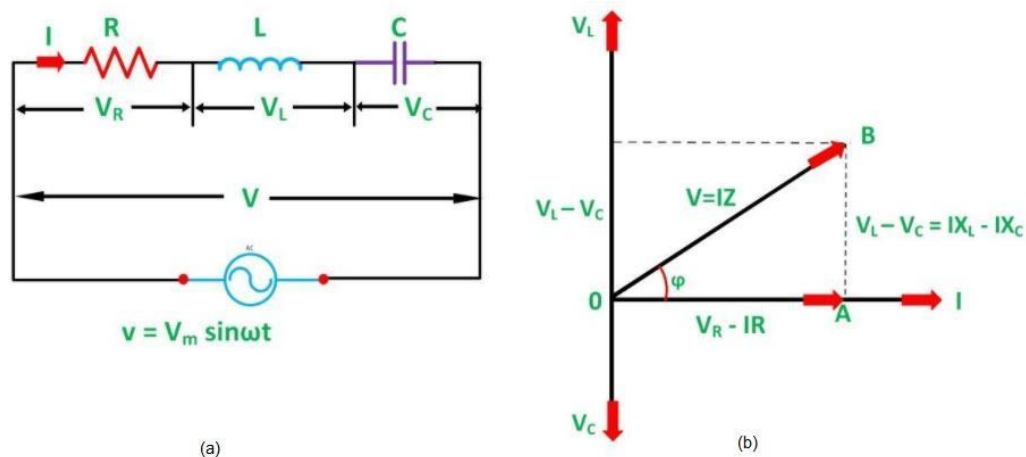


**(Fig.2.19.(**a) Circuit diagram of RLC series circuit (b) Phasor diagram of RLC series circuit)

In right angle triangle OAB $\qquad$ $V_R = IR,$ $\qquad$ $V_L - V_C = IX_L - IX_C$

So supply voltage $V = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$

$$= I\sqrt{(R)^2 + (X_L - X_C)^2}$$

$$= IZ \quad \text{.....(2.11)}$$

Where Z = Impedance = $\sqrt{(R)^2 + (X_L - X_C)^2}$

So $I = \dfrac{V}{Z}$

Phase angle: -

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{IX_L - IX_c}{IR} = \frac{X_L - X_C}{R}$$
$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

The voltage drop $V_L$ is in phase opposition to $V_C$. It shows that the circuit can either be effectively inductive or capacitive. There can be three cases of RLC series circuit.

- When $X_L > X_C$, the phase angle φ is positive. In this case, RLC series circuit behaves as an RL series circuit. The circuit current lags behind the applied voltage and power factor is lagging. In this case, if the applied voltage is represented by the equation; v=$V_m$ Sinωt
  then, the circuit current will be represented by the equation; i = $I_m$ Sin (ωt - φ).

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- When $X_L < X_C$, the phase angle φ is negative. In this case, the RLC series circuit behaves as an RC series circuit. The circuit current leads the applied voltage and power factor is leading. In this case, the circuit current will be represented by the equation: $i = I_m \sin(\omega t + \varphi)$.

- When $X_L = X_C$, the phase angle φ is zero. In this case, the RLC series circuit behaves like a purely resistive circuit. The circuit current is in phase with the applied voltage and power factor is unity. In this case, the circuit current will be represented by the equation: $i = I_m \sin(\omega t)$.

## CONCEPT OF POWER AND POWER FACTOR:-

An understanding of load characteristics in electrical power systems involves the concept of power and power factor. The power consumed by a load will be comprised of several individual power components. These components are apparent power, reactive power, and active or real power. Power factor (PF) is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA).It is also defined as cosφ and φ is the angle between voltage and current.

### Power Components

1. Apparent power (S) :- It is the product of voltage and current only.

   **S=VI**        - unit is volt ampere (VA or KVA)

2. Active Power (P or W) :- It is the power which is actually dissipated in the circuit resistance

   **P= VI Cos φ   or   I $^2$R** -Unit is watts or kw

3. Reactive power (Q) :-It is the power developed in the inductive reactance of the circuit
   **Q= VI Sin φ  or I$^2$X -** Unit is VAR or KVAR

## IMPEDANCE TRIANGLE AND POWER TRIANGLE:-

### Power triangle:-

$$(\text{Apparent Power})^2 = (\text{active power})^2 + (\text{Reactive power})^2$$

$$S^2 = P^2 + Q^2$$
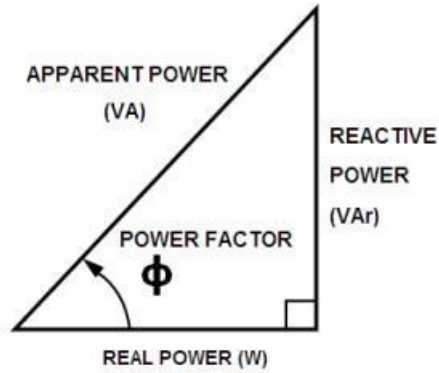
(**Fig.2.20.**Power Triangle)

$VA = \sqrt{W^2 + VAR^2}$;

$W = VA \cos \emptyset$ ; and

$VAR = VA \sin \emptyset$

### (i) R-L Series Circuit
Active Power P= VI Cos $\varphi$ = $I^2R$
Reactive Power Q= VI Sin $\varphi$ = $I^2X_L$
Apparent Power S=VI = $I^2Z$

### (ii) R-C Series Circuit
Active Power P= VI Cos $\varphi$ = $I^2R$
Reactive Power Q= VI Sin $\varphi$ = $I^2X_C$
Apparent Power S=VI = $I^2Z$

### (iii) R-L-C Series Circuit
Active Power P= VI Cos $\varphi$ = $I^2R$
Reactive Power Q= VI Sin $\varphi$ = $I^2(X_L-X_c)$
Apparent Power S=VI = $I^2Z$

## Impedance triangle

### (i) Impedance triangle R-L circuit
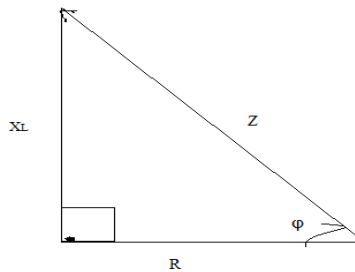


(**Fig.2.21.**Impedance Triangle of RL Series Circuit)

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Impedance, $$Z = \sqrt{R^2 + X_L^2}$$

$$\tan \emptyset = \frac{X_L}{R}$$

$$\sin \emptyset = \frac{X_L}{Z}$$

Power factor= $\cos \emptyset = \frac{R}{Z}$

**(ii) Impedance triangle R-C circuit**
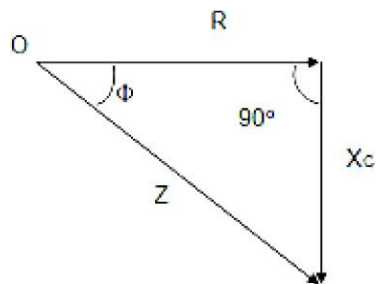


(**Fig.2.22.**Impedance Triangle of RC Series Circuit)

Impedance, $$Z = \sqrt{R^2 + X_c^2}$$

$$\tan \emptyset = \frac{X_c}{R}$$

$$\sin \emptyset = \frac{X_c}{Z}$$

Power factor= $\cos \emptyset = \frac{R}{Z}$

**(iii)Impedance triangle R-L-C circuit**
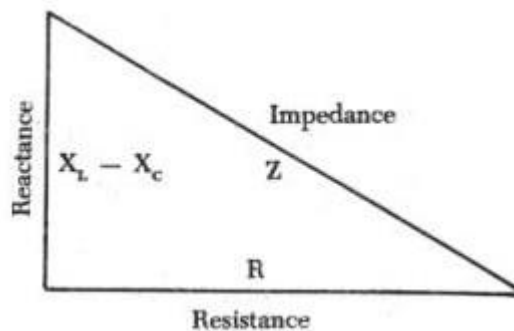


(**Fig.2.23.**Impedance Triangle of RLC Series Circuit)

Impedance, $$Z = \sqrt{(R)^2 + (X_L - X_C)^2}$$

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$$\tan \emptyset = \frac{X_L - X_C}{R}$$

$$\sin \emptyset = \frac{X_L - X_C}{Z}$$

Power factor= $\cos \emptyset = \frac{R}{Z}$

**Example 2.3:-** A Capacitor of capacitance 79.5µF is connected in series with a non-inductive resistance of 30 ohm across a 100V, 50Hz supply. Find (i) impedance (ii) current (iii) phase angle.

**Solution:**

$$X_c = \frac{1}{2\pi f C} = \frac{1}{2*3.14*50*79.5*10^{-6}} = 40\Omega$$

i) $Z = \sqrt{R^2 + X_c{}^2} = \sqrt{30^2 + 40^2}$ =50Ω

ii) $I = \frac{V}{Z} = \frac{100}{50} = 2A$

iii) Phase angle = $\tan^{-1}(\frac{X_c}{R})$ = $\tan^{-1}(\frac{40}{30})$ = 53°

**Example 2.4:-** A resistance of 20 Ω and inductance of 0.2H and a capacitance of 100µF are connected in series with 220 volt, 50 Hz mains. Determine (a) impedance (b) current (c) voltage across R, L, C (d) power in watts and VA (e) p.f. and angle of lag.

**Solution**

R= 20Ω;   L=0.2 H;    C=10⁻⁴F

$X_l = 2\pi f L$ =0.2×314 = 62.8 Ω ≈ 63 Ω

$X_c = \frac{1}{2\pi f C} = \frac{1}{314*10^{-4}}$ =31.847 ≈ 32Ω;   $X_L$ - $X_c$ = 63-32 = 31Ω (inductive)

(a) Z=$\sqrt{20^2 + 31^2}$ = 37Ω          (b) I = 220/37= 6A

(c) $V_R$ = I × R = 6 × 20 = 120 v;    $V_L$ = 6 × 63 = 278 V;   $V_c$ = 6 × 32 = 192 V

(d) Power in VA = 6×220 = 1320 VA

Power in watts = 6×220×0.54= 713 W

(e) p.f. = $\cos \emptyset = \frac{R}{Z} = \frac{20}{37}$ = 0.54;   $\emptyset = \cos^{-1}(0.54) = 57°18'$

**Example 2.5:- A 230 V, 50 Hz ac supply is applied to a coil of 0.06 H inductance and 2.5 Ω resistance connected in series with a 6.8 µF capacitor. Calculate (i) Impedance (ii) Current (iii)Phase angle between current and voltage (iv) power factor**

**Solution**

$X_L = 2\pi f L = 2 \times 3.141 \times 50 \times 0.06 = 18.84 ohm$

$X_C = \dfrac{1}{2\pi f c} = \dfrac{1}{2 \times 3.141 \times 50 \times 6.8 \times 10^{-6}} = 468 ohm$
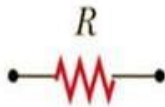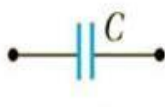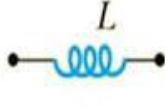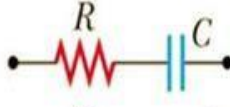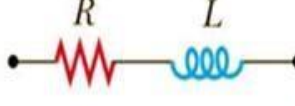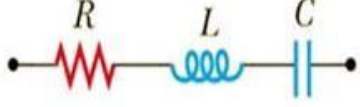
(i)  $Z = \sqrt{(R)^2 + (X_L - X_C)^2} = \sqrt{(2.5)^2 + (18.84 - 468)^2} = 449.2$ ohm

(ii)  $I = \dfrac{V}{Z} = \dfrac{230}{449.2} = 0.512A$

(iii)  $\varnothing = \tan^{-1}\left(\dfrac{X_L - X_C}{R}\right) = \tan^{-1}\left(\dfrac{18.84 - 468}{30}\right) = -89.7°$

(iv)  $power\ factor = \cos\varnothing = \cos(-89.7°) = 0.0056 lead$

## SUMMARY OF CIRCUIT ELEMENT, IMPEDANCE AND PHASE ANGLE

| Circuit Elements | Impedance Z | Phase Angle $\phi$ |
|---|---|---|
| $R$ (resistor) | $R$ | $0°$ |
| $C$ (capacitor) | $X_C = 1/\omega C$ | $-90°$ |
| $L$ (inductor) | $X_L = \omega L$ | $+90°$ |
| $R$, $C$ | $\sqrt{R^2 + X_C^2}$ | Negative, between $-90°$ and $0°$ |
| $R$, $L$ | $\sqrt{R^2 + X_L^2}$ | Positive, between $0°$ and $90°$ |
| $R$, $L$, $C$ | $\sqrt{R^2 + (X_L - X_C)^2}$ | Negative if $X_C > X_L$ <br> Positive if $X_C < X_L$ |

# QUESTIONS FOR PRACTICE

**Short Answer Questions**

1. Define average value, RMS value.
2. What is Time period and frequency?
3. Define amplitude of a sinusoidal wave.
4. Define instantaneous value of a wave.
5. What is a phasor?
6.  Define a series RL circuit:
7.  Define impedance
8.  What is the unit of measurement for impedance?
9. What is the formula for impedance in an RL Series circuit?
10. With a 5 ohm resistor and a 10 ohm inductive reactance, what is the total impedance?
11. Define True Power.
12.  What is reactive power?
13. What is apparent power?
14. What are the formulas for Power Factor (PF)?
15. Define a series RC circuit.
16. Draw the impedance triangle and mention its sides.
17. With a 7 ohm resistor and a 10 ohm capacitance reactance, what is the total impedance?
18. What is the formula for total impedance in a RLC circuit?

**Long Answer Questions:-**
1. If the voltage in an ac circuit is represented by the equation, $v = 220\sqrt{2}\sin(314t - \varphi)$ V . Calculate (a) peak and rms value of the voltage (b) average voltage (c) frequency of AC.
2. A 400 mH coil of negligible resistance is connected to an AC circuit in which an effective current of 6 mA is flowing. Find out the voltage across the coil if the frequency is 1000 Hz.
3. A capacitor of capacitance $102/\pi$ µF is connected across a 220 V, 50 Hz A.C. mains. Calculate the capacitive reactance, RMS value of current and write down the equations of voltage and current.
4. The inductance of a choke-coil is 0.2 henry and its resistance is 0.50 Ω . If a current of 2.0 ampere (rms value) and frequency 50Hz be passed through it, what will be the potential difference across its ends ?
5. A 10µF capacitor, an inductor and a resistor of 100 Ω are connected to an alternating source of emf 200 as shown in the figure. What is the r.m.s current in the circuit and the value of the inductance if the current and the source voltage attain their maxima simultaneously? What is the average power consumed in this case?
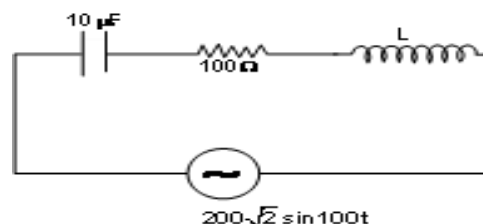
# CHAPTER-3

## GENERATION OF ELECTRICAL POWER

### THERMAL POWER PLANT:-

A generating station which converts heat energy of coal combustion into electrical energy is known as a steam power station.

The heat produced for burning of coal & with the help of water steam is produced. This produced steam flow towards turbine i.e. kinetic energy is converted into mechanical energy. The input steam drives the prime mover or turbine, simultaneously the generator also start to rotate. At that time mechanical energy is converted into electrical energy.

### Selection of Site for Thermal Power Plant:

**1. Supply of Fuel:** The Steam power station should be located near the coal mine so that transportation cost of fuel is minimum.

**2. Available of Water:** A huge amount of water is required in boiler & condenser, so that the plant should be located near the river, lake etc.

**3. Transportation Facility:** For steam power station provide better transportation facility for the transportation of man, machinery etc.

**4. Cost & Type of Land:** The Steam Power Station should be located where the cost of land is cheap & also future extension is possible.

**5. Near to Load Centre:** In order to reduce transmission & distribution losses the plant should be located near to load centre.

**6. Distance from Populated Area:** As the thermal power plant produces flue gases, these gases will effect to live human being, so that the plant should be located away from thickly populated area.

**7. Disposal Facility Provided:** As the thermal power plant produces ash, while burning of coal. So that disposal of ash facility provided.

**8. Availability of labour:** Skilled and unskilled labour should be available nearly.

### Schematic arrangement of Thermal Power Plant:
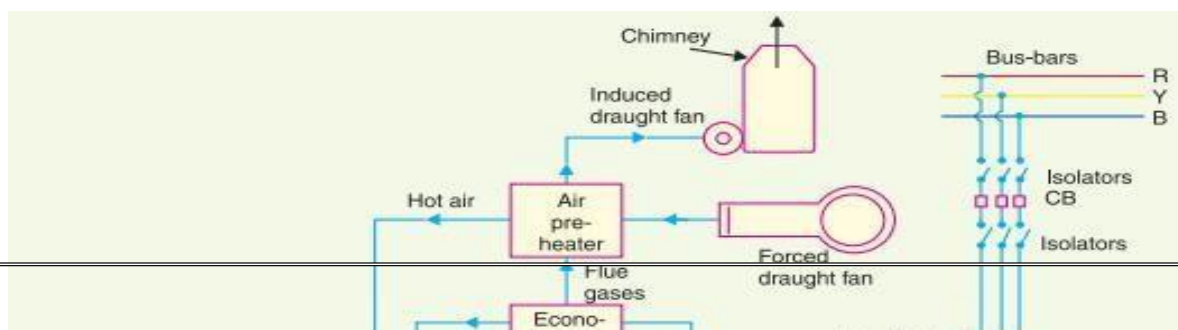
(**Fig.3.1.** Block Diagram of Thermal Power Plant)

### 1. Coal Storage & Coal Handling Plant:

The coal is transported to the power station by road or rail and is stored in the coal storage plant. From the coal storage plant, coal is delivered to the coal handling plant where it is pulverised (i.e., crushed into small pieces).The pulverised coal is fed to the boiler by belt conveyors.

### 2. Ash handling Plant & Ash Storage:

The coal is burnt in the boiler and the ash produced after the complete combustion of coal is removed to the ash handling plant and then delivered to the ash storage plant for disposal.

### 3. Boiler: (Steam Generating Plant):

A boiler is a closed vessel in which water is converted into steam by utilizing the heat of coal combustion. The heat of combustion of coal in the boiler is utilised to convert water into steam at high temperature and pressure. The flue gases from the boiler make their journey through super heater economiser, air pre-heater and are finally exhausted to atmosphere through the chimney.

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**4. Super-Heater:**

The steam produced in the boiler is wet and is passed through a super heater where it is dried and superheated (i.e. steam temperature increased above that of boiling point of water) by the flue gases on their way to chimney.

**5. Economiser:**

An economiser is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economiser before supplying to the boiler. The economiser extracts a part of heat of flue gases to increase the feed water temperature.

**6. Feed water Arrangement:**

The condensate from the condenser is used as feed water to the boiler. Some water may be lost in the cycle which is suitably made up from external source. The feed water on its way to the boiler is heated by water heaters and economiser.

**7. Air Pre-heater:**

An air pre-heater increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced draught fan and is passed through air pre-heater before supplying to the boiler furnace.

**8. Condenser:**

A condenser is a device which condenses the steam at the exhaust of the turbine. This helps in converting heat energy of steam into mechanical energy in the prime mover. The condensed steam can be used as feed water to the boiler.

**9. Cooling arrangement:**

During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled. The cold water from the cooling tower is reused in the condenser.

**10. Steam Turbine:**

The dry and superheated steam from the super heater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy.

**11. Induced Draught fan (IDF):**

Its (IDF) function is to remove rapidly flue gases (smoke) from the furnace chamber produced during combustion.

**12. Forced Draught fan (FDF):**

Its **(FDF)** function is to provide forced air (oxygen) for combustion process in furnace.

**13. Cooling Tower:**

The cooling tower is used to reduce the temperature of water coming from condensers & reused the same.

**14. Chimney:**

To reduce air pollution flue gas should be passed in air as high as possible with the help of Chimney.

**15. Alternator:**

The steam turbine is coupled to an alternator. The alternator converts mechanical energy of turbine into electrical energy.

**ADVANTAGES:**

i) The Fuel (i.e. Coal) used is quite cheap.

ii) Less initial cost as compared to other generating stations.

iii) It can be installed at any place & the coal can be transported by Rail / Road.

iv) It requires less space as compared to hydro-electric Power Station.

**DISADVANTAGES:**

i) It pollutes air / atmosphere due to smoke / fumes

ii) Running cost is higher than hydro power plant.

## HYDRO POWER PLANT:-

A generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as a hydro-electric power station.

Water is stored in dam by using rain water. This stored water contains Potential energy, due to height or head of dam. When this water is flow towards turbine, at that time the Kinetic Energy is converted into Mechanical Energy. The turbine or prime mover is mechanically coupled with generator. Whenever turbine starts to rotate with the help of high pressure water, automatically generator starts to rotate & it produced an electrical energy.

**Selection of Site for Hydro-Electric Power Plant:**

**1. Quantity of Water Required:** As we know that, the hydro-electric power plant totally runs on water, so that ample quantity of water is continuously available throughout the year.

**2. Hilly Area Required:** For storage of ample quantity of water, both side of dam hilly area or strong mountains required for storage of water.

**3. Civil Work:** It should have strong foundation or the cost of foundation should be as low as possible.

4.  **Large Catchment Area:** Large catchment area required, so that the water in it should never fall below the minimum level.

5.  **Transportation Facility:** For Workers & Civil Material required better transportation facility.

6.  **Near to Load Centre:** To reduce cost of Transmission & Distribution the plant should be located near to load centre.

7.  **Availability of Material:** At the time of erecting the dam & power house a huge amount of civil material is easily available without any shortage.

**8. Future Expansion:** For increasing per MW Capacity of plant the space is available for future expansion.


## Schematic arrangement of Hydro-Electric Power Plant:
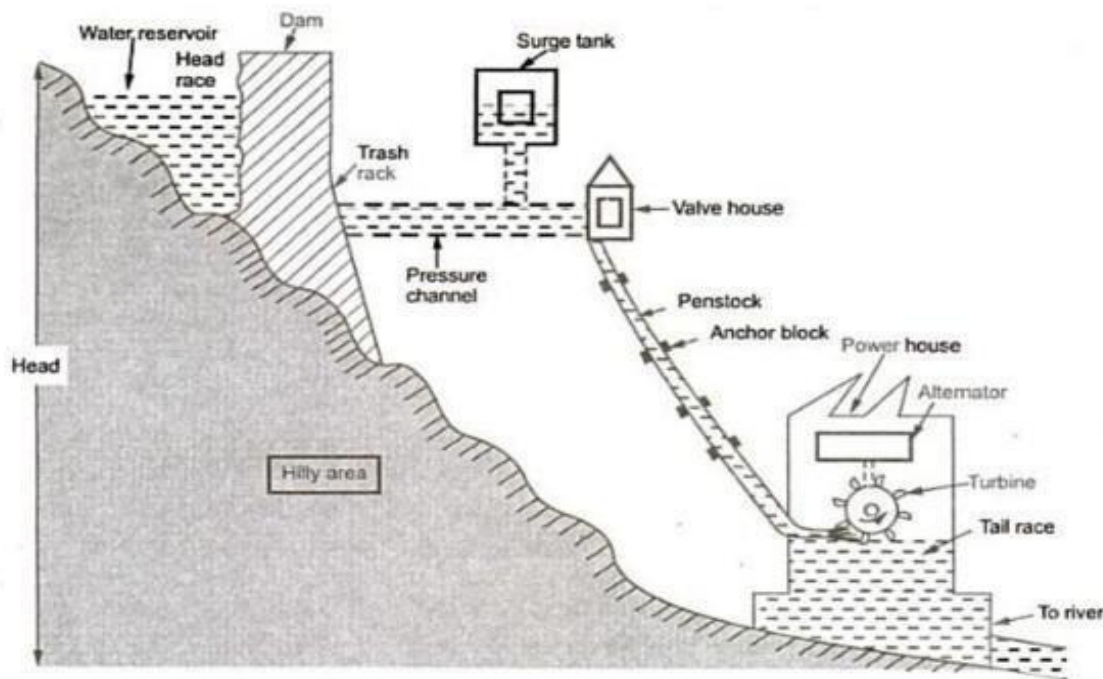


(**Fig.3.2.** Block Diagram of Hydro Power Plant)

### 1. Catchment Area:

In hydro-electric power plant collect the rain water through surrounding hilly area, the surrounding all water collect & stored area to those place is known as catchment area.

### 2. Reservoir:

The function of reservoir is to store the water near dam; this water is useful to drive the water turbines. The reservoir is useful to provide a head of stored water.

### 3. Head-Race Level:

The water surface in the reservoir up to the dam is known as head-race level.

**4. Dam:**

The dam is used in hydro-electric power plant to store the water. Whenever the dam stored the water, it provides suitable head to this stored water. This stored water is useful throughout the year to run the hydro-electric power plant. Dam is made up of cement, concrete & sand materials..

**5. Spill Way:**

The excess water from dam is discharges through spillway at a permissible level.

**6. Penstock:**

It is the device which is used in hydro-electric power plant for the purpose of flow of water. The water flow of from dam towards turbine with the help of penstock.

**7. Surge tank:**

It is a device which is connected in between dam & power house. It is of vertical type. When load on power plant or alternator decreases then Governor (valve) reduces discharge of water. Due to sudden reduction in water discharge causes increase in pressure of the water in the penstock. Due to high pressure penstock may damage. At that time surge tank helps by storing this rejected water immediately.

**8. Generator:**

It is used to convert the mechanical energy into electrical energy. For that purpose the turbine & generator are mechanically coupled.

**ADVANTAGES**

i) It requires no fuel as water is used for the generation of Electrical Energy.

ii) It is quite neat & clean as no smoke or ash is produced.

iii) Running cost is very less as water is used.

iv) It is simple in construction & requires less maintenance.

v) It can be started quality as compared to Thermal Power Station.

vi) In addition to generation of Electrical Energy these plants are also helpful in irrigation & control of floods.

**DISADVANTAGES**

i) It involves high capital lost due to construction of dams.

ii) Generation depends on average rainfall round the year.

iii) High cost of transmission as these plants are located in hilly areas quite for off from localities.

## NUCLEAR POWER PLANT:-

The Power Plant which uses nuclear energy of radioactive material (Uranium or Thorium) converted into Electrical Energy is known as Nuclear Power Plant.

As we know that, the freely moving neutrons bombarded with radioactive material ($U^{235}$ or $Th^{232}$) the heat energy produced, with the help of this heat energy water a steam produced at high pressure & temperature. High pressure steam passes towards turbine where KE is converted to ME. We know that, turbine & generator are mechanically coupled through this combination an Electrical Energy is produced in Nuclear Power Plant.

### Selection of Site for Nuclear Power Plant:

**1. Availability of water:** Sufficient supply of water is obvious for generating steam & cooling purposes in nuclear power station.

**2. Disposal of Waste:** The wastes of nuclear power station are radioactive and may cause severe health hazards. Because of this, special care to be taken during disposal of wastes of nuclear power plant.

**3. Distance from Populated Area:** As there is always a probability of radioactivity, it is always preferable to locate a nuclear station sufficiently away from populated area.

**4. Transportation Facilities:** During commissioning period, heavy equipment to be erected, which to be transported from manufacturer site. So good railways and road ways availabilities are required.

### Schematic Arrangement of Nuclear Power Plant:
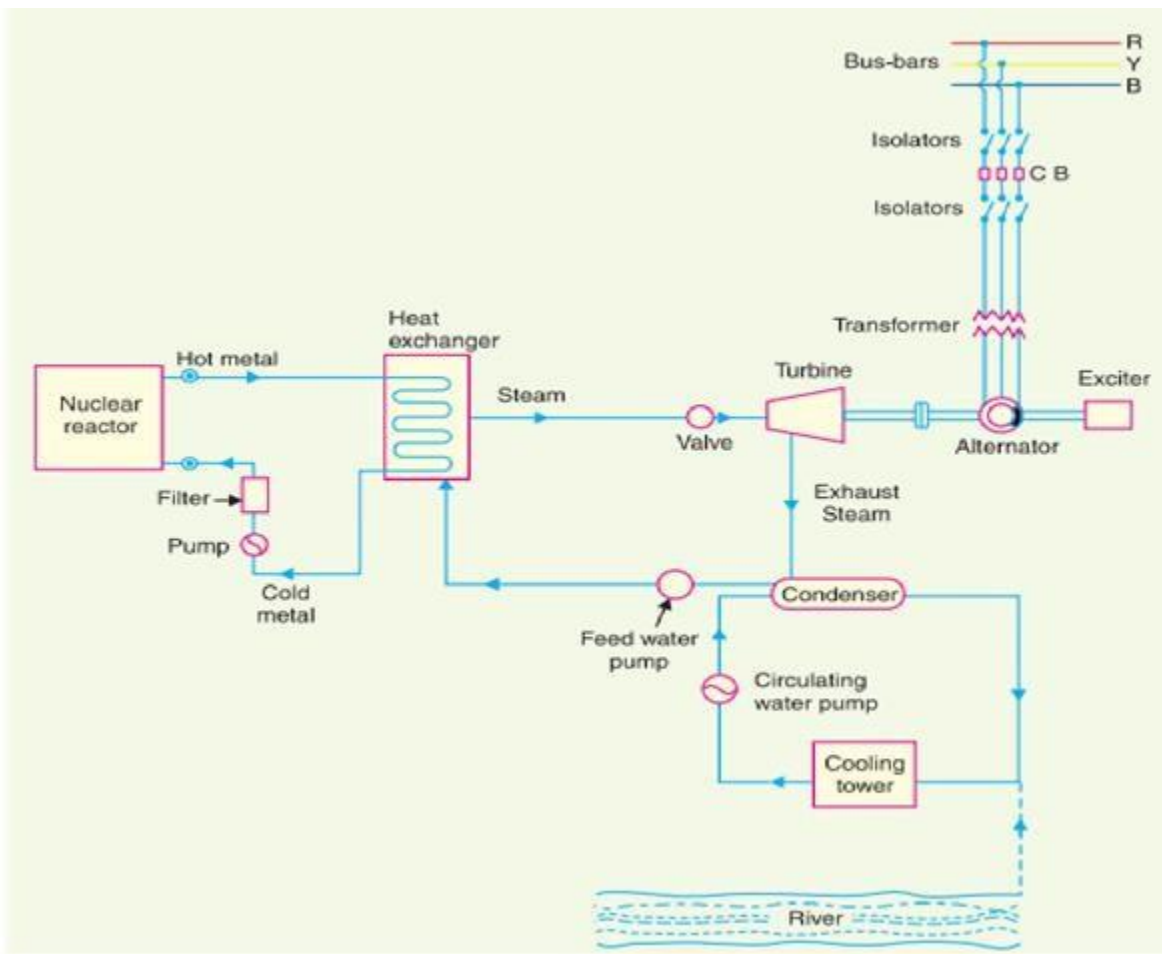
(**Fig.3.3.** Block Diagram of Nuclear Power Plant)

### 1. Nuclear Fuel:

In Nuclear Power Plant the fuels used are $U^{235}$ or $Pu^{239}$ or$Th^{232}$.Out of the three fuel any one of the fuel used in nuclear power plant. The fuel is required in nuclear power plant to produce a huge amount of heat energy. The fuel are inserted in fuel rod, these fuel rods are bombarded with slow moving neutrons. Separate provision provided for bombarded or hits the neutron to the fuel rod, this device is known as neutron bombardment device.

### 2. Moderator:

In nuclear power plant, moderator is a device, of rod shaped. Moderator is placed near the nuclear fuel rod. The main function of moderator in nuclear power plant is reduce the speed of neutrons (neutron at slower speed is required to produce fission) & increases the fission processes. Moderator rod is made up of graphite or heavy water or beryllium material.

### 3. Control Rods:

In nuclear power plant, the control rods are placed in between nuclear fuel rod, moderator and then control rod. In nuclear power plant the main function of control rod is to control the chain reaction. If the control rod is inserted then it absorbs the freely moving neutrons & stop the chain reaction, if it is no inserted chain reaction is in process, means chain

reaction continued. The steady rate or to stop the chain reaction is maintained through control rods. The control rods are made up of cadmium, boron (alloyed with steel or aluminium).

**4. Nuclear Reactor**:

It is an apparatus in which the nuclear fuel($U^{235}$) is subjected to nuclear fission.

**5. Heat Exchanger:**

The main function of heat exchanger in nuclear power plant is the boiled the cold water and produces steam at high temperature & pressure.

**6. Turbine:**

Turbine receives steam from heat exchange at high pressure, and it rotates at high speed then alternator also rotates, this way electrical power produced. The exhaust steam from turbine passes to condenser for further use.

## ADVANTAGES

i) There is saving in fuel transportation as amount of fuel required is less.

ii) A Nuclear Power Plant requires less space as compared to other plants.

iii) This type of plant is economical for producing bulk Electrical Energy.

## DISADVANTAGES

i) Fuel is expensive and difficult to recover.

ii) Capital lost is higher than other plants.

iii) Experienced workman ship is required for plant erection & commissioning.

iv) The Fission by-products are radioactive & can cause dangerous radio-active pollution.

# QUESTIONS FOR PRACTICE

**Short Answer Questions**

1. What are the function of following elements in Hydro Power Plant?
   (a) Surge Tank (b) Penstock  (c) Generator (d) Dam (e) Spillway
2. Write down the function of following elements in Thermal Power Plant?
   (a) Boiler (b) Super-heater (c) Economiser (d) Feed-water Heater (e) Air Pre Heater
   (f) Condenser (g) Induced Draught Fan (h) Forced Draught Fan (i) Chimney (j) Cooling tower (k) Alternator
3. Describe the function of following elements in Nuclear Power Plant?
   (a) Moderator (b) Control Rod (c) Nuclear Reactor (d) Heat Exchanger (e) Turbine

**Long Answer Questions**

1. Write down the advantages & disadvantages of Hydro Power Plant, Thermal Power Plant & Nuclear Power Plant
2. Draw the block diagram of Hydro Power Plant and explain the function of each elements of it.
3. Draw the block diagram of Nuclear Power Plant and explain the function of each elements of it.
4. Draw the block diagram of Thermal Power Plant and explain the function of each elements of it.

# CHAPTER - 4

## CONVERSION OF ELECTRICAL ENERGY

### INTRODUCTION:-

A DC machine is a device which converts mechanical energy into electrical energy. When the device acts as a generator mechanical energy is converted into electrical energy. On the other hand when the device acts as a motor, the electrical energy is converted into mechanical energy. However, during the conversion process a part of the energy is converted into heat, which is lost and is not reversible. Thus an electrical machine can be made to work either as a generator or a motor.

### PARTS OF DC MACHINE:-
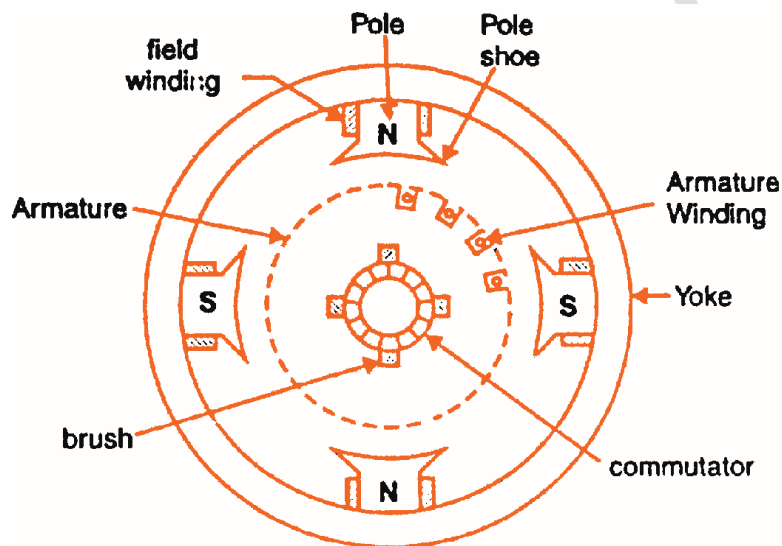


(**Fig.4.1.** Different Parts of DC Machine)

The DC machine consists of the following essential parts:

**Magnetic frame or Yoke: -** Purpose of Yoke is:
   (a) It act as a protecting cover for whole machine.
   (b) It also provides mechanical support for poles.
   (c) It carries the magnetic flux produced by poles

**Pole Cores and Pole Shoes: -** The field magnets consist of pole cores and pole shoes. The Pole shoes serve two purposes:
(a) They spread out the flux in the air gap
(b) They support the exciting coils

**Field winding: -** The field winding is wound on the pole core with a definite direction. Function of field winding is to carry current due to which pole core on which the winding is placed behaves as an electromagnet, producing necessary flux.

**Armature Core: -** Armature core is cylindrical in shape mounted on the shaft. It is made up of laminated construction to keep eddy current loss as low as possible. Function of armature core is:

1. Armature core provides house for armature winding i.e., armature conductors.

2. To provide a path of low reluctance path to the flux it is made up of magnetic material like cast iron or cast steel.

**Armature Windings or Conductors: -** Armature winding is the inter connection of the armature conductors, placed in the slots provided on the armature core. Function of armature conductor is:

1. Generation of emf takes place in the armature winding in case of generators.
2. To carry the current supplied in case of dc motors.
3. To do the useful work it the external circuit.

**Commutator: -** The function of Commutator is to facilitate collection of current from the armature conductors and converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit. The commutator is made up of insulated copper segments.

**Brushes and Bearings: -** Brushes are normally made up of soft material like carbon. Brushes are used to collect current from commutator and make it available to the stationary external circuit. Bearings are used for smooth running of the machine.

## CLASSIFICATION OF DC GENERATOR/MOTOR:-

DC generators/motors are usually classified according to the way in which their fields are excited.

DC generators/motors may be divided into

**(a) Separately excited DC generators/motors**

**(b) Self-excited DC generators/motors**

**a) Separately excited DC generators/motors:** - Separately excited generators/motors are those whose field magnets are energized from an independent external source of dc current.

**b) Self-excited DC generators/motors**: - Self excited generators/motors are those whose field magnets are energized by the current produced by the generators/motors themselves.

There are three types of self-excited dc generators/motors named according to the manner in which their field coils (or windings) are connected to the armature.

**(i) Shunt wound DC generator/motor**: - In shunt the two windings, field and armature are in parallel.

**(ii) Series wound DC generator/motor**: - In series type both field and armature winding are in series.

**(iii) Compound wound DC generator/motor**: - There are two types of compound wound DC generator/motor.

**(a) Long shunt compound DC generator/motor**: - The shunt field winding is parallel with both armature and series field winding.

**(b) Short shunt compound DC generator/motor**: - The shunt field winding is in parallel with armature winding only.
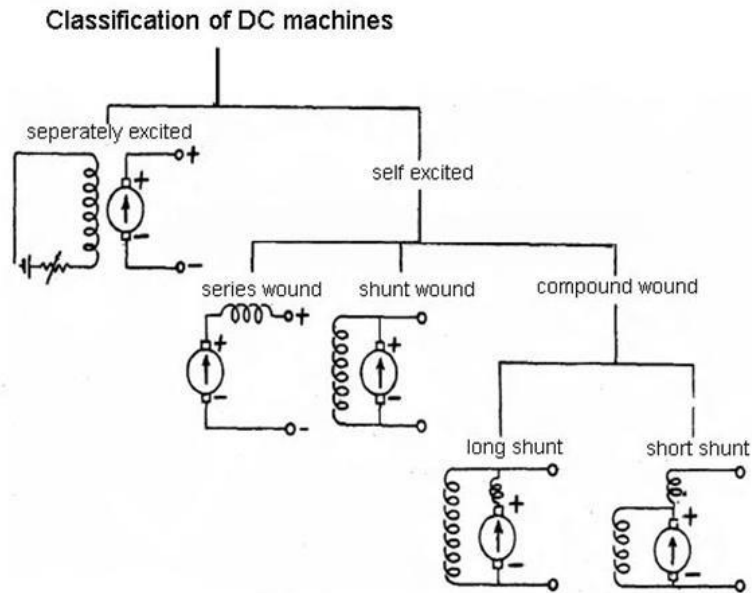
(**Fig.4.2.** Classification of DC machine)

## USES OF D.C. GENERATORS:-
**(1) Shunt Generator**
       (i) Lighting and Power Supply
       (ii) Charging batteries.
**(2) Series Generator**
       (i) Boosters.
**(3) Compound Generator**
       (i) Large range load
       (ii) Power Supply

## USES OF D.C. MOTORS:-
**(1) Shunt Motor**
       (i) Constant speed drive
       (ii) Drilling machine, lathes, elevators, water pump, cutting machine.
**(2) Series Motor**
       (i) Electric Cranes
       (ii) Electric Trains
       (iii) Hoists
**(3) Compound Motor**
       (i) Heavy tool machines
       (ii) Printing machines

## TYPES OF SINGLE PHASE INDUCTION MOTOR:-

(1) Split phase motor
(2) Capacitor start motor
(3) Capacitor start – Capacitor run single phase Induction Motor.
(4) Shaded Pole Motor
(5) Repulsion Motor

## USES :
### (1) Split phase motor:
      (i) Small Pumps
      (ii) Grinders
### (2) Capacitor start motor
      (i) Compressor
      (ii) Pumps
### (3) Capacitor start capacitor Run Motor
      (i) Compressor of Air-conditioner
      (ii) Water Cooler
### (4) Shaded Pole Motor
      (i) Small fans
### (5) Repulsion Motor
      (i) Mixing Machine
      (ii) Blowers

## CONCEPT OF LUMEN:-
It is the unit of luminous flux. It is defined as the luminous flux emitted by a source of one candle power per unit solid angle in all directions.

**Lumen = candle power of source × solid angle.**

**Lumen = CP × $\omega$**

Total flux emitted by a source of one candle power is $4\pi$ lumens.

## DIFFERENT TYPES OF LAMPS:-

### (a) Filament Lamp:-

**Construction**
- It consists of an evacuated glass bulb and an aluminum or brass cap is provided with two pins to insert the bulb into the socket.
- The inner side of the bulb consists of a tungsten filament and the support wires are made of molybdenum to hold the filament in proper position.
- A glass button is provided in which the support wires are inserted.
- A stem tube forms an air-tight seal around the filament whenever the glass is melted.
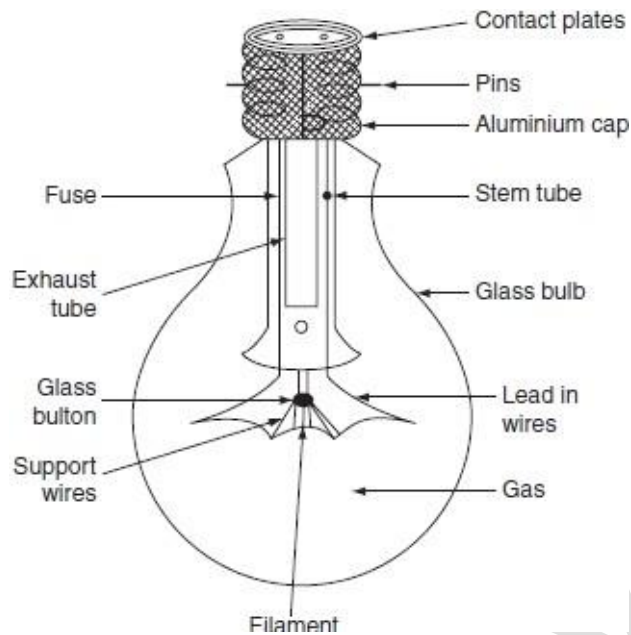
(**Fig.4.3.** Construction of Filament Lamp)

**Principle**

- When electric current is made to flow through the fine metallic tungsten filament, its temperature increases. At very high temperature, the filament emits both heat and light radiations, which fall in the visible region.
- The tungsten filament lamps can be operated efficiently beyond 2,000°C, it can be attained by inserting a small quantity of inert gas nitrogen with small quantity of argon.

## (b) Fluorescent Lamp:-

Fluorescent lamp is a hot cathode low-pressure mercury vapor lamp.

**Construction**

- It consists of a long horizontal tube, due to low pressure maintained inside of the bulb; it is made in the form of a long tube.
- The tube consists of two spiral tungsten electrode coated with electron emissive material and are placed at the two edges of long tube.
- The tube contains small quantity of argon gas and certain amount of mercury, at a pressure of 2.5 mm of mercury.
- Normally, low-pressure mercury vapor lamps suffer from low efficiency and they produce an objectionable colored light. Such drawback is overcome by coating the inside of the tube with fluorescent powders. They are in the form of solids, which are usually knows as phosphors.
- A glow starter switch contains small quantity of argon gas, having a small cathode glow lamp with bimetallic strip is connected in series with the electrodes, which puts the electrodes directly across the supply at the time of starting.

- A choke is connected in series that acts as ballast when the lamp is running, and it provides a voltage impulse for starting. A capacitor of 4μF is connected across the starter in order to improve the power factor.
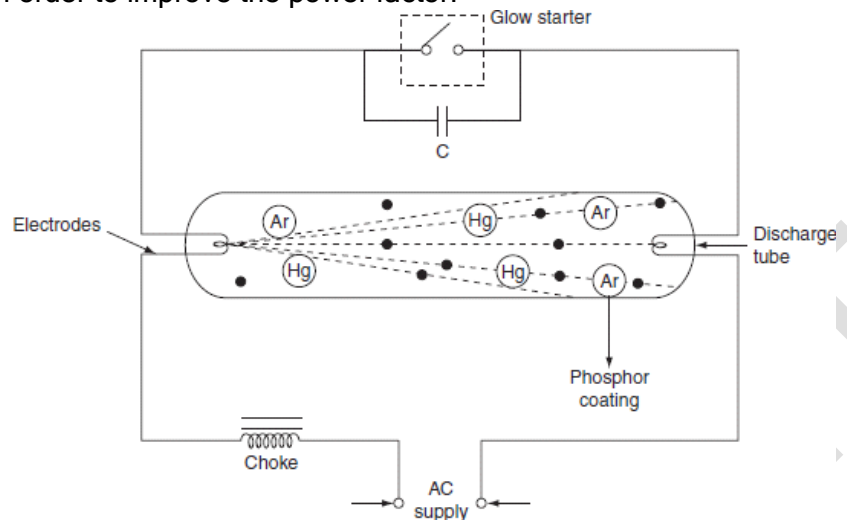


(**Fig.4.4.** Construction of Filament Lamp)

**Principle**

- At the time of starting, when both the lamp and the glow starters are cold, the mercury is in the form of globules.
- When supply is switched on, the glow starter terminals are open circuited and full supply voltage appeared across these terminals, due to low resistance of electrodes and choke coil.
- The small quantity of argon gas gets ionized, which establishes an arc with a starting glow.
- This glow warms up the bimetallic strip thus glow starts gets short circuited. Hence, the two electrodes come in series and are connected across the supply voltage.
- Now, the two electrodes get heated and start emitting electrons due to the flow of current through them.
- These electrons collide with the argon atoms present in the long tube discharge that takes place through the argon gas. So, in the beginning, the lamp starts conduction with argon gas as the temperature increases, the mercury changes into vapor form and takes over the conduction of current.
- In the meantime, the starter potential reaches to zero and the bimetallic strip gets cooling down. As a result, the starter terminals will open. This results breaking of the series circuit.
- A very high voltage around 1,000 V is induced, because of the sudden opening of starter terminals in the series circuit. But in the long tube, electrons are already present; this induced voltage is quite sufficient to break down the long gap. Thus, more number of electrons collide with argon and mercury vapor atoms.
- The excited atom of mercury gives UV radiation, which will not fall in the visible region. Meanwhile, these UV rays are made to strike phosphor material; it causes the re-emission of light of different wavelengths producing illumination. The phenomenon of the emission is called as luminescence.

## (c) LED Lamp:-

- A Light emitting diode bulb consists of two semiconducting material i.e. p-type material and n-type material. A p-n junction is formed, by connecting these two types of materials.

- When the p-n junction is forward biased, the majority carriers; either electrons or holes; start moving across the junction.



(**Fig.4.5.** Construction of LED Lamp)
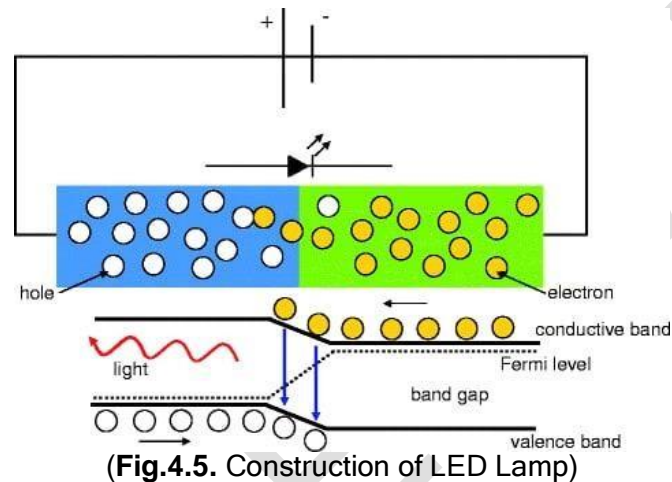
- As shown in the figure above, electrons start moving from n-region and holes start moving from p-region. When they moved from their regions they start to recombine across the depletion region. Free electrons will remain in the conduction band of energy level while holes remain in the valence band of energy level.
- The Energy level of the electrons is high than holes because electrons are more mobile than holes i.e. current conduction due to electrons are more. During the recombination of electrons and holes, some portion of energy must be dissipated or emitted in the form of heat and light.
- The phenomenon into which light emits from the semiconductor under the influence of the electric field is known as electroluminescence.
- Always remember that the majority of light is produced from the junction nearer to the p-type region. So diode is designed in such a way that this area is kept close to the surface of the device to ensure that the minimum amount of light is absorbed.
- The electrons dissipate energy in different forms depending on the nature of the diode used. Like for silicon and germanium diodes, it dissipates energy in the form of heat while for gallium phosphide (GaP) and gallium arsenide phosphide (GaAsP) semiconductors, it dissipates energy by emitting photons.
- For the emission of different colors, different semiconductors are used. For example; phosphorus is used for a red light, gallium phosphide for the green light and aluminum indium gallium phosphide for yellow and orange light.

## STAR RATING OF HOME APPLIANCES:-

• **Terminology**

White goods > Home appliances (refrigerator, a/c etc)
Brown goods > Portable appliances (television and wireless sets, microwave ovens, coffee makers)
BEE > Bureau of Energy Efficiency
EER > Energy Efficiency Ratio
BTU > British thermal unit

• **Energy Efficiency**

It is defined as energy service per unit of energy consumption.

• **Star Rating**

  • An energy efficiency rating scheme for Electrical appliances is known as Star labelling.
  • Star Rating is the average amount of electricity used by the equipment in a year i.e kWh/year or unit/year under standard test conditions.
  • Star ratings are provided to all the major kind of appliances in the form of labels. These star ratings are given out of 5 and they provide a basic sense of how energy efficient each product is.



(**Fig.4.6.** Star rating of appliance)

# QUESTIONS FOR PRACTICE

**Short Answer Questions**

1. What is a motor?
2. Classify dc machine.
3. What is the function of (i) Yoke (ii) armature (iii) commutator (iv) brush
4. Define (i) BEE (ii) EER (iii) BTU
5. Define star rating.
6. What is Lumen?
7. State two uses of capacitor start motor and shaded pole motor.
8. What is the use of starter in fluorescent lamp?
9. Which materials are used in LED bulb?
10. What is the importance of using tungsten filament?
11. Which type of motor is used in Electric trains and cranes?
12. What is the function of Series Generator?
13. What is the unit of energy consumed?

## Long Answer Questions
1. Draw the schematic diagram of a dc machine and label the parts. State the function of every part.
2. Describe the construction of filament lamp with a neat diagram.
3. Explain the working of fluorescent lamp.
4. Write short notes on
   (i) Types of single phase induction motor and their uses.
   (ii) LED Lamp, its construction and uses.
   (iii) Star rating of home appliances
   (iv)Uses of different types of dc motors

# CHAPTER-5

## WIRING AND POWER BILLING

### ELECTRICAL WIRING:-

A network of cables connecting various electrical accessories for distribution of electrical energy from the supplier meter board to the various electrical energy consuming devices such as lamps, fans, radio, TV and other domestic appliances through controlling and safety devices is known as wiring system.

### TYPES OF WIRING FOR DOMESTIC INSTALLATIONS:-

Electrical wiring system is classified into five categories:

- Cleat wiring
- Wooden casing and capping wiring
- CTS or TRS or PVC sheath wiring
- Lead sheathed or metal sheathed wiring
- Conduit wiring
  - Surface or open Conduit type
  - Concealed or underground type Conduit

- **Cleat Wiring**

  - In this system of wiring cables are supported and gripped between porcelain cleats above the wall or roof.
  - The porcelain cleats are made in two halves. The main part is base, which is grooved to accommodate the cables, the other part is the cap which is put over the base
  - The lower cleat (base) and upper cover (cap), after placing cables between them are then screwed on wooden gutties.
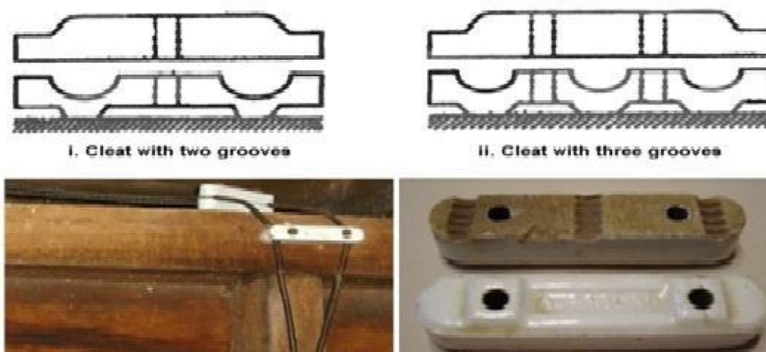


(**Fig.5.1.** Cleat Wiring)

**Advantages:**
- It is the cheapest system.
- Installation and dismantling is easy.
- Less skilled persons are required.

- Inspection is easy.
- Alterations and additions are easy.
- As the cables and wires of cleat wiring system is in open air, therefore fault in cables can be seen and repair easily
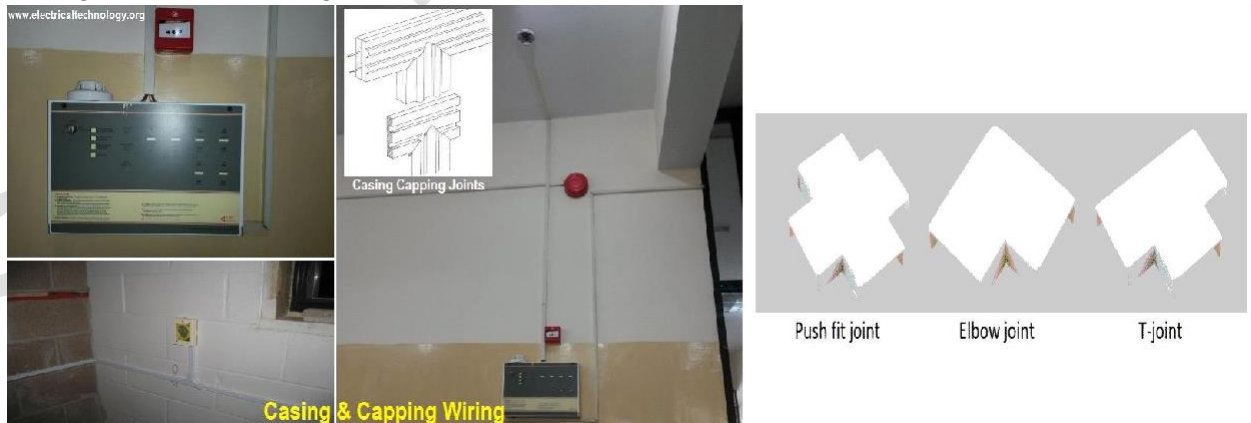
**Disadvantages:**
- It is purely temporary wiring system.
- Appearance is not good.
- Cables are exposed to atmosphere and there is a possibility of mechanical injury.
- This system should not be used in damp places otherwise insulation gets damaged.
- It is not lasting wire system because of the weather effect and wear & tear
- It can be only used on 250/440 Volts on low temperature.
- There is always a risk of fire and electric shock.
- It can"t be used in important and sensitive location and places.
- It is not reliable and sustainable wiring system.

**Application:**
- It is suitable for temporary installation in dry places i.e. under construction building or army camping

- **Casing and Capping wiring**

- It consists of rectangular blocks made from seasoned and knots free wood or PVC.
- The casing has usually two (or three) „U" shaped grooves, (two in number) into which the VIR or PVC cables are laid in such a way that the opposite polarity cables are laid in different grooves.
- The casing is covered by means of a rectangular strip of the same width as that of casing known as capping and is screwed to it.



(**Fig.5.2.** Casing & Capping Wiring)

**Advantages:**
- It provides good mechanical strength.
- Easy to inspect by opening the capping.
- It is cheap wiring system as compared to sheathed and conduit wiring systems.

- It is strong and long-lasting wiring system.
- If Phase and Neutral wire is installed in separate slots, then repairing is easy.
- Stay for long time in the field due to strong insulation of capping and casing..
- It stays safe from oil, Steam, smoke and rain.
- No risk of electric shock due to covered wires and cables in casing & capping
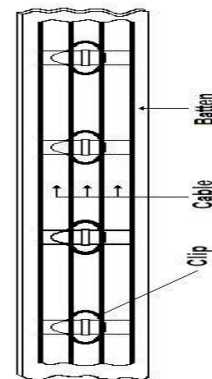
**Disadvantages:**
- Difficulty in finding any fault caused in the wire.
- There is a high risk of fire in casing & capping wiring system.
- Not suitable in the acidic, alkalies and humidity conditions
- Costly repairing and need more material.
- Material can"t be found easily in the contemporary
- White ants may damage the casing & capping of wood.
- This system cannot be used in damp places.

**Application:**
Used in low voltage residential and office building.

• ## **Batten Wiring (CTS or TRS)**

- The cables are run or carried on well-seasoned, perfectly straight and well varnished (on all four sides) teak wood batten of thickness 10 mm. at least.
-  The width of the batten depends upon the number and size of cables to be carried by it..
- The wooden battens are fixed to the walls or ceilings by means of  PVC gutties or wooden plugs with flat head wooden screws, the wooden screws should be fixed on the batten at an interval not exceeding **75cm**.



(**Fig.5.3.** Batten Wiring)

**Advantages:**
- Wiring installation is simple and easy
- cheap as compared to other electrical wiring systems
- Repairing is easy
- Strong and long-lasting
- Appearance is better.

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- Customization is easy
- Less chance of leakage current

**Disadvantages:**
- Not suitable for outdoor wiring
- Humidity, smoke, steam etc. directly affect on wires.
- Heavy wires are not recommended for this wiring scheme.
- Only suitable for below 250 V.
- High risk of fire.

**Application:**
- Used in domestic, commercial or industrial wiring except workshops
- Used for low voltage installation

- ## **Lead Sheathed Wiring**

- The type of wiring employs conductors that are insulated with VIR and covered with an outer sheath of lead aluminum alloy containing about 95% of lead.
- The metal sheath given protection to cables from mechanical damage, moisture and atmospheric corrosion.
- The whole lead covering is made electrically continuous and is connected to earth at the point of entry to protect against electrolytic action due to leaking current and to provide safety in case the sheath becomes alive.
- The cables are run on wooden batten and fixed by means of link clips just as in TRS wiring.

**Advantages:**
- Provides protection against mechanical injury better than TRS wiring.
- Easy to fix and looks nice
- Long life if proper earth continuity is maintained.
- Can be used in damp situation and in situation exposed to rain & sun.

**Disadvantages:**
- Costlier than TRS wiring
- Not suitable for chemical corrosion.
- In case of damage of insulation the metal sheath becomes alive & give shock.
- Skilled labour & proper supervision is required.

**Application:**
- Commonly used for laying sub mains from pole to electric meter

- ## **Conduit Wiring**

- There are two additional types of conduit wiring according to pipe installation
  - **Surface Conduit Wiring**

- **Concealed Conduit Wiring**

- **Surface Conduit Wiring**
- If conduits installed on roof or wall, It is known as surface conduit wiring. In this wiring method, they make holes on the surface of wall on equal distances and conduit is installed then with the help of rawal plugs.
- **Concealed Conduit wiring**
- If the conduits is hidden inside the wall slots with the help of plastering, it is called concealed conduit wiring. In other words, the electrical wiring system inside wall, roof or floor with the help of plastic or metallic piping is called concealed conduit wiring. obliviously,
- It is the most popular, beautiful, stronger and common electrical wiring system nowadays.
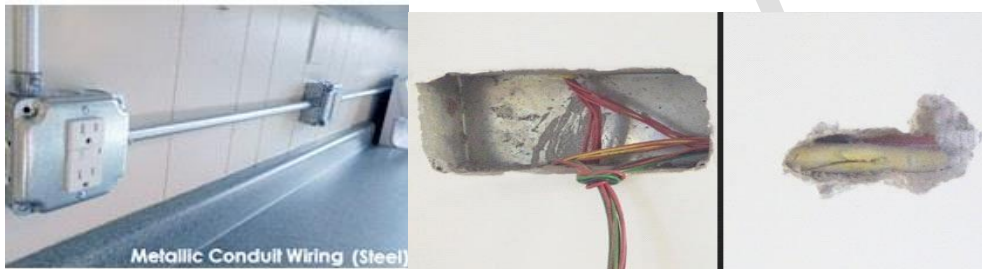

(**Fig.5.4.** Conduit Wiring)

**Advantages:**
- The safest wiring
- Appearance is better
- No risk of fire or mechanical wear and tear.
- No risk of damage of cable insulation
- Safe from humidity, smoke, steam etc.
- No risk of shock
- Long lasting
- Repairing and maintenance is easy.

**Disadvantages:**
- Very expensive
- Installation is not easy
- Not easy to customize for future
- Hard to detect the faults.
- Risk of Electric shock (In case of metallic pipes without proper earthing system)
- Experienced & highly skilled labour is required

**Application**:
- Places where dust is present such as in textile mills, sawmills, flour mills etc.
- Damp situation
- In workshop
- Residential, commercial and public building

## LAYOUT OF HOUSEHOLD ELECTRICAL WIRING:-
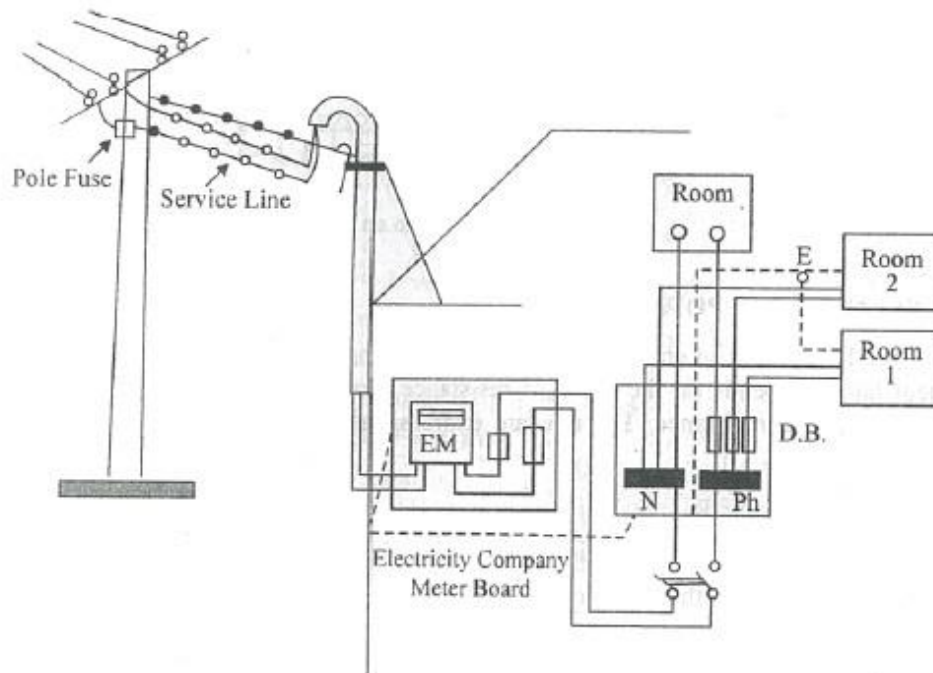


(**Fig.5.5.** Layout of Household Electrical Wiring)

## BASIC PROTECTIVE DEVICES USED IN HOUSE HOLD WIRING:-

- • Fuse
- • MCB (Miniature Circuit Breaker)
- • Lightening arrester
- • Earthing Wire

## ELECTRICAL ENERGY:-

- Energy is the capacity to do work, and is measured in joules (J).
- The electric power utility companies measure energy in watt-hours (WH) or Kilo watt-hours (KWH)

**Example 5.1.** A building has the following electrical appliances
(i) A 1 HP motor running for 5 hrs in a day.
(ii) Three fans each of 80W running for 10 hrs. in a day.
(iii) Four tube lights of 40W running for 15 hrs. per day.
Find the monthly bill for the month of November if unit cost of bill is Rs.2.50.

**Solution:**

| Sl.No. | Name of Appliances | Quantity | Power Rating in KW | Working Hrs in a day | Energy consumed in KWH |
|--------|--------------------|----------|---------------------|----------------------|-------------------------|
| 01 | Motor | 1No. | 1HP = 746W=0.746KW | 5 | 1×0.746×5=3.73 |

| 02 | Fans | 3Nos | 80W = 0.08KW | 10 | 3×0.08×10=2.4 |
|----|------|------|--------------|----|----------------|
| 03 | Tubelight | 4Nos | 40W = 0.04KW | 15 | 4×0.04×15=2.4 |
| | | | | Total Energy consumed in KWH= | 3.73+2.4+2.4=8.53 |

As we know 1KWH = 1unit

So, 8.53 KWH = 8.53 units.

In the month of November total Electrical Energy Consumed = 8.53 X 30 = 255.9 units.

Monthly bill = 255.9 X Rs.2.5 = Rs. 639.75P.

**Example 5.2.** A building has the following electrical appliances

(i) Two bulb each of 60 watt and one bulb of 100 watt.

(ii) Tube light 40 watt -2 nos.

(iii) Three Fans of 60 watt each

(iv) One Refrigerator of 150 watt.

All the lighting devices works for 6 hrs a day, fans work for 10 hrs and refrigerator works for 24 hrs. The electric tariff is as follows:- for first 100 units @ Rs. 1.40/-,next 100 units @ Rs. 2.30/- Rest @ Rs. 3.10/- .Calculate the bill for the month of 30 days.

**Solution:**

| Sl.No. | Name of Appliances | Quantity | Power Rating in KW | Working Hrs in a day | Energy consumed in KWH |
|--------|--------------------|----------|--------------------|----------------------|------------------------|
| 01 | Bulb | 2 | 0.060 | 6 | 2×0.06×6=0.72 |
| 02 | Bulb | 1 | 0.100 | 6 | 1×0.1×6=0.6 |
| 03 | Tube light | 2 | 0.040 | 6 | 2×0.04×6=0.48 |
| 04 | Fan | 3 | 0.060 | 10 | 3×0.06×10=1.8 |
| 05 | Refrigerator | 1 | 0.150 | 24 | 1×0.150×24=3.6 |
| | | | | Total energy consumed | 7.2 KWH |

As we know 1KWH = 1unit

So, 7.2KWH = 7.2units.

In the month of 30 days, total Electrical Energy Consumed = 7.2 X 30 = 216 units.

Monthly bill = 100 X Rs.1.40/- = Rs. 140/-

           100 .X Rs 2.30/- = Rs. 230/-

           16 X Rs 3.10/-  = Rs. 49.6/-

           Total = Rs. 419.6/-

# QUESTIONS FOR PRACTICE

**Short Answer Questions**

1. Expand the abbreviations VIR, PVC, CTS, and TRS.

2. Name the different types protective devices used in house wiring.

3. Define one unit of electrical energy.

4. State the relation between

      (i) Kilowatt and joule

      (ii) H.P and Joule

      (iii) Energy and power

5. Which type of wiring is used for temporary installation?

**Long Answer Questions**

1. Writes on (i) CTS wiring (ii) Conduit wiring (iii) Batten wiring (iv) Casing and capping wiring (v) Lead sheathed wiring

2. Draw a layout of wiring of a domestic installation.

3. Find out the cost of electrical energy consumed in the month of September for the following electrical appliance @ Rs. 2.30/- per unit.

 (i) Four 60 watt lamp for 8 hours.

 (ii) Six 80 watt ceiling fans for 10 hrs.

 (iii) Two A.C of 1KW for 6 hrs.

 (iv) One 0.5 HP motor for 2 hrs.

# CHAPTER-6
# MEASURING INSTRUMENTS

## INTRODUCTION TO MEASURING INSTRUMENTS:-

- The measurement of a given quantity is the result of comparison between the quantity to be measured and a definite standard. The instruments which are used for such measurements are called **measuring instruments**.
- The three basic quantities in the electrical measurement are current, voltage and power.
- The instrument which measures the current flowing in the circuit is called ammeter while the instrument which measures the voltage across any two points of a circuit is called voltmeter. The instruments which are used to measure the power are called wattmeter.

## CLASSIFICATIONS OF ELECTRICAL INSTRUMENTS:-

Electrical instruments are broadly classified into two types
**1) Absolute instruments**
Absolute instruments are those which give the value of the quantity to be measured in terms of the constants of the instrument and their detection only. No previous calibration or comparison is necessary in their case.
**Example:** Tangent galvanometer, which gives the value of current, in terms of the tangent of deflection produced by the current, the radius and number of turns of wire used and the horizontal component of earth's field.
**2) Secondary instruments**
Secondary instruments are those, in which the value of electrical quantity to be measured can be determined from the deflection of the instruments, only when they have been pre-calibrated by comparison with an absolute instrument.
**Example:** Ammeter, Voltmeter etc.

- The secondary instruments are again divided into the following three types
a) Indicating instruments
b) Recording instruments
c) Integrating instruments
**a) Indicating instruments:**
Indicating instruments are those which indicate the instantaneous value of the electrical quantity being measured at the time at which it is being measured. Their indications are given by pointers moving over calibrated dials.
Example: Ordinary ammeters, voltmeters and wattmeter
**b) Recording instruments:**
These instruments give a continuous record of the given electrical quantity which is being measured over a specific period. The examples are various types of recorders. In such recording instruments, the readings are recorded by drawing the graph. The pointer of such instruments is provided with a marker i.e. pen or pencil, which moves on graph paper as per the reading.

Example: X-Y plotter, ECG.
**c) Integrating instruments:**
These instruments measure the total quantity of electricity delivered over period of time.

Example: a household energy meter.

## <u>TORQUES IN INSTRUMENT:-</u>

In case of measuring instruments, the effect of unknown quantity is converted into a mechanical force which is transmitted to the pointer which moves over a calibrated scale. The moving system of such instrument is mounted on a pivoted spindle. For satisfactory operation of any indicating instrument, following torques must be present in an instrument.
1) Deflecting system producing deflecting torque ($T_d$)
2) Controlling system producing controlling torque ($T_c$)
3) Damping system producing damping torque

### 1) Deflecting Torque:
In most of the indicating instruments the mechanical force proportional to the quantity to be measured is generated. This force or torque deflects the pointer. The system which produces such a deflecting torque is called deflecting system and the torque is denoted as $T_d$.

### 2) Controlling Torque:
This system should provide a force so that current or any other electrical quantity will produce deflection of the pointer proportional to its magnitude. The important functions of this system are,
1) It produces a force equal and opposite to the deflecting force in order to make the deflection of pointer at a definite magnitude. If this system is absent, then the pointer will swing beyond its final steady position for the given magnitude and deflection will become indefinite.
2) It brings the moving system back to zero position when the force which causes the movement of the moving system is removed. It will never come back to its zero position in the absence of controlling system.

The controlling torque in indicating instruments may be provide by one of the following two methods.
a) By weighting of moving parts i.e., Gravity Control
b) By one or more springs i.e., Spring Control

### 3) Damping Torque:
The deflecting torque provides some deflection and controlling torque acts in the opposite direction to that of deflecting torque. So before coming to the rest, pointer always oscillates due to inertia, about the equilibrium position. Unless pointer rests, final reading cannot be obtained. So to bring the pointer to rest within short time, damping system is required. The system should provide a damping torque only when the moving system is in motion.

Damping torque is proportional to velocity of the moving system but it does not depend on operating current

The following methods are used to produce damping torque.
a) Air friction damping
b) Fluid friction damping
c) Eddy current damping.

## DIFFERENT USES OF PMMC TYPES INSTRUMENT:-

(i) Ammeter: - When PMMC used as an ammeter, except for a very small current range, the moving coil is connected across a suitable low resistance shunt, so that only small part of the main current flows through the coil.
(ii) Voltmeter: - When PMMC used as voltmeter, the coil is connected in series with high resistance. The same PMMC instrument can be used as voltmeter or ammeter
(iii) Galvanometer: - It is used to measure a small value of current along with its direction and strength.
(iv) Ohm meter: - It is used to measure the resistance of the electric circuit by applying a voltage to a resistance with the help of battery.

## DIFFERENT USES OF MI TYPES INSTRUMENT:-

● They are suitable for measurement of current, voltage and power factor in electrical circuit.
● They are used for DC as well as low frequency AC in high power circuits.
● MI ammeter can be designed for full scale deflection current of 0.1Amp to 30Amp without use of shunt
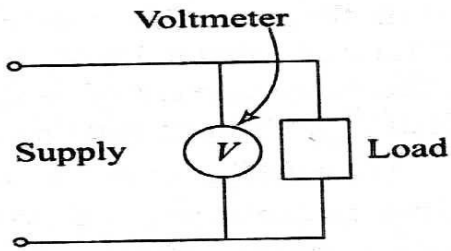● MI voltmeter of ranges over 50V without series resistance are in common use.
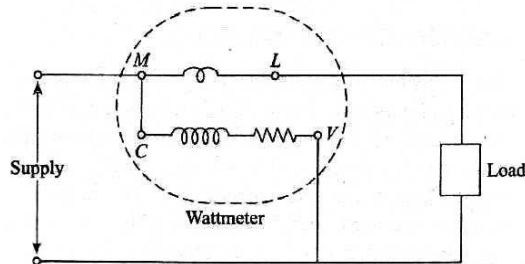
## CONNECTION DIAGRAM:-

(i) Ammeter:
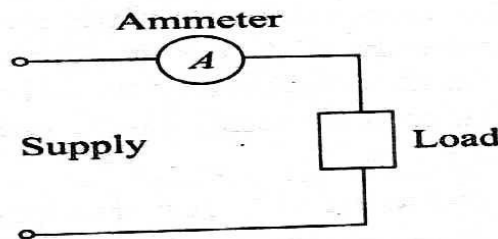


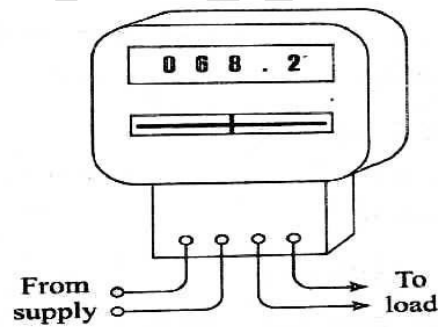(**Fig.6.1.** Connection Diagram of Ammeter)

(ii) Voltmeter:

(**Fig.6.2.** Connection Diagram of Voltmeter)

(iii) Wattmeter


(**Fig.6.3.** Connection Diagram of Wattmeter)

(iv) Energy meter


(**Fig.6.4.** Connection Diagram of Energy meter)

# QUESTIONS FOR PRACTICE

## Short Answer Questions

1. Which device is used for measuring current & voltage?
2. Draw layout diagram 1-phase energy meter used for domestic purpose.
3. Name three torques in measuring instruments.
4. Sketch connection diagram of :-
   (i) Ammeter
   (ii) Voltmeter
   (iii) Wattmeter

## Long Answer Questions

1. Discuss the torques required in measuring instruments in detail.
2. Explain uses of PMMC type instruments.
3. Explain uses of MI type of instruments.

# REFERENCES

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