VEDANG INSTITUTE OF TECHNOLOGY , BHUBANESWAR, KHORDHA

LECTURE NOTES ON

Basic Electrical & Electronics Engineering

(Th- 04(a),(b))

(As per the 2023-24 syllabus prepared by the SCTE&VT, Bhubaneswar, Odisha)

1^{st} & 2^{nd} Sem. common

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BASIC ELECTRICAL ENGINEERING

CHAPTER WISE DISTRIBUTION OF PERIODS & MARKS

Sl No.	Chapter No.	Topics	Periods as per Syllabus	Expected marks
01	01	Fundamentals	05	12
02	02	A.C Theory	08	12
03	03	Generation Of Electric Power	03	08
04	04	Conversion Of Electrical Energy	07	08
05	05	Wiring And Power Billing	04	05
06	06	Measuring Instruments	03	05
Total			30	50

CHAPTER NO:-01

FUNDAMENTALS

Learning Objectives:

1.1 Concept of current flow.
1.2 Concept of source and load.
1.3 State Ohm's law and concept of resistance.
1.4 Relation of V, I & R in series circuit.
1.5 Relation of V, I & R in parallel circuit.
1.6 Division of current in parallel circuit.
1.7 Effect of power in series & parallel circuit.
1.8 Kirchhoff's Law.
1.9 Simple problems on Kirchhoff's law.

CHARGE:-

- The most basic quantity in an electric circuit is the electric charge.
- Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field.
- Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).
- Charge may be positive or negative, is denoted by the letter q or Q.
    - electron = -ve charge
    - proton = +ve charge
    - neutron = having no charge $e = -1.6 \times 10^{-19}$ C

1.1 Concept of current flow : Current:-

The rate of flow of charge or electrons in a closed circuit is called as current.

Mathematically : $I = Q / t$.

Where Q is the charge measured in Coulombs (C),

I is the current in amperes (A) t
is the time in second (s).

 Generally currents are of Two types :

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.

Voltage (Or) Potential Difference(V) :-

A Charged body has capacity to do work by moving other charges by force of attraction or repulsion. The capacity of a charged body to do work is called electric potential.
It is also called as voltage.
Electric potential of a charged body is given by :

$$\text{Potential(V)} = \frac{work\ done(W)}{charge(Q)}$$

Unit of electric potential is joule/coulomb or volt.

Power(P) :

Power is the rate of doing work in an electric circuit.

$$\text{Electric power} = \frac{work\ done}{time}$$

Or
The electric power is the product of voltage and current.
i.e power= voltage * current .(P = V * I), watt watt = volt * ampere.
Unit of power is joule/second or Watt.

- Bigger unit of power are Kilowatt and Megawatt.
- 1KW = 1000W , 1MW= 10^6 W 1HP(HORSE POWER) = 746W

Energy(E):

Energy is the capacity to do work.
In electrical circuit the energy is the product of power and time.
Electrical Energy = power * Time

$$= P * t = V * I * t = I^2Rt = \frac{V^2}{R}t$$

It's unit is Watt-hour or KWh.

1.2 Concept of source and load:

1. 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.
Example: generator, battery, alternator.

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 orcurrent that is completely independent of other circuit elements.

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.

2. 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.

1.3 State Ohm's law and concept of resistance.

Ohm's law:-

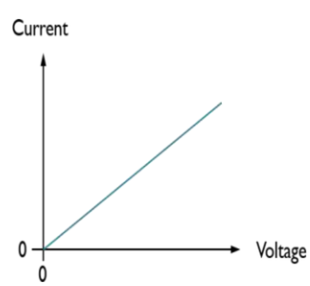
Statement: It states that" At constant temperature, the current(I) flowing through a metallic conductor is directly proportional to the potential difference(V) between the two ends of the conductor ".

Mathmatically : Iav

=> V/ I = R , => V = IR

Where R is a constant of proportionality and is called resistance of the conductor. The

V-I relation for resistor according to Ohm"s law is



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

Solution:

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

Concept of resistance:-

This physical property, or ability of a material to resist the flow of current, is known as resistance and is represented by the symbol R.
The Resistance is measured in ohms (Ω).

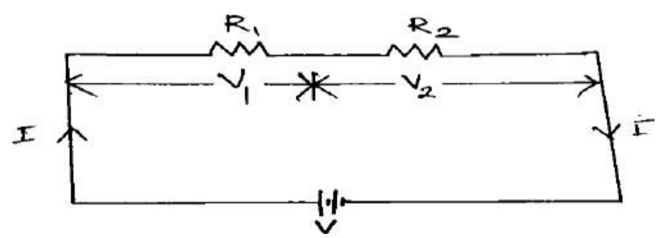
Laws of resistance : The resistance R of a conductor depends on the following factors:

- It varies directly as its length 'l'.
- It varies inversely as the cross-section 'A' of the conductor.
- It depends on the nature of the material.
- It also depends on the temperature of the conductor.

R = ϐ (L/A) ,   Where ϐ = specific resistance or resistivity.

1.4 Relation of V, I & R in series circuit :

The resistors are said to be connected in series ,if they are joined cascaded or end –on –end.



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 $V_1=iR_1$, $V_2= iR_2$--------- (1)
Here total voltage becomes

$$V= V_1 + V_2 \text{ --------------- (2)}$$

Combining equation(1) and (2), we get

$$V = V_1 + V_2 = iR_1 + iR_2 = i(R_1+R_2) \text{ -------------- (3)}$$

Equation (3) can be written as $V = iR_{eq}$ --------- *(4)*

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

From equation(3), we get $i=\frac{V}{R_{eq}} = \frac{V}{R_1+R_2}$ - - - - - -(5)

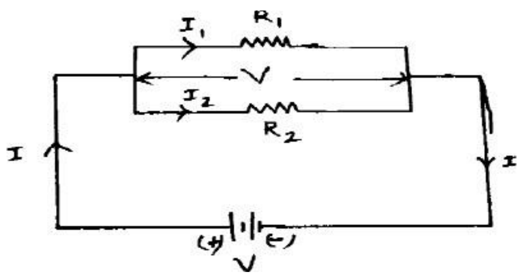
In general, the equivalent resistance of any number of resistors connected in series is the sum of the individual resistances.

Voltage Division Rule

To determine the voltage across each resistor in above fig, we substitute Eq. (5) in to Eq. (1) and obtain

$$V^1 = \frac{V}{R_1+R_2} R_1 \text{ and } V^2 = \frac{V}{R_1+R_2} R_2$$

1.5 Relation of V,I and R in parallel circuit :



The resistors are said to be connected in parallel, if the starting points of all resistors are connected in one point and finishing points are connected in one point .

where two resistors are connected in parallel andtherefore have the same voltage across them.

$$v = i_1 R_1 = i_2 R_2 \text{ -------------------- (1)}$$

$$i^1 = \frac{v}{R1} \text{ and } i^2 = \frac{v}{R2} \text{ -- - -- - - -- (2)}$$

Here total current ,

$$i = i_1 + i_2 \text{ ------------- (3)}$$

Substituting Equation 2 into 3, we get

$$i = \frac{V}{R_1} + \frac{V}{R_2} = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{V}{R_{eq}} \text{ - - -- - - - (4)}$$

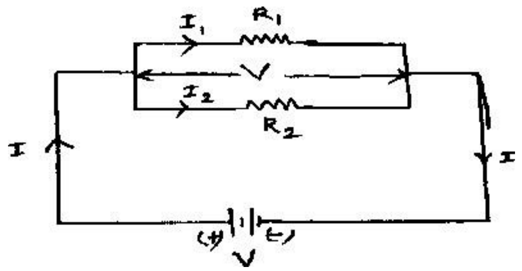
Where Req is the equivalent resistance of the resistors in parallel.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

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

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + - - - - + \frac{1}{R_N}$$

1.6 Division of current in parallel circuit:



Let,

V= Supply voltage in V.

I= Circuit current in A.

I_1= Branch current at R_1 in A.

I_2= Branch Current at R_2 in A.

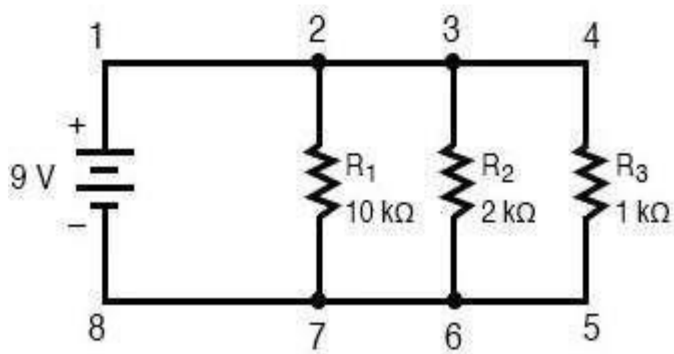
We know that the equivalent resistor has the same voltage.

$V = I\,R_{eq} = I * \frac{R_1 R_2}{R_1+R_2}$ - -- - - - - -- - - -(5)

Substituting equation (5) in I equation(2)$*R$ we get

$I_1 = \frac{I*R_2}{R_1+R_2}$ and $I_2 = \frac{1}{R_1+R_2}$

Q.1 Find the current I passing through and the current passing through each of the resistors in the circuit below.



Solution:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{10*10^3} + \frac{1}{2*10^3} + \frac{1}{1*10^3}$$

Equivalent resistance, $= 0.0016$

R_{eq} = 625 ohm.

$I = V/R_{eq}$ = 9/625 = 0.0144, A =14.4 mA

$I_{R1} = V/R_1 = 9/10 * 10^3 = 0.9$ mA
$I_{R2} = V/R_2 = 2/10 * 10^3 = 4.5$ mA I
$_{R3} = V/R_3 = 1/10 * 10^3 = 9$ mA

1.7 Effect of power in series & parallel circuit:

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

2

$_1 = \frac{V^2}{P}$ $\qquad _2 = \frac{V^2}{P_2}$ Rand Ras P= V / R

When connected in1 series, then their effective resistance is $R = R_1 + R_2$

$$\frac{V}{P} = \frac{V}{P_1} + \frac{V}{P_2}$$ 2 2 2

So

$$\Rightarrow \frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$$

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

2

$_1 = \frac{V^2}{P_1}$ $\qquad _2 = \frac{V^2}{P_2}$ Rand Ras P= V / R

When connected in parallel, then their effective resistance is

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

so $$\frac{P}{V^2} = \frac{P_1}{V^2} + \frac{P_2}{V^2}$$

$\Rightarrow P = P_1 + P_2$ **Circuit**: A circuit is a closed conducting path through which an

electric current flow.

1.8 Kirchhoff's Law:

There are two types of Kirchhoff´s law

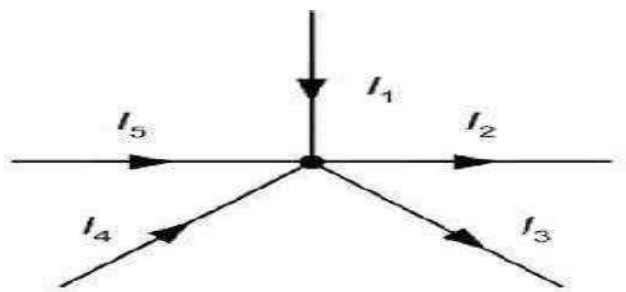
i. Kirchhoff´s current law (KCL) or point law
ii. Kirchhoff´s voltage law (KVL) or mesh law

Kirchhoff´s current law (KCL) or point law:

Statement :" The algebraic sum of currents meeting at a point or junction is zero" .

Mathematically,

$$\sum_{i=1}^{n} I = 0$$



Sign convention :

Incoming current are taken as + ve.

Outgoing current are taken as – ve

In the above figure,

I_1, I_4 and I_5 are incoming currents.

I_2 and I_3 are outgoing currents.

According to KCL,

$+I_1 - I_2 - I_3 + I_4 + I_5 = 0 \Rightarrow +I_1 + I_4 + I_5 = I_2 + I_3$ Hence Algebraic sum of currents entering a node=Algebraic sum of current leaving a node.

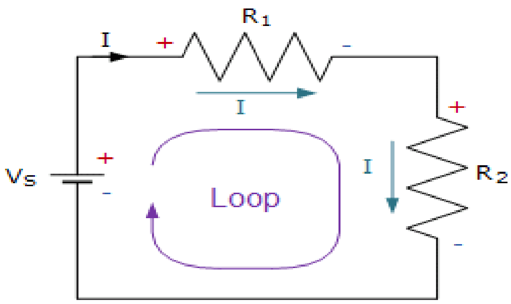
Kirchhoff´s voltage law (KVL) or mesh law:

Statement : "The algebraic sum of emf ´s and potential drops across resistors in a closed circuit is zero".

Mathematically, $\Sigma V = 0$

Sign convention for emf:

- From –ve to +ve terminal of battery ,there is a rise of potential .so emf is taken as +ve.
- From +ve to – ve terminal of battery ,there is a fall of potential.so emf is taken as –ve. **Sign convention of voltage drop:**
- Along the direction of current in a closed circuit potential drop across the resistor is taken as –ve.
- Against the the direction of current voltage is taken as +ve



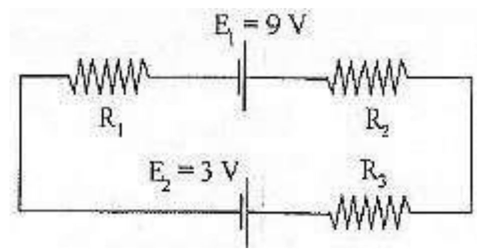
Consider the closed path ABCD in above figure .As we travel around the circuit in the clock wise direction different voltage drops will have the following signs.

Applying KVL on above circuit ,we get.

$+V_S - IR_1 - IR_2 = 0$

1.9 Simple problems on Kirchhoff's Laws:

Q-1 : If R1 = 2Ω, R2 = 4Ω, R_3 = 6Ω, determine the electric current flows in the circuit below. **Given Data :**



Resistor 1 (R1) = 2Ω

Resistor 2 (R2) = 4Ω

Resistor 3 (R3) = 6Ω

Source of emf 1 (E1) = 9 V

Source of emf 2 (E2) = 3 V

Required Data : Electric current (I)

Assumption

- First, choose the direction of the current. You can choose the opposite current or direction in the clockwise direction.
- Second, when the current through the resistor (R) there is a potential decrease so that V = IR signed negative.
- Third, if the current moves from low to high voltage (- to +) then the source of emf (E) signed positive because of the charging of energy at the emf source.
- If the current moves from high to low voltage (+ to -) then the source of emf (E) signed negative because of the emptying of energy at the emf source.

In this solution, the direction of the current is the same as the direction of clockwise rotation.

Solution :

Applying KVL to the above circuit we get :

$– I R1 + E1 – I R2 – I R3 – E2 = 0$

$– 2 I + 9 – 4 I – 6 I – 3 = 0$

$– 12 I + 6 = 0$

$– 12 I = – 6$

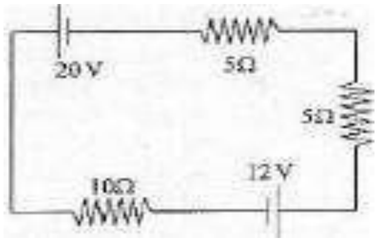
$I = -6 / -12$

$I = 0.5$

The electric current flows in the circuit are 0.5 A.

The electric current signed positive means that the direction of the electric current is the same as the direction of clockwise rotation. If the electric current is negative then the electric current is opposite to the clockwise direction.

Q. 2. Determine the electric current that flows in the circuit as shown in the figure below.



Solution
:

In this solution, the direction of the current is the same as the direction of clockwise rotation.

-20 – 5I -5I – 12 – 10I = 0

-32 – 20I = 0

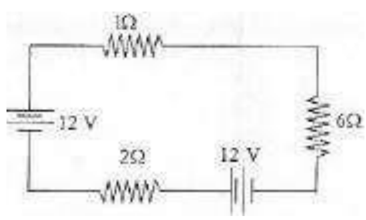
-32 = 20I

I = -32 / 20

I = -1.6 A

Because the electric current is negative, the direction of the electric current is actually opposite to the clockwise(assumed) direction. The direction of electric current is not the same as estimation.

Q.3 : Determine the electric current that flows in the circuit as shown in the figure below.



Solution :

In this solution the direction of current is same as the direction of clockwise rotation.

– I – 6I + 12 – 2I + 12 = 0

-9I + 24 = 0

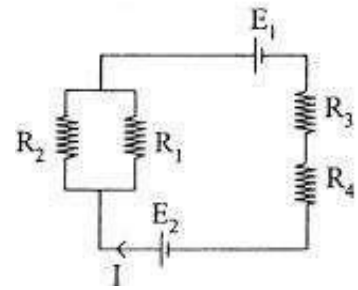
-9I = -24

I = 24 / 9

I = 8 / 3 A

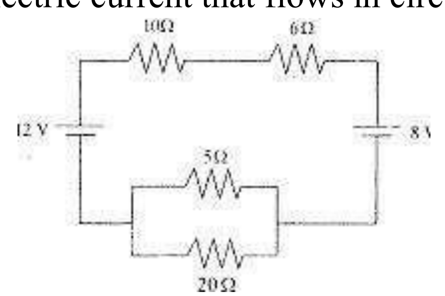
Q. 4: An electric circuit consists of four resistors, R_1 = 12 Ohm, R_2 = 12 Ohm, R_3 = 3 Ohm and R_4 = 6 Ohm, are connected with source of emf E_1 = 6 Volt, E_2 = 12 Volt. Determine the electric current flows in the circuit as shown in figure below.

Given Data :
Resistor 1 (R_1) = 12 Ω
Resistor 2 (R_2) = 12 Ω
Resistor 3 (R_3) = 3 Ω
Resistor 4 (R_4) = 6 Ω
Source of emf 1 (E_1) = 6 Volt
Source of emf 2 (E_2) = 12 Volt



Required Data : The electric current flows in the circuit (I)
Solution :
Resistor 1 (R_1) and resistor 2 (R_2) are connected in parallel. The equivalent resistor : $1/R_{12} = 1/R_1 + 1/R_2 = 1/12 + 1/12 = 2/12$
$R_{12} = 12/2 = 6$ Ω
In this solution, the direction of current is same as the direction of clockwise rotation.
$– I R_{12} – E_1 – I R_3 – I R_4 + E_2 = 0$
$– 6 I – 6 – 3I – 6I + 12 = 0$
$– 6I – 3I – 6I = 6 -12$
$– 15I = – 6$
$I = -6/-15$
$I = 2/5$ A

Q.5. Determine the electric current that flows in circuit as shown in figure below.



Given Data:
Resistor 1 (R_1) = 10 Ω
Resistor 2 (R_2) = 6 Ω
Resistor 3 (R_3) = 5 Ω
Resistor 4 (R_4) = 20 Ω
Source of emf 1 (E_1) = 8 Volt
Source of emf 2 (E_2) = 12 Volt
Required Data : The electric current that flows in circuit Solution
:

Resistor 3 (R_3) and resistor 4 (R_4) are connected in parallel. The equivalent resistor :

$1/R_{34} = 1/R_3 + 1/R_4 = 1/5 + 1/20 = 4/20 + 1/20 = 5/20$

$R_{34} = 20/5 = 4\ \Omega$

In this solution, the direction of current is same as the direction of clockwise rotation.

$– I R_1 – I R_2 – E_1 – I R_{34} + E_2 = 0$

$– 10I – 6I – 8 – 4I + 12 = 0$

$– 10I – 6I – 4I = 8 – 12$

$– 20I = – 4$

$I = -4/-20$

$I = 1/5$ A

$I = 0.2$ A

SHORT QUESTIONS WITH ANSWER:

Q-1 Define current . (W-17, S-19)

Ans: The rate of flow of charge or electrons in a closed circuit is called as current.
Mathematically : $I = q/t$
Unit of current is ampere (A).

Q-2 Define resistance. (W-17)

Ans: It may be defined as the property of a substance due to which it opposes the flow of electrons through it.
• The unit of resistance is ohm (Ω).

Q-3 Define Ohm's Law . (W-17, S-18,19,W-20)

Ans: : Statement:" At constant temperature, the current flowing through a metallic conductor is directly proportional to the potential difference between the two ends of the conductor ". Mathematically : I a v

=> $V/I = R$

Q-4 Define load.

Ans: The device which consumes electrical energy is called as load.
Example: DC motor, electric bulb, AC motor ,ceiling fan, table fan, washing machine etc.

Q-5 Define source.

Ans: The device which supplies electrons to keep the current flowing in the external circuit is called as source.
Example: Generator, Battery, Alternator.

Q-6 State KCL. (S-18,19)

Ans: **Statement** :" The algebraic sum of currents meeting at a point or junction is zero" .
Mathematically,

$$\sum_{i=1}^{n} I = 0$$

.

Q-7 State KVL. (S-18,19)

Ans: Statement "The algebraic sum of emf ´s and potential drops across resistors in a closed circuit is zero".

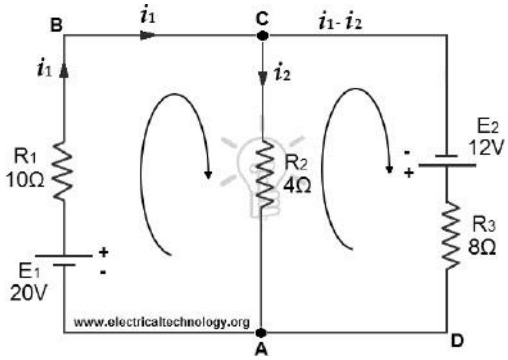
Mathematically,

$$\Sigma V = 0$$

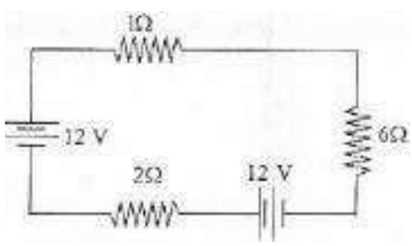
LONG QUESTIOS :

Q-1 State and explain about Kirchhoff's laws. (W-16)

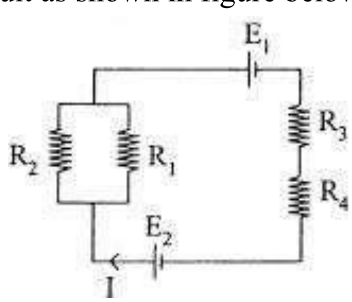
Q-2 Resistors of $R_1 = 10\Omega$, $R_2 = 4\Omega$ and $R_3 = 8\Omega$ are connected up to two batteries (of negligible resistance) as shown. Find the current through each resistor.



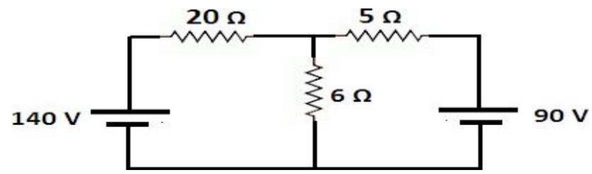
Q-3. Determine the electric current that flows in the circuit as shown in the figure below.



Q-4. An electric circuit consists of four resistors, R1 = 12 Ohm, R2 = 12 Ohm, R3 = 3 Ohm and R4 = 6 Ohm, are connected with source of emf E1 = 6 Volt, E2 = 12 Volt. Determine the electric current flows in the circuit as shown in figure below.



Q- 5.Determine the electric current that flows in circuit as shown in figure below.



Q.6 Deduce the relation of V,I,R in parallel Circuit. (S-18)

CHAPTER NO:-02 A.C THEORY

Learning Objectives:

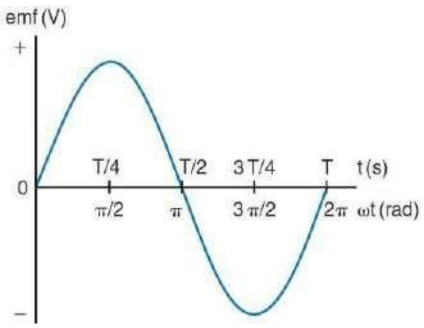
2.1 Generation of alternating emf.
2.2 Difference between D.C. & A.C.
2.3 Define Amplitude, instantaneous value, cycle, Time period, frequency, phase angle, phase difference.
2.4 State & Explain RMS value, Average value, Amplitude factor & Form factor with Simple problems.
2.5 Represent AC values in phasor diagrams.
2.6 AC through pure resistance, inductance & capacitance
2.7 AC though RL, RC, RLC series circuits.
2.8 Simple problems on RL, RC & RLC series circuits.
2.9 Concept of Power and Power factor
2.10 Impedance triangle and power triangle.

Current: The rate of flow of electrons in a closed circuit is called as current.

Types of current: According to the nature current may be A.C or D.C.

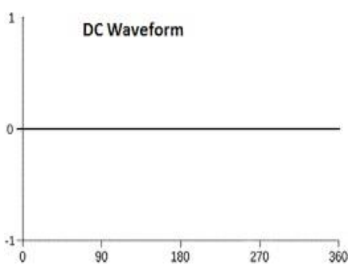
Alternating current(AC): The type of current in which magnitude and direction changes with time periodically is called AC.

Representation of AC



Sine wave

Direct current (DC): The type of current whose magnitude does not changes with time is called dc or steady current.



2.1 Generation of alternating emf :

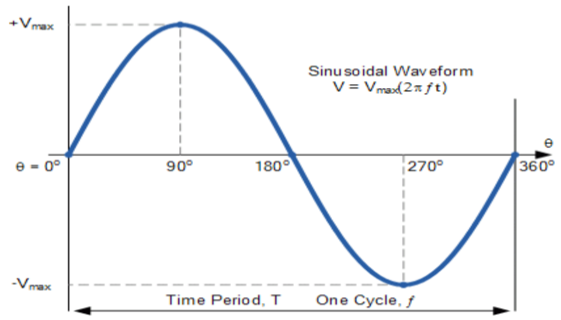
- Principle of alternating voltage and current is based upon Faraday´s laws of electromagnetic induction .
- When armature is rotated within magnetic field an induced emf is established in conductors .
- When magnetic field is rotated by its prime mover (turbine) within stationary armature (stator),magnetic fluxes are cut by the stationary conductors alternatively .So induced emf which is alternatively in nature is set-up according to electromagnetic principle.

2.2 Difference between DC and AC:

AC	DC
Here magnitude and direction changes periodically	Here magnitude and direction is always constant
Frequency of AC generation is 50 HZ in india.	Frequency on DC is zero.
It is more dangerious .	It is less dangerious.
AC usually used for several purposes .	DC is used for special purposes .
AC motor is small in nature.	DC motor is large in size of same rating.
Resistance ,inductance and capacitance comes into picture.	Only resistance.

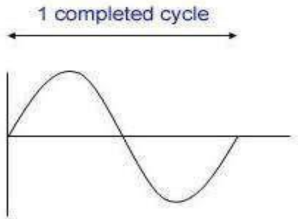
2.3 Define Amplitude,Instantaneous value,Cycle,Time period,Frequency, Phase angle,Phase difference.

Some definition related to Alternating quantity:



Cycle: One complete set of positive and negative values of an alternating quantity is called as cycle.

1cycle = 1 revolution =2∏ radians= 360^0



Time period (T): Time taken by an alternating quantity to complete one cycle is called time period.

or

It is the reciprocal of frequency (f)

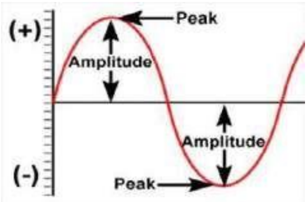
It´s unit is sec. T = 1/f

Frequency (f): The number of cycles per second is called the frequency of the alternating quantity.

It´s unit is Hertz (Hz).

f=1/T

Amplitude: The maximum value ,positive or negative of an alternating quantity is known as its amplitude, or peak value or crest value.

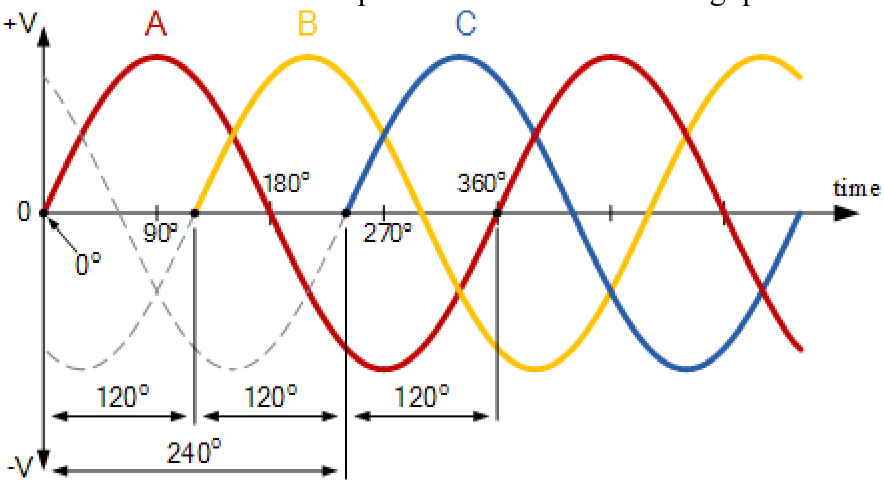


Instantaneous value: The value of an alternating quantity at any instant of time is called as instantaneous value.

Phase : Phase of an alternating quantity is meant the fraction of time period of that alternating quantity **Phase angle**: Phase angle of an alternating quantity is the fraction of angle in radian.

Phase difference :

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



Let, V(t) = Vm sin wt, here the phase is zero as function starts from origin.
V(t)= Vm sin(wt-θ), here the phase of function is θ degrees to right shift.
V(t)= Vm sin(wt+θ), here the phase of the function is θ degrees to the left shift.

2.4 State and Explain RMS value, Average value , Amplitude factor and form factor with simple problems:

RMS value: It is that value of AC which produces same heat as that of dc for a given circuit and given time.

$I_{RMS} = I_m/\sqrt{2}$

$V_{RMS} = V_m/\sqrt{2}$

Where I_M=Maximum value of current.

Average value : It is that value of AC which produces same charge as that of DC for a given circuit and given time.

$I_{AV} = 2Im/\prod$ for sine wave.

$I_{AV}= I_1+ I_2$

Form factor: It is defined as the ratio of rms value to average value of an alternating quantity .

KF = RMS value/ average value = 0.707 Im/0.637 Im= 1.1

Crest or peak or amplitude factor : (K_a) It is defined as the ratio of maximum value to rms value of an alternating quantity.

K_a= Maximum value / rms value = Im/(Im/√2)=√2=1.414

Simple problems:

Q-1: An alternating current of frequency 50Hz has a maximum value of 100A .Give its instantaneous expression . Solution Given data: f=50 HZ

Im=100A

Required data:

Instataneous current expression ? Ans:

ω=2¶f=2¶×50=100¶=100×3.142=314.2 rad/sec

We know µ

i=Im sinωt=100 sin314.2t A (Ans)

Q-2: An alternating voltage is expressed as V=300 sin314t.Find(i)Peak voltage(ii) frequency (iii)rms voltage (iv)Find the instantaneous value of 1/600 sec.

Solution:

Given data:

V=300 sin314t

t=1/600 sec

Required data:

(i) Peak voltage (Vm)=?

(ii) Frequency (f)= ?

(iii) rms voltage(VrmS)=?

(iv) V = ?

Ans:

(i) Vm=300 V (Ans)

(ii) f=314/2¶=50 Hz (Ans)

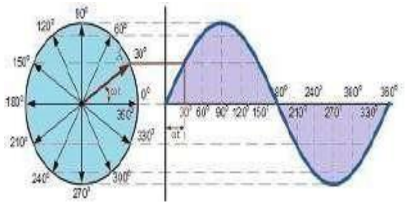
(iii) Vrms= 300/√2 =.707 ×300 = 212.1 V (Ans)

(iv) V =300 sin314 ×(1/600) = 2.74 V (Ans)

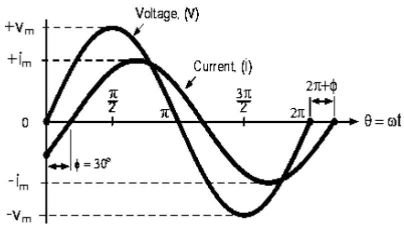
2.5 Represent AC values in phasor diagrams:

Phasor diagrams

- Phasor diagrams are the representations of voltage-current relationship in AC circuits. ➢ A phasor is a vector capable of rotating about the origin with (angular velocity) 'ω' ➢ The vertical component of phasor will represent the sinusoidally varying quantity.
- Considering V = Vm sinωt then the vertical component represents the instantaneous value of voltage.
- The magnitude(length of the vector) of the phasor is the peak value at that instant of time.



Phase Difference of a Sinusoidal Waveform

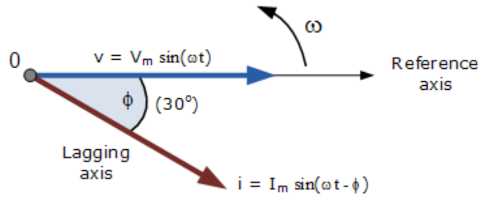


The generalised mathematical expression to define these two sinusoidal quantities will be written as:

$$v_{(t)} = V_m \sin(\omega t)$$

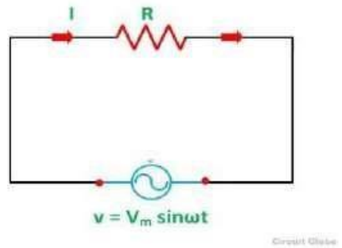
$$i_{(t)} = I_m \sin(\omega t - \phi)$$

Phasor Diagram of a Sinusoidal Waveform



2.6 AC through pure resistance ,inductance and capacitance :

AC through pure resistance:



In above figure ,

V= Applied voltage in volt.

I= Current in amp.

R= Resistance in ohm.

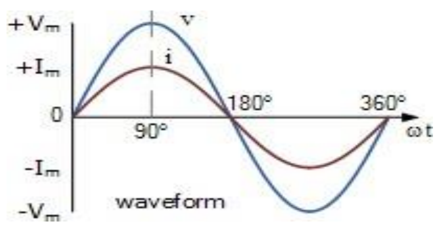
V_R=Drop across R in volt.

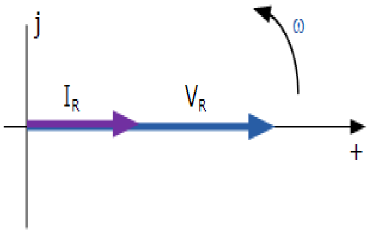
Here the voltage equation ,

V= VmSinωt .... (i)

I= ImSinωt................... (ii)

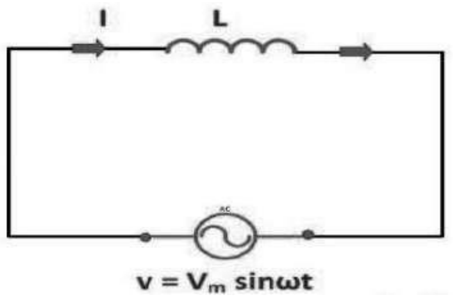
From (i) and (ii) we found that v and I are in the same phase.





(wave diagram)   (phasor diagram)

AC through pure inductance :



Let, v= applied voltage in volt. i= circuit current in amp.

L= inductance in Henry.

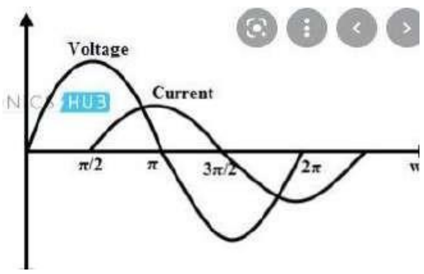
V_L= voltage across inductor in volt.

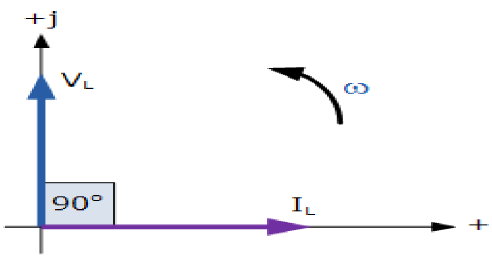
v=VmSinωt .... (i) i=ImSin(ωt−∏/2) .... (ii)

X_L=ωL= inductive reactance in ohm.

Im=Vm/ωL= Vm/X_L= maximum value of current in amp.

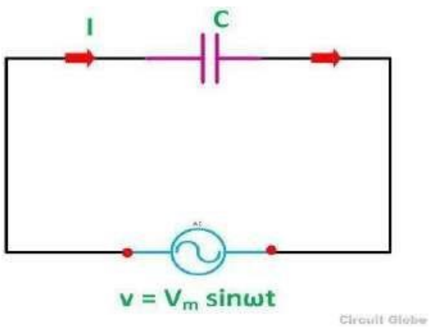
From (i) and (ii) we found that current lags behind voltage by an angle 900 or ∏/2.





(Wave diagram)   (phasor diagram)

AC through pure capacitance:



Let ,

V= applied voltage in volt.

i= current in amp. c= capacitance in farad.

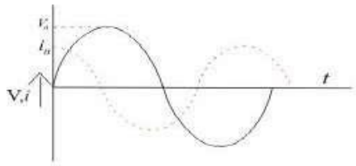
V_C=voltage drop in capacitor in volt.

v=VmSinωt .... (1)

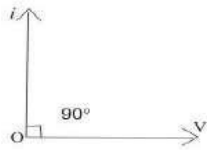
i=Im Sin(ωt+90)… .... (2)

Im=Vm/X_C= maximum current in amp X_C= 1/ωc=1/2∏fc= capacitive reactance in ohm.

From (1) and (2) we found that current leads voltage by an angle 90or ∏/2.



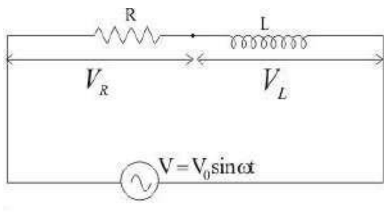
Sinusoidal representation



Phaser diagram representation

2.7 AC through RL , RC and RLC series circuit:

AC through R-L series circuit:



A.C. Circuit containing inductor and an resistor

In above fig, v= supply voltage in volt. i= circuit current in amp. R= Resistance in ohm.

L=Inductance in Henery.

V_R=Voltage drop across R in volt.

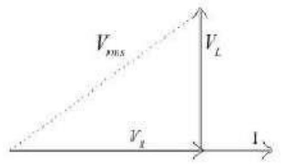
V_R= IR

V_L=voltage drop across L in inductor in volt= IX_L

X_L=ωL=2∏f L = inductive reactance in ohm.

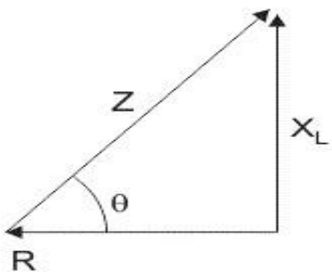
For pure resistor I and V_R are in same phase.

For pure inductor I lags behind V_L by 900.



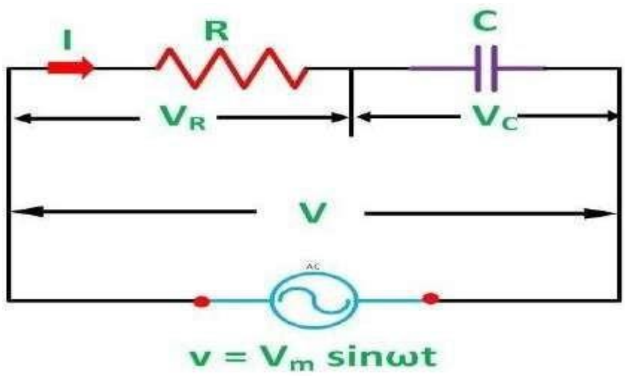
Voltage phasor diagram for LR series circuit

ϕ=phase angle between V and I.
V=√ V_{R2}+V_{L2}



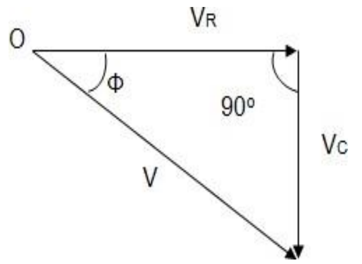
(Impedance triangle)
Z= √(R^2+X_L^2
Z=R+jX_L
Where Z= impedance in ohm.
Impedance (Z): It is the phasor sum of resistance and inductive reactance. From voltage triangle we see that I lags behind voltage by an angle ϕ.

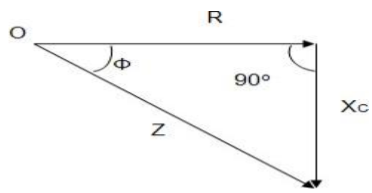
AC through R-C series circuit :



In above figure, v=
supply voltage in volt. i=
current in amp.
R= resistance in ohm.
C= capacitance in farad.
V_R= voltage drop across R in volt =IR.
V_C= voltage drop across C in volt = IX_C. X_C=
capacitive reactance in ohm.
X_C=1/2∏fc=1/ωc

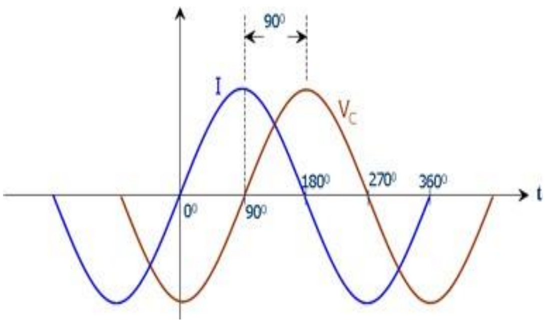
V_R and I are in same phase in a pure resistive circuit.
I and V_C by an angle 90 in a pure capacitive circuit. Taking
I as reference vector.



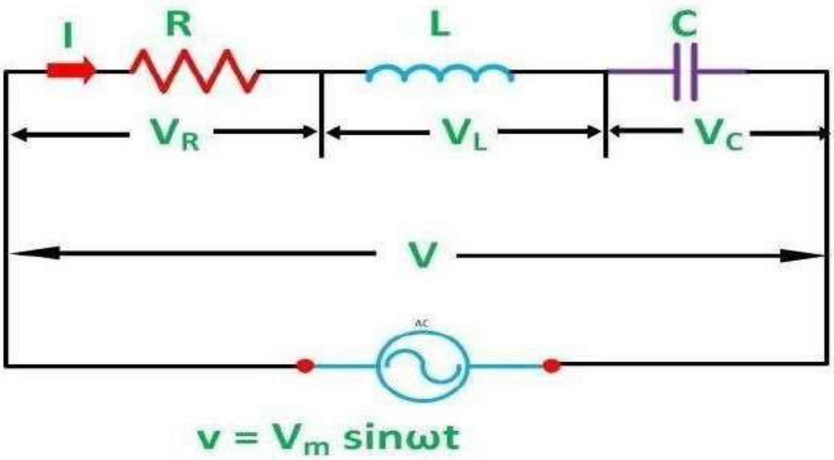


(Voltage triangle) (Impedance triangle)

$Z= R-jX_c$
$Z= \sqrt{(R^2+ Xc^2)}$
Impedance (Z):Impedance(Z) of an R-C series circuit is the phasor sum of resistance (R) and capacitive reactance(X_c).
From voltage triangle we see that I leads voltage by an angle ϕ.
Hence i= Im(Sinωt+ϕ)

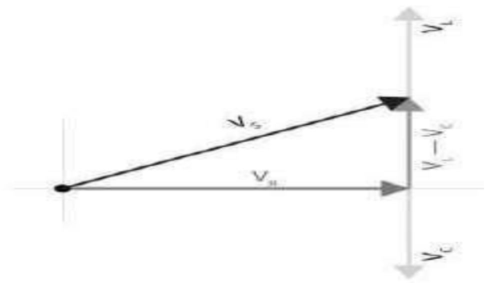


AC through R-L-C series circuit:



Let, v= supply voltage in volt.
V_R=potential drop in resistor in volt=IR.
V_L=potential drop in inductor in volt=IX_L
V_C= potential drop in capacitor in volt=IX_C
I=current in the circuit in amp. R=
resistance in ohm L=Inductance in Henery.
C= Capacitance in Farad.

X_C=Capacitive reactance in ohm=$X_C=1/2\prod fc=1/\omega c$
X_L=Inductive reactance in ohm=$X_L=\omega L=2\prod f L$ V_R
and I in same phase .
I lags VL by 90.
I leads VC by 90.



Voltage triangle for an RLC Series circuit

From above OAB right angle triangle .

$OB^2=OA^2+AB^2$

$=> V^2=(IR)^2+(IX_L-IX_C)^2 =$

$I^2R^2+I^2X_L^2+I^2X_C^2-2IX_L IX_C$

$=I^2R^2+I^2X_L^2+I^2X_C^2-2 I^2X_L X_C$

$= I^2(R^2+X_L^2+X_C^2-2X_L X_C)$

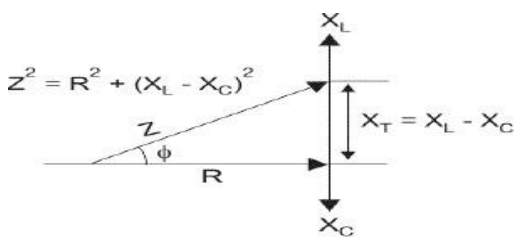
$= I^2[R^2+(X_L-X_C)^2]$

$=> V^2/I^2 =[R^2+(X_L-X_C)^2]$
$=> Z=\sqrt{[R^2+(X_L-X_C)^2]}$

$=> Z= R+j(X_L-X_C)$

$=>Z= \sqrt{R^2+X^2}$

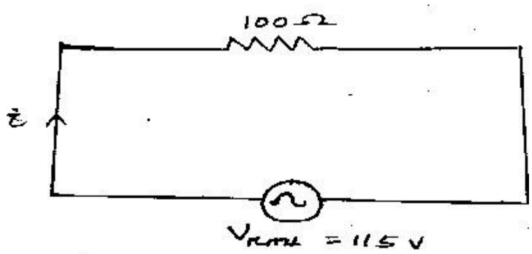
Where ,
Z= Impedance of R-L-C series circuit in ohm.
X= Net reactance of R-L-C series circuit in ohm.
$X= X_L-X_C$
Here impedance is the phasor sum of resistance (R) and net reactance (X) of R-L-C series circuit.



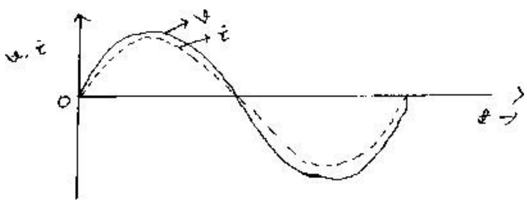
(Impedance triangle) Circuit
behaves
(a) like inductive ,if $X_L > X_C$
(b) like capacitive ,if $X_L < X_C$
So in R-L-C series circuit current lags or leads the supply voltage by angle ϕ.

2.8 Simple problems on RL , RC and RLC series circuits:

Q-1 : A 60 Hz voltage of 115 V (RMS) is impressed on a 100 Ω resistance .(i) Write the time equation for the voltage and the resulting current.Let the zero point of voltage wave be at t =0 .(ii) Show the voltage and current on a time diagram (iii) Show the voltage and current on a phasor diagram .
Solution:
Given data: f
= 60 Hz Vrms
= 115 V R =
100 Ω ϕ = 0
Required data:
(i) Write V and I time equation
(ii) Show V and I time diagram (iii) Show V and I Phasor diagram
Ans:

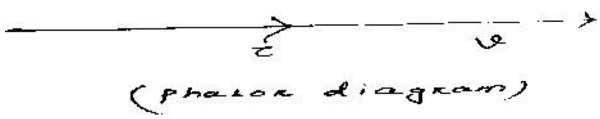


(i) We know
Vm= Vrms× √2 =115 × √2 = 162.63 V ω
= 2¶ × f = 2¶ × 60 = 376.99 = 377 rad/s
So the time equation for the voltage ,
V(t) = 163 sin377t (Ans) Then
we know i(t) = Im sinωt
Im = Vm/R = 163 /100 = 1.63 A
So the time equation for the current , i(t)
= 1.63 sin377t (Ans)
(ii)



wave diagram or time diagram

(iii)



Q-2 : The reactance of a capacitor at 50 Hz is 5 Ω.If the frequency is increased to 100 Hz .Calculate the new capacitive reactance .

Solution :

Given data:

X_C = 5 Ω f

= 50 Hz

R = 5 Ω

Required data:

X_C1= ?

Ans:

X_C = 1/2¶fc

=> C = 1/(2¶×f× XC)

=> C = 1/(2¶×50×5) =0.00063 F

X_C1 = 1/(2¶×100×0.00063) = 0.25 Ω (Ans)

Q-3 : A 50 µF capacitor is connected across a 230 V, 50 Hz supply .Calculate (a) the reactance offered by the capacitor (b) the maximum current and (c) the rms value of the current drawn by the capacitor .

Solution:

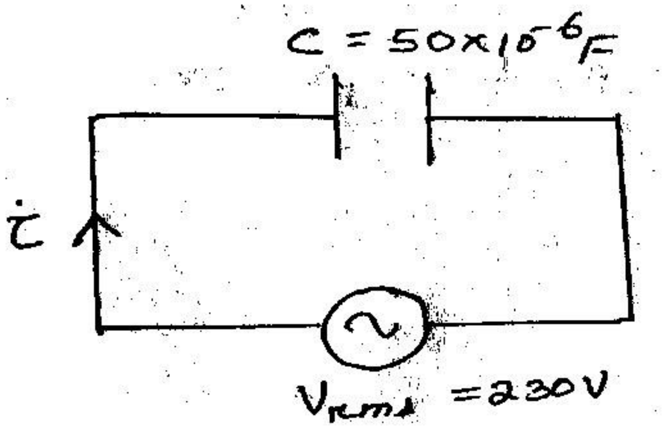
Given data:

C=50µF=50×10-6F

Vrms=230V f=50Hz

Required data:

(a) X_C=? (b) Im=? (c) Irms=?



Ans:

We know,

(a)X_C=1/2¶fc=1/(2¶×50×50×10-6)=63.66 Ω (Ans)

(b) Vm=Vrms×√2=325.26 V

Im=Vm/X_C=325.26/63.66=5.10Ω (Ans)

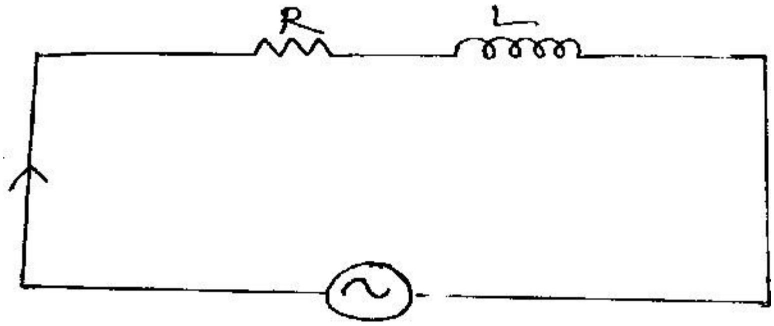
(c) Irms= Im/√2=5.10/√2=3.61 A (Ans)

Q-4 A choke coil takes 4A from AC source of 20V and 50Hz .The power factor of the coil is 0.8 lagging .Find the resistance and inductance of the circuit .

Solution:

Given data:

R-L series circuit
I=4A ,V=20V ,f=50Hz ,pf=0.8(lagging) Required data:
(a) R=? (b) L=? Ans:



(a) we know ,Z=V/I=20/4=5 Ω,

cosØ= R/Z =>R=ZcosØ=5×0.8=4Ω (Ans)

$Z^2=R^2+X_L^2$

$=>5^2=4^2+X_L^2$

$=>X_L^2=25-16$

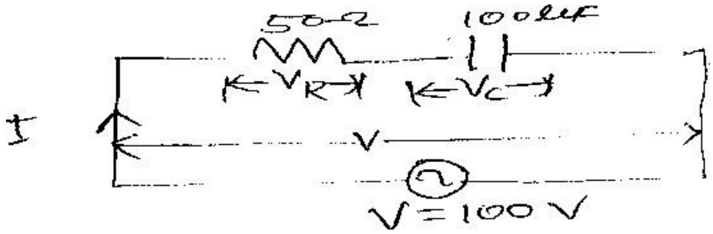
$=>X_L=\sqrt{9}=3\Omega$ (Ans)

$X_L=\omega L=2$¶fL

$=>L=X_L/2$¶$f=3/(2$¶$\times 50)=0.0095$ H (Ans)

Q-5 A pure resistance of 50Ω is in series with a pure capacitance of 100μF.The series combination is connected across 100V,50Hz supply.Find (a) the impedance (b) current (c) power factor (d) phase angle (e) voltage across resistor (f) voltage across capacitor. Solution:
Given data:
V=100V f=50Hz
C=100μF=100×10-6F
R=50Ω
C=100μF=100×10-6F
Required data:
(a) Z=?
(b) I=?
(c) pf=?
(d) ϕ=?
(e) VR=?

Ans:



We know,
X_C=1/2¶fc=1/(2¶×50×100×10^{-6})=31.83 Ω

(a) Z=√R^2+X_C^2=√50^2+31.83^2=59.27Ω (Ans)

(b) I=V/Z=100/59.27=1.687 A (Ans)

(c) p.f= R/Z=50/59.27=0.843 (Lead) (Ans)

(d) ϕ=$\cos^{-1}$(0.843)=32.54° (Ans)

(e) V_R=IR=1.687×50=84.35 V (Ans)

(f) V_C=IX_C=1.687×31.83=53.69 V (Ans)

Q-6 A series circuit consists of resistance of 10Ω and inductive reactance of 50Ω and capacitive reactance of 30Ω.It is connected to a 230V,50Hz ac supply.calculate (i) the current(ii) active and reactive power consumed (iii) power factor(iv)apparent power of the circuit .

Solution:

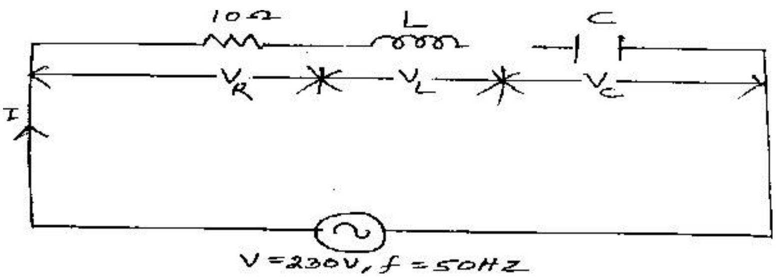
Given data: Required data:

R-L-C series circuit (i) I=?

R=10Ω (ii) cosϕ=?

X_L=50Ω (iii) P=? and Q=?

X_C=30Ω (iv) S=? V=230V f=50Hz Ans:



We know,

Z=√R^2+$(X_L-X_C)^2$=√10^2+$(50-30)^2$=√100+400=√500=22.36Ω

(i) I=V/Z=230/22.36=10.28A (Ans)

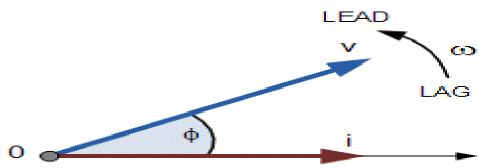
(ii) cosϕ=R/Z=10/22.36=0.44(lagging) (Ans) ϕ=$\cos^{-1}$(0.44)=63.89^0

(iii)Active power, P=VIcosϕ=230×10.28×0.44=1040.33=1.043 KW (Ans)
Reactive power ,Q=VI sinϕ=230×10.28×sin 63.89=2123.11 VAR=2.123 KVAR (Ans)

(iv) Apparent power ,S = √P^2+Q^2=√1.043^2+2.123^2=2.36 KVAR(Ans)

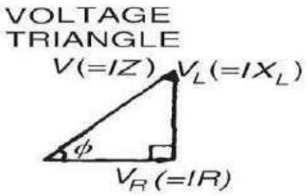
2.9 Concept of power and Power factor (p.f): Power factor can be defined as follows :

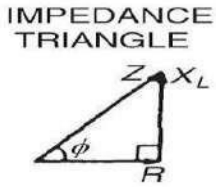
(1) It is the cosine angle made by phase voltage and phase current.



p.f=cosϕ

(2) p.f: It is the ratio of resistance to impedance.





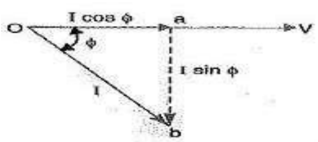
Cosϕ=V_R/V　　　　Cosϕ=R/Z

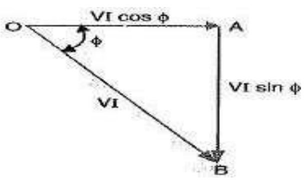
Power in A.C circuit:

Power (p) is known to be three types

(i) Active power or real power or actual power.

(ii) Reactive power or virtual power . (iii) Total power or apparent power.





Active power(p): It is the product of voltage and active component of current .

P=V I COSϕ

Its unit is watt,kilowatt,megawatt in SI unit.

Reactive power (Q): It is the product of voltage and reactive component of current .

Q= VI sin ϕ.

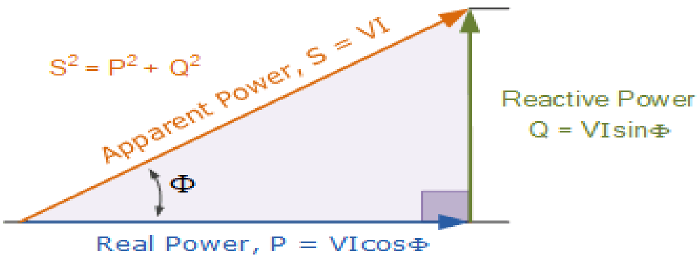
Its unit is VAR,KVAR,MVAR in SI system.

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

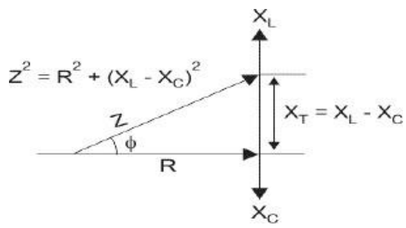
S= V I.

Its unit is VA,KVA,MVA in SI system.

2.10 Impedance triangle and power triangle:



(POWER TRIANGLE)



(Impedance triangle)

SHORT QUESTIONS WITH ANSWER:

Q-1 Define AC current.
Ans: The type of current in which magnitude and direction changes with time periodically is called as AC.

Q-2 Define frequency. (S-18)
Ans: The number of cycles per second is called the frequency of the alternating current.

Q-3 Define amplitude . (W-17)
Ans: The maximum value of positive or negative o an alternating quantity is known as its amplitude or peak value or crest value.

Q-4 Define time period .
Ans: Time taken by an alternating quantity to complete one cycle is called time period .

Q-5 Define form factor . (S-18,19)
Ans: It is defined as the ratio of rms value to average value of an alternating quantity .

Q-6 Define Amplitude factor or crest factor . (S-18,19)
Ans: It is defined as the ratio of maximum value to rms value of an alternating quantity.

Q-7 Define impedance.
Ans: It is the phasor sum of resistance and net reactance of the R-L-C series circuit.

Q-8 Define power factor. (S-19, W-19)
Ans: It is the cosine of angle made by phase voltage and phase current.
$\cos\phi = \frac{R}{Z}$

Q-9 Define active power.
Ans: It is the product of voltage and active component of current.
$P=VI\cos\phi$, W

Q-10 Define reactive power.
Ans: It is the product of voltage and reactive component of current.
$Q=VI\sin\phi$,VAR

Q-11 Define apparent power .
Ans: It is the product of voltage and current . S=VI
,VA

LONG QUESTIONS:

Q-1 Write the difference between AC and DC. (W-19)

Q-2 : A 60 Hz voltage of 115 V (RMS) is impressed on a 100 Ω resistance .(i) Write the time equation for the voltage and the resulting current.Let the zero point of voltage wave be at t =0 .(ii) Show the voltage and current on a time diagram (iii) Show the voltage and current on a phasor diagram . **Q-3** The reactance of a capacitor at 50 Hz is 5 Ω.If the frequency is increased to 100 Hz .Calculate the new capacitive reactance .

Q-4 A 50 μF capacitor is connected across a 230 V, 50 Hz supply .Calculate (a) the reactance offered by the capacitor (b) the maximum current and (c) the rms value of the current drawn by the capacitor. **Q-5** A series circuit consists of resistance of 10Ω and inductive reactance of 50Ω and capacitive reactance of

30Ω.It is connected to a 230V,50Hz ac supply. calculate (i) the current(ii) active and reactive power consumed (iii) power factor(iv)apparent power of the circuit .

Q.6 Explain a.c through R-C series circuit. (S-18,19)

Q.7 Explain a.c through R-C series circuit. (S-18)

CHAPTER-3 GENERATION OF ELECTRICAL POWER

Learning Objectives:

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

Power plant :

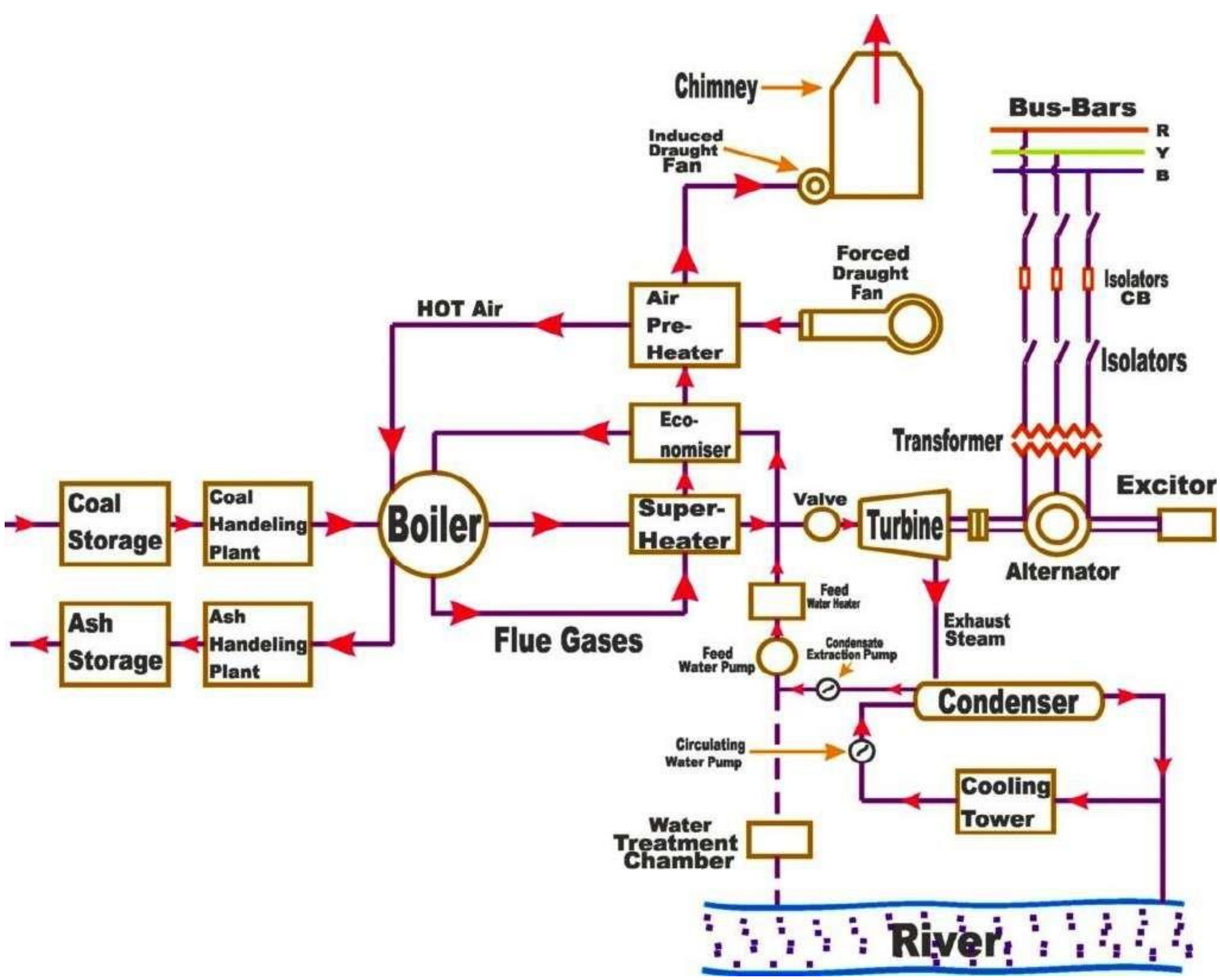
Bulk electric power is produced by special plants known as generating stations or power plants.

1. Steam power station (thermal station)
2. Hydro-electric power station
3. Nuclear power station

3.1 Generation of electricity from thermal power station:

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

SCHEMATIC ARRANGEMENT OF STEAM POWER STATION



Working of Thermal power Plant :

In thermal power plant ,coal, hot air, hot water taken into boiler. The coal are burnt in the boiler which converts hot water into high pressure steam. This high pressure steam, super heated in the super heater by flue gases. Now superheated high pressure steam passed through valve into the turbine blade ,so steam turbine blade rotate .Then turbine able to rotate the alternator ,because turbine shaft and alternator shaft coupled with each other .So the electrical power /energy produced in the alternator .The alternator energy is supplied to bus bar through circuit breaker.

ADVANTAGES :

- The Fuel (i.e. Coal) used is quite cheap.
- Less initial cost as compared to other generating stations.
- It can be installed at any place & the coal can be transported by Rail /Road.
- It requires less space as compared to hydro-electric PowerStation.

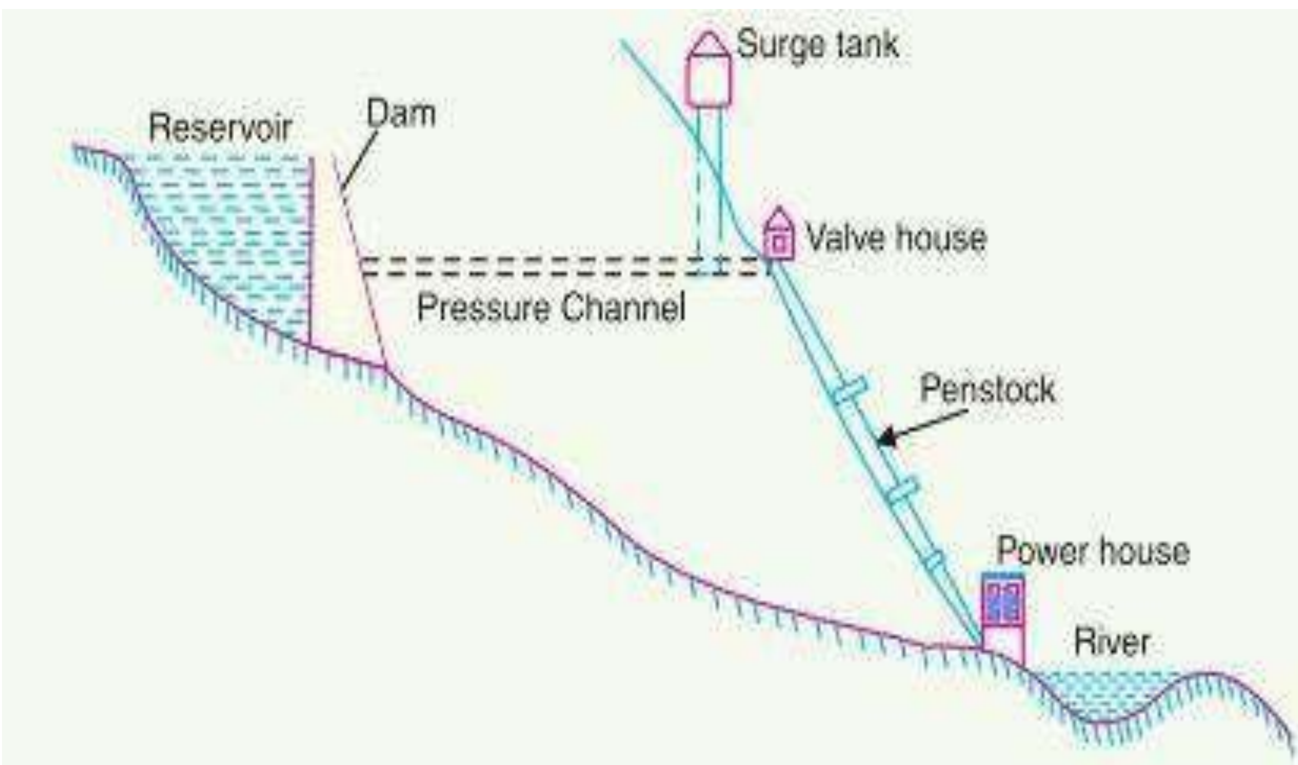
DISADVANTAGES

- It pollutes air / atmosphere due to smoke /fumes. ➢ Running cost is higher than hydro power plant.

3.1 Generation of electricity from Hydro-electric power station:

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.

SCHEMATIC ARRANGEMENT OF HYDROELECTRIC POWER PLANT:



Working of Hydro-Electric Power Plant :

In hydroelectric power plant ,water stores in a reservoir by constructed a dam across a river or lake. Then water passed through surge tank and valve house by pressure channel to the penstock. From penstock water strikes water turbine blade ,hence turbine rotate .Once water turbine, alternator rotate. So the electrical energy produced in the alternator.

ADVANTAGES :

- It requires no fuel as water is used for the generation of Electrical Energy.
- It is quite neat & clean as no smoke or ash is produced.
- Running cost is very less as water is used.
- It is simple in construction & requires less maintenance.
- It can be started quality as compared to Thermal PowerStation.
- In addition to generation of Electrical Energy these plants are also helpful in irrigation & control of floods.

DISADVANTAGES

- It involves high capital lost due to construction ofdams.
- Generation depends on average rainfall round the year.
- High cost of transmission as these plants are located in hilly areas quite for off from localities.

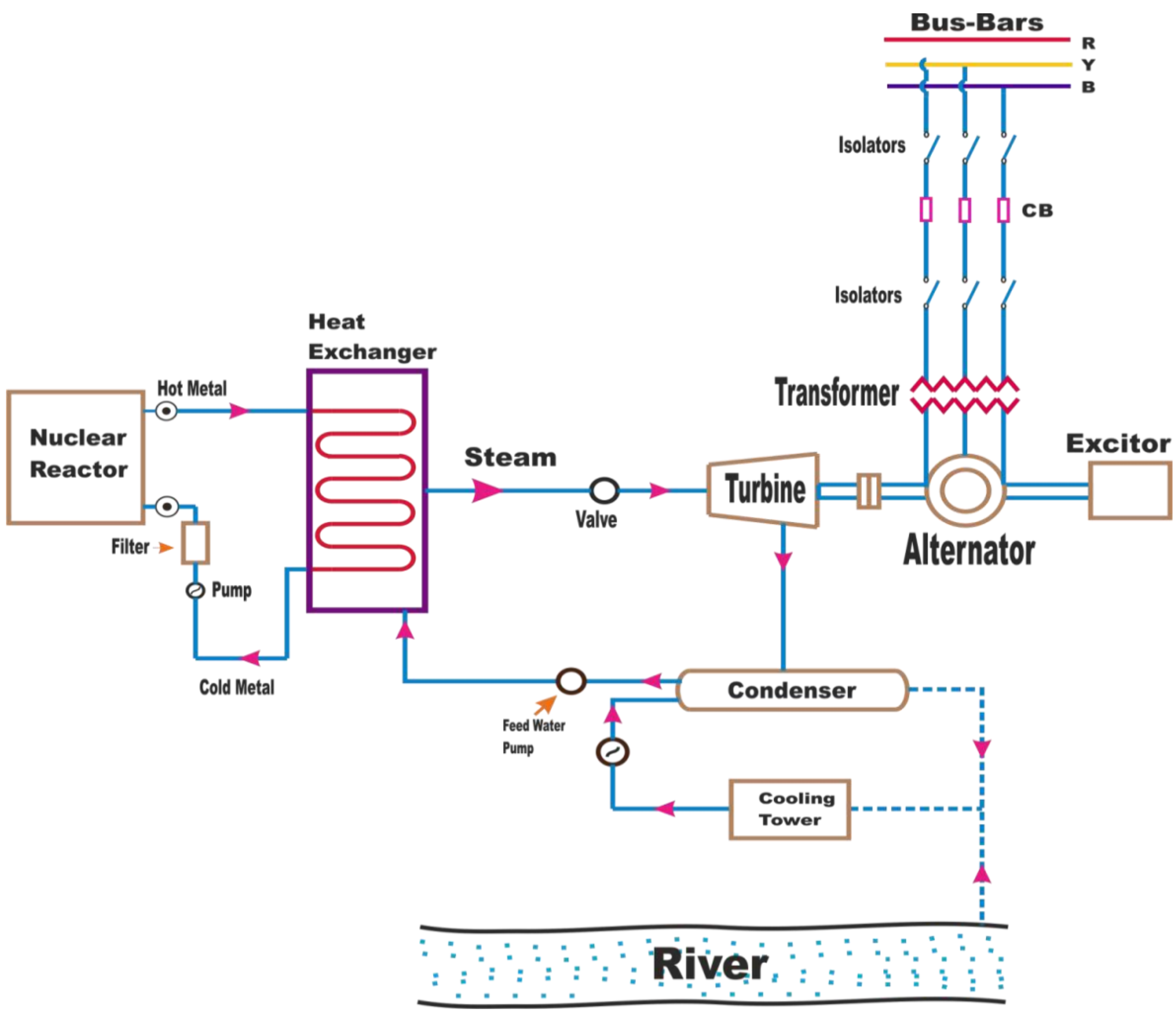
3.1 Generation of electricity from Nuclear power station:

A generating station in which nuclear energy is converted into electrical energy is known as a nucler power station .

NUCLEAR FUEL

I. URANIUM(U^{235})
II. PLUTONIUM(Pu^{239})
III. THORIUM(Th^{232})

SCHEMATIC ARRANGEMENT OF NUCLEAR POWER STATION :



Working of Nuclear PowerPlant:

In nuclear power station ,radio active elements such as Uranium (U) or Thorium (Th) are subjected to nuclear fission in a special apparatus known as a reactor. The heat energy thus released in nuclear reactor utilized in producing steam ,by heat exchanger at high pressure steam strikes the stem turbine blade which converts steam energy into mechanical energy. The turbine drives the alternator ,which converts mechanical energy into electrical energy.

ADVANTAGES :

- There is saving in fuel transportation as amount of fuel required is less.
- A Nuclear Power Plant requires less space as compared to other plants.
- This type of plant is economical for producing bulk Electrical Energy.

DISADVANTAGES :

- Fuel is expensive and difficult to recover.
- Capital lost is higher than other plants.
- Experienced workman ship is required for plant erection &commissioning.
- The Fission by-products are radio active & can cause dangerous radio-active pollution. The disposal of by-product is big problem.

Short questions with answer:

Q-1 Write down the function of superheater.
Ans- Over all efficiency is increased. Too much condensation in the last stage of turbine is avoided.

Q-2 Write the function of economizer.(W-17)
Ans: It is a feed water heater to the boiler. It increases the feed water temperature.

Q-3 Write down the function of air preheater. (S-19)
Ans: It increases the temperature of the air supplied for coal burning by deriving heat from flue gases. It Increases the thermal efficiency. It increases the steam capacity per square metre of boiler surface.

Q-4 Write down the function of penstocks. Ans: Penstocks are open or closed conduits which carry water to the turbine.

Q-5 Write the function of surge tank . (W-20) Ans: It protects the penstocks from over load and low load condition.

Q-6 Write the function of spillways .
Ans: In order to discharge the surplus water from the storage reservoir into the river on the down stream side of the dam ,spillways are used.

Q-7 Write down the function of dam. Ans: A dam is a barrier which stores water and creates water head.

Q-8 Write down the fuel name of nuclear powe station .
Ans: Uranium (U^{235}) and Thorium (Th^{232}).

Q-9 Write down the function of condensers .
Ans: A condenser is a device which condenses the steam at the exhaust of turbine. It creates low pressure at the exhaust of turbine thus permitting expansion of the steam in the prime mover to a very low pressure. Condensed steam can be used as feed water to the boiler .

Q-10 Write down the types of steam turbines used as prime mover in steam power station. Ans: There are two types of steam turbine used in a power station that is impulse turbine and reaction turbine.

Q-11 Write down the name of control rod used in a nuclear power plant.
Ans: The name of control rod used in a nuclear power plant is cadmium.
Q-12 Write down the function of control rod . Ans: Cadmium is strong neutron absorber and thus regulates the supply of neutrons for fission.

Q-13 Write down the name of coolant used in a nuclear power plant. Ans: The name of coolant used in a nuclear power plant is sodium metal.

Q-14 Write down the name of moderator used in a nuclear power plant.
Ans: The moderator used in a nuclear power plant is graphite.

Long questions:

Q-1 Explain with neat sketch about Thermal power plant.(S-18)

Q-2 Explain with neat sketch about Hydroelectric power plant. (W-17, S-19)

Q-3 Explain with neat sketch about nuclear power plant.(S-18, W-19, S-19)

CHAPTER 4.0 CONVERSION OF ELECTRICAL ENERGY

Learning Resources:

4.1 Introduction of DC machines.
4.2 Main parts of DC machines.
4.3 Classification of DC generator
4.4 Classification of DC motor.
4.5 Uses of different types of DC generators & motors.
4.6 Types and uses of single phase induction motors.
4.7 Concept of Lumen
4.8 Different types of Lamps (Filament, Fluorescent, LED bulb) its Construction and Principle.
4.9 Star rating of home appliances (Terminology, Energy efficiency, Star rating Concept)

4.1 Introduction of DC machines.

The electromagnetic system is an essential element of all rotating electrical machines and electrochemical devices as well as static devices like the transformer. Practically all electric motors and generators ,ranging in size from fractional kilowatt power units found in domestic appliances to the several thousand kW motors used in heavy industries and several hundred MW generators installed in generating stations.

DC machine

DC generator **DC motor**

DC generator : It is defined as a DC electrical machine which converts mechanical energy into electrical energy .

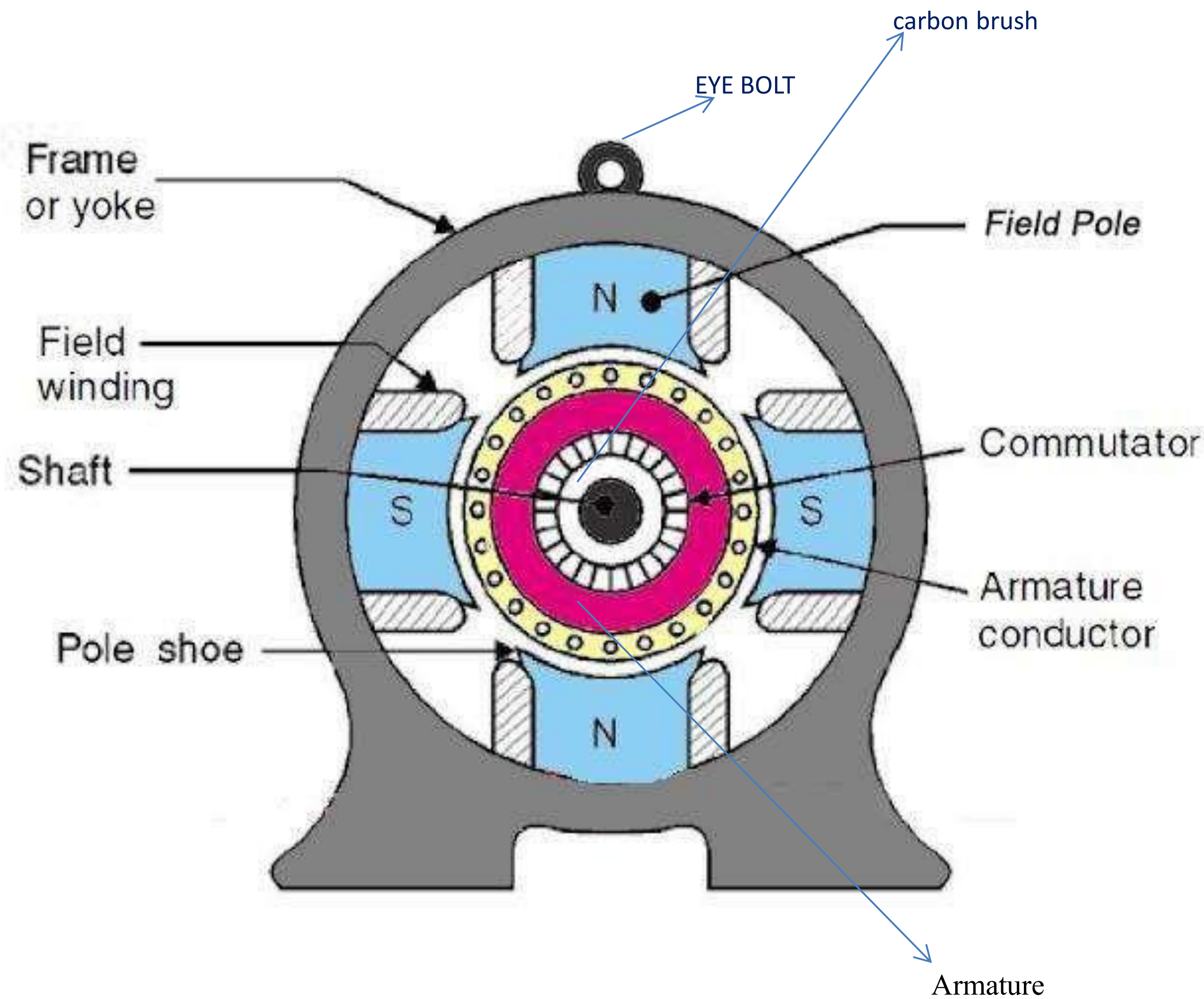
DC generator principle: It based on the principle of dynamically induced emf.

DC motor: It is defined as DC electrical machine which converts electrical energy into mechanical energy .

DC motor principle: It works under the principle that " Whenever a current carrying conductor is placed in a magnetc field then a mechanical force is experienced by the conductor ".

4.2

Main parts of DC machines:

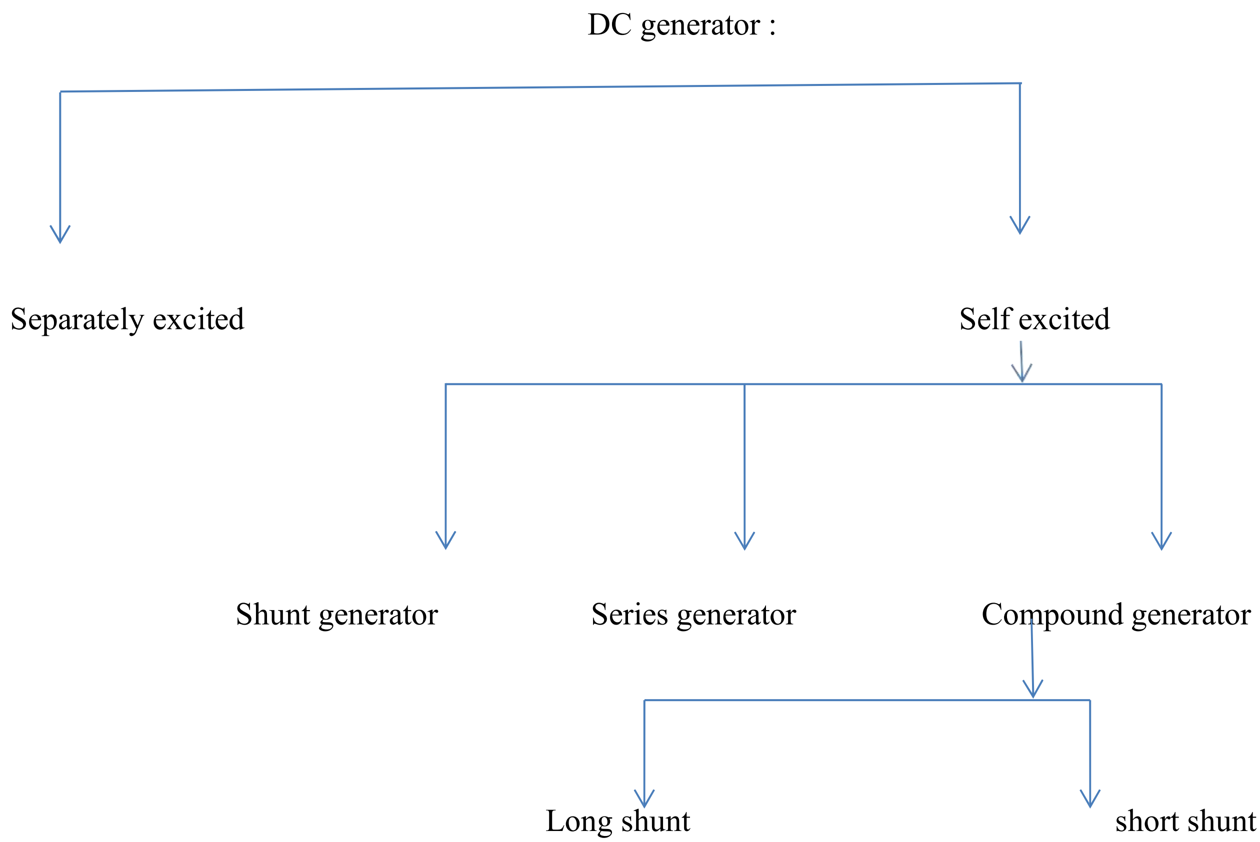


Following are the important parts of a DC machine,

- Eye bolt
- Yoke
- Field winding
- Pole shoes
- Field pole
- Armature conductors and windings
- Armature
- Commutator
- Carbon brush

4.3

Classification of DC generator:



Separately excited DC Generator: If field windings of a DC generator are excited by some external DC source then it is called as separately excited DC generator.

Self excited DC generator: If the field windings of a DC generator are excited or energized by the current produced of its own then it is said to be self excited DC generator.

DC shunt generator: If field windings of a self excited DC generator are connected in parallel then it is called as DC shunt generator .

DC series generator: If the field windings of a self excited DC generator are connected in series then it is called as DC series generator .

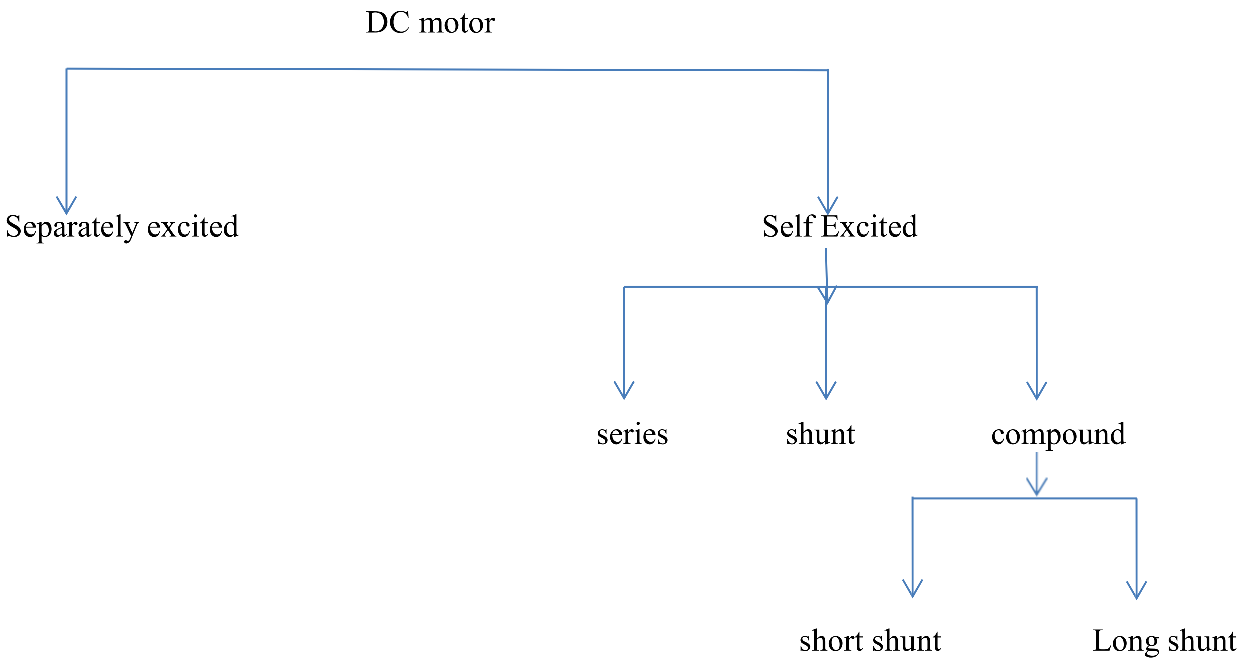
DC compound generator : In a self excited DC generator ,if shunt field windings are simultaneously used then it is called as DC compound generator .

Long shunt compound generator: In a compound generator if shunt field winding is connected across both the series field and armature winding then it is called as long shunt compound generator .

4.4

Short shunt compound generator: If shunt field winding of a compound generator is connected across the armature only leaving the series field then it is called as short shunt compound generator.

Classification of DC motor:



4.5 Uses of different types of DC generators:

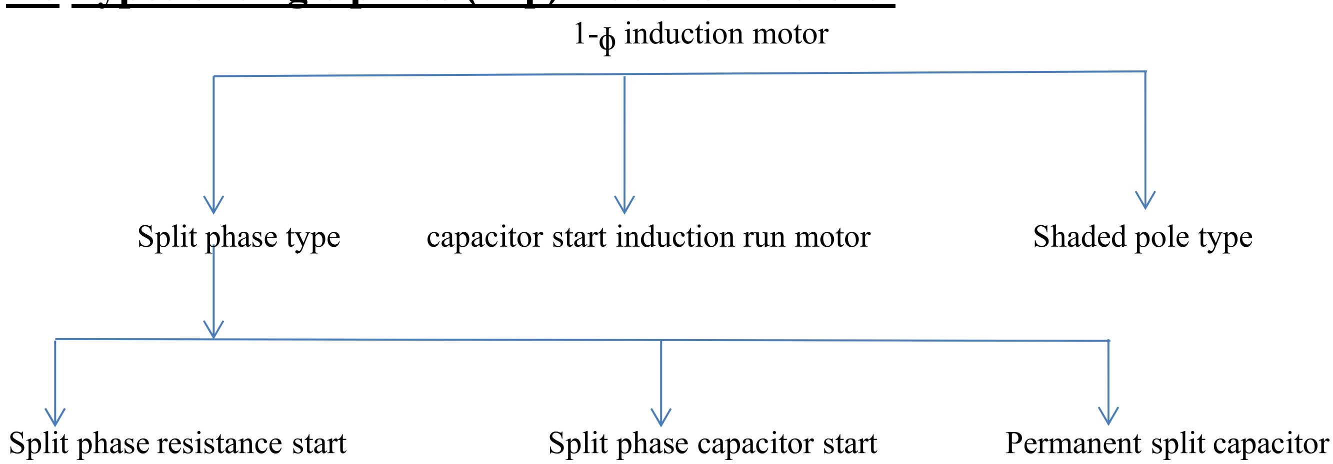
Name of DC generator	Applications
Series generator	➢ Ordinary lighting and power supply purposes. ➢ Charging batteries.
Shunt generator	➢ Booster ➢ Railway distribution systems
Compound generator	➢ Electric railways. ➢ Motor drives. ➢ Arc weldings

Uses of different types DC motors:

4.5

Name of DC motor	**Applications**
Shunt motor	➢ Centrifugal pumps. ➢ Machine tools. ➢ Blowers and fans. ➢ Reciprocating pumps.
Series motor	➢ Electric locomotives. ➢ Rapid transit system. ➢ Cranes and hoists. ➢ Tolley cars. ➢ Conveyors
Compound motor	➢ Shears and punches. ➢ Elevators. ➢ Rolling mills. ➢ Ice machines. ➢ Air compressors. ➢ Printing press.

4.6 Types of single phase (1-ϕ) induction motors:



Uses of single phase (1-ϕ) induction motor:

Name of single phase induction motor	**Uses**

4.6

Split phase resistance start induction motor.	➢ Blower ➢ Centrifugal pumps ➢ Washing machine ➢ Small machine tools ➢ Small domestic refrigerator
Split phase capacitor start induction motor	➢ Compressor ➢ Washing machine ➢ Air conditioner ➢ Refrigerator
Permanent split capacitor induction motor	➢ Ceiling fan ➢ Table fan ➢ Pedestal fan ➢ Exhaust fan ➢ Water pumps

4.7 Concept of Lumen: It is the product of candle power and solid angle.

lumens=candle power × solid angle

=C.P × ω

Candle power: Candle power of a source is the number of lumens emitted in a unit solid angle in a given direction.

or

It is defined as the number of lumens per unit solid angle.

C.P= Lumens/ω

Solid angle(ω): A solid angle(ω) is subtended at a point in space by an area and is the angle enclosed in the volume formed by an infinite number of lines lying on the surface of the volume and meeting at a point.

Solid angle, $\omega = \text{Area}/(\text{Radius})^2 = A/R^2$

Solid angle is represented in steradian.

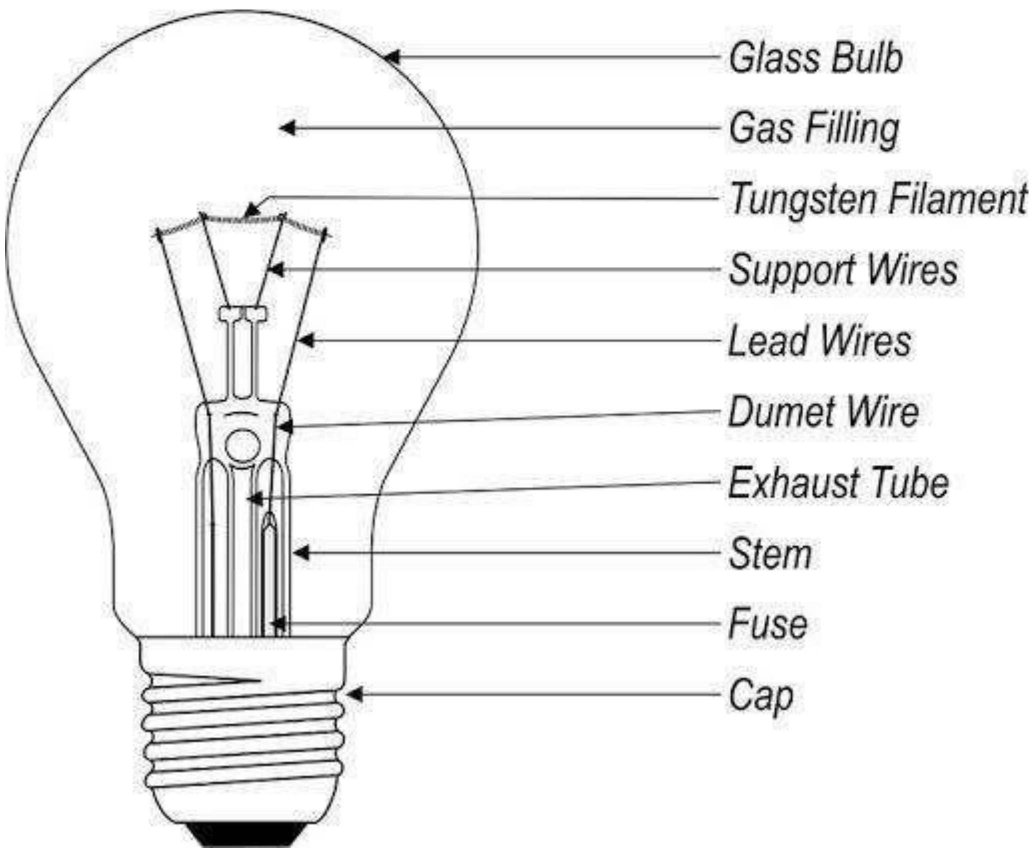
4.8 Different types of lamps:

- Filament lamps
- Florescent lamp
- LED bulb

Filament lamp:

Principle: Filament lamp work on the principle of incandescence.

Construction:

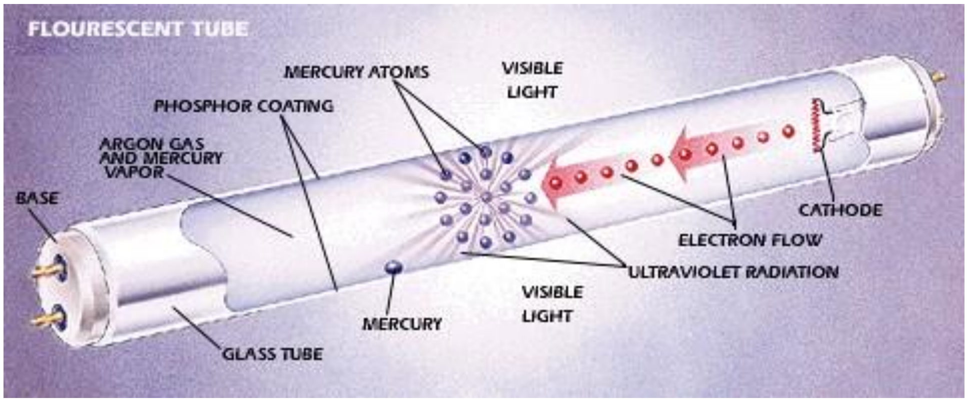


One glass bulb holds the filament inside it. The lamp has a metal cap. This metal cap provides the electrical connectivity to the filament from an external electrical circuit. This cap also helps the holder to hold the lamp. In the vacuum type variant, the air is sucked out from the bulb. But in the gas-filled variant we fill the bulb with argon or nitrogen like inert gases.

Florescent lamp:

principle: Florescent lamp work on the principle of florescence.

Construction:



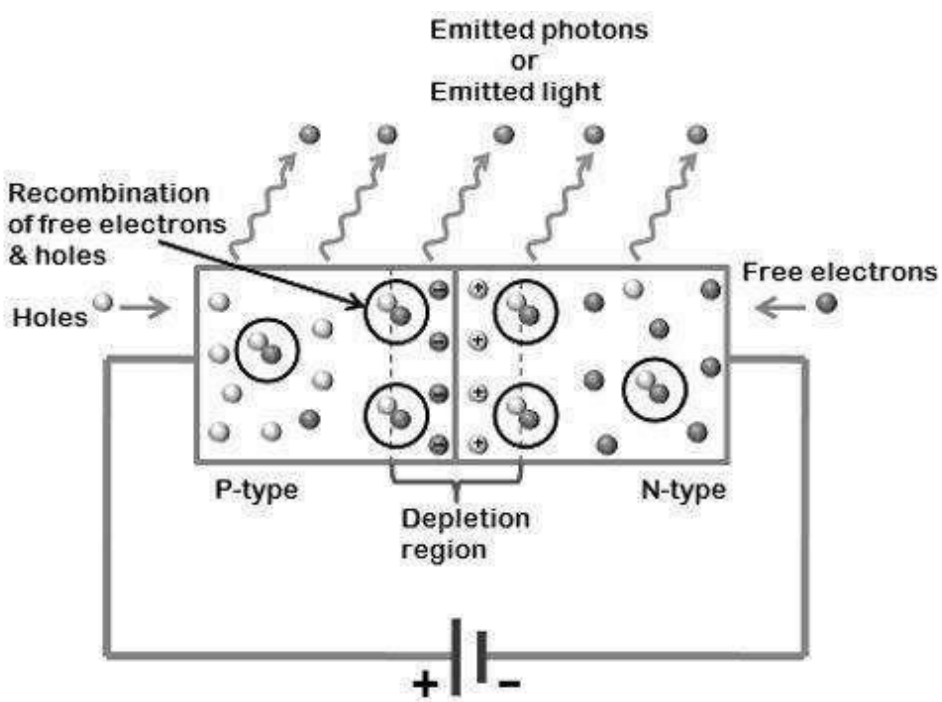
A fluorescent tube light consists of

1. a lime glass tube
2. drop of mercury
3. argon gas
4. phosphor coating
5. electrode coils(cathode)
6. mounting assemblies
7. aluminum cap(base)

LED(Light emitting diode):

Principle: It works under the principle of P-N junction diode.

Construction:



The semiconductor material used in LED is Gallium Arsenide (GaAs), Gallium Phosphide (GaP) or Gallium Arsenide Phosphide (GaAsP). Any of the above-mentioned compounds can be used for the construction of LED, but the colour of radiated light changes with the change in material. Below are some of the material and their respective colour of light which they emit. In addition to it, the ranges of typical forward voltage are also given below.

4.9 Star rating of Home appliances:

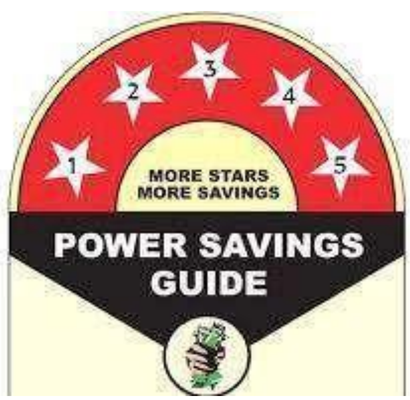
A home appliance, domestic appliance or household appliance, is a machine which assists in household functions such as cooking, cleaning and food preservation.

Examples: Refrigerator, toaster, kettle, microwave,air conditioner,washing machine,cloth washers etc.

Energy efficiency:

- It is defined as energy service per unit of energy consumption.
- Energy efficiency simply means using less energy to perform the same task – that is, eliminating energy waste.
- Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level. **Star rating concept**:

- An energy efficiency rating scheme for Electrical appliances is known as Star labeling.
- 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.
- The star rating system was devised by the Bureau of Energy Efficiency (BEE) India, with a range of 1 to 5 stars. This system ensured that the energy efficiency of appliances was easily understood by the common man.



Short questions with answer:

Q-1 Write down the various parts of dc machines. (W-16,17,18)

Ans: The various parts of dc machines are :

- Eye bolt

- Yoke
- Field winding
- Pole shoes
- Field pole
- Armature conductors and windings
- Armature
- Commutator
- Carbon brush

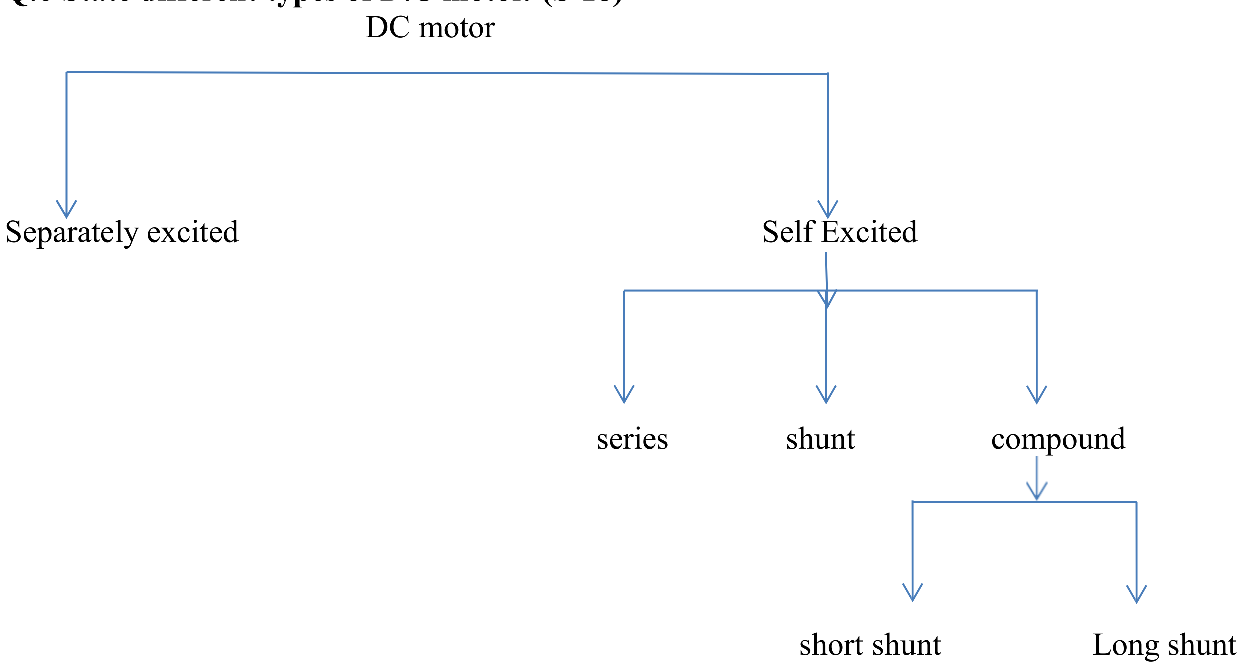
Q-2 Write down the name of DC generator which is used as charging of batteries.
Ans: DC series generator.

Q-3 Write down the name of DC generator which is used as booster. Ans:
DC shunt generator.

Q-4 Write down the DC motor which is used as a reciprocating pumps.
Ans: DC shunt motor.

Q-5 Write down the name of single phase induction motor which is used as a ceiling fan.
Ans: Permanent split capacitor induction motor.

Q.6 State different types of D.C motor. (S-18)



Q.7 Why Commutator is used in D.C machines? (S-18)

Ans: Commutator is used in D.C machines because it converts a.c to d.c in d.c generator and d.c to a.c in d.c motor.

LONG QUESTIONS:

Q-1 Write down the classification of dc generator.

Q-2 Write down the types and uses of single phase induction motor.

Q-3 Draw the constructional features of Fluorescent lamps.

Q-4 Write the classification of DC motor with circuit diagram .(W-17)

CHAPTER - 5 WIRING AND POWER BILLING

Learning Resources:

5.1 Types of wiring for domestic installations.

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

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

5.4 Calculate energy consumed in a small electrical installation.

Electrical wiring:

Electrical wiring is an electrical installation of cabling and associated devices such as switches, distribution boards, sockets, and light fittings in a structure.

5.1 Types of wiring for domestic installations.

Following are the types of internal wiring usually employed in industries and house wiring:

1. Cleat wiring
2. Wooden casing and capping wiring
3. T.R.S or Batten wiring
4. Conduit wiring

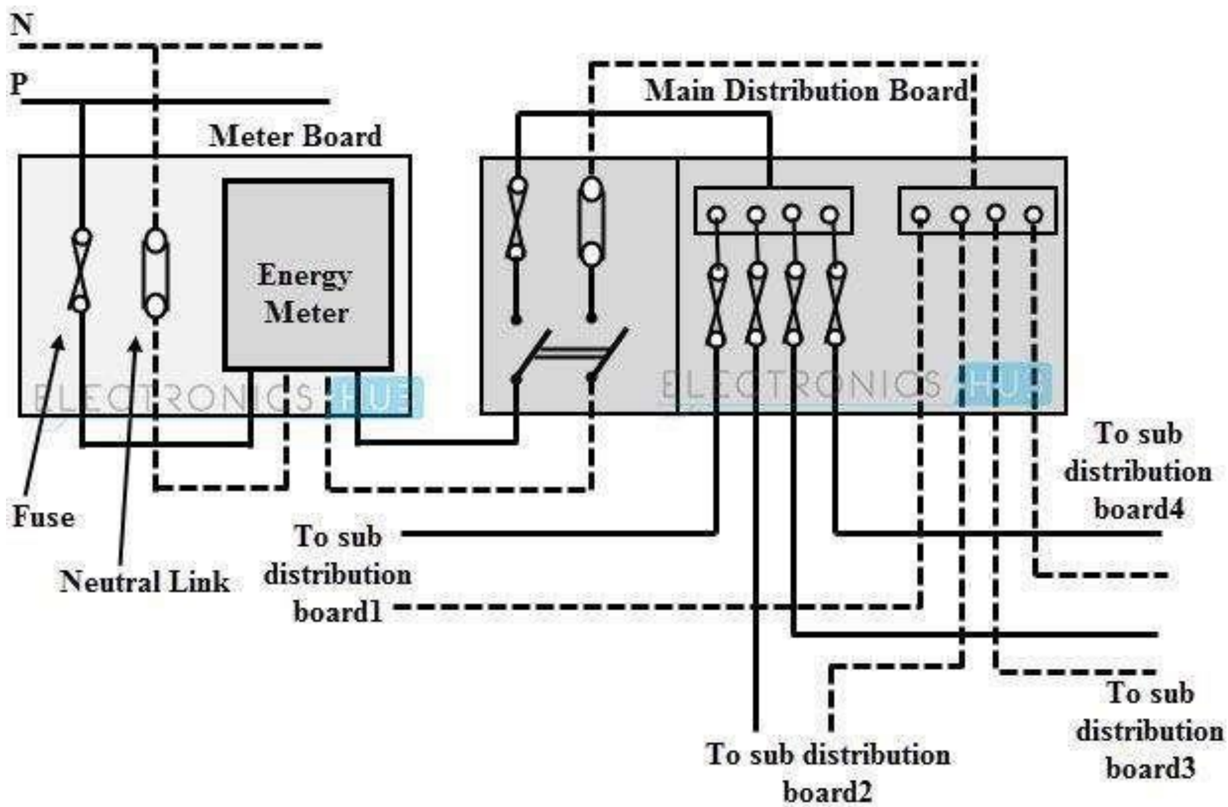
Again conduit wiring divided into 3 types:

1. Surface conduit wiring
2. Concealed conduit wiring
3. Flexible conduit wiring

Comparision between various systems of wiring:

Sl no.	Particulars	Cleat wiring	Wooden casing and capping wiring	TRS wiring	Concealed wiring
01	Cost	Very low	Medium	Low	Very costly
02	Voltage	Up to 250v	Up to 250v	Up to 250v	Up to 660v
03	Life	Very short	Fairly long	Long	Very long
04	Protection against fire	Poor	No	Fair	Very good
05	Appearance	Not good	Fair	Good	Very good
06	Field of application	For temporary wiring e.g functions, building under construction	For residential ,commercial ,office building.	For residential ,commercial ,office building.	For residential ,commercial ,office building, godowns, private building etc.

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



5.3 List out the basic protective devices used in house hold wiring :

The basic protective devices used in house hold wiring are :

- DPIC (Double pole iron clad) main switch of 5,15,30 A rating 220V.
- TPIC (Tripole pole iron clad) main switch of 30,60,100,200 A rating 440V.
- DPMCB (Double pole miniature circuit breaker) of 5,10,16.32,45 and 63 A rating 250V.
- TPMCB (Tripole pole miniature circuit breaker) of 16,32,45 and 63A rating 500V.
- MCCB (Mouled case circuit breaker) of 100,200,300,500A rating 660V.
- TPNMCB (Tripole pole with neutral miniature circuit breaker) of 16,32,45 and 63 A rating 500V. ➢ Flush switches
- Kit-kat fuse units
- ELCB (Earth leakage circuit breaker) or RCCB (Residential current circuit breaker)

5.4 Calculate energy consumed in a small electrical installation.

Q -1 A residential house of a farmer has the following loads used in average :

Bed room 1 no.

2 light points for 6 hours /day
1 fan point for 12 hours/day
Drawing room 1 no.
2 light points for 8 hours/day
1 fan point for 16 hours/day
Kitchen room 1 no.
1 light point for 10 hours/day 1 heater 1000W for 7 hours/day Store room 1 no.
2 light points for 6 hours/day
Verandah
1 light point for 8 hours/day
1 fan light point for 8 hours/day
Find out the energy bill for the month of January 2021 when the unit price of the energy is RS 2.00/unit.
ANS: Energy consumed /day by various loads:

Sl no	Place	Loads	Number	Wattage	Working hours/day	Energy consumed/day
01	BED ROOM 1 NO.	Light Fan	2 1	60 80	6 12	2×60×6=720WH 1×80×12=960WH
02	DRAWING ROOM 1 NO.	Light Fan	2 1	60 80	8 16	2×60×8=960WH 1×80×16=1280WH
03	KITCHEN ROOM 1 NO.	Light Heater	1 1	60 1000	10 7	1×60×10=600WH 1×1000×7=7000WH
04	STORE ROOM 1 NO.	Light	2	60	6	2×60×6=720WH
05	VERANDAH	Light Fan	1 1	60 80	8 8	1×60×8=480WH 1×80×8=640WH
						Total energy consumed /day=13360Wh=13.3 6KWH

Hence total monthly consumption (Jan 2021)=13.36×31=414.16 KWH
We know 1 unit= 1KWH
So total unit consumption=414.16 unit.
The energy bill for month of jan 2021 = 414.16×2(given 1 unit =Rs 2) =Rs 828.32/ (Ans)

Short questions with answer:

Q-1 Write the full form of DPIC.

Ans:The full form of DPIC is double pole iron clad main switch.

Q-2 Write the full form of ELCB .

Ans: The full form of ELCB is earth leakage circuit breaker.

Q-3 Which wiring is very costly ?

Ans: concealed wiring is very costly.

Q-4 How much watt hour is one unit for electrical energy calculation ?

Ans:1000 watt hour is one unit for electrical energy calculation.

Q-5 What are the protective device used in house hold wiring. (W-17), (S-18)

Ans: The protective device used in houe hold wiring are fuse,MCB,ELCB,earthing or grounding.

Q-6 Name types of wiring ? (S-18) ,(W-19)

Ans: Following are the types of internal wiring usually employed in industries and house wiring:

- Cleat wiring
- Wooden casing and capping wiring
- T.R.S or Batten wiring
- Conduit wiring Again conduit wiring divided into 3 types:

- Surface conduit wiring
- Concealed conduit wiring
- Flexible conduit wiring

LONG QUESTIONS:

Q-1 Write down the protective devices used in house hold wiring.

Q-2 Explain about types of internal wiring .(W-17,S-18,S-19)

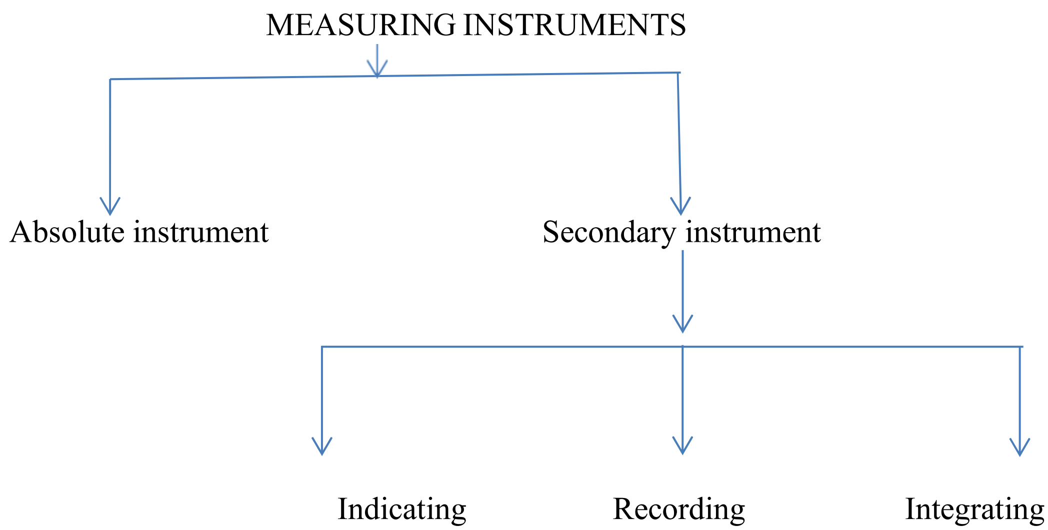
CHAPTER - 6 MEASURING INSTRUMENTS

Learning Resources:

6.1 Introduction to measuring instruments.
6.2 Torques in instruments.
6.3 Different uses of PMMC type of instruments (Ammeter & Voltmeter).
6.4 Different uses of MI type of instruments (Ammeter & Voltmeter).
6.5 Draw the connection diagram of A.C/ D.C Ammeter, voltmeter, energy meter and wattmeter. (Single phase only).

6.1 Introduction to measuring instrument:

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. **Classifications of electrical measuring instruments:-**



6.2 Torques in instruments

There are three types of torques,

I. Deflection torque(T_d)/operating torque
II. Controlling torque (T_C)/restoring/balancing torque III. Damping torque

Deflection torque: It is the torque which deflects the point on a calibrated scale according to the electrical quantity passing through the instrument .

Controling torque: It is the torque which controls the movement of the pointer on a particular scale according to the quantity of electricity passing through it.

Damping torque: It is the torque which avoids the vibration of the pointer on a particular range of scale.

6.3 Different uses of PMMC type of instruments (Ammeter & Voltmeter) :

PMMC type instruments:

- PMMC (Permanent magnet moving coil)
- It uses only for DC PMMC type ammeter:

- It uses only DC circuit.
- PMMC type ammeter measure current in DC circuit only.

PMMC type voltmeter:

- It uses only in DC circuit.
- PMMC type voltmeter measures voltage in DC circuit only.

6.4 Different uses of MI type instruments (Ammeter and Voltmeter) :

MI type type instrument:

 Movng iron type used both in AC and DC circuit.

MI type ammeter:

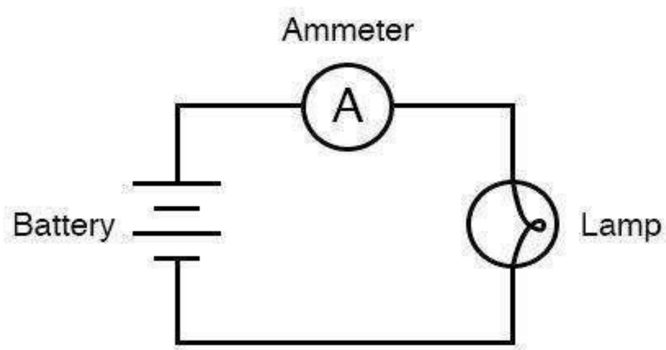
 MI type ammeter measure current in both AC and DC circuit.

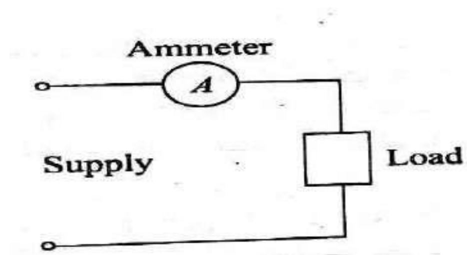
MI type voltmeter:

 MI type voltmeter measure voltage in both AC and DC circuit.

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

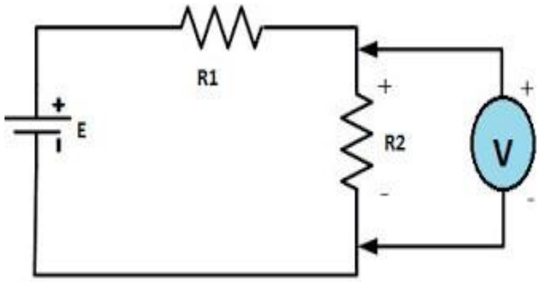
Connection diagram of ammeter:

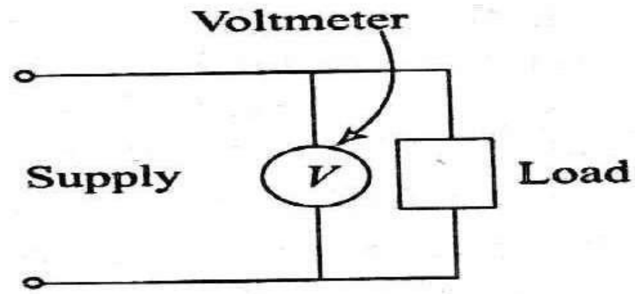


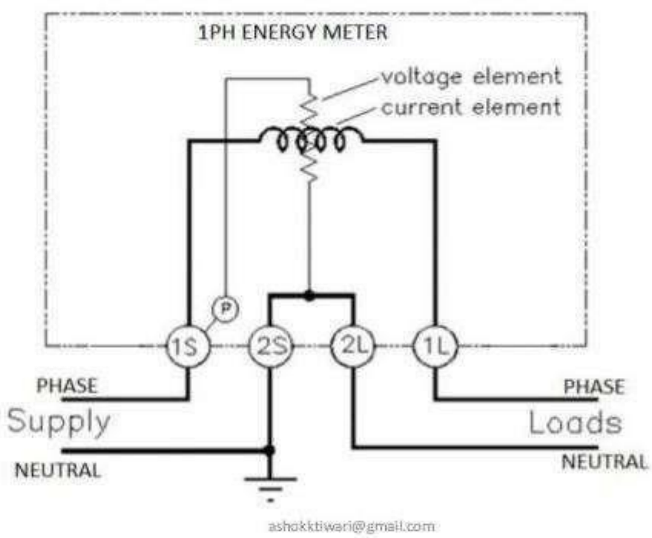


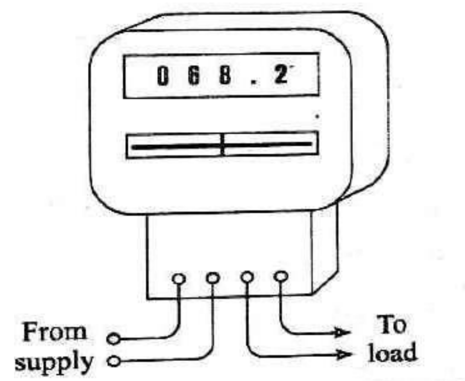
- Ammeters are always connected in series with the circuit.

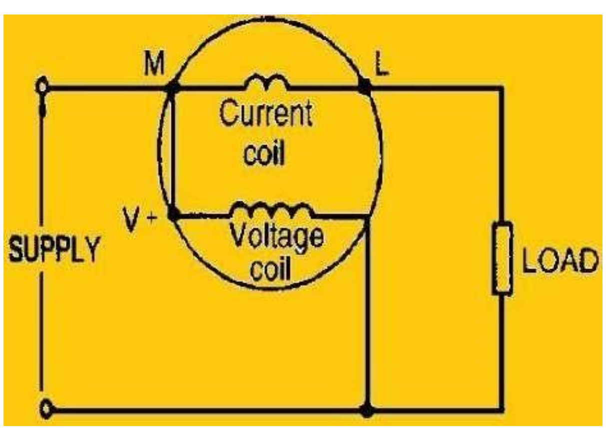
Connection diagram of voltmeter:

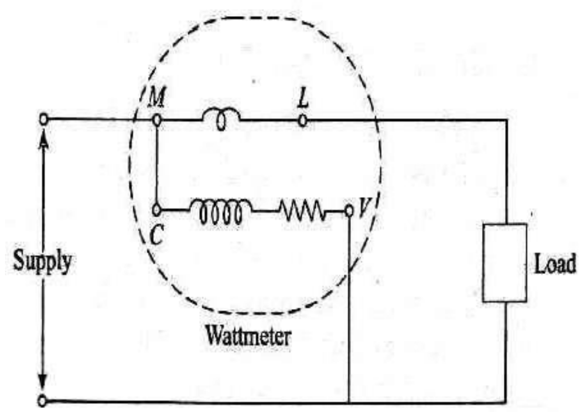












Connection diagram of energy meter

Connection diagram of single phase wattmeter

- Voltmeters are always connected in parallel.

Short questions with answer:

Q-1 Write a example of integrating type instruments.

Ans: Single phase energy meter is a example of integrating type instruments.

Q-2 Which type of instrument used to measure both AC and DC ?

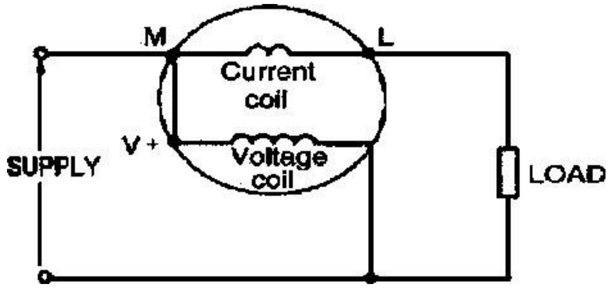
Ans: MI type instrument used to measure both AC and DC.

Q-3 Which type of instruments are used to measure only DC ?

Ans: PMMC type instrument used to measure only DC.

Q-4 Draw the connection diagram of single phase wattmeter . (W-16)

Ans:



Q-4 What are the different torque in measuring instruments ? (S-19)

Ans: The different torque torque in measuring instruments are : I. Deflecting torque. II. Controlling torque

III. Damping torque.

Long questions :

Q-1 Draw the connection diagram of single phase energy meter.

Q-2 Draw the connection diagram of wattmeter.

Q-3 Draw the connection diagram of voltmeter and ammeter.

Q-4 State uses of MI type ammeter and voltmeter with connection diagram. (S-18)

Q-5 State different uses of MI type instruments instruments briefly. (S-19)

Q-6 State different uses of PMMC type instrument. (S-18)

Theory: 2 Periods per Week | I.A : 10 Marks
Total Periods: 30 Periods | End Sem Exam : 40 Marks
Examination: 1.5 Hours | TOTAL MARKS : 50 Marks

Topic wise Distribution of Periods and Marks

Sl.No.	Topics	Periods
1	Electronic Devices	8
2	Electronic circuits	9
3	Communication System	3
4	Transducers & Measuring instruments	10
	Total	**30**

Objective

1. To be familiar with Electronic devices
2. To be familiar with Electronic circuits
3. To be familiar with communication system
4. To be familiar with Electronic measuring instruments

1. ELECTRONIC DEVICES

1.1 Basic Concept of Electronics and its application.
1.2 Basic Concept of Electron Emission & its types.
1.3 Classification of material according to electrical conductivity (Conductor, Semiconductor & Insulator) with respect to energy band diagram only.
1.4 Difference between Intrinsic & Extrinsic Semiconductor.
1.5 Difference between vacuum tube & semiconductor.
1.6 Principle of working and use of PN junction diode, Zener diode and Light Emitting Diode (LED)
1.7 Integrated circuits (I.C) & its advantages.

2.ELECTRONIC CIRCUITS

2.1 Rectifier & its uses.

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

2.3 Functions of filters and classification of simple Filter circuit (Capacitor, choke input and π)

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

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

2.6 Need of biasing and explain different types of biasing with circuit diagram.(only CE configuration)

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

2.8 Electronic Oscillator and its classification

2.9 Working of Basic Oscillator with different elements through simple Block Diagram .

3. COMMUNICATION SYSTEM

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

3.2 Concept of Modulation and Demodulation, Difference between them

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

4. TRANSDUCERS AND MEASURING INSTRUMENTS

4.1 Concept of Transducer and sensor with their differences.

4.2 Different type of Transducers & concept of active and passive transducer. 4.3 Working principle of photo emissive, photoconductive, photovoltaic transducer and its application

4.4 Multimeter and its applications

4.5 Analog and Digital Multimeter and their differences

4.6 Working principle of Multimeter with Basic Block diagram

4.7 CRO, working principle of CRO with simple Block diagram

ELECTRONIC DEVICES

ELECTRONICS:-

Electronics is a branch of engineering which deals with the current conduction through vacuum or gas or semiconductor.

Electronics devices are capable of performing following function:-

1) Rectification
   It is the process of conversion of AC into DC.

2) Amplification
   It is the process of raising the strength of a weak signal

3) Generation
Oscillators are those devices which converts DC power into AC power of any frequency

4) Conversion of light into electricity and vice versa.

ELECTRON EMISSION:-

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

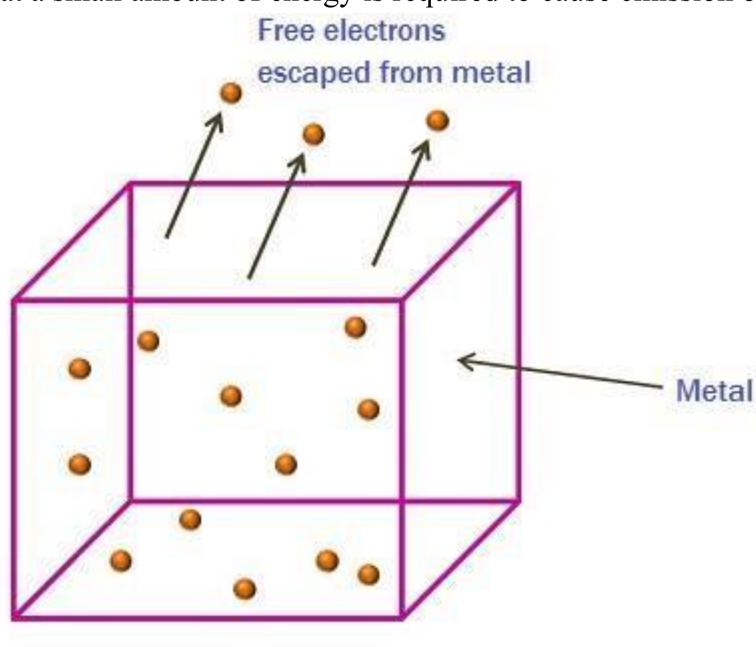
For electron emission, metals are used because they have many free electrons.

In a metal at room temperature, the electrons are free only to the extent that they may transfer from one atom to another within it but they cannot leave the metal surface to provide electron emission.

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

The work function of pure metal varies roughly from 2 to 6 ev. It depends upon the nature of metal, its purity and the condition of its surface.

It is desired that a metal used for electron emission should have low work function so that a small amount of energy is required to cause emission of electrons.



Electron emission

For instance:-
Total energy required to liberate an electron from a metal is 4 ev.
The energy possessed by the electron is 0.5 ev. Work
Function= 4-0.5=3.5 ev.

Electrons are emitted from the metal surface only if additional energy is supplied from external source.

This external energy may come from a variety of source such as heat energy, light energy, energy stored in electric field, kinetic energy of the electric charges bombarding the metal surface.

Depending upon the various energy sources, electron emission are classified into four types:-

a) Thermionic emission

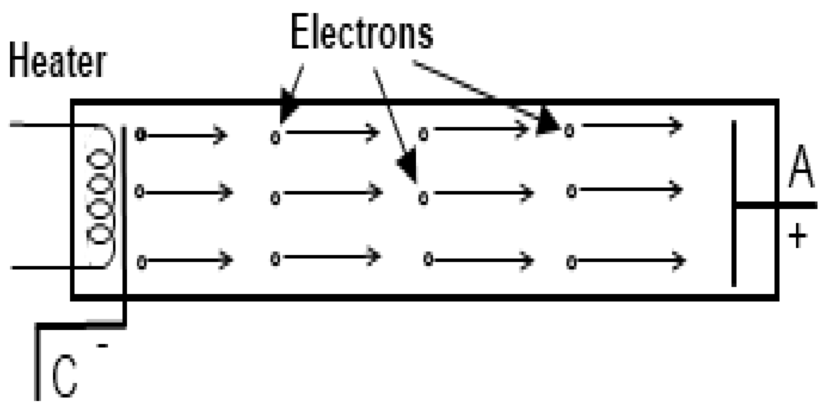
b) Photo-electric emission

c) Field emission

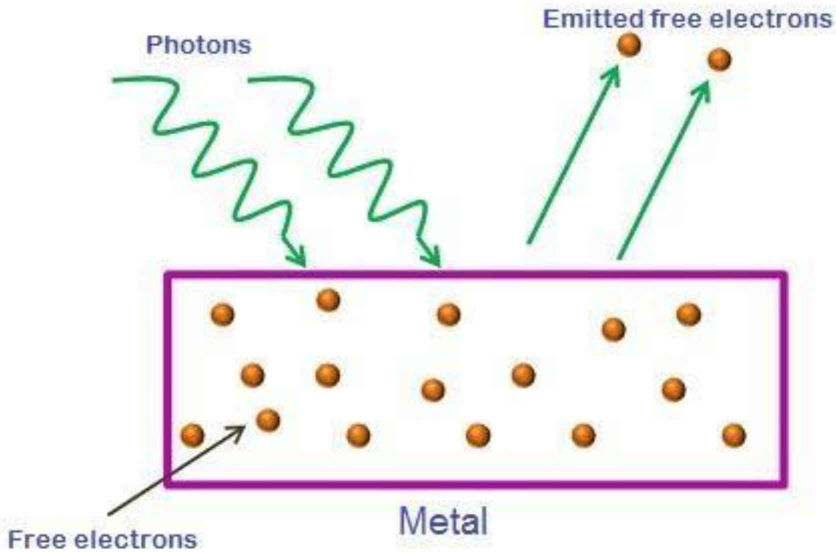
d) Secondary emission

a) THERMIONIC EMISSION

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



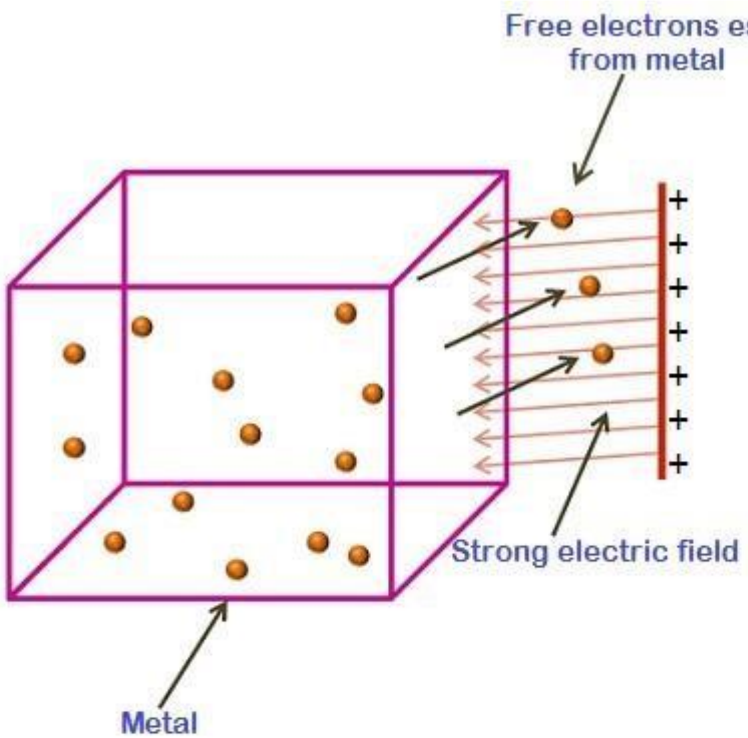
b) PHOTOELECTRIC EMISSION



c) FIELD EMISSION

Electron emission from metallic surface by the application of light is known as photoelectric emission.

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

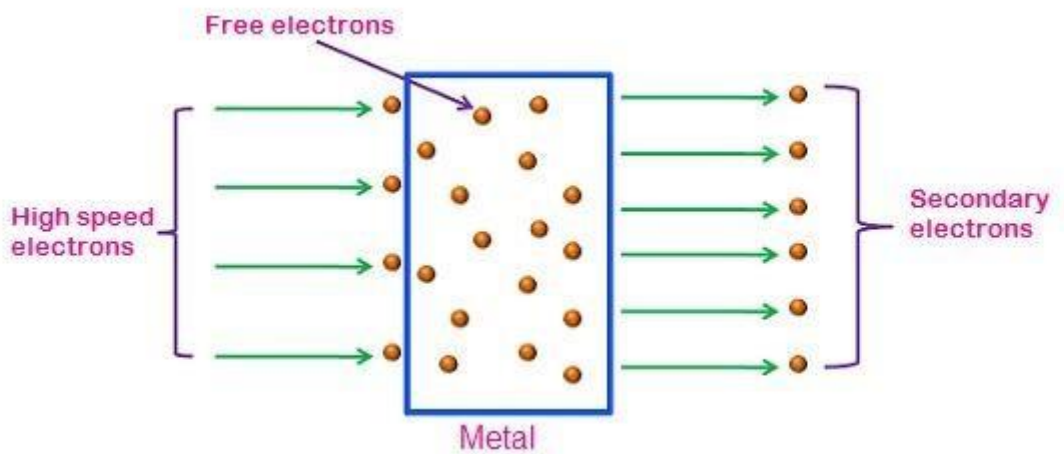


d) SECONDARY EMISSION

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

When high speed electrons suddenly strike a metallic surface they may give some or all of their kinetic energy to the free electrons in the metal.

If the energy of the striked electrons is sufficient it may cause free electrons to escape from the metal surface. This phenomenon is called secondary emission.



EXPLANATION OF SECONDARY EMISSION

When a beam of light strikes the metal (e.g. Na and K) surface, the energy of photons of light is transferred to the free electrons within the metal.

If the energy of the striked photons is greater than the work function of the metal, then the electrons are knocked out from the metal surface.

The emitted electrons are known as photo-electrons and the phenomenon is known as photoelectric emission.

ATOMIC STRUCTURE:-

All materials are composed of very small particle called atoms.

An atoms consist of a central nucleus around with negatively charged particles called electrons revolves in different orbits

The nucleus of a atom consist of a proton and neutron A proton is a positively charged particle.

A neutron has same mass as that of proton but has no charge

Atomic weight = No. of protons+ no. of neutrons

Atomic number = total no. of protons or electrons in an atoms An electron is a negatively charged particle.

The no. of electrons in an orbit $=2n^2$

Where, n= no. of orbits

For 1st orbit, no. of electrons= $2(1)^2=2$

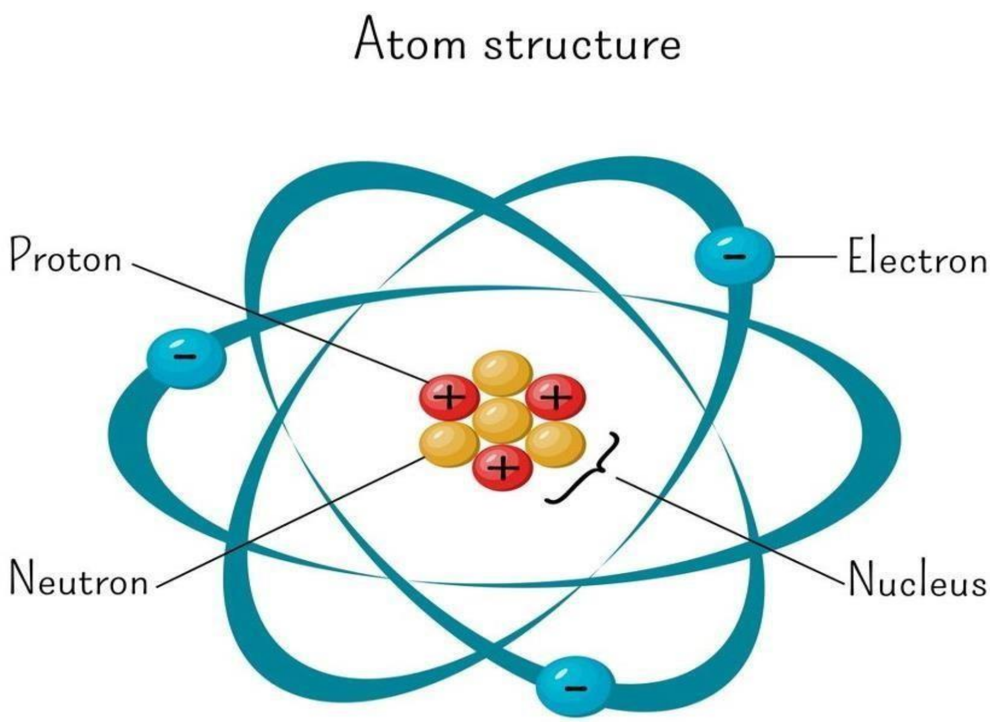
2nd Orbit, no. of electrons= $2(2)^2=8$

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

The Valance electrons which are loosely attached to the nucleus are called free electrons.

Charge of a an electron = 1.602×10^{-19} coulombs

Mass of an electron = 9.1×10^{-31}kg Radius of an electron = 1.9×10^{-15}mt.



ENERGY OF AN ELECTRON:-

An electron possesses two types of energies,

I. Kinetic energy due to its motion
II. Potential energy due to the charge of the nucleus

✞The energy of an electrons of the as its distance from the nucleus increase. Thus, an electron in the 1st orbit.

1 electron volt = c.v

= 1.602×10^{-19} coulomb x 1 volt =1.602×10^{-19} joule.

ENERGY BAND:-

The range of energy possessed by an electron in a solid is known as energy band. The prime important energy band in a solid are:-

✞VALANCE BAND

It is the range of energy possessed by valance electrons.

This band maybe completely or partially filled.

For insert gases valance band is full whereas for other materials it may be partially filled.

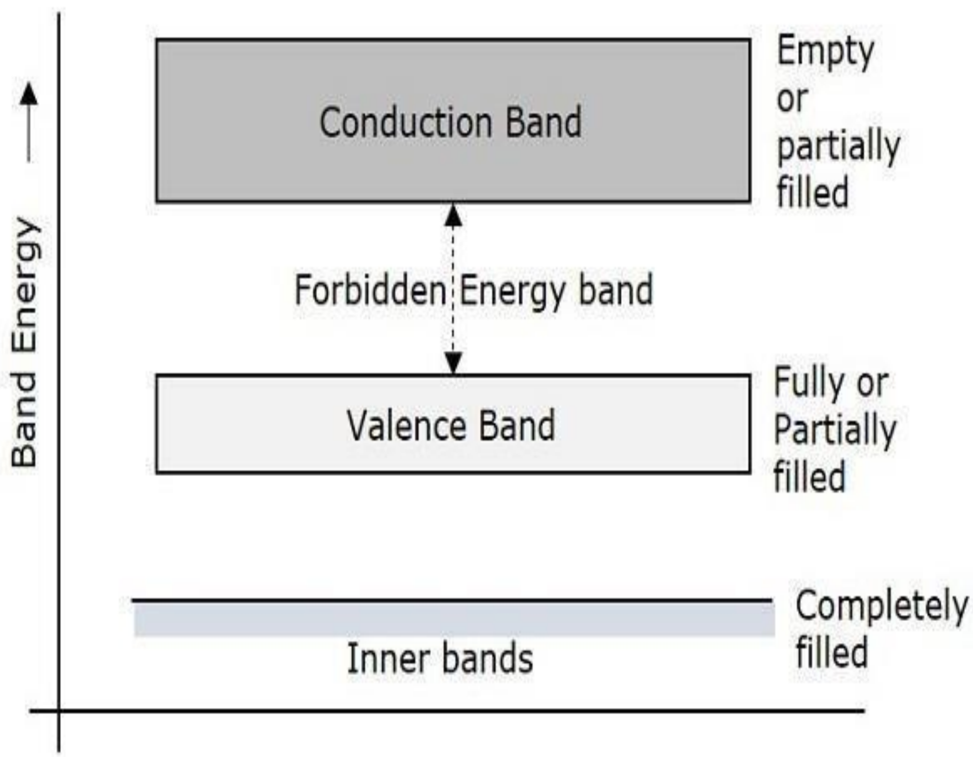
✞CONDUCTION BAND

It is the range of energies possessed by conduction electrons.

Generally insulators have empty conduction band while for conductors they are partially filled.

✞FORBIDDEN ENERGY GAP

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



CLASSIFICATION OF SOLIDS:-

Solids are classified into three types:-

i. Insulators ii. Conductors iii. Semi-conductors

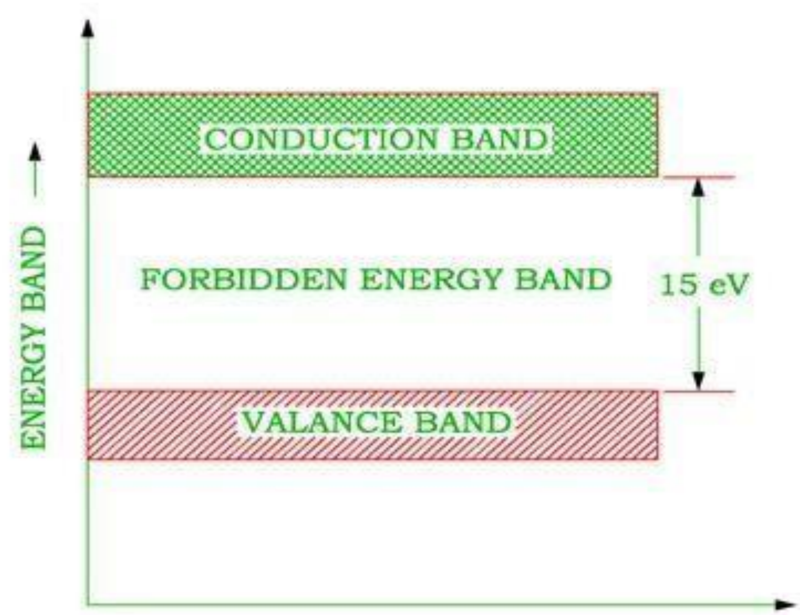
i) INSULATORS

Insulators don’t allow electric current to pass through them.

Insulators or non-metals have valance electrons more than 4.

Insulators have large forbidden energy gap i.e.>15ev.

At room temperature the valance electrons of the insulators do not have enough energy to cross over to the conduction band. But when temp is increased some of the valance electrons jump into the conduction band but that is not enough for conduction.



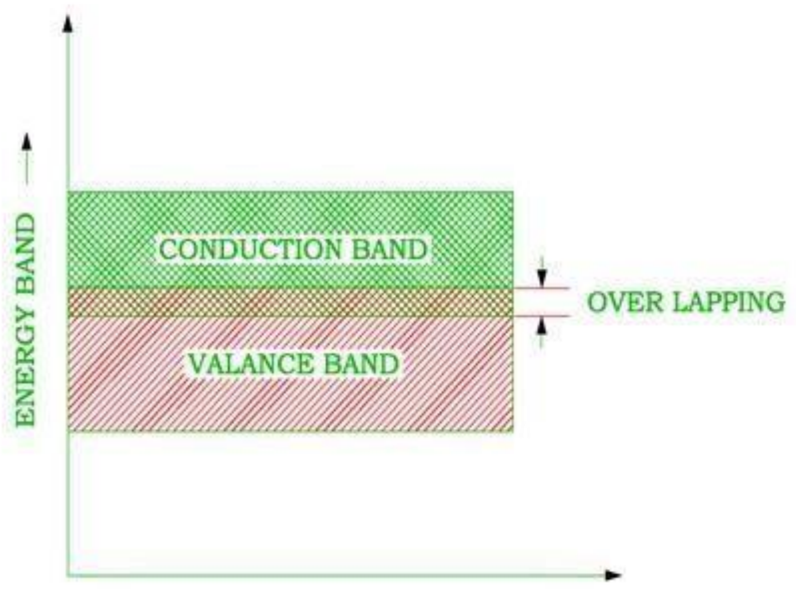
ENERGY BAND DIAGRAM FOR INSULATOR

ii) CONDUCTORS

A conductor allows easy passage of electric current through them.

A conductor or a metal have valance electrons less than 4

In a conductor valance band and conduction band overlaps each other. So a slight potential difference causes electric current to flow.



ENERGY BAND DIAGRAM FOR CONDUCTOR

iii) SEMICONDUCTORS

A semiconductor is a material whose electrical conductivity lies in between those of a conductor & an insulator.

Ex- Germanium (Ge) & silicon (si)

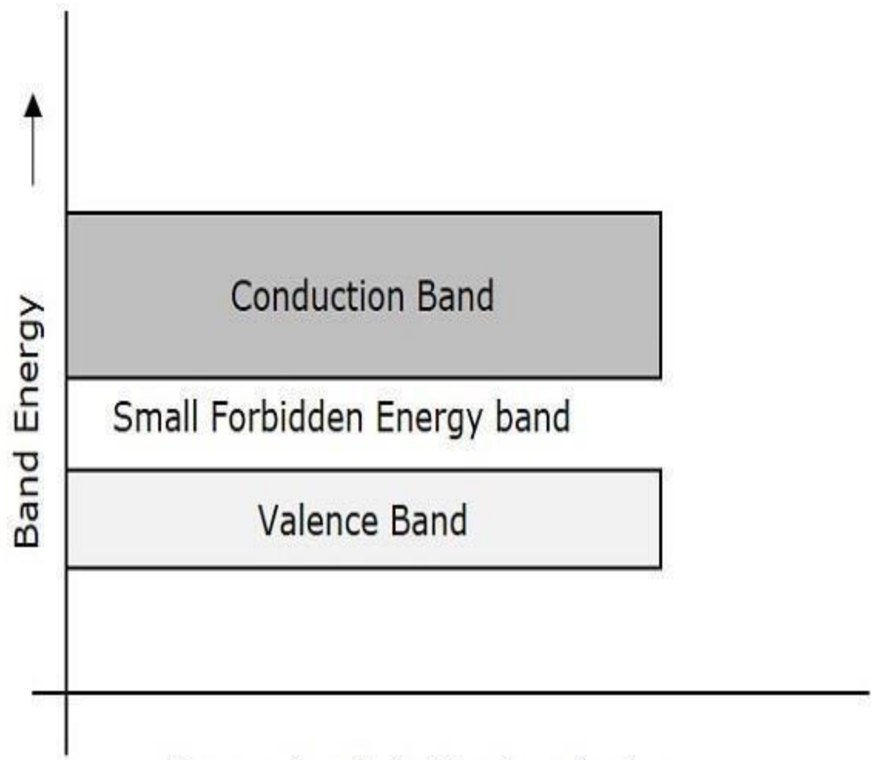
In a S.C, Valance band is almost filled & conduction band is almost empty. Semiconductors have valance electrons equal to 4.

Forbidden energy gap for Ge is 0.7ev & Si is 1.1ev

As the energy gap is very small, so under the application of small electric field electrons can jump easily from valance band to conduction band.

Semiconductors have –ve temp. Coefficient of resistance i.e. resistance of a semiconductor decreases with increase in temp or vice-versa.

In a semiconductor, bonds are formed between the atoms by sharing of valance electrons. Such bonds are called as covalent bonds.



Energy bands in Semiconductors

TYPES OF SEMICONDUCTORS:-

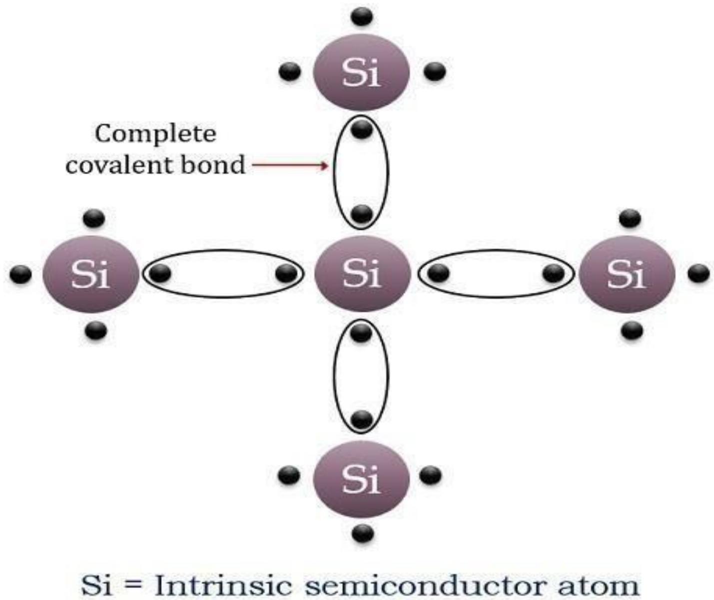
Semiconductors are classified into two types:-

- Intrinsic semiconductors
- Extrinsic semiconductors
  - Extrinsic semiconductors are also of two types:-
    - P-type semiconductors
    - N-type semiconductors

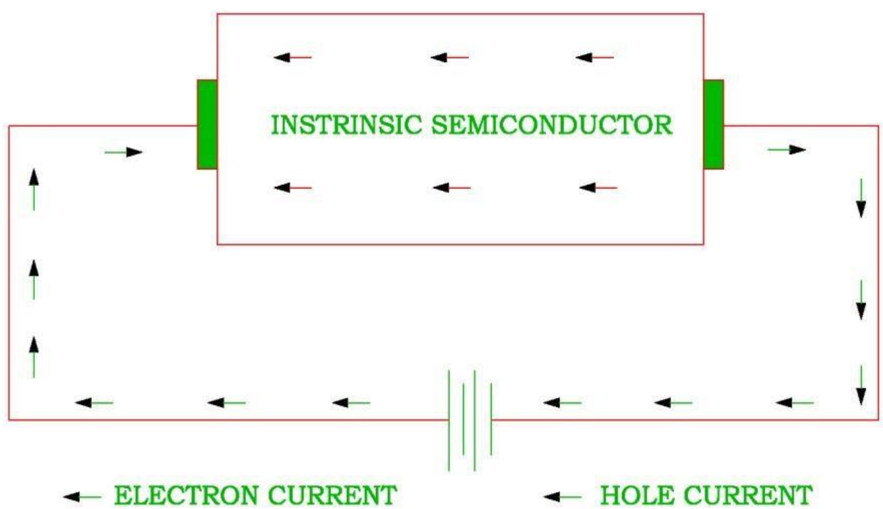
INTRINSIC SEMICONDUCTORS

A semiconductor in its extremely pure form is known as intrinsic semiconductors.

In an intrinsic semiconductors S.C, no. of holes is equal to no. of electrons.



Crystalline structure of Intrinsic semiconductor



EXTRINSIC SEMICONDUCTORS

When impurities are added to a pure semiconductor, such semiconductors are known as extrinsic S.C.

The process of deliberately adding impurities to a s.c is known as doping.

The purpose of adding impurities is to increase either the no, of electrons or holes in a S.C crystal.

Depending upon the type of impurity added extrinsic S.C are classified into two types:-

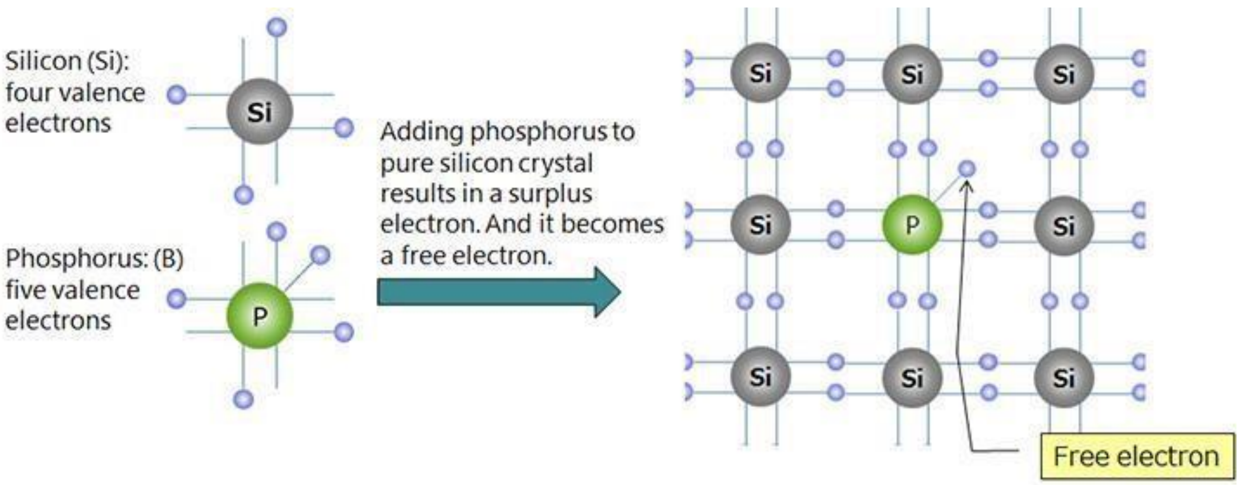
(1) N-type semiconductors

(2) P-type semiconductors

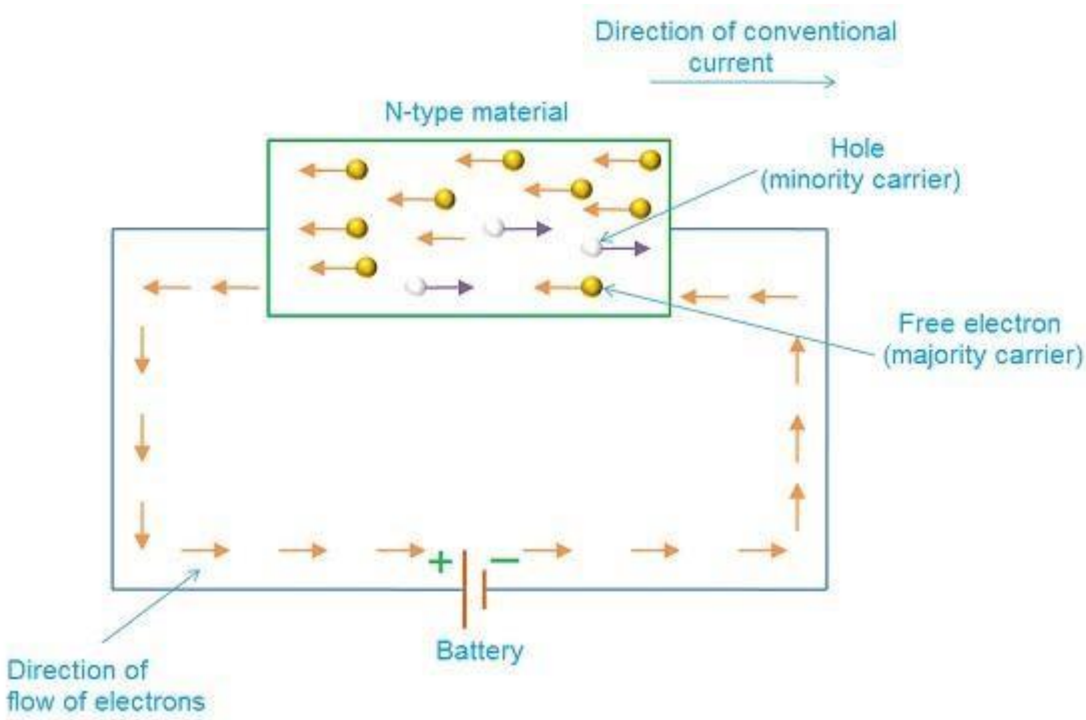
N-TYPE SEMICONDUCTORS

When a small l amount of pentavalent impurity is added to a pure S.C it is known as N-type semiconductors.

Ex. Of pentavalent impurities are referred to as donor impurities because they donate or provide free electrons to S.C crystal.



- When P.D is applied across a n-type S.C the free electrons in the crystals gets attracted towards the positive terminal of the battery constituting electric current.



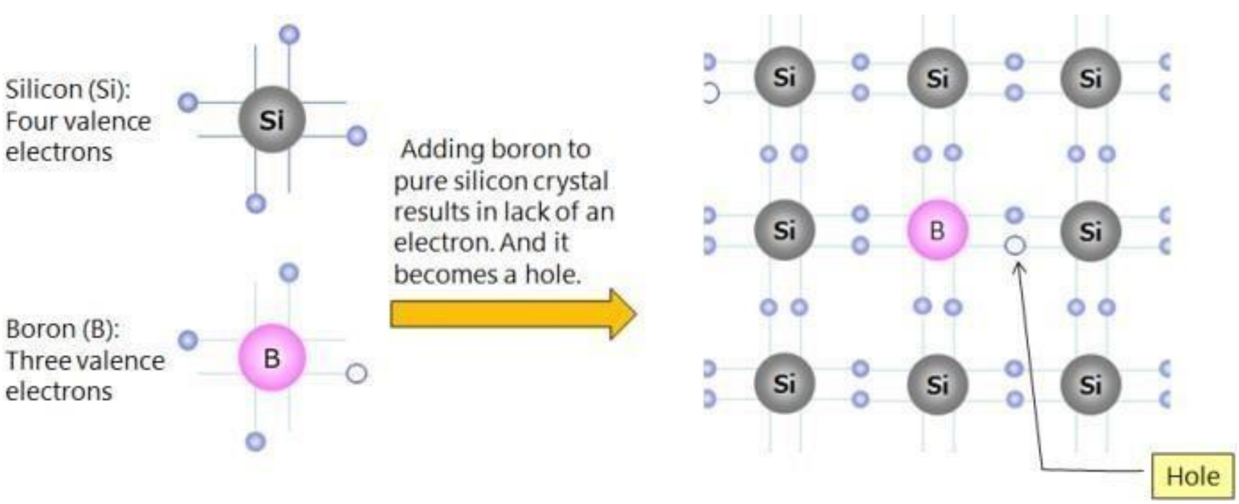
P-TYPE SEMICONDUCTORS

When small amount of trivalent impurities are added to a pure semiconductors it is known as P-type S.C.

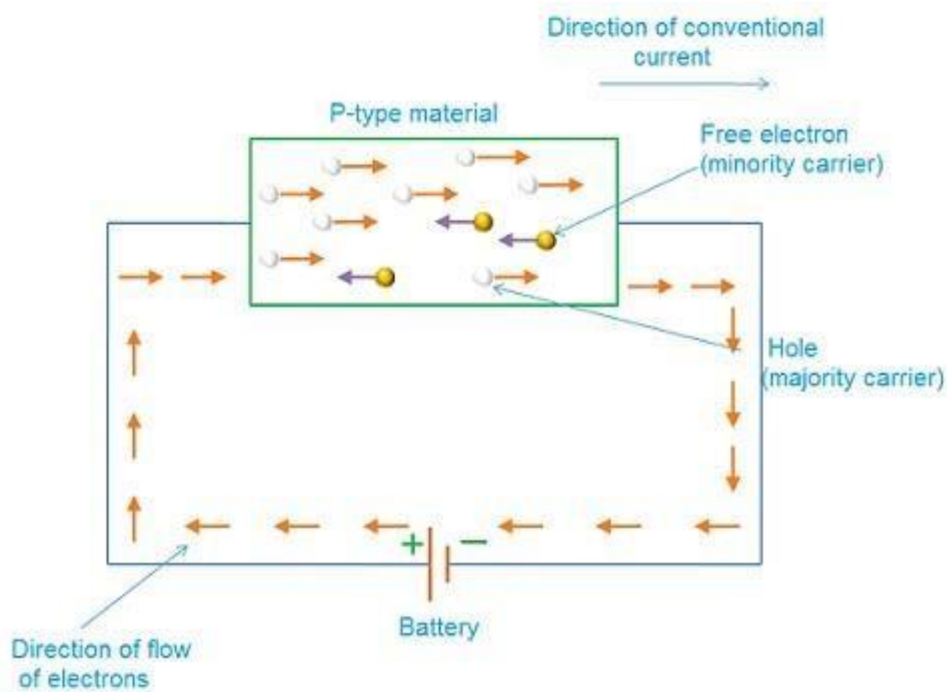
Ex. Of trivalent impurities are Gallium , Indium

Trivalent impurities are referred to as acceptor impurities because the holes created can accept electrons.

The missing electron is called hole.



When P.D is applied to a P-type S.C the majority carriers of a P-type S.C i.e. holes which are +ve.



DIFFERENCE BETWEEN INTRINSIC SEMICONDUCTOR AND EXTRINSIC SEMICONDUCTOR

INTRINSIC SEMICONDUCTOR	EXTRINSIC SEMICONDUCTOR
These are pure semiconductors.	These are impure semiconductors.

Its conductivity is poor.	Its conductivity is large.
Here the number of electrons and holes are equal.	Here the number of electrons and holes are not equal.
They have low operating temperature.	They have high operating temperature
These are not practically used.	These are practically used.
In these the Fermi energy level lies in the middle of valance band and conduction band.	In these the Fermi energy level is shifted towards valance band and conduction energy band.
Here the charge carriers are produced only due to thermal agitation.	Here the charge carriers are produced due to impurities and also due to thermal agitation.
Ex:-Si, Ge etc	Ex:-Si & Ge doped with B, Ga, As, Sb etc

DIFFERENCE BETWEEN VACCUM TUBE & SEMICONDUCTOR

VACCUM TUBE	SEMICONDUCTOR
Bulky, hence less suitable for portable products.	It has smaller size and lighter weight.
Higher operating voltage generally required.	It operates at low voltage.
High power consumption.	Less power consumption.
Glass tubes are fragile.	It has a long life and is robust in construction.
Sometime more prone to microphones.	

Cathode electron –emitting materials are used up in operation.	The semiconductor diode does not produce any current in the absence of applied voltage.
Higher cost	Cost is less

PN JUNCTION:-

When a p type semiconductor is suitably joined with a n type semiconductor, the contact surface is called as pn junction.

N type semiconductors have high concentration of electrons whereas p type semiconductors have high concentration of holes.

Suppose p type and n type materials are suitably joined to form a pn junction. At the junction, free electrons have the tendency to diffuse over to the n side. This process is called diffusion.

Due to this process of diffusion, p side gets more and more negatively charged while n side gets more and more positively charged.

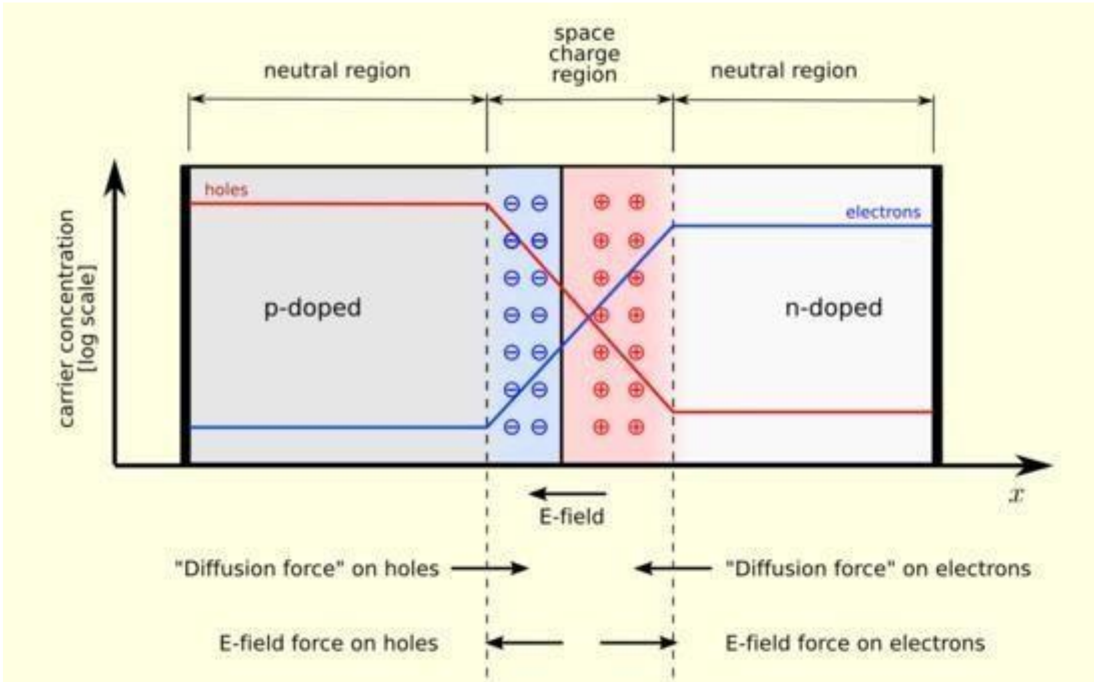
As now p side gets negatively charged it repels free electrons to enter from n type to p type.

Similarly, when n side gets more positively charged it repels holes to cross from p side to n side. Thus, stopping the process of diffusion.

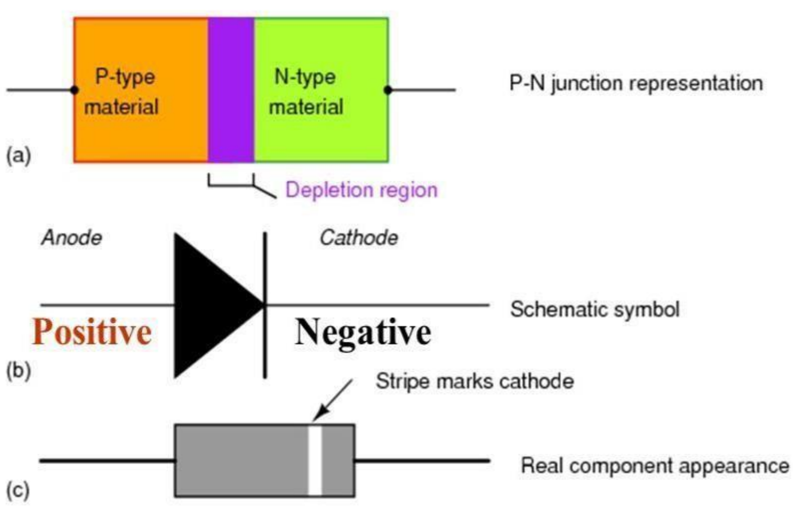
Due to the above process, a barrier is set up to prevent further movement of charge carriers i.e. holes and electrons.

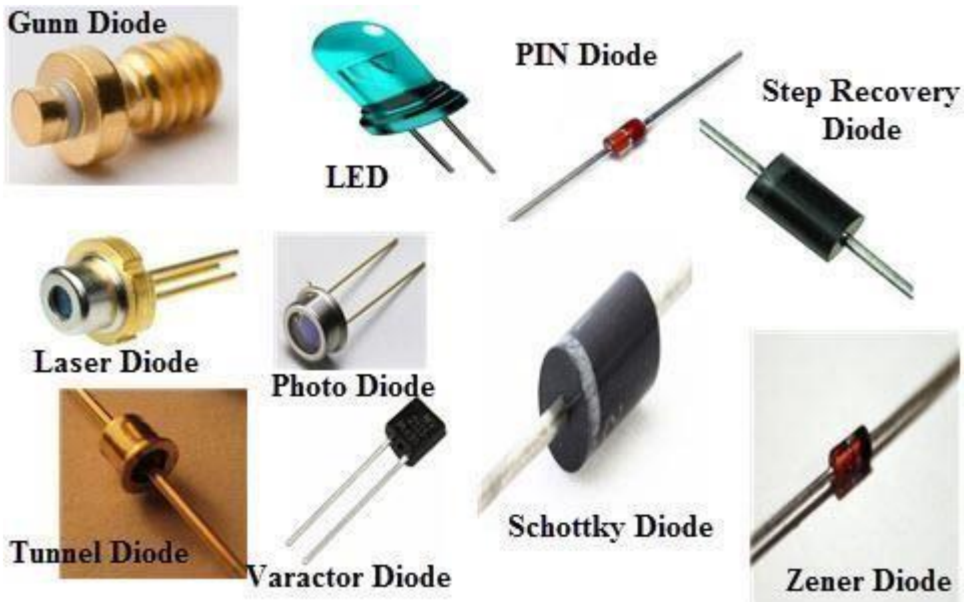
This barrier is called potential or junction barrier. It is of the order 0.1 to 0.3 volts.
This potential barrier sets up an electric field to prevent respective majority carriers from crossing the barrier region.

Outside the barrier on each side of the junction, the material is still neutral.
Inside the barrier, n side is positively charged and p side is positively charged. This region is called Depletion Region.



Diode Symbol





LIGHT EMITTING DIODE:-

A light emitting diode is a diode that emits visible light when forward biased.

LEDs are also known as infrared emitting diodes.

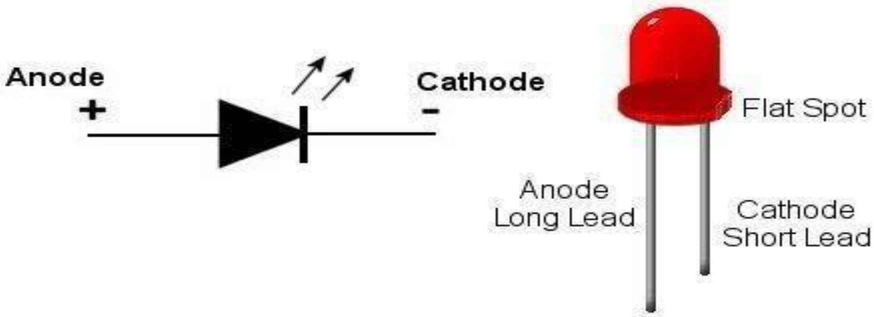
LEDs are not made up of germanium and silicon but are made by using elements like gallium, phosphorous and arsenic.

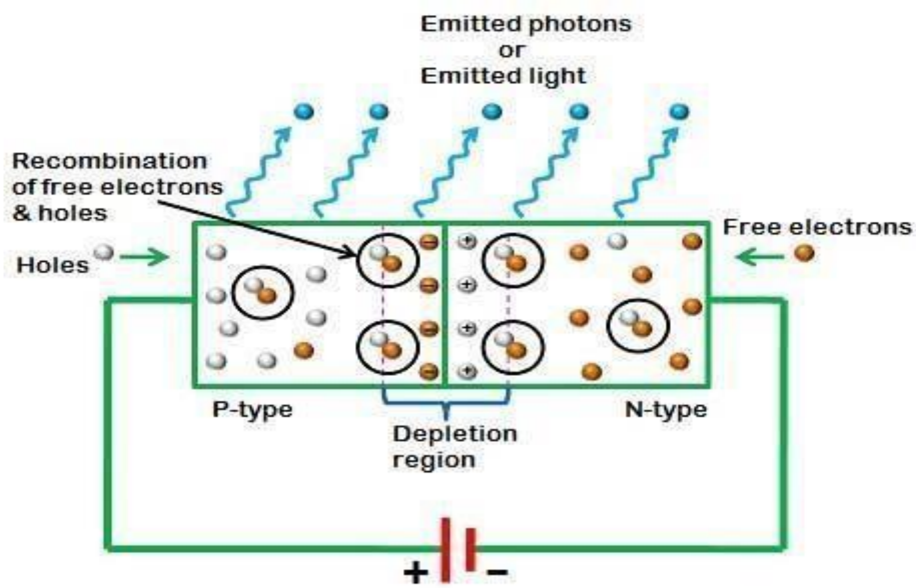
By varying the quantities of these elements, different color lights of different wavelengths can be produced.

For instance:- when LED is made up of gallium arsenide red color light is produced

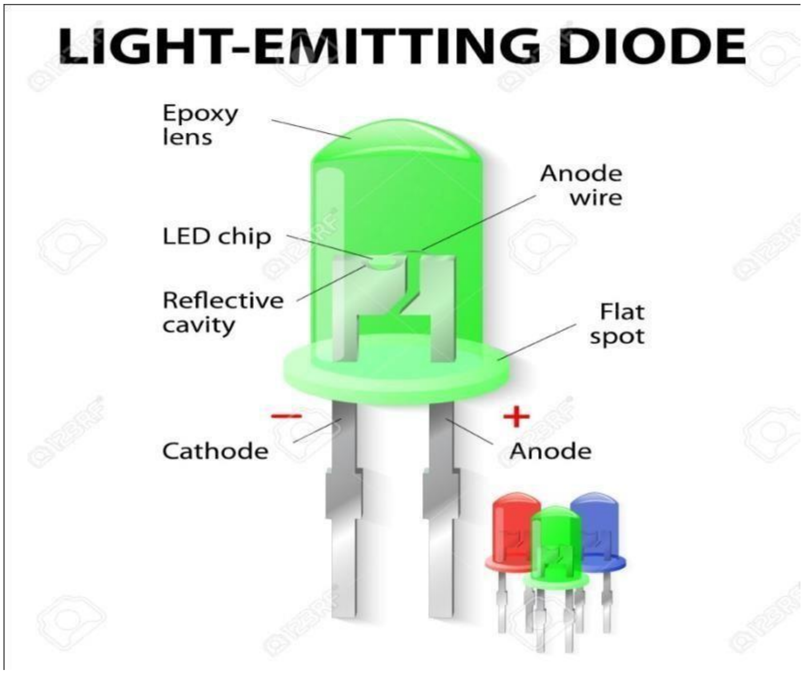
.

When LED is made up of gallium phosphide, green light is produced.





Light Emitting Diode (LED)



When a LED is forward biased , the electrons cross from the N region and recombine with the holes existing in the p region

Free electrons are in the conduction band of energy levels while holes are in the valance energy band

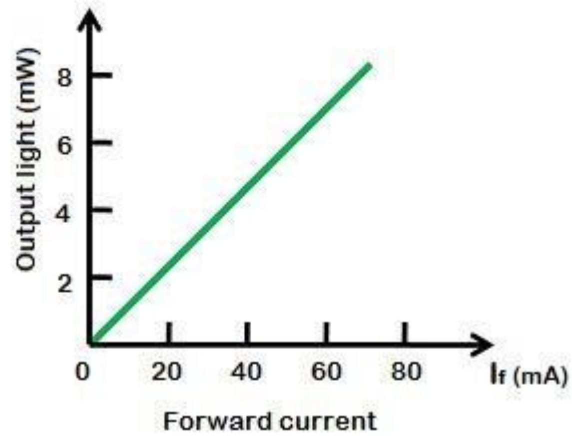
Thus the energy level of the holes is less than that of the energy level of electrons. So, when the recombination of holes & electrons takes place, the recombined electrons releases energy in the form of heat and light.

The electrons dissipate energy in the form of heat for silicon & germanium diodes. While the electron dissipate energy in the form of light for gallium arsenide phosphide & gallium arsenide semiconductors.

If the semiconductor is translucent, the junction becomes the source of light as it is emitted, thus becoming a LED.

A LED does not emit light when the junction is reverse biased.

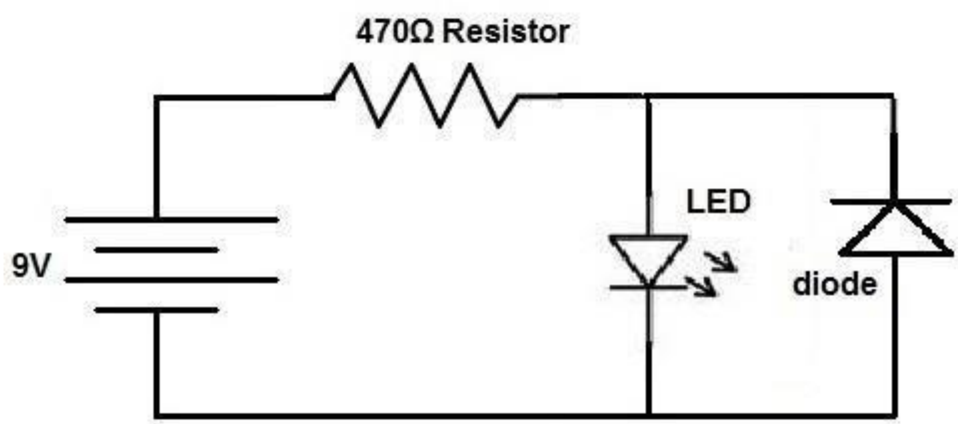
It is clear from the graph that the intensity of radiated light is directly proportional to the forward current of LED.



PROTECTING LED AGAINST REVERSE BIAS-

LEDs have low reverse voltage ratings.

LED has a maximum reverse voltage of 3volts.



When reverse voltage greater than 3v is applied to a LED, the LED may be destroyed.

So, to protect the LED, a rectifier diode is connected in parallel with it.

When reverse voltage greater than 3v is accidentally applied to LED, the rectifier diode will be turned ON & thus protects LED from damage.

ADVANTAGES:-

It consumes very low voltage and current It is miniature in size & light in weight An LED has a longer life.

It is rugged in construction and hence can withstand shock & vibrations.

Fast on-off switching.

ZENER DIODE:-

Zener diode is basically like an ordinary PN junction diode but normally operated in reverse biased condition.

A Zener diode is a heavily doped PN junction diode.

When a PN junction diode is reverse biased, the depletion layer becomes wider.

If this reverse biased voltage across the diode is increased continually, the depletion layer becomes more and more wide.

At the same time, there will be a constant reverse saturation current due to minority carriers.

After certain reverse voltage across the junction, the minority carriers get sufficient kinetic energy due to the strong electric field.

Free electrons with sufficient kinetic energy collide with stationary ions of the depletion layer and knock out more free electrons.

These newly created free electrons also get sufficient kinetic energy due to the same electric field, and they create more free electrons by collision cumulatively.

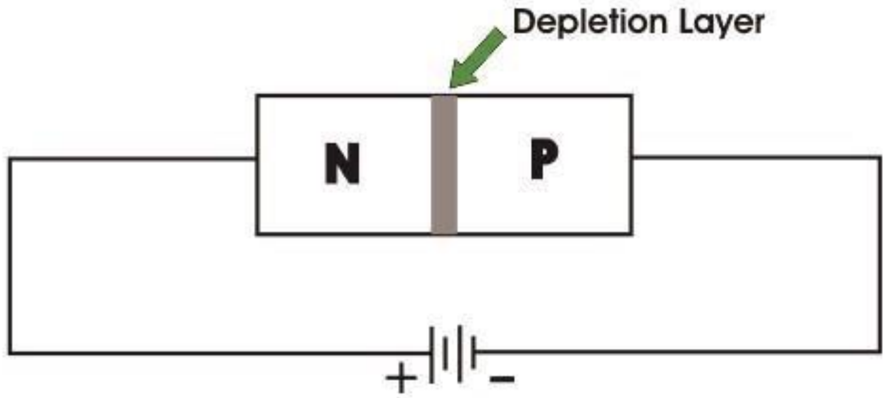
Due to this commutative phenomenon, very soon, huge free electrons get created in the depletion layer, and the entire diode will become conductive.

This type of breakdown of the depletion layer is known as avalanche breakdown, but this breakdown is not quite sharp.

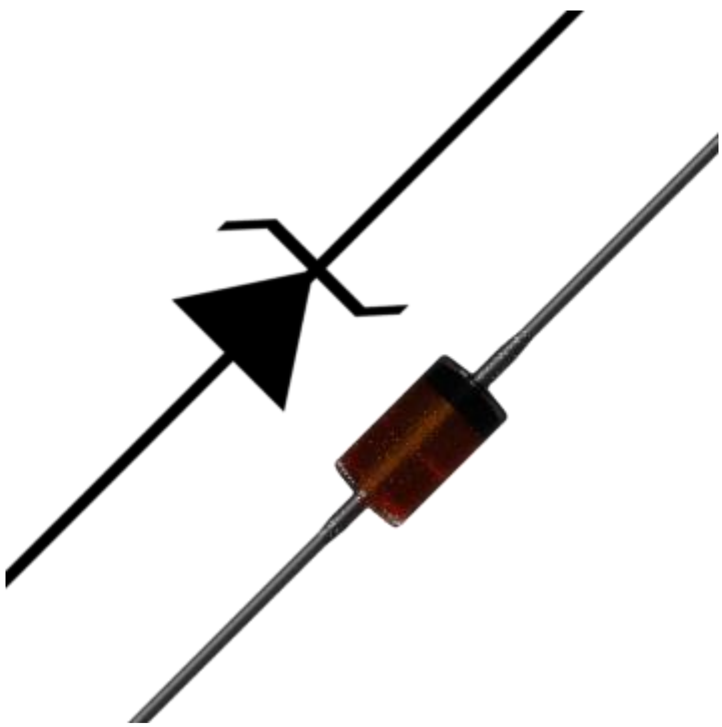
There is another type of breakdown in depletion layer which is sharper compared to avalanche breakdown, and this is called Zener breakdown.

When a PN junctionis diode is highly doped, the concentration of impurity atomswill be high in the crystal.

This higher concentration of impurity atoms causes the higher concentration of ions in the depletion layer hence for same applied reverse biased voltage, the width of the depletion layer becomes thinner than that in a normally doped diode.Due to this thinner depletion layer, voltage gradient or electric field strength across the depletion layer is quite high. If the reverse voltage is continued to increase, after a certain applied voltage, the electrons from the covalent bonds within the depletion region come out and make the depletion region conductive. This breakdown is called Zener breakdown. The voltage at which this breakdown occurs is called Zener voltage. If the applied reverse voltage across the diode is more than Zener voltage, the diode provides a conductive path to the current through it hence, there is no chance of further avalanche breakdown in it. Theoretically, Zener breakdown occurs at a lower voltage level then avalanche breakdown in a diode, especially doped for Zener breakdown. The Zener breakdown is much sharper than avalanche breakdown. The Zener voltage of the diode gets adjusted during manufacturing with the help of required and proper doping. When a **zener diode** is connected across avoltage source, and the source voltage is more than Zener voltage, the voltage across a Zener diode remain fixed irrespective of the source voltage. Although at that condition current through the diode can be of any value depending on the load connected with the diode. That is why we use a Zener diode mainly for controlling voltage in different circuits.

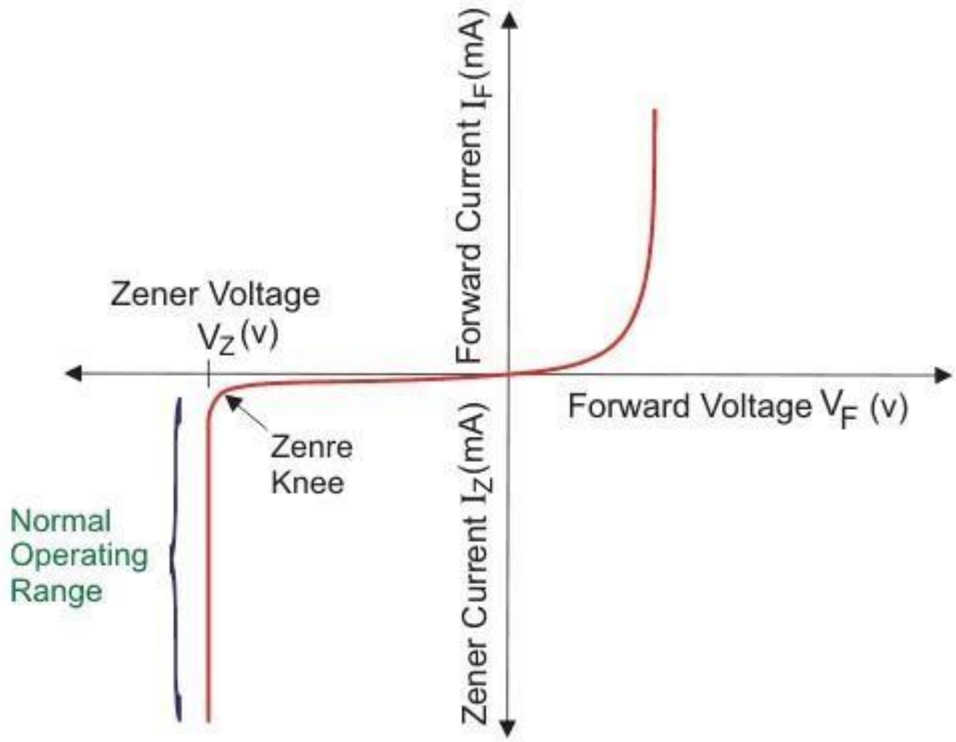


The circuit symbol of a **Zener diode** is also shown below.



Characteristics of a Zener Diode

The graphical representation of the operation of the Zener diode is called the V-I characteristics of a Zener diode.



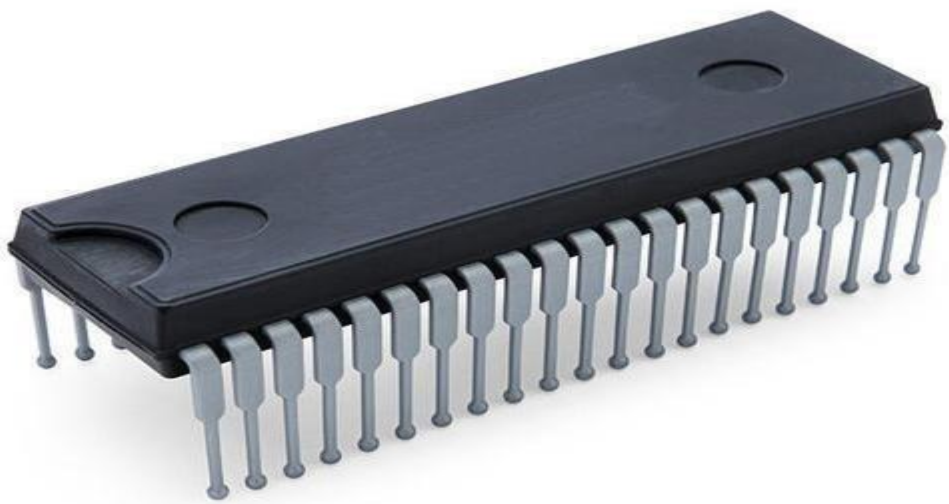
The above diagram shows the V-I characteristics of a Zener diode.

When the diode is connected in forward bias, this diode acts as a normal diode but when the reverse bias voltage is greater than Zener voltage, a sharp breakdown takes place.

In the V-I characteristics above V_z is the Zener voltage.

It is also the knee voltage because at this point the currentincreases very rapidly.

INTEGRATED CIRCUIT (I.C):-



An integrated circuit or I.C is a packaged electronic circuit in which both active and passive components are fabricated on a single chip.

It is a small chip that can function as an amplifier, oscillator, timer, microprocessor or even computer memory.

It is a small wafer, usually made of silicon, that can hold anywhere from hundreds to millions of transistors, resistors and capacitors.

This I.C can perform calculations and store data using either digital or analog technology.

Digital I.Cs use logic gates, which work only with values of 1s and 0s.

A low signal sent to a component on a digital I.C will result in a value of 0, while a high signal creates a value of 1.

Digital I.Cs is the kind we usually find in computers, networking equipment and most consumer electronics.

Analog or linear I.Cs work with continous values. This means a component on a linear I.C can take a value of any kind and output another value.

The term linear is used since the output value is a linear function of the input.

Linear I.Cs is typically used in audio and radio frequency amplification. E.X.:Operational Amplifiers and power management circuits.

For example:-A Component on a linear IC may multiple an incoming values by a factor of 2.5 and O/P the result.

Analog ICs perform analog functions such as amplifications, active filtering, mixing.

Analog ICs ease the burden of circuit designers by having expertly designed analog circuits available instead of designing AND/OR constructing a difficult analog circuit from scratch.

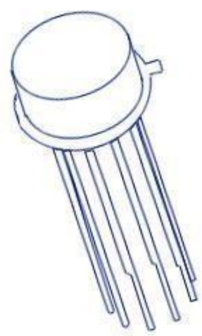
ICs can also combine analog and digital circuits on a single chip to create functions such as analog to digital converters and digital to analog converters.

ADVANTAGES:-

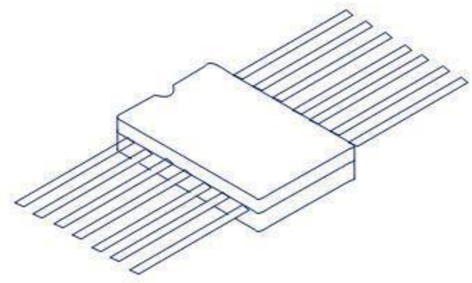
- The entire physical size of IC is extremely small than that of discrete circuit.
- The weight of an IC is very less as compared to entire discrete circuits.
- It is a more reliable
- It consumes low power
- It can be easily replaced but it can be hardly repaired in case of failure
- It has increased operating speed
- It is suitable for small signal operation

DISADVANTAGES

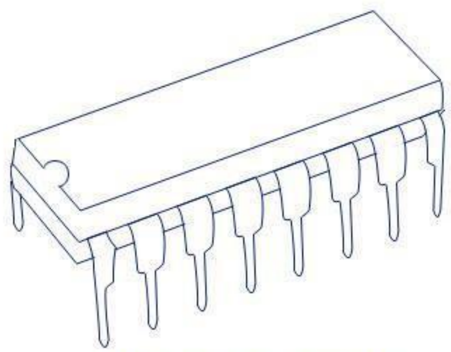
- Coils or indicators cannot be fabricated
- It can handle only limited amount of power
- Power dissipation surface on is limited to ten watt
- Inductors cannot be fabricated directly
- Low noise and high voltage operation are not easily obtained
- Inductors and transformers are connected exterior to the semi conductor chip as it is not possible to fabricate them on the semi conductor chip.



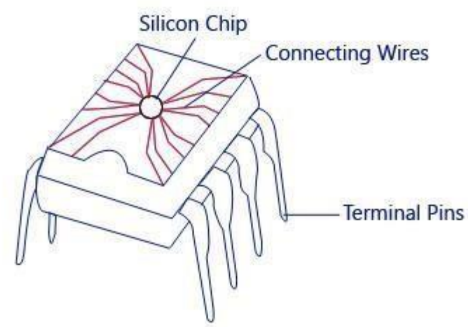
Metal Can IC



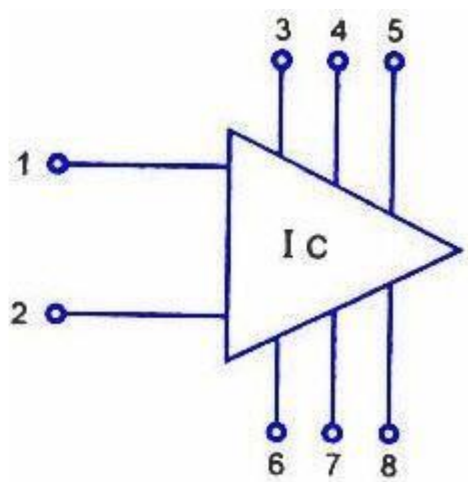
Ceramic Flat Pack IC

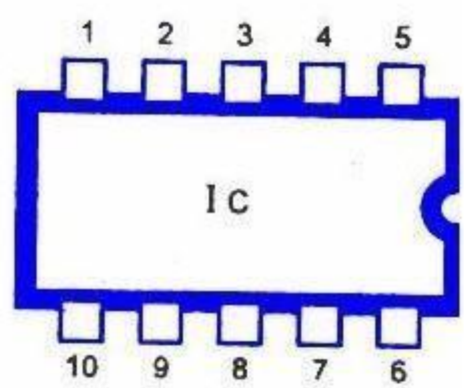


14 Pin Dual In-line Package (DIP)



8 Pin Dual In-line Package (DIP) Plastic





UNIT-2

ELECTRONIC CIRCUITS

RECTIFIERS:-

Rectifiers are nothing but a simple diode or group of diodes which are used to convert ac in to dc.

PN junction diodes or crystal diodes are used as rectifiers.

Rectifiers are mainly classified into two types depending on the number of diodes used in the circuit or arrangement of diodes in the circuit.

a) Half wave rectifier

b) Full wave rectifier

a)HALF WAVE RECTIFIER

In **Half Wave Rectifier**, when AC supply is applied at the input, positive half cycle appears across the load, whereas the negative half cycle is suppressed.

This can be done by using the semiconductor PN junction diode.

The diode allows the current to flow only in one direction. Thus, converting the AC voltage into DC voltage.

Circuit Diagram of Half Wave Rectifier

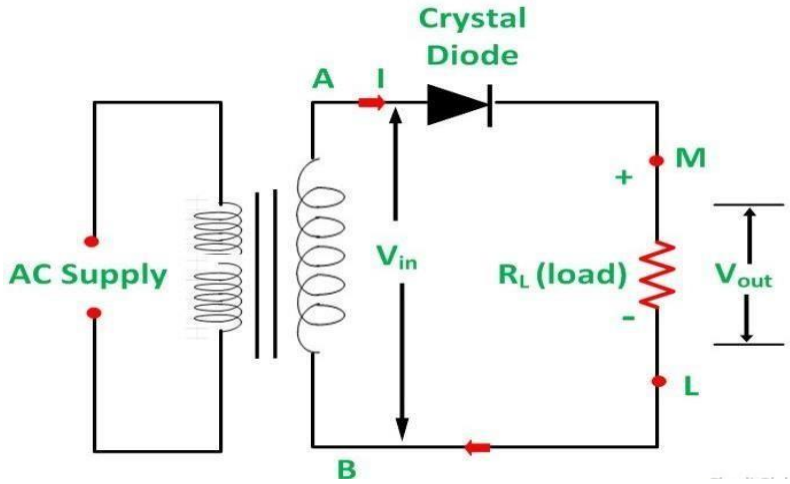
In a half wave rectifier, only one crystal diode is used.

The half wave rectifier is the simplest form of rectifier.

The half wave rectifier is made up of an A.C source, transformer (step down), diode and resistor (load).

The diode is placed between the transformer and resistor (load).

It is connected in the circuit as shown below.



AC source

The AC source supplies Alternating Current to the circuit.

The alternating current is often represented by a sinusoidal waveform. The AC supply to be rectified is generally given through a transformer.

Transformer

Transformer is a device which reduces or increases the AC voltage.

The step-down transformer reduces the AC voltage from high to low whereas the step-up transformer increases the AC voltage from low to high.

In half wave rectifier, we generally use a step-down transformer because thevoltageneeded for the diode is very small.

Applying a large AC voltage without using transformer will permanently destroy the diode. So we use step-down transformer in half wave rectifier. However, in some cases, we use a step-up transformer.

In the step-down transformer, the primary winding has more turns than the secondary winding. So the step-down transformer reduces the voltage from primary winding to secondary winding.

It also isolates the rectifier from power lines and thus reduces the risk of electric shock.

Diode

A diode is a two terminal device that allows electric current in one direction and blocks electric current in another direction.

Resistor

A resistor is an electronic component that restricts the current flow to a certain level.

Operation of Half Wave Rectifier

In a half wave rectifier ckt, the rectifier conducts current only during the positive half cycle of the input ac voltage.

The ac voltage across the secondary winding AB changes polarity after every half cycle.

During the +ve half cycle of the input a.c voltage, end A becomes +ve with respect to end B.

Thus the diode becomes forward biased & conducts current.

During the –ve half cycle of the input a.c voltage, end A becomes –ve with respect to end B.

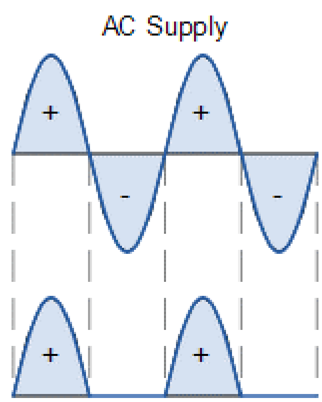
Thus the diode becomes reverse biased& conduct no current.

So in this rectifier current flows only during the +ve half cycle of the input a.c voltage.

As current flows only in one direction through load RL, dc output is obtained across RL.

The output obtained is pulsating.

These pulsations in the output can be smoothened with the help of filter circuit.



Rectified Output Waveform
No Negative Half-cycle

ADVANTAGES:-

Use of only one diode reduces the cost

As transformer isolates the rectifier ckt from the power line, the chances of the electric shock is being reduced.

DISADVANTAGES:-

As current flows during the positive half cycle of the input ac voltage, the output is low.

b)FULL WAVE RECTIFIER:-

In a full wave rectifier current flows through the load in the same direction for both half cycles of input ac voltages Full wave rectifiers are classified into:-

i. full wave centre tap rectifier
ii. Full wave bridge rectifier

i)FULL WAVE CENTRE TAP RECTIFIER:-

A center tapped full wave rectifier is a type of rectifier which uses a center tapped transformer and two diodes to convert the complete AC signal into DC signal.

Circuit Diagram of Full Wave Centre Tap Rectifier:

The center tapped full wave rectifier is made up of an AC source, a centre tapped transformer, two diodes and a load resistor.

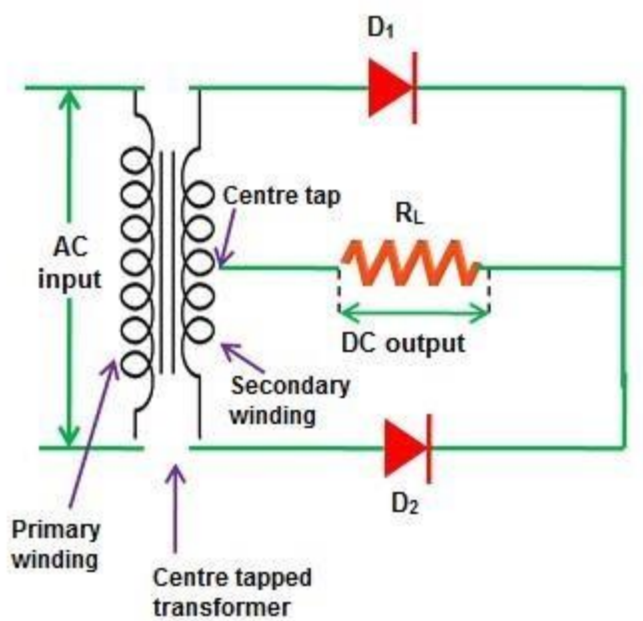
The AC source is connected to the primary winding of the center tapped transformer.

A center tap (additional wire) connected at the exact middle of the the secondary winding divides the input voltage into two parts.

The upper part of the secondary winding is connected to the diode D_1 and the lower part of the secondary winding is connected to the diode D_2.

Both diode D_1 and diode D_2 are connected to a common load R_L with the help of a center tap transformer.

The center tap is generally considered as the ground point or the zero voltage reference point.



The above ckt employs two diodes D1&D2

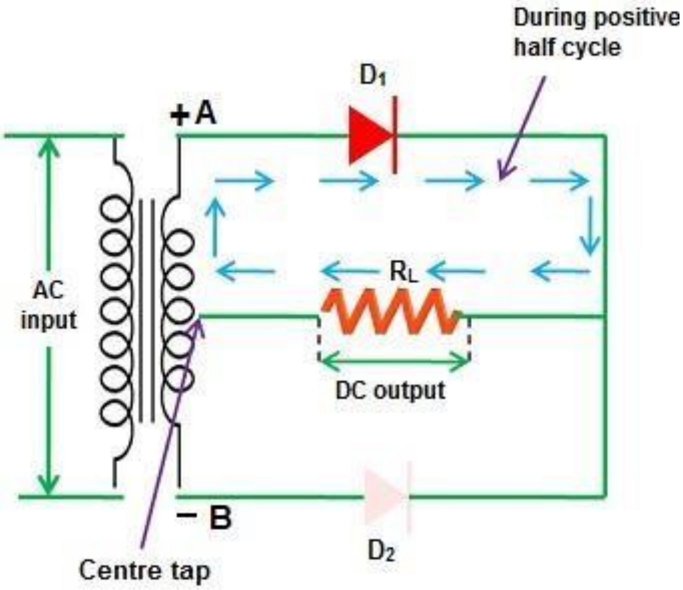
Operation of Full Wave Rectifier:

During the positive half cycle of the input voltage, end A becomes +ve& end B of secondary winding becomes –ve.

Thus, diode D1 becomes forward biased &diode D2 becomes reverse biased.

This means that diode D1 conducts while diode D2 does not conducts.

The conventional current flows through diode D1, load resister RL and upper half of secondary winding.



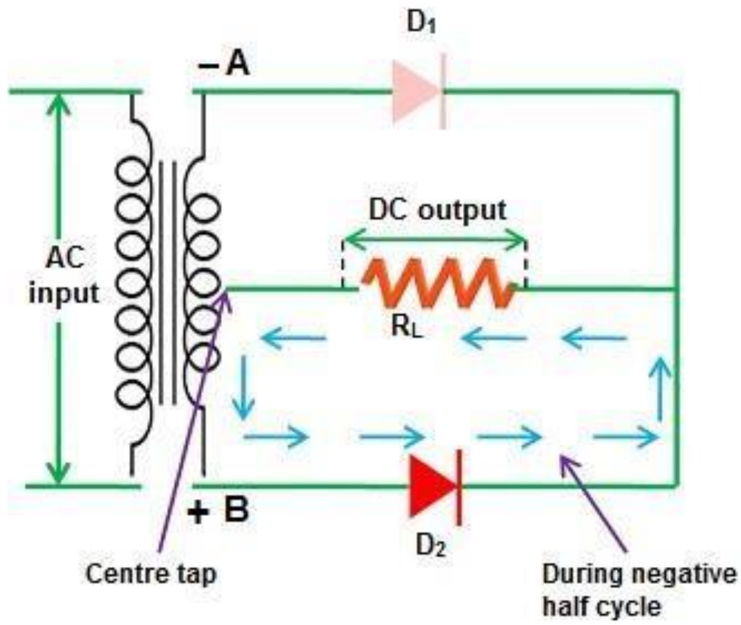
During the –ve half cycle of the input voltage, end A becomes –ve& end B becomes +ve.

Thus diode d1 becomes reverse biased &diodeD2 becomes forward biased. This means that diode D2 conducts while diode D1 doesn't conducts.

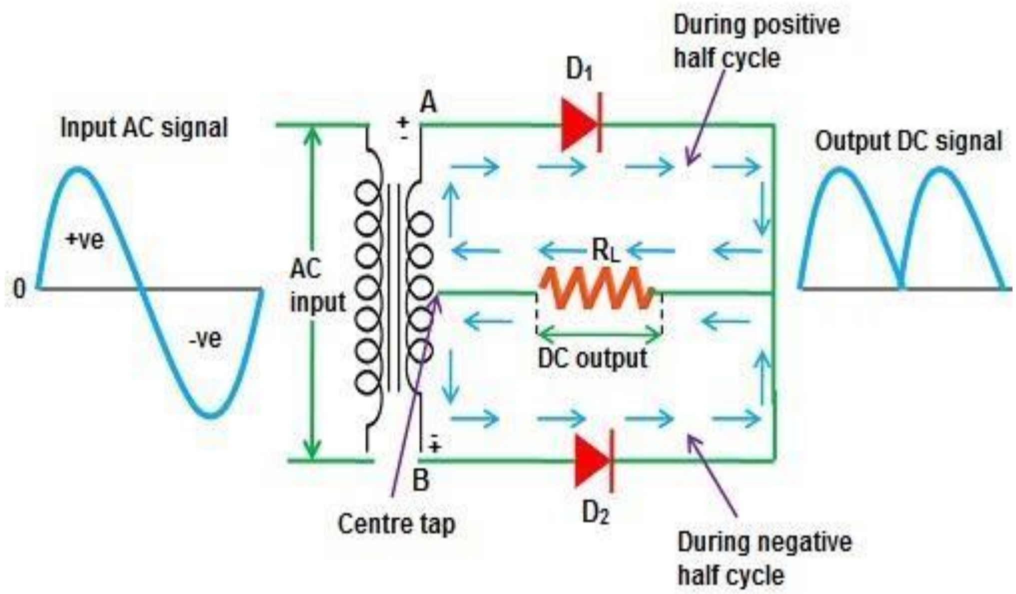
The conventional current flows through diode D2, load resister RL & lower half of secondary winding.

From the figure it is clearly seen that the current in the load RL is in the same direction for both half cycle of input ac voltages.

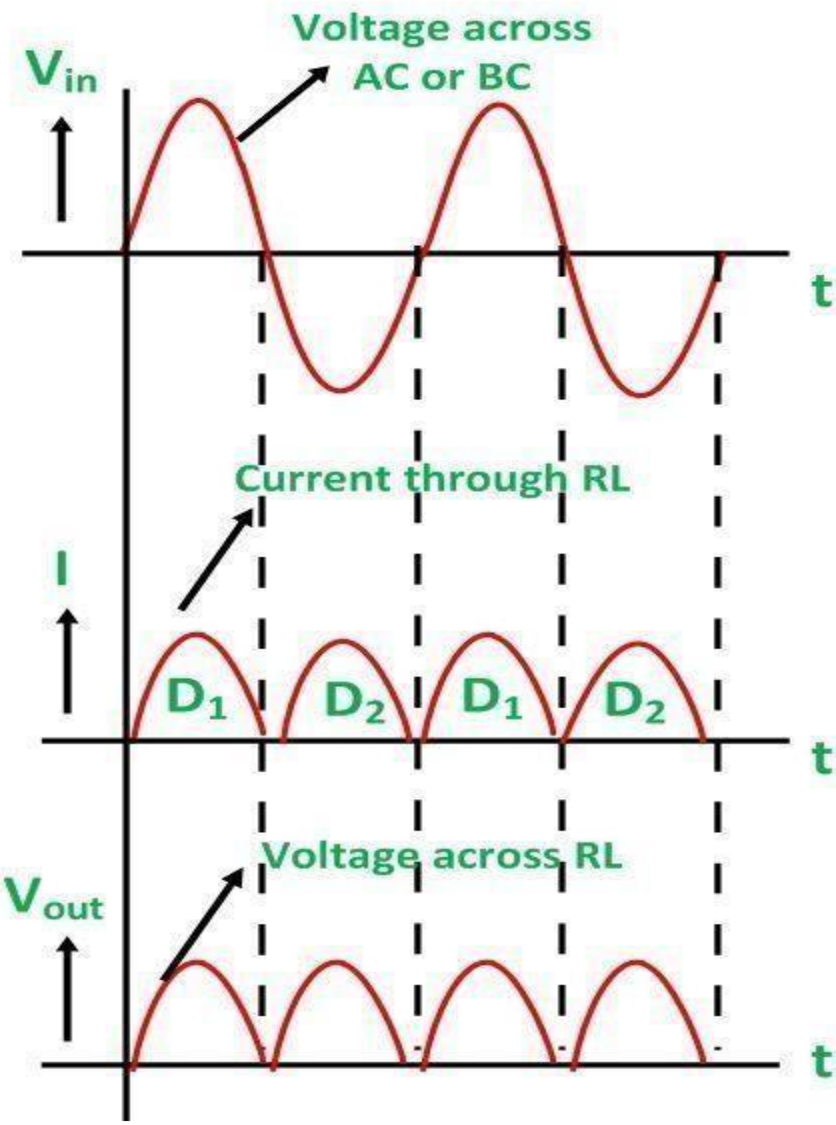
Thus, output is obtained across load RL.



D1
– A
AC
input
DC output
RL
+ B
D2
Centre tap
During negative
half cycle



During positive
half cycle
D1
A
Input AC signal
Output DC signal
+ve
0
-ve
AC
input
RL
DC output
B
Centre tap
D2
During negative
half cycle



ADVANTAGES:-

Output is obtained for both cycles of input ac voltages.

Efficiency is higher than that of half wave rectifier.

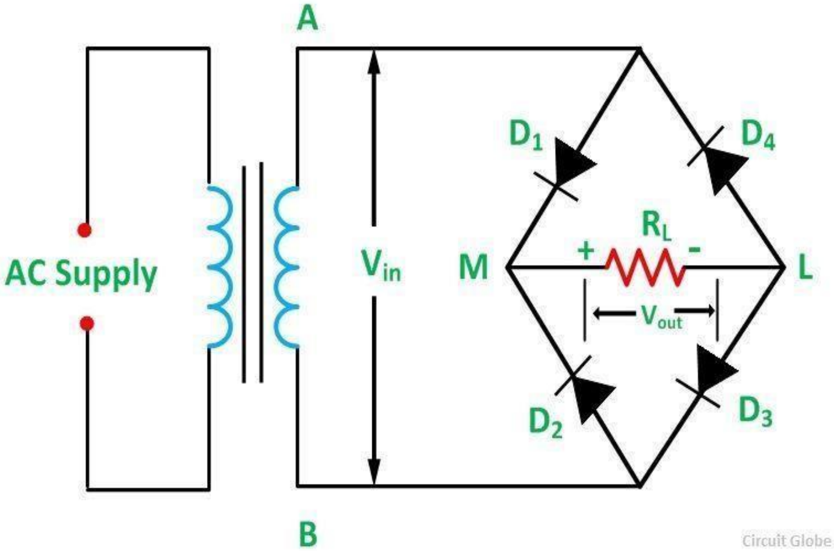
DISADVANTAGES:-

Locating centre tap on the secondary winding is difficult.

The diodes used have high PIV.

The d.c output is small as each diode utilizes only one half of the transformer secondary voltage.

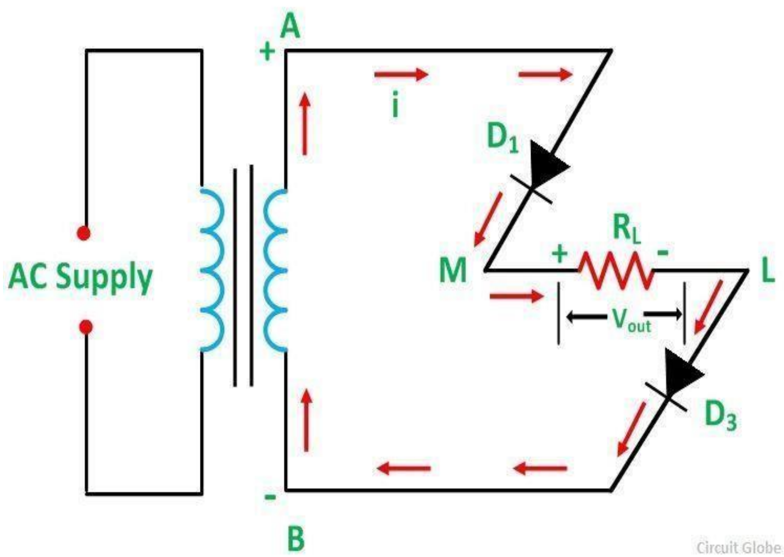
ii)FULL WAVE BRIDGE RECTIFIER



This rectifier employs 4diodes i.e. D1,D2,D3&D4

During the +ve half cycle of the input ac voltage, end A of secondary winding becomes +ve& end B becomes –ve.

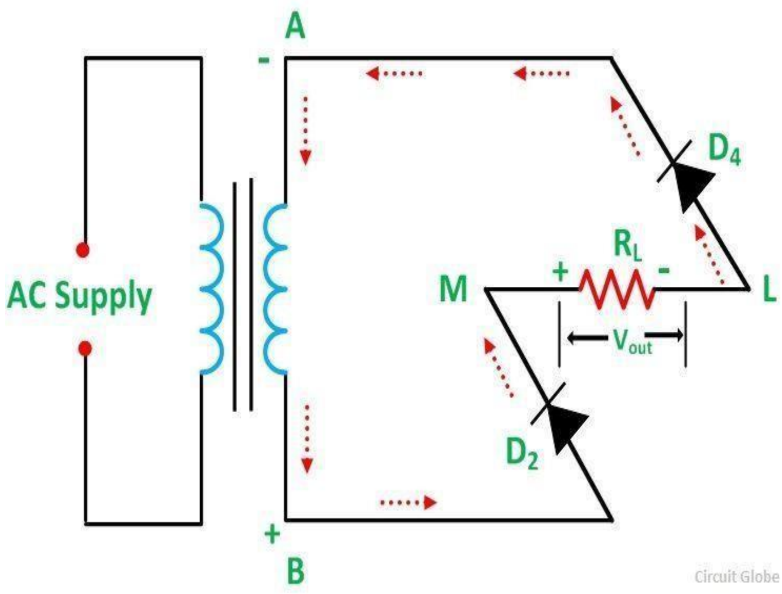
This makes diode D1 & D3 forward biased while diode D2& D4 becomes reverse biased. Thus, only diode D1 & D3 conducts. The conventional current flow is shown by dotted arrows.

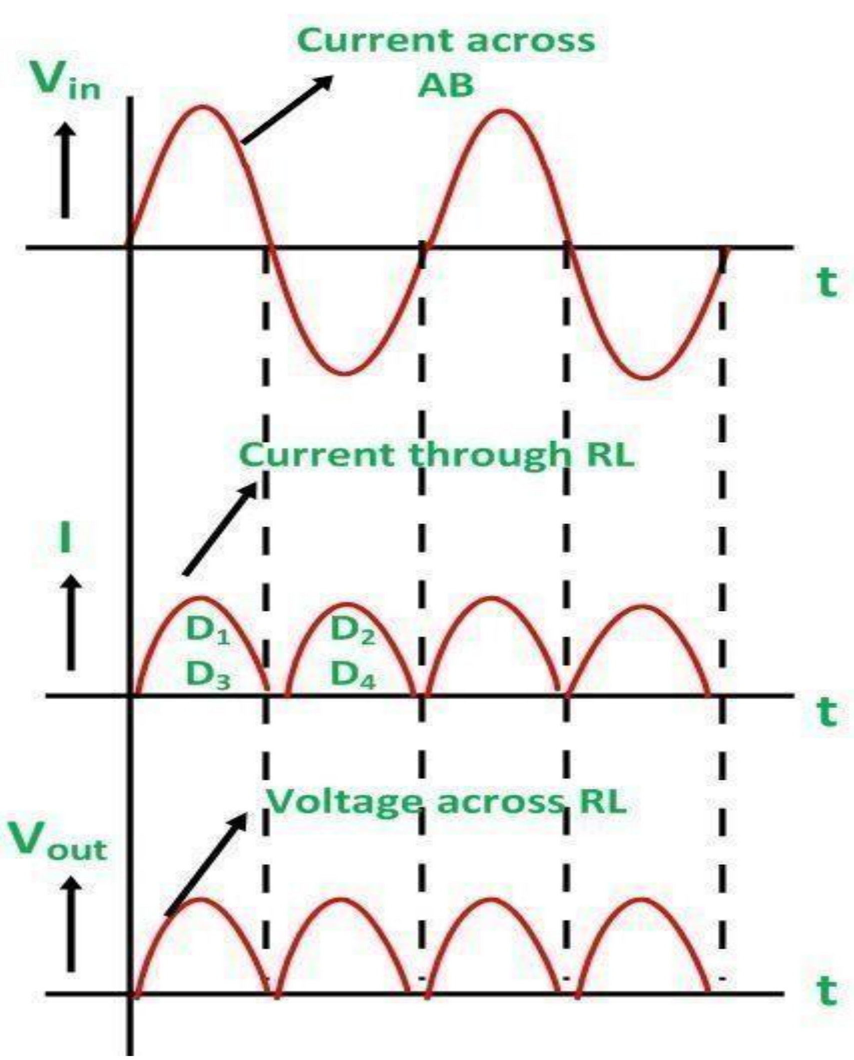


During the –ve half cycle of input voltage, end A becomes –ve& end B becomes +ve.

This makes diode D2 & D4 forward biased while diode D1 & D3 reverse biased. Thus, only diode D2 & D4 conducts.

The conventional current flow is shown by solid arrows.





ADVANTAGES:-

PIV is one half that of centre tap circuit.

Output is twice that of centre tap circuit.

Need for centre tapped transformer is eliminated.

DISADVANTAGES:-

Requires 4 diodes which increase the cost.

FILTERS:-

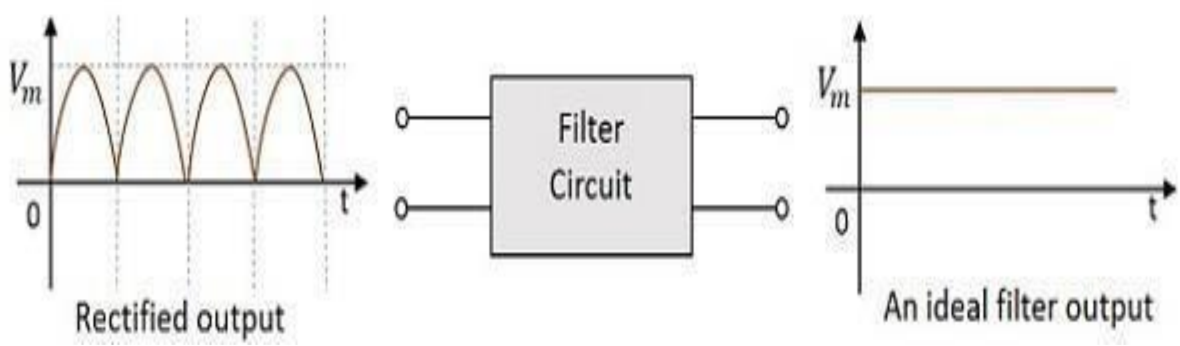
A filter is a device which removes the ac component of rectifier output but allows the dc component to reach the load.

A filter should be connected between the rectifier output & the load.

A filter circuit is a combination of inductor & capacitor.

A capacitor passes ac readily but does not pass dc at all.

An inductor opposes ac but allows dc to pass through it.



Filter circuits are classified into four types

1. Inductor filter
2. Capacitor filter
3. Choke input filter
4. Capacitor input filter or π filter

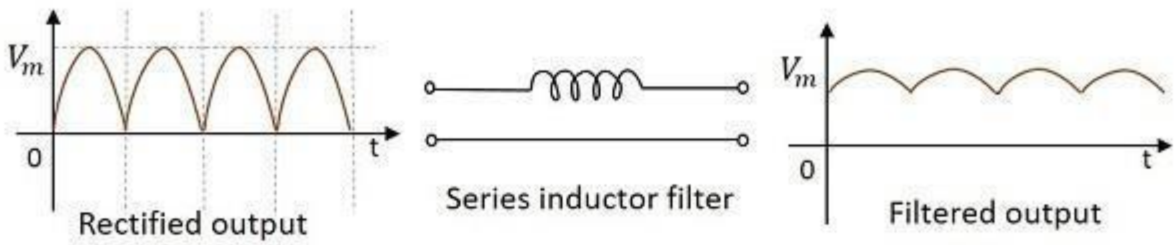
1.INDUCTOR FILTER:-

An inductor filter consists of an inductor which is connected in series, so also named as series inductor filter.

The pulsating output of the rectifier is applied across the terminal 1&2 of the filter circuit.

As the pulsating output consists of both ac & dc components, the choke offers high opposition to the passage of ac component but negligible opposition to dc component.

But some leakage ac component manages to pass through the inductor.



Hence, due to the presence of that leakage A.C component the output is pulsating one which can be removed by using more number of filter stages or by adjusting the component values.

2. CAPACITOR FILTER:-

A Capacitor filter consists of a capacitor which is connected in parallel with the load R_L.

The pulsating direct voltage of a rectifier is applied across the capacitor.

As the rectifier voltage increases, it charges the capacitor and also supplies current to the load.

But when rectifier voltage reaches point a, the capacitor is charged to its peak value.

After reaching point a when rectifier voltage starts decreasing, the capacitor discharges through the load and the decrease in voltage is shown by line AB.

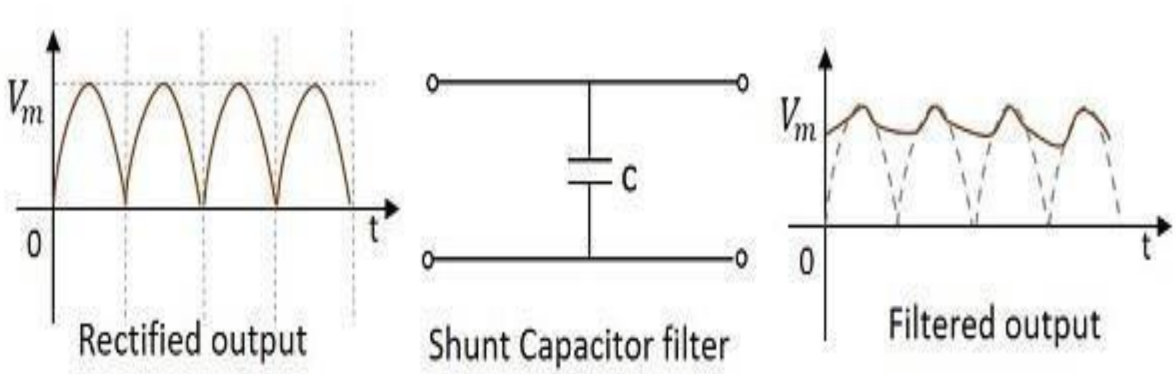
The voltage across the load will decrease only slightly because immediately the next voltage peak comes and recharges the capacitor.

This process is repeated again and again and output voltage waveform becomes ABCDE.

In such filter circuits, a very small ripple is left out.

This filter circuit is extremely popular because of its low cost, small size, little weight and good characteristics.

Capacitor Filter is used in transistors radio battery eliminators.



<u>NOTE:-</u>

For D.C, Frequency=0,

$X_c = 1/2\pi fC$

$= 1/0 = \infty$

$X_L = 2\pi fL = 0$

So, capacitor has high/infinite reactance to d.c component and inductor has low/zero reactance to d.c component.

3. CHOKE INPUT FILTER:-

This filter circuit consists of an inductor L which is connected in series with the rectifier output and a capacitor C which is connected across the load.

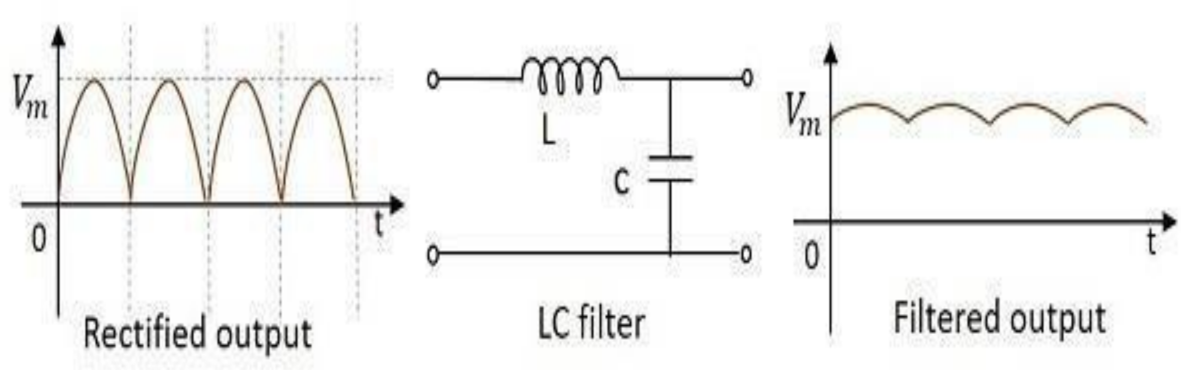
The pulsating output of the rectifier is applied across the terminals 1 and 2 of the filter circuit.

As the pulsating output consist of both A.C and D.C components, the choke offers high opposition to the passage of A.C components but negligible opposition to D.C components.

Thus only D.C components has small amount of leakage A.C component of the rectifier output passes though the choke.

The capacitor C further bypasses the A.C component but prevents D.C components to flow through it.

Thus, only small amount of ripple content is obtained along with the D.C component at the load.



4. CAPACITOR INPUT FILTER:-

It consists of a capacitor C1 which is connected across the rectifier output, a choke L in series and a capacitor C2 which is connected across the load RL.

The capacitor C1 offers low reactance to A.C components of rectifier output while it offers infinite reactance to D.C component.

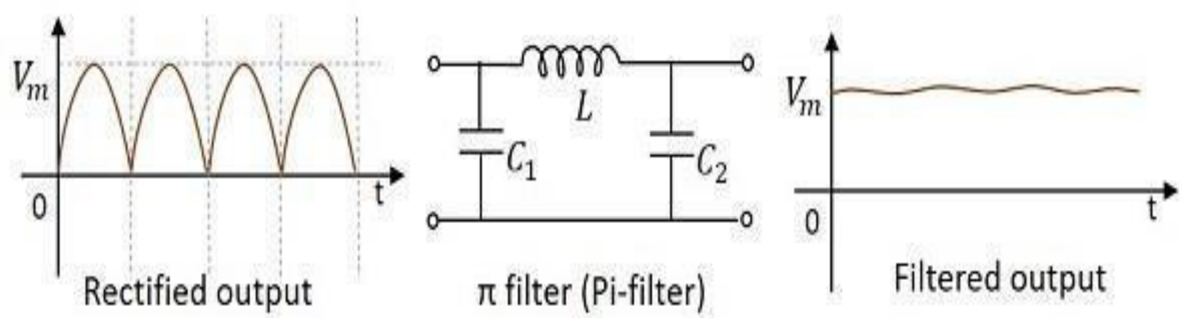
Thus, capacitor C1 bypasses appreciable amount of A.C component while D.C component along with the leakage A.C component continues to move towards choke L.

The choke L offers high reactance to A.C component but offers zero reactance to D.C component.

Thus, D.C component pass though it thereby blocking the A.C component.

The capacitor C2 bypasses the A.C component which the choke has failed to block.

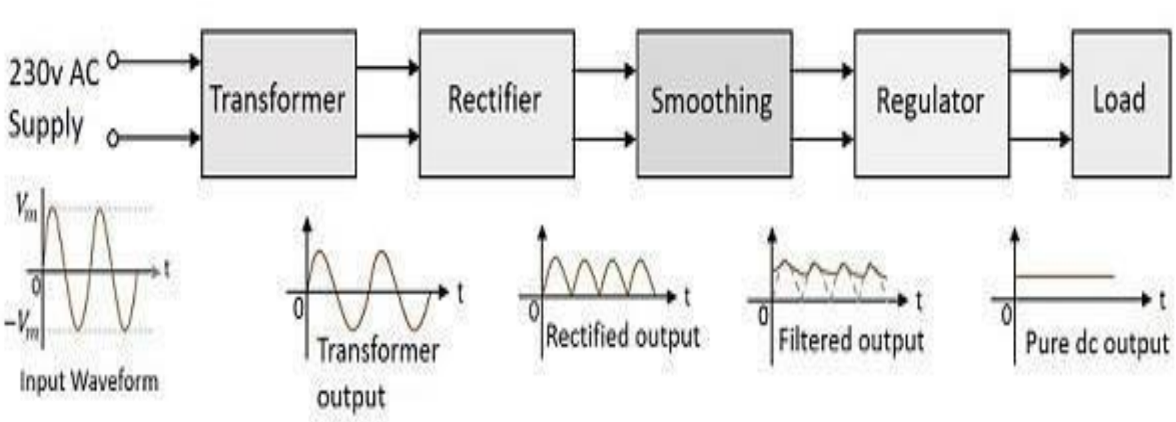
Thus, only D.C component appears across the load.



VOLTAGE REGULATORS:-

A voltage regulator is a device which converts unregulated ac into a constant dc.

BASIC BLOCK DIGRAM OF DC REGULATED POWER SUPPLY:-



Transformer : -

When an alternating voltage is applied across the primary winding of a transformer, it transforms the voltage either to a higher or lower value without any change in frequency.

As a transformer isolates the rectifier ckt from the power line, the chances of electric shock is being reduced.

RECTIFIER :-

When the secondary winding ac voltage is applied to a rectifier, a pulsating DC voltage is obtained.

FILTER :-

When the pulsating DC voltage is applied to a filter, it removes the ac component of the rectifier output.

It allows the dc component to reach the regulator.

- REGULATOR :-

The unregulated ac from the filter is applied to the regulator.

The regulator converts unregulated ac into a constant dc.

This constant dc then drives the load.

TRANSISTORS

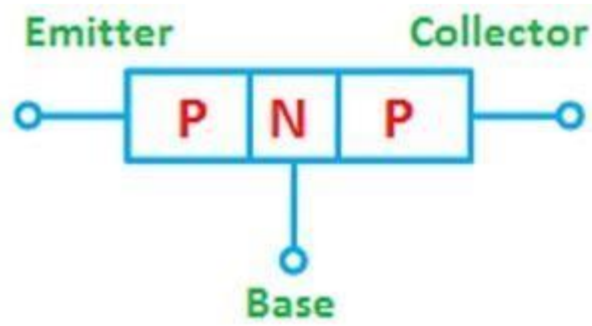
A transistor consists of two PN junction formed by sandwiching either P type or N type material between a pair of opposite types

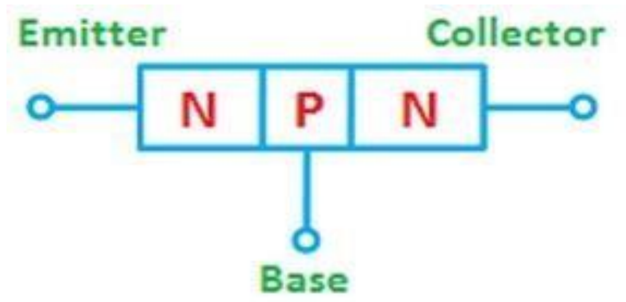
A transistor transfers signals from low resistance to high resistance

A transistor has two pnjunction , one pn junction is forward biased while other pn junction is reversed biased

The forward biased pn junction provides lower resistance path while the reverse biased pn junction provides high resistance path. Transistors are of two types

1. N -P-N transistor
2. P-N-P transistor





A transistor has mainly three sections

a) Emitter
b) Base
c) Collector
d)

a)EMITTER

It is heavily doped and thick.

It supplies charge carriers (electrons or holes).

It is always forward biased with respect to base.

b)BASE

It is moderately doped and thin.

It passes most of the emitter charge carriers to the collector.

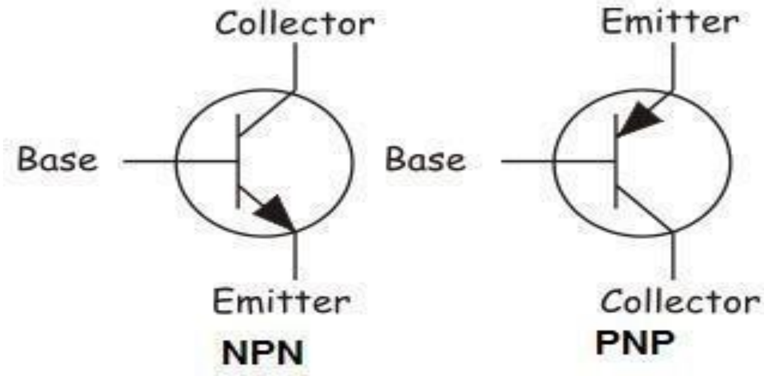
The function of the base is to control the flow the charge carrier.

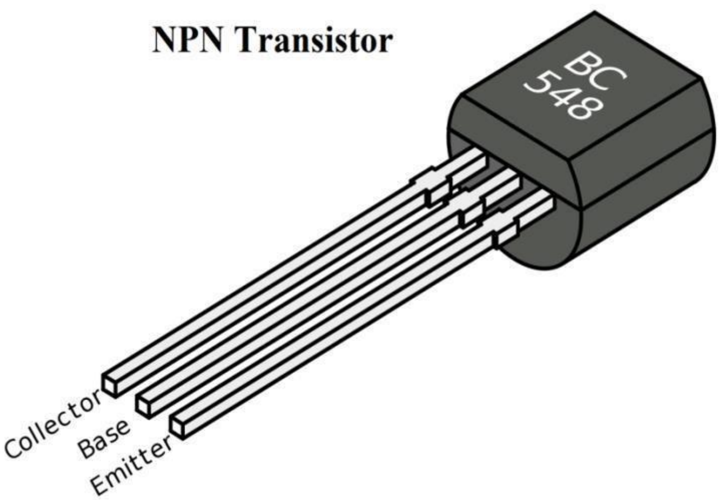
c)COLLECTOR

It is moderately doped and made wider than the both emitter and base to dissipate the heat produced at the collector junction.

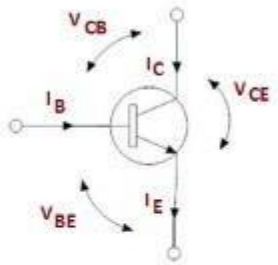
Collector collects the charges.

It is always reversed biased with respect to base.

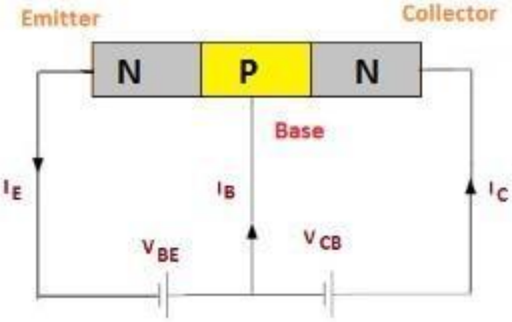

Collector
Base
Emitter
NPN
Emitter
Base
Collector
PNP


NPN Transistor
BC
548
Collector
Base
Emitter

WORKING OF NPN TRANSISTORS:-



Electrical Symbol of NPN Transistor



Structure of NPN Transistor

In the above figure the BE junction is forward biased and BC junction is reverse biased. The Forward biased causes the electrons in the n type emitter to flow towards the base. This constitutes the emitter current (IE).

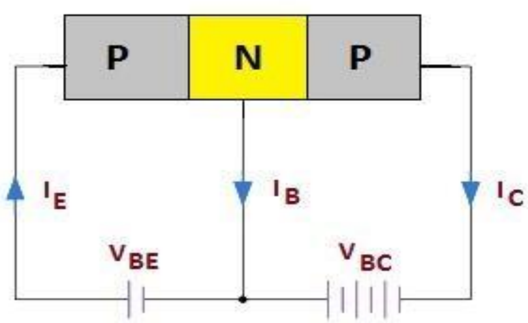
The electrons flowing towards the base tends to combine with the holes. As the base is lightly doped and thin, so only a few electrons combine with the holes to constitute base current (IB).

The remaining electrons flows into the collector region to constitute collector current (IC)

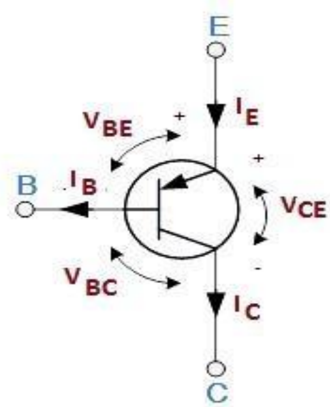
Thus, in this way entire emitter current flows through the collector circuit.

$$IE = IB + IC$$

WORKING OF PNP TRANSISTORS:-



Construction



Circuit Symbol

$$I_C = I_E - I_B$$

The forward bias in the BE junction causes the holes in the p type semiconductor to flow towards the base. This constitutes the emitter current (IE).

The holes flowing towards the base tends to combine with the electrons. As the base is lightly doped and thin, so only few holes combine with the electrons to constitute base current (IB).

The remaining holes flows into the collector region to constitute the collector current

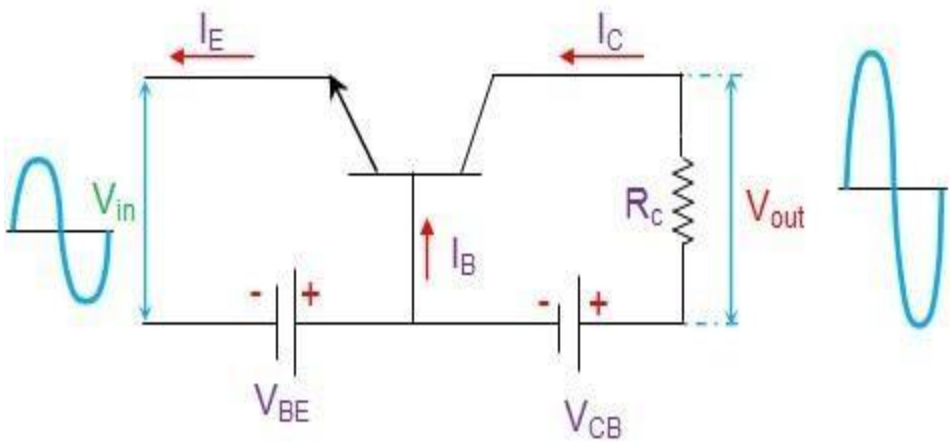
(IC).

Thus, in this way entire emitter current flows through the collector circuit.

IE = IB + IC

Current conduction within PNP transistor is by holes .However, in the external connecting wires, the current is still by electrons.

TRANSISTOR AS AN AMPLIFIER:-



A weak signal is applied between BE junction & output is obtained across load RC.

The load RC is connected in the collector circuit.

In order to faithfully amplify the signal, the input circuit should always remain forward biased.

To achieve this, a D.C. voltage VBE is applied to the input section along with the ac i/p signal.

This dc voltage is known as bias voltage.

As the input circuit is of low resistance, so a very small change in the input voltage causes a large change in the emitter current.

We clearly know that emitter current is approximately equal to the collector current(IC).

Thus, due to the large change in IE, there is also a large change in IC.

This IC flowing through RC produces a large voltage across it.

Thus, a weak signal applied to the input circuit appears in its amplified form in the collector circuit.

Thus, in this way a transistor acts as an amplifier.

For instance:-

A 5v signal was applied at the input.

This causes 5mA IE to flow. We know that IE approximately equal to IC.

So , a Ic of approx 5mA flows through Rc

Thus , voltage obtained across Rc = 5mA * 5KΩ =25 volt

A change of 1 volt is done at the input, so input applied now is 6 volts.

A change in 1 volt at the input brings out a change of 1 mA in IE. This causes 6 mA

IE to flow.

Thus, approx 6 mA Ic flows through Rc

So, voltage obtained across RC =6 mA*5KΩ=30 volts.

Thus, from the above it is clear that a small change at the input produces a large change at the output.

So, a transistor produces a change of about 30 V - 25 V =5V due to change of 1 V at the input.

TRANSISTOR CONNECTION:-

A transistor can be connected in a circuit in the following three ways:

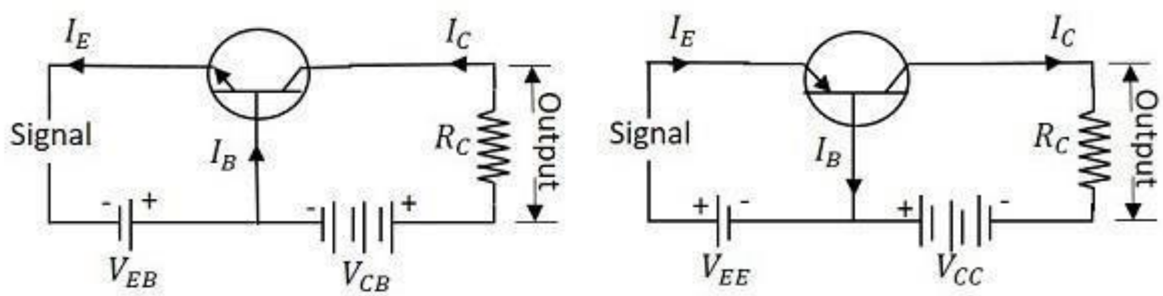
a) common base connection
b) common emitter connection
c) common collector connection

a)Common base connection

In this circuit arrangement, input is applied between emitter and base & output is obtained from collector base.

In CB connection, base of the transistor is common to input & output circuit.

Common Base Connection



Using NPN transistor

Using PNP transistor

<u>CURRENT AMPLIFICATION FACTOR (α)</u>

It is the ratio of the change in collector current to change in emitter current at constant collector base voltage.

$$\alpha = \frac{\Delta I_C}{\Delta I_E}$$

α is less than unity.

It can be increased by decreasing the base current.

Base current can be decreased by doping the base lightly & making it thin.

<u>EXPRESSION OF COLLECTOR CURRENT</u>:-

The total collector current consists of

i) Parts of IE which reaches the collector terminal.

ii) As CB junction is reversed biased, so some leakage current flows due to minority carriers.

IC =α IE+I leakage

=α (IB+IC) + ICBO (: I leakage is abbreviated as ICBO)

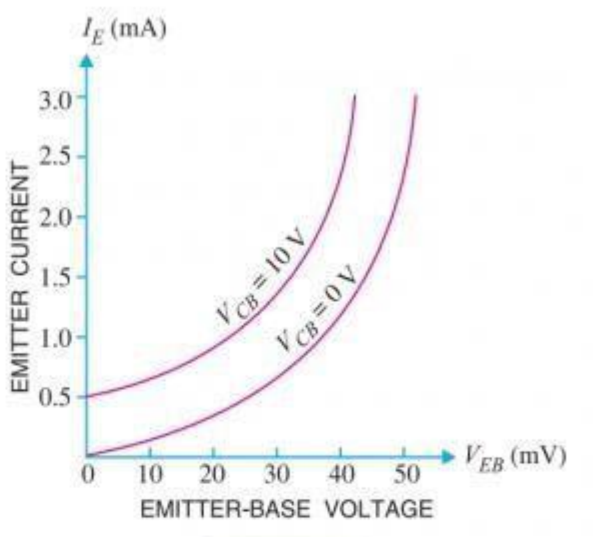
=α IB+α IC+ICBO

IC-α IC =α IB+ICBO

IC (I-α) = α IB +ICBO

$$IC = \frac{\alpha}{(I-\alpha)} IB + \frac{1}{(I-\alpha)} ICBO$$

INPUT CHARAC TERISTICS



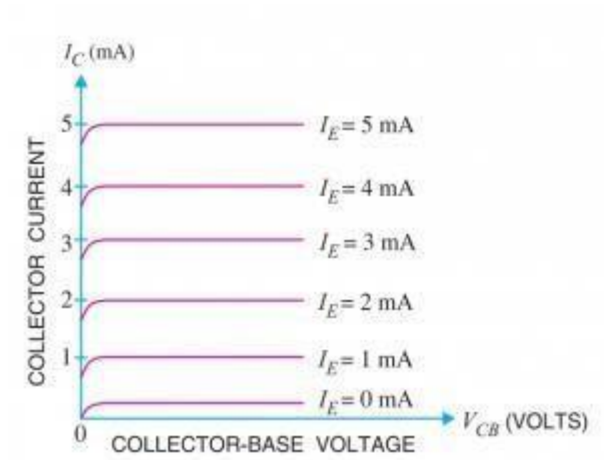
It is the curve between emitter current (IE) & base emitter voltage (VBE) at constant VCB.

By keeping VCB constant at a particular value, when there is small increase in VBE, the IEincreases rapidly .This means that the input resistance is very small.

Input resistance is the ratio of change in VBE to the change in IE at constant VCB.

$$\text{Input resistance } (r_i) = \frac{\Delta V_{BE}}{\Delta I_E} \text{ at constant VCB.}$$

OUT PUT CHARACTERISTICS



It is the curve between IC & VCB At constant IE.

By keeping IEconstant at a particular value, when there is an increase between VCB, there is a small size in collector, current.

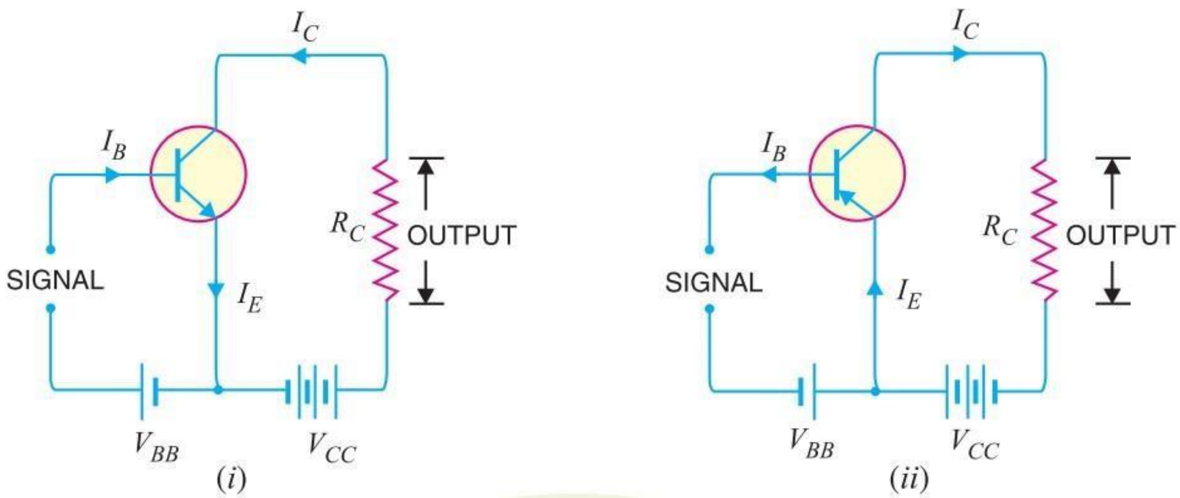
But when voltage VCB is increased above 1-2 volts, the collector current becomes constant.

This means that the output resistance is very high.

Output resistance is the ratio of change in VCB Is change in IC at constant IE.

$$\text{Output resistance } (r_O) = \frac{\Delta V_{CB}}{\Delta I_C} \text{ at constant IE.}$$

COMMON EMITTER CONNECTION:-



In the above circuit arrangement, input is applied between base & emitter & output is obtained from collector & emitter.

Here, emitter is common to both input & output circuits, hence named as CE connection.

CURRENT AMPLIFICATION FACTOR (β)

It is the ratio of the change in IC to change in IB.

$$\beta = \Delta I_C / \Delta I_B$$

The value of β ranges from 20 to 500.

RELATION BETWEEN α AND β

$\Delta I_E = \Delta I_B + \Delta I_C$

$\Delta I_B = \Delta I_E - \Delta I_C$

$$\beta = \frac{\Delta I_c}{\Delta I_b} = \frac{\Delta I_c}{\Delta I_e - \Delta I_c}$$

Divide numerator and denominator by ΔIE

$$\beta = \frac{\Delta I_c / \Delta I_e}{\frac{\Delta I_e}{\Delta I_e} - \frac{\Delta I_c}{\Delta I_e}} = \frac{\alpha}{1-\alpha}$$

Putting α=1, $\beta = \frac{1}{1-1} = \frac{1}{0} = \infty$

Thus, it is clear that CE connection provides very high current gain. So, CE connections are more preferred over other two connections.

EXPRESSION FOR COLLECTOR CURRENT

$I_C = \alpha I_E + I_{CBO}$

$I_C = \alpha (I_B + I_C) +$

I_{CBO} $I_C = \alpha I_B + \alpha I_C$

$+ I_{CBO}$

$I_C - \alpha I_C = \alpha I_B + I_{CBO}$

$I_C (1 - \alpha) = \alpha I_B + I_{CBO}$

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}$$

$I_C = \beta I_B + I_{CEO}$

Where, $I_{CEO} = \frac{I_{CBO}}{1-\alpha}$ =Collector emitter current with base open.

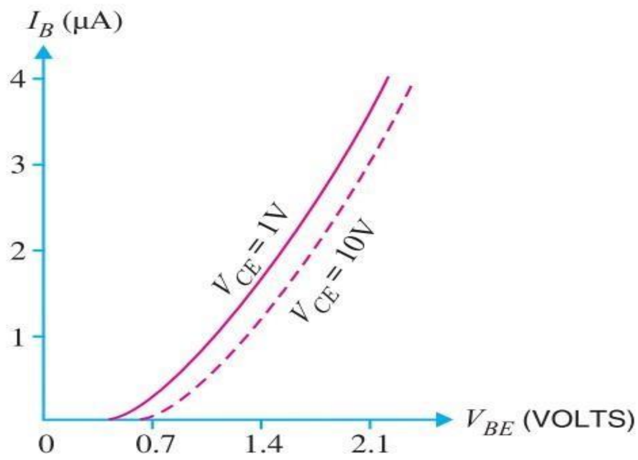
INPUT CHARAC TERISTICS

It is the curve between IB and VBE.

Keeping VCE constant, when VBE is increased, IB increases less rapidly. This means that it has high input resistance than that of CB circuit.

Input Resistance (ri) is the ratio of the change in VBE to change in IB at constant VCE.

Input resistance (ri) $= \Delta V_{BE} / \Delta I_B$ at constant VCE.



OUTPUT CHARAC TERISTICS

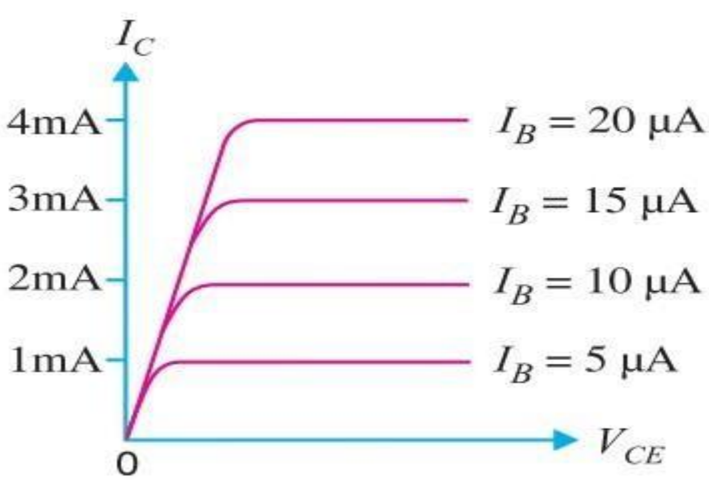
It is the curve drawn between IC and VCE at constant IB.

By keeping IB constant when VCE is increased, IC also increases slowly up to knee voltage.

When VCE is increased beyond knee voltage, the collector current becomes almost constant.

Output resistance (rO) is the ratio of the change in VCE to change in IC.

Output resistance (rO) =ΔVCE/ΔIC at constant IB.



NOTE:-

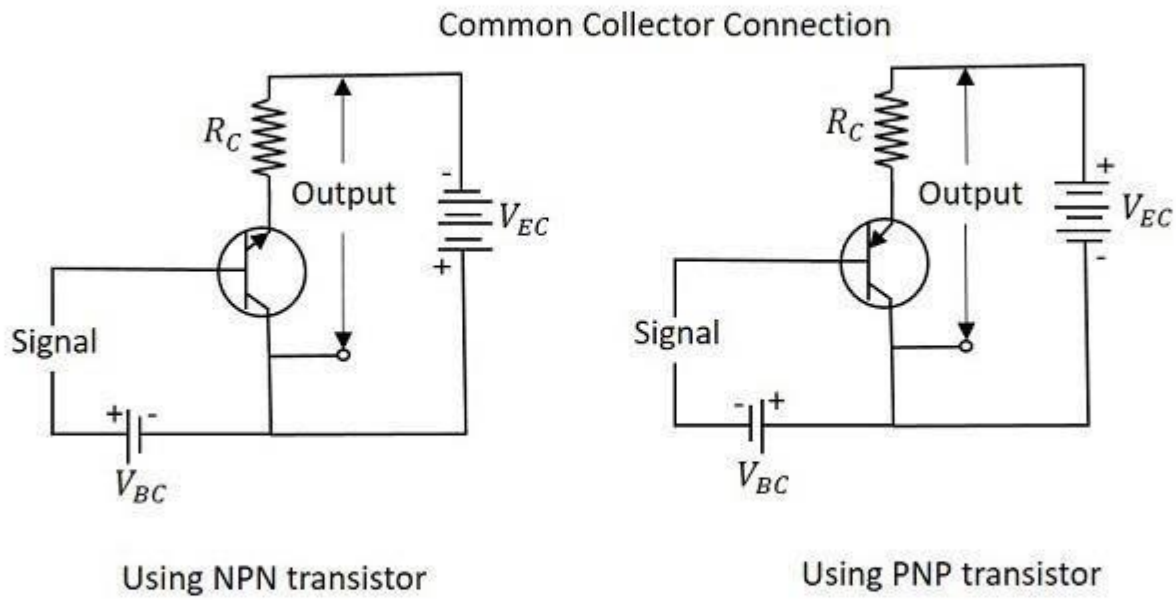
Common base (CB) Transistor gives high current gain but low voltage gain.

In another side, common collector (CC) transistor gives high voltage gain but low current gain.

In CE transistor it gives high current gain and high voltage gain**.** This is the main reason for using CE transistors in most amplifying circuit.

CE transistor is best for amplifying circuits because it has high power gain (because both current gain and voltage gain is high). Hence it is used widely in many applications.

COMMON COLLECTOR CONNECTIONS:-



In this circuit arrangement, input is applied between base and collector, while output is obtained between the emitter and collector.

In this connection, collector of the transistor is common to both input and output circuits and hence they are named as common collector connection.

CURRENT AMPLIFICATION FACTOR (γ)

It is the ratio of change in emitter current IE to the change in base current IB.

In common collector CC configuration it is denoted by **γ**.

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

The current gain in CC configuration is same as in CE configuration.

But it provides a very poor voltage gain i.e. less than 1.

RELATION BETWEEN γ AND α

$$\gamma = \frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$

Dividing numerator and denominator by ΔIE

$$\gamma = \frac{\Delta I_E / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{1}{1 - \alpha}$$

EXPRESSION FOR COLLECTOR CURRENT

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E - I_B = \alpha I_E + I_{CBO} \qquad (\text{As } I_E = I_B + I_C)$$

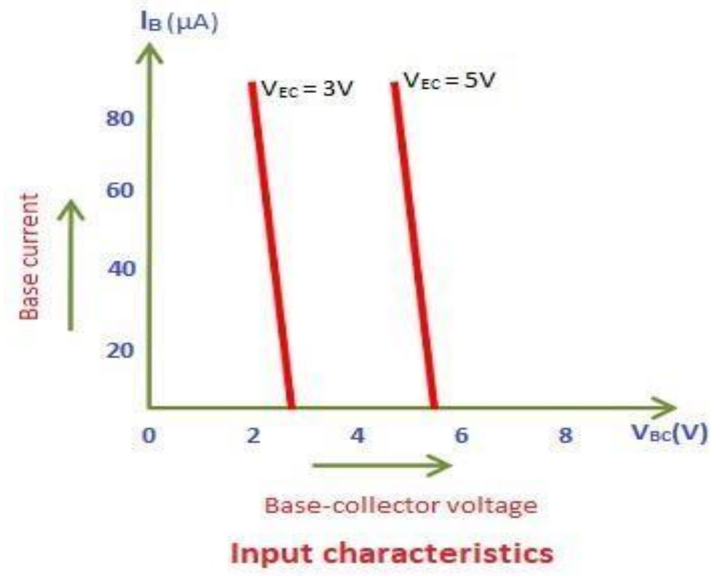
$$I_E - \alpha I_E = I_B + I_{CBO}$$

$$I_E (1 - \alpha) = I_B + I_{CBO}$$

$$I_E = I_B / (1-\alpha) + I_{CBO} / (1-\alpha)$$

INPUT CHARACTERISTICS

It is the curve drawn between base current (I_B) and collector base voltage V_{CB} at constant V_{CE}.

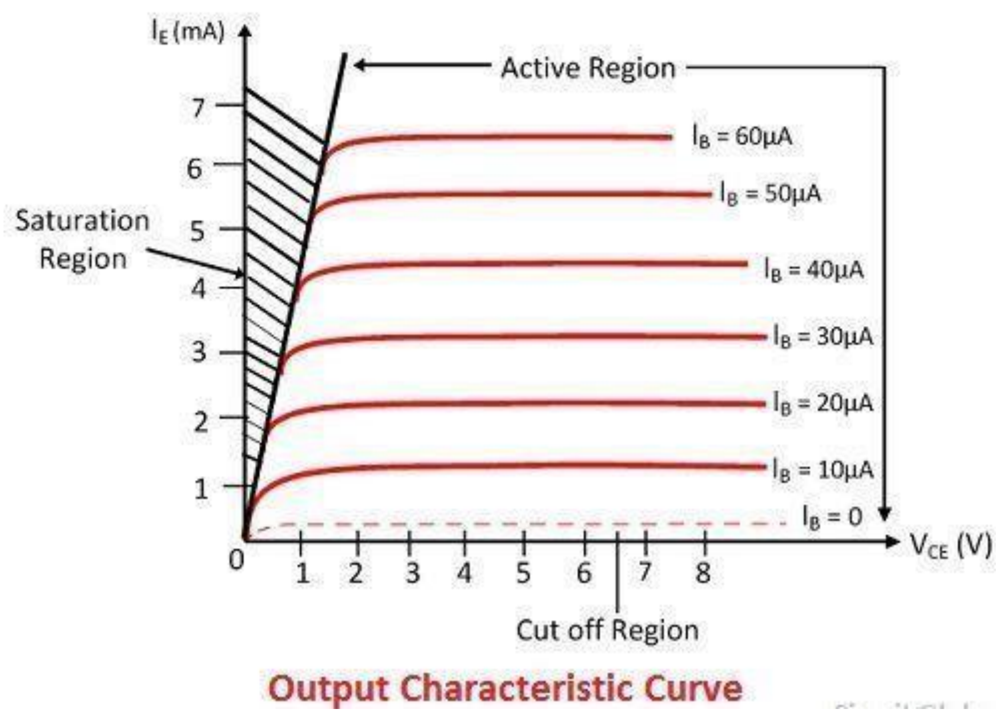


OUTPUT CHARACTERISTICS

It is the curve drawn between IE and VCE at constant IB.

By keeping IB constant when VCE is increased. IC also increases slowly up to knee voltage.

When VCE is increased beyond knee voltage, the collector current (IC) becomes almost constant.



NOTE:-

Common collector connections provide high input impedance and low output resistance so voltage gain is less than 1 and thus used for impedance matching (That means, to drive a low impedance load from a high impedance source).

This configuration provides current gain but no voltage gain.

The input and output signals are in phase.

The sum of collector current and base current equals emitter current.

This configuration works as non-inverting amplifier output.

Comparison of Transistor Connection

S. No.	Characteristic	Common base	Common emitter	Common collector
1.	Input resistance	Low (about 100 Ω)	Low (about 750 Ω)	Very high (about 750 kΩ)
2.	Output resistance	Very high (about 450 kΩ)	High (about 45 kΩ)	Low (about 50 Ω)
3.	Voltage gain	about 150	about 500	less than 1
4.	Applications	For high frequency applications	For audio frequency applications	For impedance matching
5.	Current gain	No (less than 1)	High (β)	Appreciable

RELATIONSHIP BETWEEN α, β AND γ:-

We know that, ΔI_C

$\alpha =$ ------------

--(1)ΔI_E

ΔI_C $\beta =$ ---

------------(2)

$\Delta I_B \gamma = {}^{\Delta I_E}$ ---

--(3)ΔI_B

Divide equation (2) by equation (3) β

$\Delta\Delta IIBC$

—

γ = ΔIE

ΔIB

= $\Delta\Delta IIBC$ * ___$\Delta\Delta IIEB$

= $\Delta IC\Delta IE$

= α So,

$$\alpha = \frac{\beta}{\gamma}$$

TRANSISTOR BIASING:-

The proper flow of zero signal collector current and the maintenance of proper collector emitter voltage during the passage of signal is known as transistor biasing.

The basic purpose of transistor biasing is to keep the BE junction properly forward biased & CE junction properly reverse biased during the application of signal.

This can be achieved with a bias battery or associating a circuit with a transistor. The latter method is more preferred because it is more effect.

The circuit which provides transistor biasing is known as biasing circuit.

VBE =0.7V

$$IE = (\beta+1)\ IB \cong IC$$

$$IC = \beta\ IB$$

Transistor biasing is basically classified into 4 types:

(a) Fixed biasing

(b) Emitter stabilized biasing

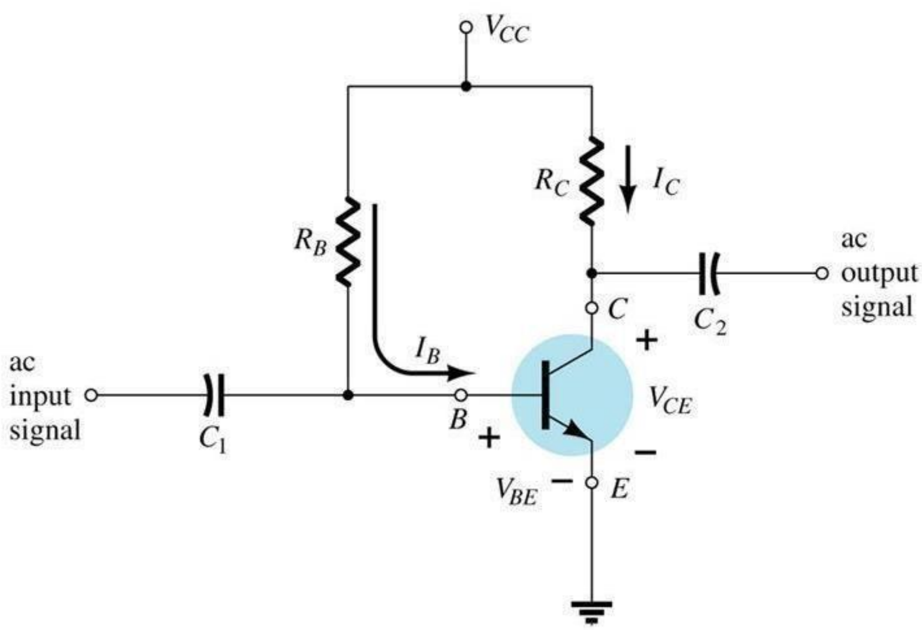
(c) Voltage divider biasing

(d) DC biasing with voltage feedback

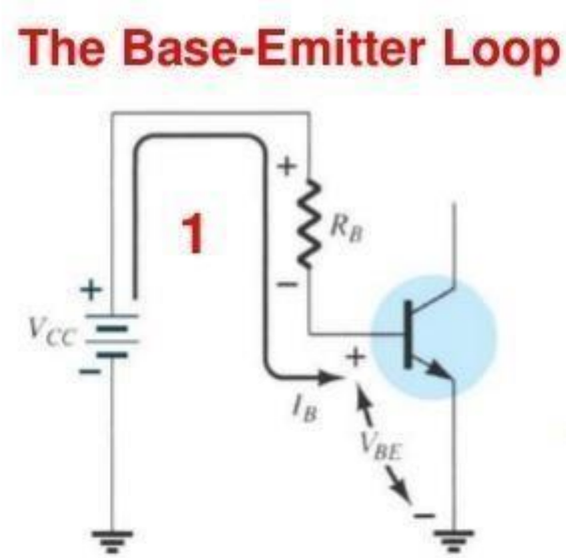
a) FIXED BIASING:-

It is also known as base biasing.

Fixed-Bias Circuit



Applying KVL to the BE loop in clockwise direction



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

$V_{CC} - V_{BE} = I_B R_B$

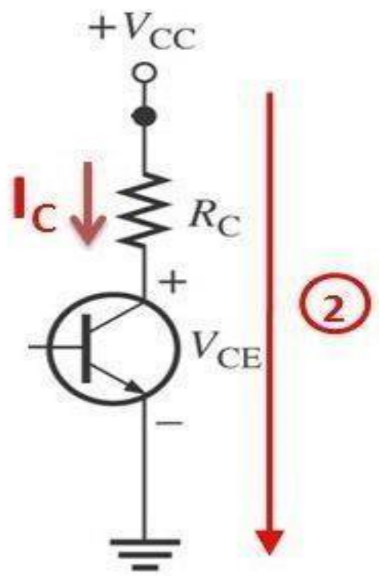
$$I_B = \frac{V_{CC} - V_{BE}}{R_B} \quad \text{-------} \quad (i)$$

$V_{BE} = V_B - V_E$

$V_{BE} = V_B$ as $V_E = 0$ volts

Applying KVL to the CE loop in clockwise direction

CE Loop Analysis



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

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

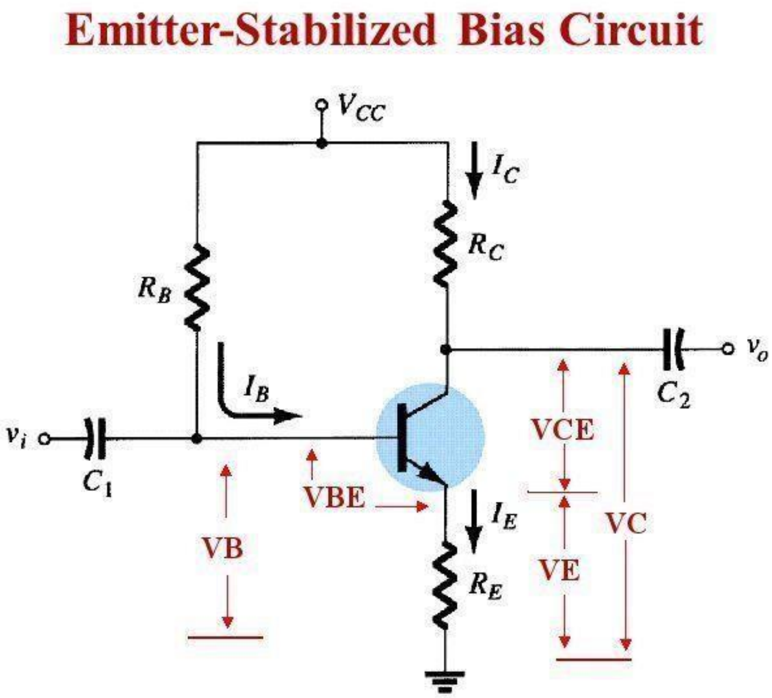
$$I_C = \frac{V_{CC} - V_{CE}}{R_C} \quad \text{-------} \ (ii)$$

$V_{CE} = V_C - V_E$

$V_{CE} = V_C$ as $V_E = 0$ volts

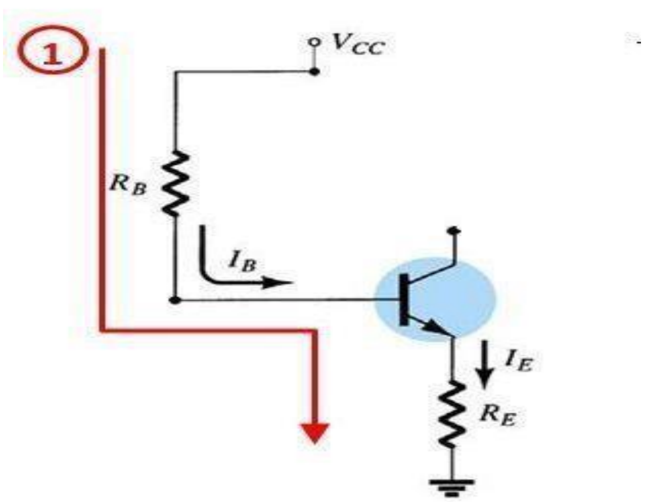
$I_C = \beta I_B$ Where, β= Current amplification factor.

b) EMITTER STABILIZED BIASING:-



Applying KVL to the BE loop in clockwise direction

BE Loop Analysis:



$V_{CC}-I_BR_B-V_{BE}-I_ER_E=0$

$I_E=(\beta+1)\ I_B$

$V_{CC}-I_BR_B-V_{BE}-(\beta+1)$

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

$=I_BR_B + (\beta+1)\, I_B R_E$

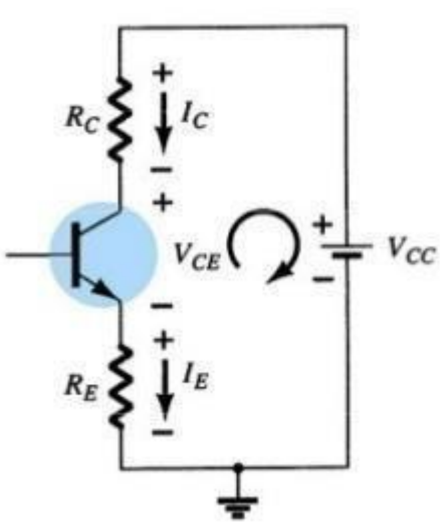
$V_{CC} - V_{BE} = I_B [\, R_B + (\beta+1) R_E \,]$

$$I_B = \frac{V_{cc}-V_{be}}{R_b+(\beta+1)\ R_e} \quad \text{-------} \ (i)$$

$V_{BE}= V_B - V_E$ ------- (ii)

$V_E= I_ER_E$ ------- (iii)

Applying KVL to the CE loop in clockwise direction



$V_{CC}-I_CR_C- V_{CE}-I_ER_E =0$

$I_E \cong I_C$

$V_{CC}-I_CR_C- V_{CE}-I_CR_E =0$ V_{CC}

$-V_{CE} = I_C R_C + I_C R_E$

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

$$I_C = \frac{V_{cc} - V_{ce}}{R_c + R_e} \quad \text{-------} \quad (iv)$$

$V_{CE} = V_C - V_E$ ------- (v)

C)VOLTAGE DIVIDER BIASING:

It is also known as universal biasing.

This is the most widely used method of providing biasing & stabilization to a transistor. In these method two resistances R1& R2 are connected across the supply voltage VCC & provides biasing.

The emitter resistance RE provides stabilization

The name voltage divider comes from the voltage divider formed by R1& R2.

There are two methods that can be applied to analyze the voltage divider configuration. They are;

(a) Exact method

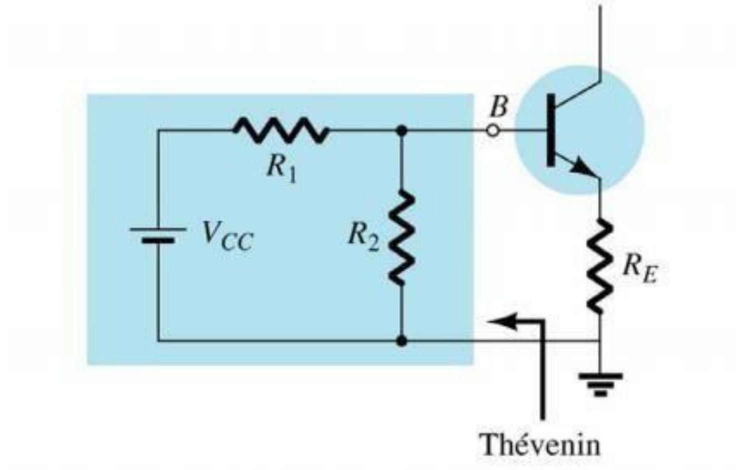
(b) Approximate method

(a) EXACT METHOD

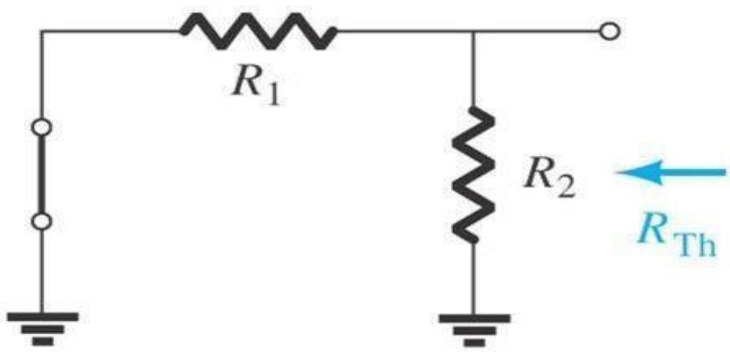
This method can be applied to any voltage divider biasing configuration.

The input side of the network can be drawn again as given below. The Thevenin's equivalent network for the circuit to the left of base terminal is

Redrawing the input circuit for the network



RTH:- Voltage source is replaced by a short circuit equivalent.

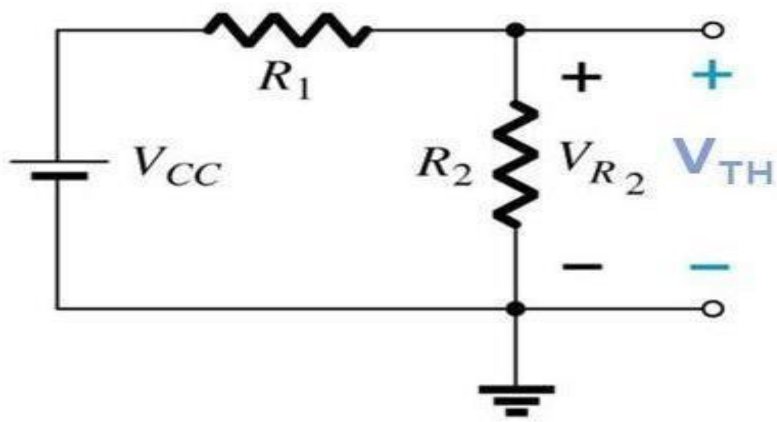


Determining R_{TH}.

$$RTH = R1 \parallel R2$$

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

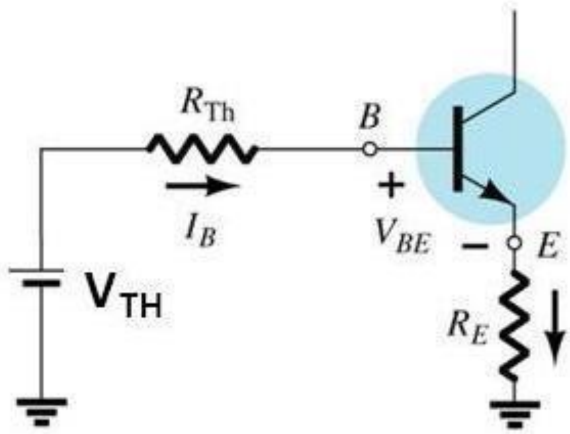
VTH:- Voltage source is returned to the network & the open circuit Thevenin's voltage is determined as follows



R2

VTH =VR2=R1+R2* VCC

Applying KVL to the Thevenin's equivalent circuit



Inserting the Thevenin equivalent circuit

VTH-IBRTH- VBE-IERE =0

IE= $(\beta + 1)$ IB

VTH- VBE = IBRTH +$(\beta + 1)$ IB RE

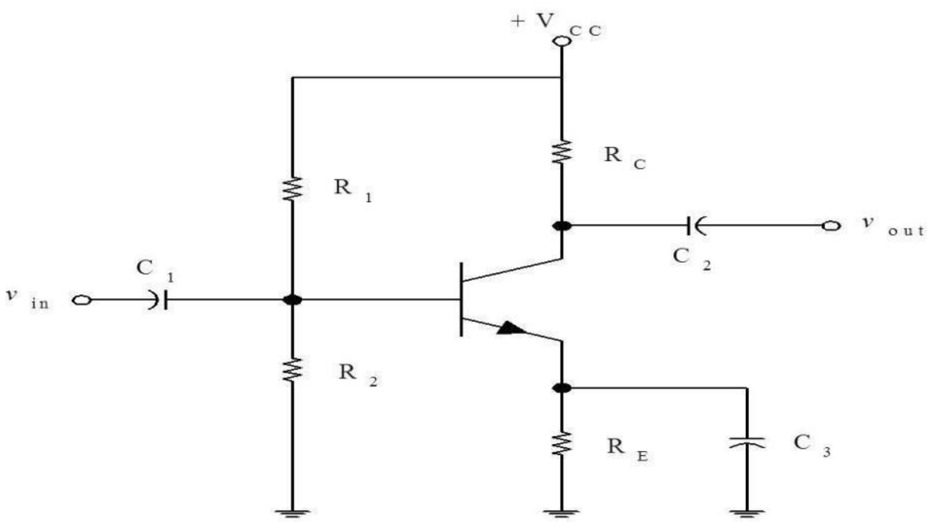
VTH- VBE = IB (RTH +(β + 1) RE)

VTH−VBE

IB = R TH+(β+1) RE -

-------- (i)VCE =VCC -IC (RC + RE) -------

----- (ii)



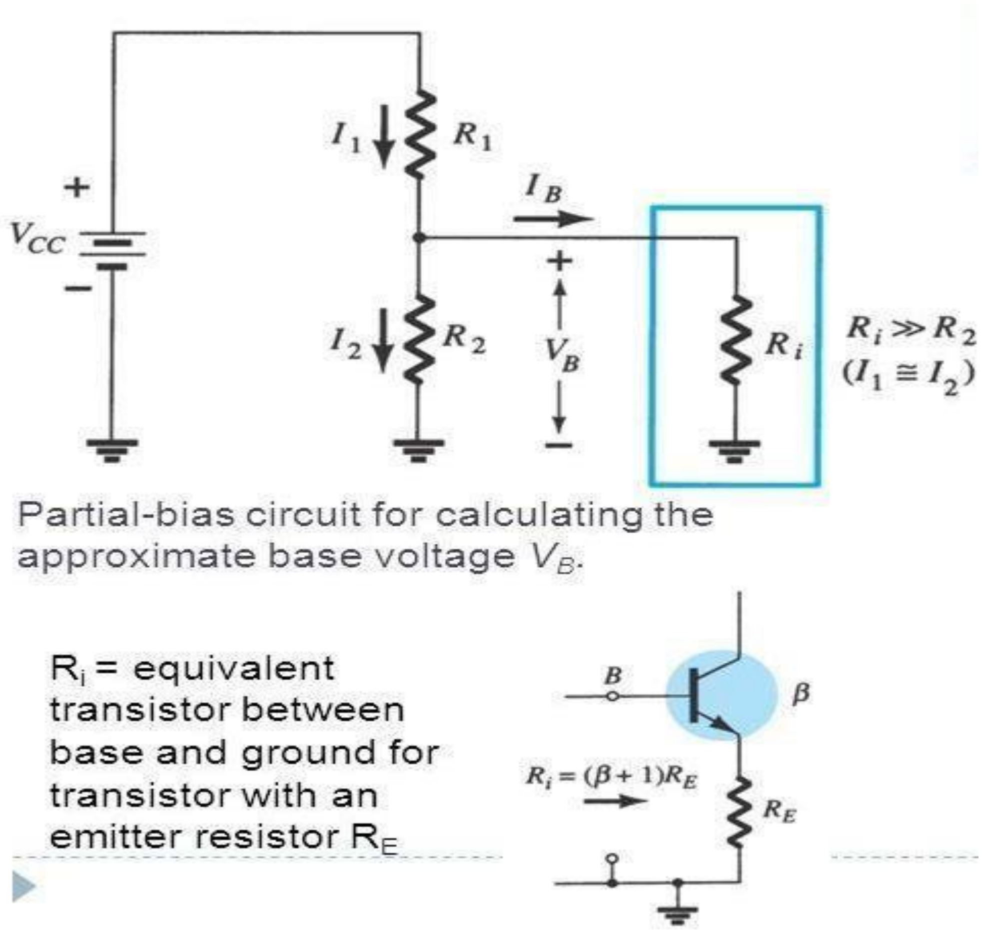
Voltage-Divider Bias circuit of BJT

(b) APPROXIMATE METHOD:

This method can be applied only if specific conditions are satisfied.

It is more preferred as it requires less time & energy.

Ri = Equivalent resistance between base & ground for the transistor with an emitter resistance RE.



CONDITION:-β

$R_E \geq 10R_2$

$V_B = \frac{R_2}{R_1 + R_2} * V_{CC}$ ---------- (i)

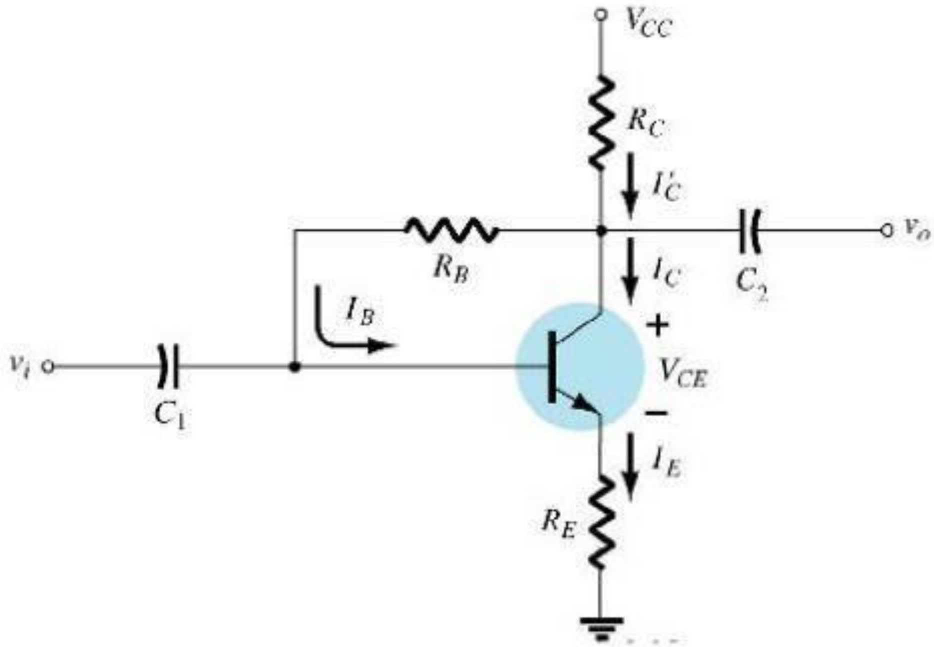
$V_{BE} = V_B - V_E$ -------------- (ii)

$V_E = I_E R_E$---------------------- (iii) Applying KVL we get,

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

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

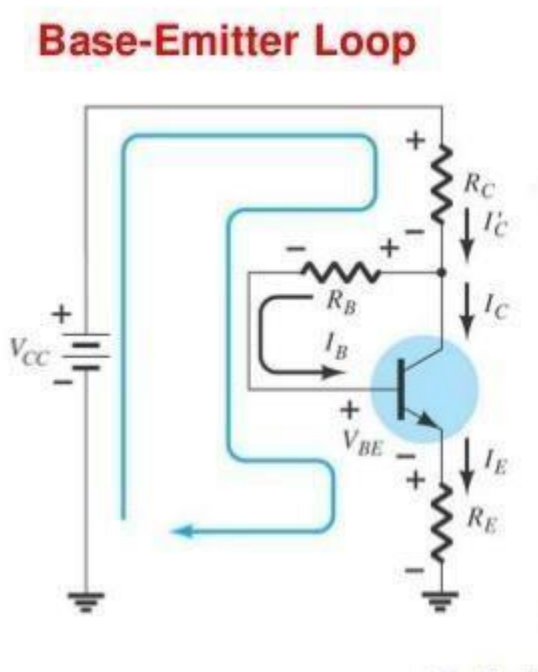
d) DC BIAS WITH VOLTAGE FEEDBACK



An improved level of stability can also be obtained by introducing a feedback path from collector to base.

It is also known as collector to base bias or base bias with collector feedback.

Applying KVL to the BE loop in clockwise direction



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

$$I_C = I_B + I'_C$$

$$I_C = I'_C \quad \text{as } I_B \text{ is very small}$$

$$I_C = I'_C = \beta I_B$$

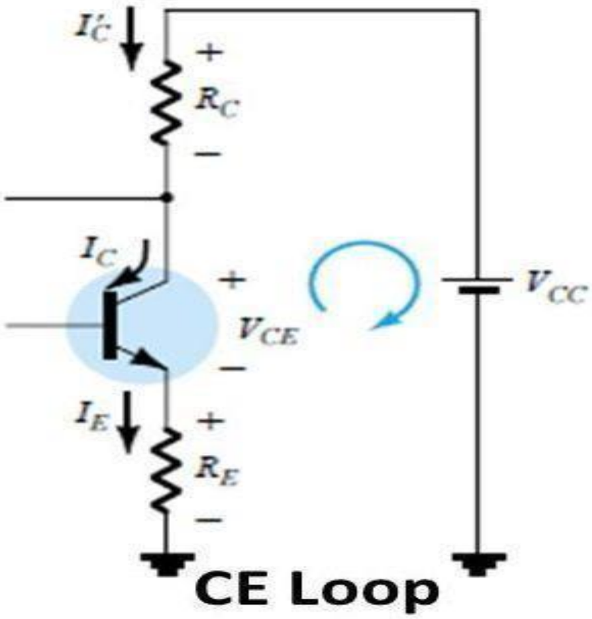
$$I_E \cong I_C$$

Hence $V_{CC} - \beta I_B R_C - I_B R_B - V_{BE} - \beta I_B R_E = 0$

$$V_{CC} - V_{BE} = I_B(\beta R_C + R_B + \beta R_E)$$

$$I_B = \frac{V_{CC} - V_{BE}}{\beta R_C + R_B + \beta R_E}$$

Applying KVL to the CE loop in clockwise direction



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

$$I_E R_E = 0 \quad I_E \cong I_C$$

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

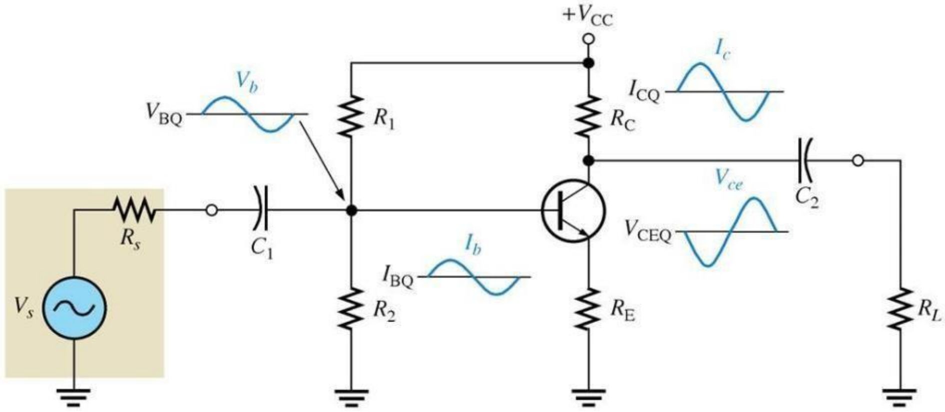
$$V_{CC} - V_{CE} = I_C R_C + I_C R_E$$

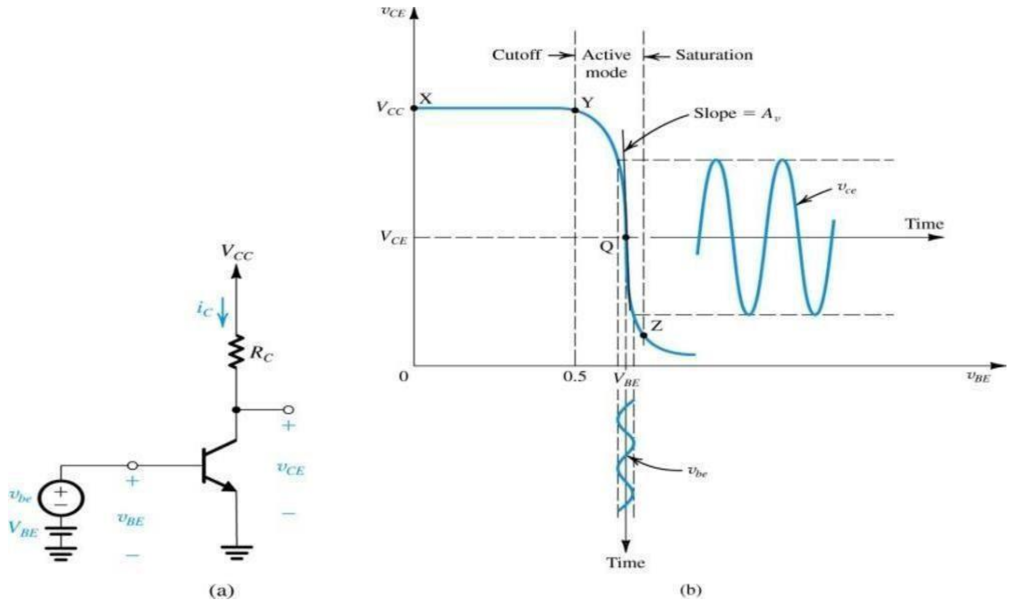
$$V_{CC} - V_{CE} = I_C (R_C + R_E)$$

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

SINGLE STAGE CE AMPLIFIER:

One of the primary uses of a transistor is to amplify ac signals. This could be an audio signal or perhaps some high frequency radio signal. It has to be able to do this without distorting the original input. The boundary between cutoff and saturation is called the linear region. A transistor which operates in the linear region is called a linear amplifier.





The above circuit shows the practical circuit of transistor amplifier with common emitter configuration. Resistance R1, R2 and RE forms the biasing and stabilization circuit. The biasing circuit must establish a proper operating point otherwise a part of the negative half cycle of the signal may be cut off in the output. This circuit consists of three capacitors Cin or C1, CE, CC or C2.

1. **Input Capacitor (Cin or C1):-** Capacitor Cin is used to couple the signal to the base of the transistor. If it is not used the source resistance will come across R2 and thus change the bias.

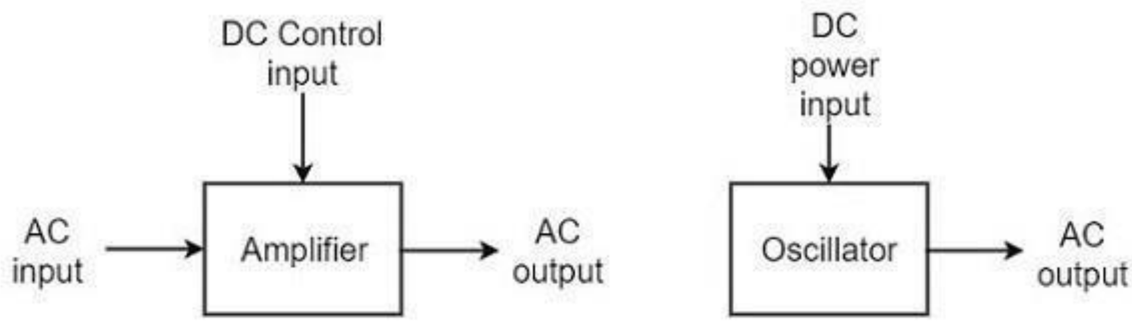
2. **Emitter bypass Capacitor (CE):-** this capacitor is used in parallel with RE to provide a low reactance path to the amplified a.c. signal.

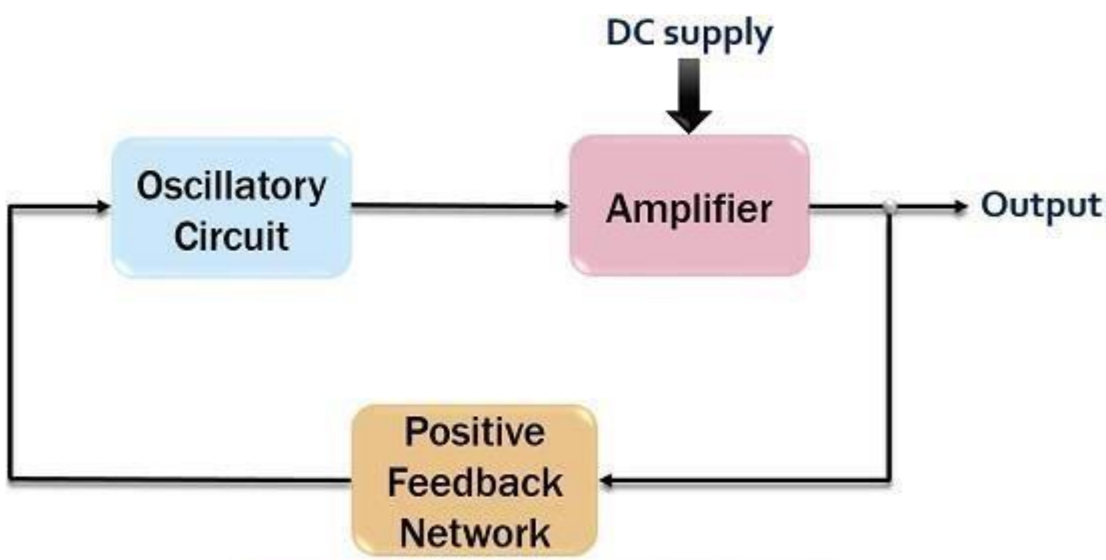
3. **Coupling Capacitor (CC or C2):-** Coupling capacitor couples one state of amplification to the next stage. To reduce the drastic change due to the shunting effect of RC.

<u>OSCILLATORS:-</u>

An oscillator is an electronic device which is used to generate oscillations of desired frequency.

Though an oscillator & an alternator perform the same operation but they are different in many aspects.





Block Diagram of Oscillator

Difference between Alternator and Oscillator

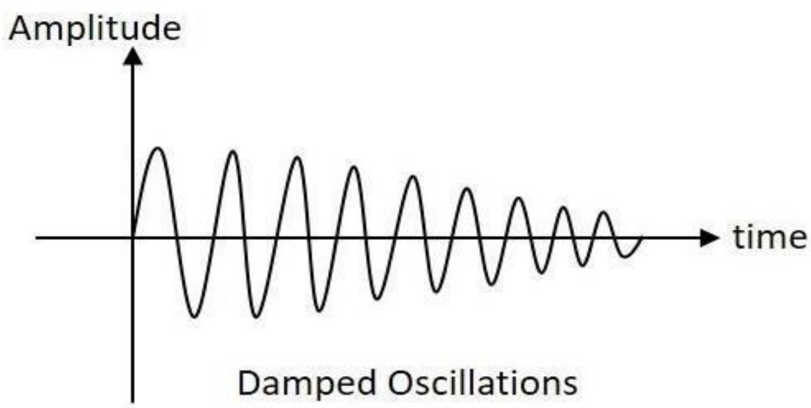
Alternator	Oscillator
An alternator is a mechanical device.	An oscillator is an electronic device.
The mechanical device which converts mechanical energy to the AC electrical energy is called the 'Alternator'.	The electronic device which converts DC supply energy into the AC energy is known as the 'Oscillator'.
An alternator can produce the highfrequency (more than 50Hz) oscillations according to prime mover rpm.	The oscillator can produce the highfrequency oscillations with the several MHz frequencies.
It is rotating and energy converting device.	It is a non-rotating and frequency generating device.
The alternator operates on the principle of **Electromagnetic Induction.**	An Oscillator operates on the principle of the **Oscillation.**

Oscillations generated by an oscillator are classified into two types. They are:- a. Damped oscillations

b. Undamped oscillation

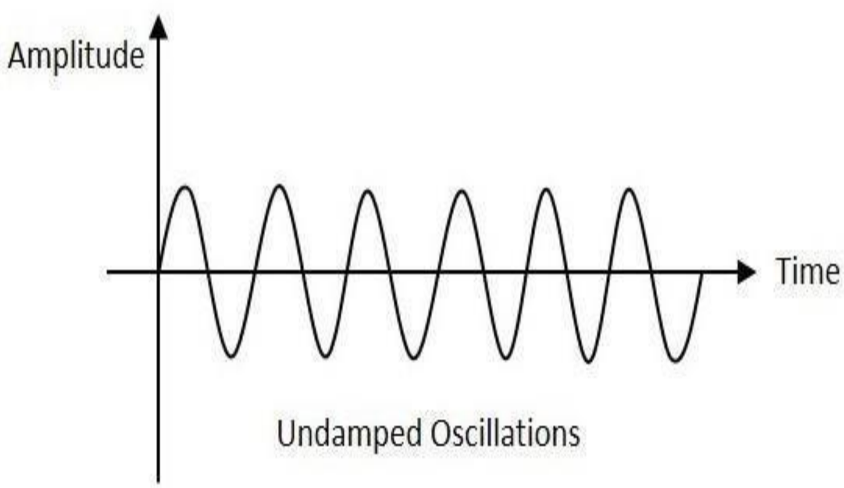
a. DAMPED OSCILLATIONS

Damped oscillations are those oscillations whose amplitude decreases with time.



b. UNDAMPED OSCILLATIONS

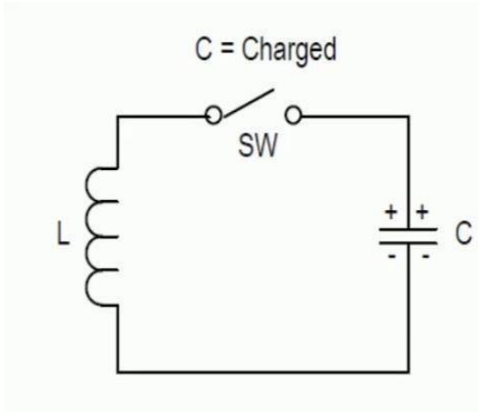
Undamped oscillations are those oscillations whose amplitude remains constant with time.



WORKING PRINCIPLE OF OSCILLATOR:-

The most basic type of oscillator circuit is the tank circuit.

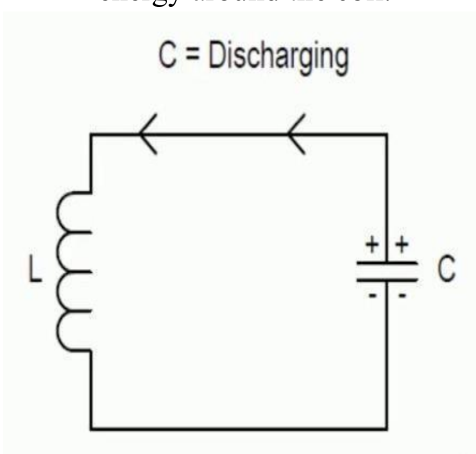
The tank circuit is a combination of single capacitor & a single inductor (coil) connected in parallel.



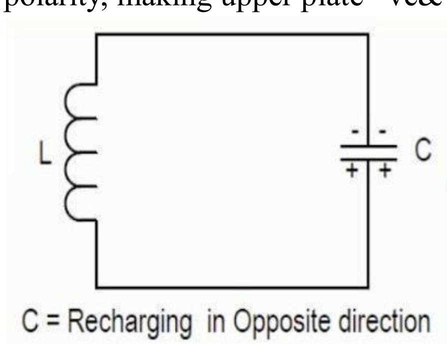
In the above fig. It is clear that the capacitor is charged from dc source and has electrostatic energy.

When switch S is closed, the capacitor starts to discharge through inductor. When the current flows through the inductor, a magnetic field is set up. Magnetic field gets more & stronger as capacitor discharges with time. So circuit current will be maximum only when the capacitor is fully discharged.

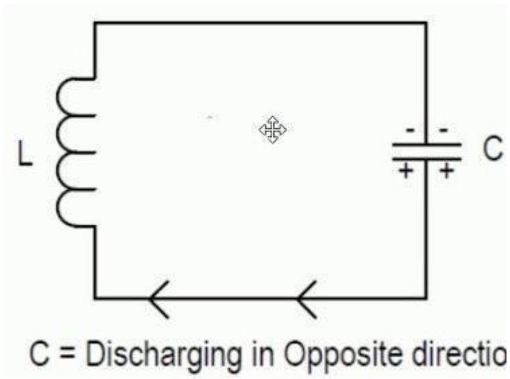
Thus, in this way the electrostatic energy across the capacitor is converted into magnetic energy around the coil.



When the capacitor is fully discharged, the magnetic field begins to collapse thereby producing counter emf. Due to this emf the capacitor is now charged with opposite polarity, making upper plate –ve& lower plate of capacitor +ve.



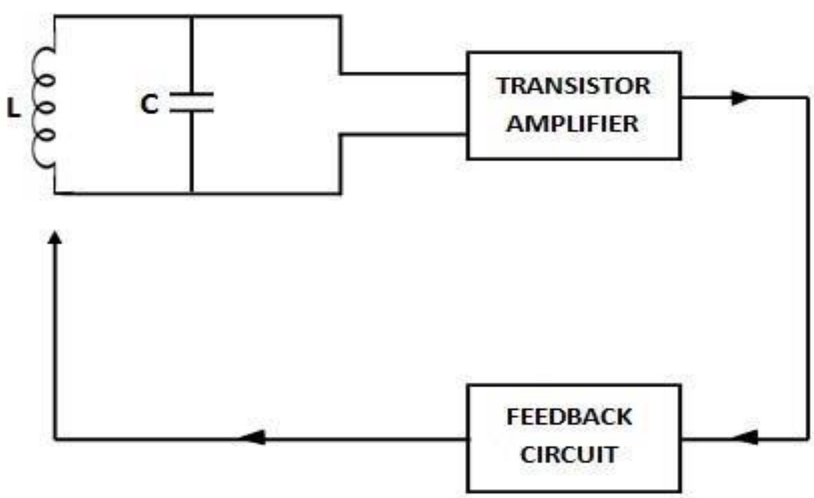
The collapsing magnetic field then recharges the capacitor due to which current now flows in opposite direction.



This continous charging & discharging produces oscillatory current. The resonant frequency of the tank ckt. is given by,

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

BARKHAUSEN CRITERION:



The Barkhausen criterion has three important rules:

1. The circuit must have a tank circuit which will produce damped oscillations.
2. The circuit must have an amplifier whose gain must be greater than unity.
3. The circuit must have a feedback circuit which produces positive feedback.

In order to get undamped continous output, the following conditions must be satisfied:-

$m_v A_v = 1$

Where, m_v =Feedback fraction

A_v=Gain of an amplifier without feedback

This relation is called as Barkhausen criterion.

The tank circuit produces damped oscillations which are further amplified by an amplifier. Then a fraction of amplified output is then fed to the feedback circuit whose output is further fed to the amplifier.

The output now obtained is sustained or undamped oscillation because of the presence of an amplifier.

TYPES OF AN OSCILLATOR:-

Oscillators are classified into two types:

a) Non-sinusoidal Oscillators

The oscillators that produce an output having a square, rectangular or sawtooth waveform are called non-sinusoidal or relaxation oscillators.
Such oscillators can provide output at frequencies ranging from 0 Hz to 20 MHz.

b) Sinusoidal Oscillators

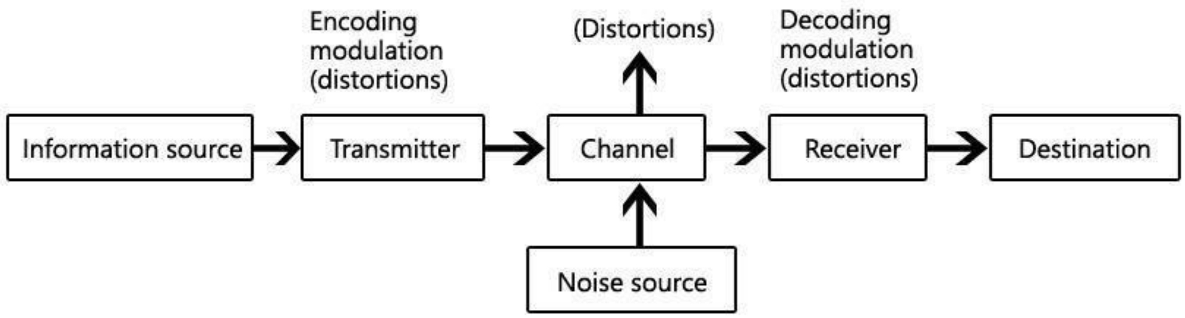
The oscillators that produce an output having a sine waveform are called sinusoidal or harmonic oscillators.
Such oscillators can provide output at frequencies ranging from 20 Hz to 1 GHz.

Sinusoidal oscillators are of various types:-

(a) Wein bridge oscillator
(b) Phase shift oscillator
(c) Hartley oscillator
(d) Colpitt oscillator
(e) Crystal oscillator

Basics of Communication Systems

Communicationis the transfer of information from one point in space and time to another point. The block diagram of a communication system is shown in Figure



Transmitter - couples the message onto the channel using high frequency signals

Receiver - restores the signal to its original form

Channel - the medium used for transmission of signals and Channels can be of two types:

(i) wired channels

(ii) wireless channels.

Modulation - the process of shifting the frequency spectrum of a message signal to a frequency range in which more efficient transmission can be achieved **Demodulation** - the process of shifting the frequency spectrum back to the original baseband frequency range and reconstructing the original form, if necessary

Baseband - refers to the lower portion of the over-all electromagnetic spectrum

Define Modulation & its need.

The process of changing some characteristic (e.g. amplitude, frequency or phase) of a carrier Wave in accordance with the intensity of the signal is known as modulation. The resultant wave is called modulated wave or radio wave and contains the audio signal. Therefore, modulation permits the transmission to occur at high frequency while it simultaneously allows the carrying of the audio signal. It is also the process of manipulating the frequency or the amplitude of a carrier wave in response to an incoming voice, video or data signal

Why Modulation needed?

Modulation is required to match the signal to the transmission medium. Some of the major reasons why modulation is required are:

Practical antenna length.

Ex- Audio frequencies range from 20 Hz to 20 kHz, therefore, if they are transmitted directly into space, the length of the transmitting antenna required would be extremely large. For instance, to radiate a frequency of 20 kHz directly into space, we would need an antenna length of 3 ×10 power 8/20 × 10 power 3 = 15,000 metres. This is too long antenna to be constructed practically. If a carrier wave say of 1000 kHz is used to carry the signal, we need an antenna length of 300 metres only and this size can be easily constructed.

Operating range. The energy of a wave depends upon its frequency. The greater the frequency of the wave, the greater the energy possessed by it. As the audio signal frequencies are small, therefore, these cannot be transmitted over large distances if radiated directly into space. Thus modulate a high frequency carrier wave with audio signal and permit the transmission to occur at this high frequency (*i.e.* carrier frequency).

Wireless communication. One desirable feature of radio transmission is that it should be carried without wires *i.e.* radiated into space. At audio frequencies, radiation is not practicable because the efficiency of radiation is poor. However, efficient radiation of electrical energy is possible at high frequencies > 20 kHz.

Modulation for ease of radiation

Modulation for frequency assignment and multiplexing *Modulation to reduce noise and interference*

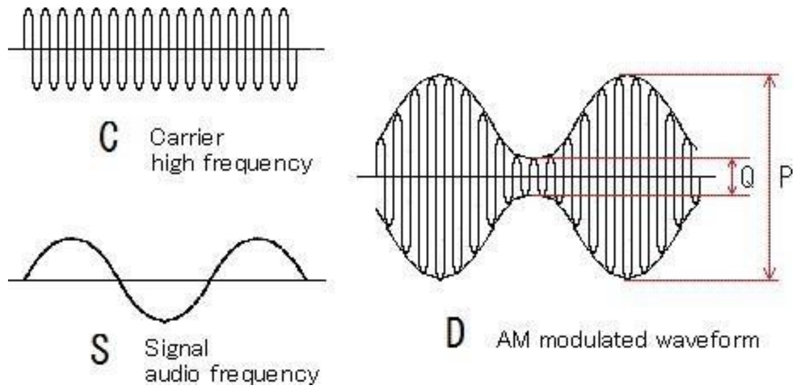
Types of Modulation

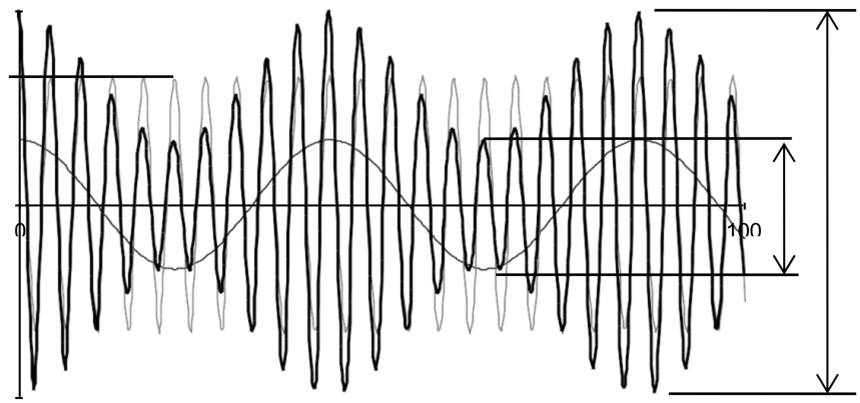
There are three basic types of modulation, namely ;

(i) Amplitude modulation **(ii)** Frequency modulation **(iii)** Phase modulation

(i)Amplitude Modulation:

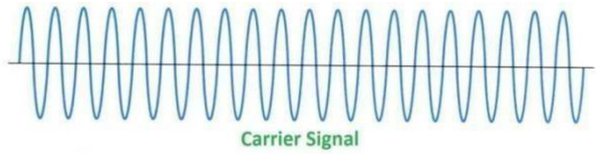
When the amplitude of high frequency carrier wave is changed in accordance with the intensity of the signal, it is called amplitude modulation. In amplitude modulation, only the amplitude of the carrier wave is changed in accordance with the intensity of the signal and the frequency of the modulated wave remains the same i.e. carrier frequency. Amplitude modulation (AM) is amodulationtechnique used in electronic communication, most commonly for transmitting information via a radio carrier waveand in portable two wayradios,VHFaircraftradioand in computer modems."AM" is often used to refer tomedium waveAMradiobroadcasting.





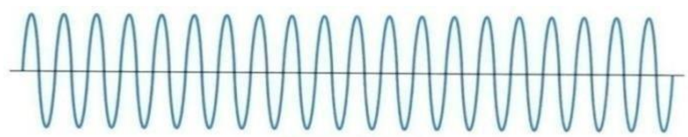
Frequency Modulation (FM):

(i)When the frequency of carrier wave is changed in accordance with the intensity of the signal, it is called frequency modulation (FM).In frequency modulation, only the frequency of the carrier wave is changed in accordance with the signal and the amplitude of the modulated wave remains the same i.e. carrier wave amplitude. The frequency variations of carrier wave depend upon the instantaneous amplitude of the signal(Compare with amplitudemodulation, in which the amplitude of the carrier wave varies, while the frequency remains constant.) It is used inradio,telemetry,radar, seismic prospecting, and monitoring newborns for seizures via EEG. FM is widely used for broadcasting music and speech, two-way radio systems, magnetic tape-recording systems and some videotransmission systems. Frequency modulation is known as phase modulation when the carrier phase modulation is the timeintegralof the FM signal.



Phase modulation (PM):

Phase modulation (PM) is a modulation pattern that encodes information as variations in theinstantaneousphaseof acarrierwave. Phase modulation is a form of modulation that can be used for radio signals used for a variety of radio communications applications. As will be seen later, phase modulation, and frequency modulation are closely linked together and it is often used in many transmitters and receivers used for a variety of radio communications applications from two way radio communications links, mobile radio communications and even maritime mobile radio communications. Unlikefrequencymodulation(FM), phase modulation is not widely used for transmittingradio waves. It is used for signal and waveform generation indigitalsynthesizers.



Demodulation:

The process of recovering the audio signal from the modulated wave is known as modulation or detection. At the broadcasting station, modulation is done to transmit the audio signal over larger distances to a receiver. When the modulated wave is picked up by the radioreceiver, it is necessary to recover the audio signal from it. This process is accomplished in the radio receiver and is called demodulation. A demodulator is an electronic circuit (or computer program in a software defined radio) that is used to recover the information content from the modulated carrier wave. Demodulation is the act of extracting the original information-bearing signal from a modulated carrier wave. A demodulator is an electroniccircuit(or computer programin a software-defined radio) that is used to recover the information content from the modulatedcarrierwave.

The comparison of FM and AM is given in the table below:

FM	AM
The amplitude of carrier remains constant with modulation	The amplitude of carrier changes with Modulation
The carrier frequency changes according to the strength of the modulating signal.	The carrier frequency remains constant with modulation.
The carrier frequency changes with modulation.	The carrier amplitude changes according to the strength of the modulating signal
The value of modulation index (mf) can be more than 1.	The value of modulation factor (m) cannot be more than 1 for distortionless AM signal.

TRANSDUCERS AND MEASURING INSTRUMENTS

Transducers are often termed as the heart of electronics instrumentation and control engineering.

This is because in instrumentation we need to measure the quantities whether it is electrical, non-electrical physical etc.

But it is not so easy to measure the magnitude of physical quantity.

Let's take an example of mercury thermometer.

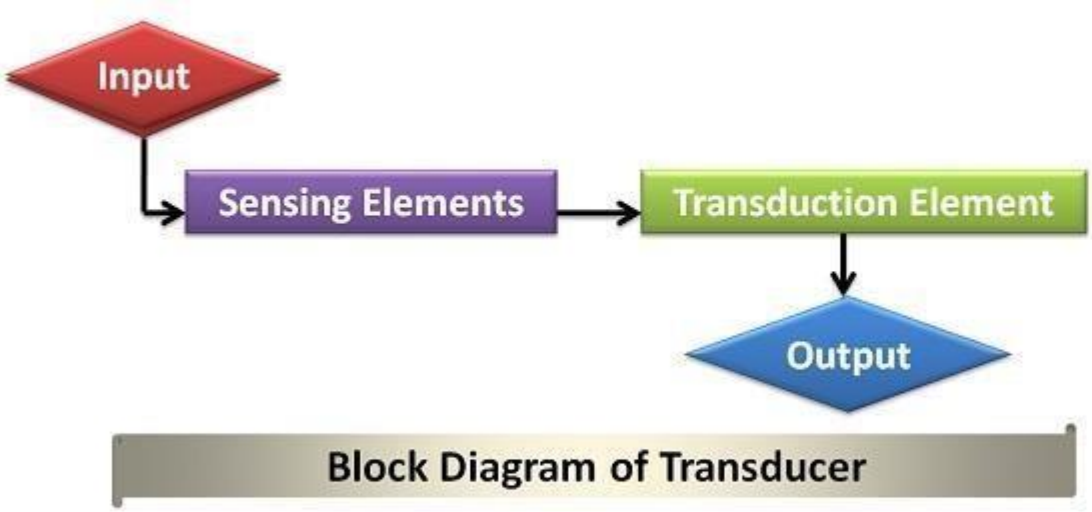
If we want to measure the body temperature, is it possible to measure it directly??

The answer will be no.

This is because we need a quantity which shows the change in the magnitude of the physical quantity.

In mercury thermometer; the height of the mercury varies with the variation in the temperature. Thus, if the temperature of the measuring body increases then the height of the mercury in the thermometer also increases.

Therefore, in instrumentation when we need to measure a physical quantity we need a transducer.



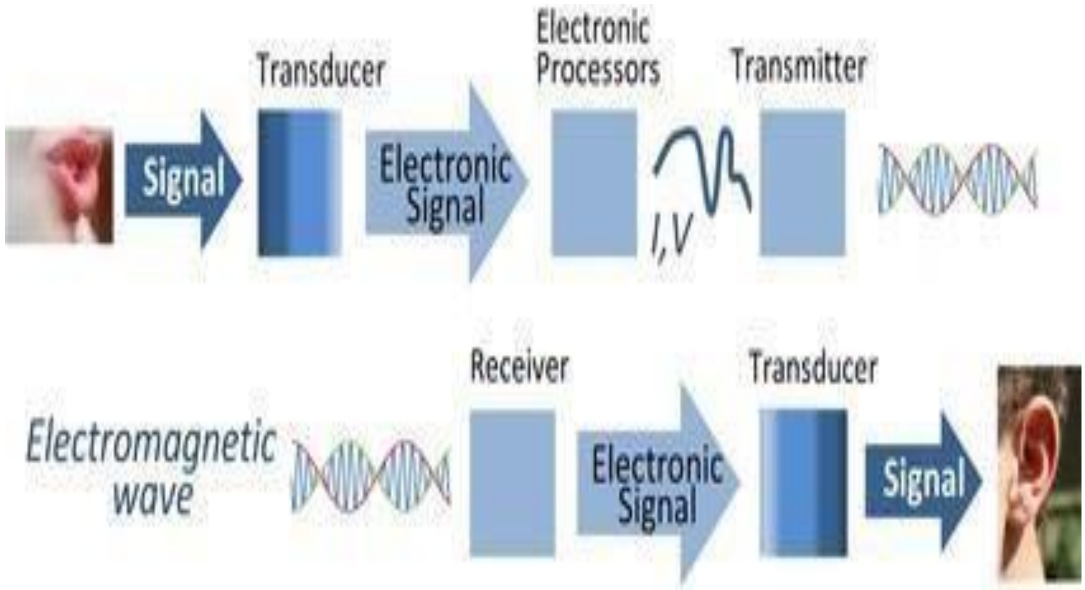
TRANSDUCER:-

Transducer is a device which converts one form of energy into another form i.e; the given non-electrical energy is converted into an electrical energy.

It converts a physical quantity like pressure, brightness or weight into an electrical signal or vice-versa.

Common examples include microphones, loudspeakers, thermometers, position and pressure sensors and antenna.

Photocells, LEDs and even common light bulbs are transducers.



Efficiency is an important consideration in any transducer.

Transducer efficiency is defined as the ratio of the power output in the desired form to the total power input.

Mathematically,

If P represents the total power input and Q represents the power output in the desired form.

$$E = \frac{Q}{P}$$

In percentage,

$$E (\%) = \frac{Q}{P} * 100$$

No transducer is 100% efficient; some power is always lost in the conversion process. Usually this loss is dissipated in the form of heat.

An antenna is also a transducer which converts electrical signal into electromagnetic waves and vice-versa.

A well designed antenna supplied with 100 watts of radio frequency (RF) power radiates 80 or 90 watts in the form of an electromagnetic field.

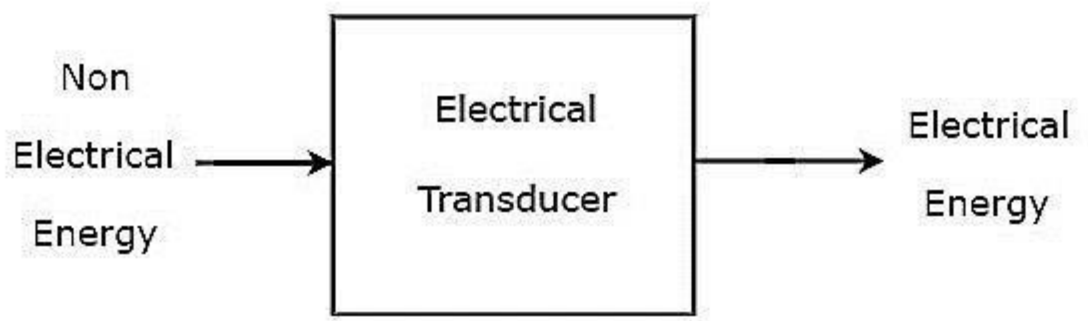
A few watts are dissipated as heat in the antenna conductors, the field line conductors, and dielectric and in objects near the antenna.

Among the worst transducers, in terms of efficiency, are incandescent lamps. A 100 watt bulb radiates only a few watts in the form of visible light. Most of the power is dissipated as heat; a small amount is radiated in the UV (ultraviolet) spectrum.

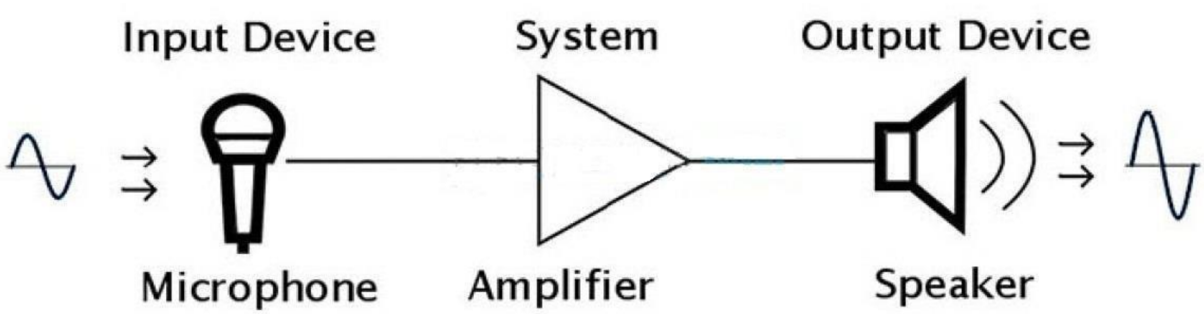
Transducers are of various types such as electrical transducers, mechanical transducer, thermal, optical, acoustic etc.

The transducer, which converts non-electrical form of energy into electrical form of energy, is known as electrical transducer.

The block diagram of electrical transducer is shown in below figure.



As shown in the figure, electrical transducer will produce an output, which has electrical energy. The output of electrical transducer is equivalent to the input, which has non-electrical energy.



DIFFERENT TYPES OF TRANSDUCERS:-

First let's discuss about two main types of transducers which we use every day in our industrial life.

They are:-

a) Active transducers

b) Passive transducers

a) Active transducers

Active transducers are those which convert one form of energy into another form (electrical) without requiring any external source of power.

These transducers draw the energy needed for their operation from the measuring system itself.

In active transducers the output produced is very small so further amplification of signal is required.

They work on the principle of energy conversion.

It is also known as self generating transducer because they self develop their electrical output signal.

Following are the examples of active transducers:-

- Piezo-electric crystals

  This converts charges generated by application of force into electric potential.

- Tachogenerator

  These are basically used to measure angular velocity

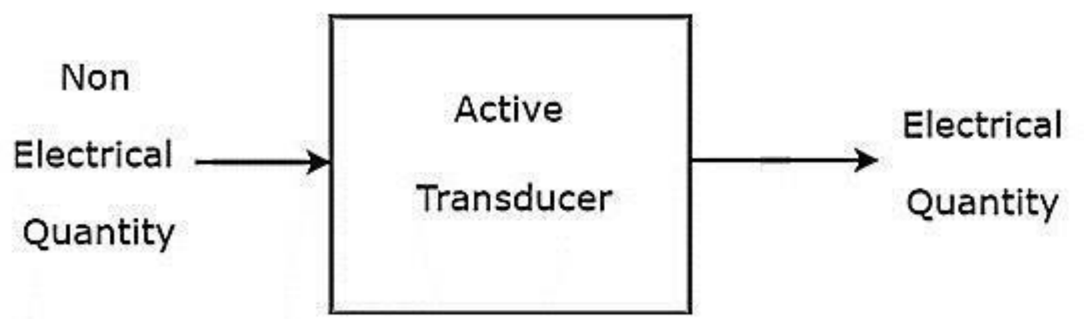
- Thermocouple

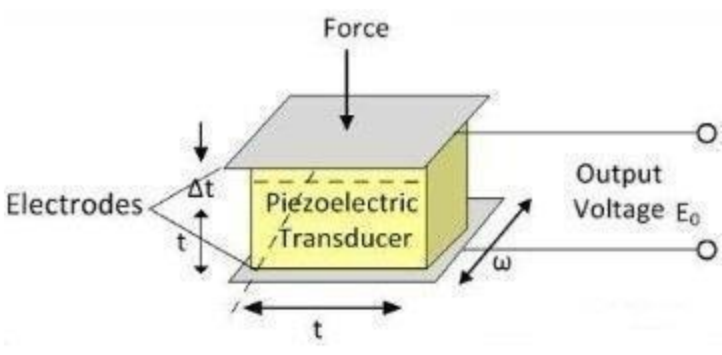
  Temperature measurement is accomplished using thermocouples.

- Photovoltaic cell

  It converts light into electrical energy.

The block diagram of active transducer is shown in below figure.





THERMOCOUPLE:-

A **thermocouple** is an active transducer that is used for temperature measurement.

It is one of the simplest and widely used devices for temperature measurement.

It works on the principle of energy conversion.

These are basically designed to measure temperature in the form of EMF.

Seebeck effect is the basis of working of the thermocouple.

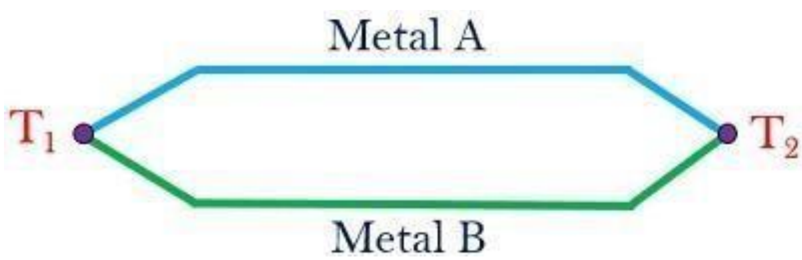
A thermocouple is formed by combining two dissimilar metals in such a way that their ends form 2 junctions after combination.

The two dissimilar metals are welded together at one end, creating a junction.

This junction is where the temperature is measured.

When the junction experiences a change in temperature, a voltage is created. The voltage can then be interpreted using thermocouple reference tables to calculate the temperature.

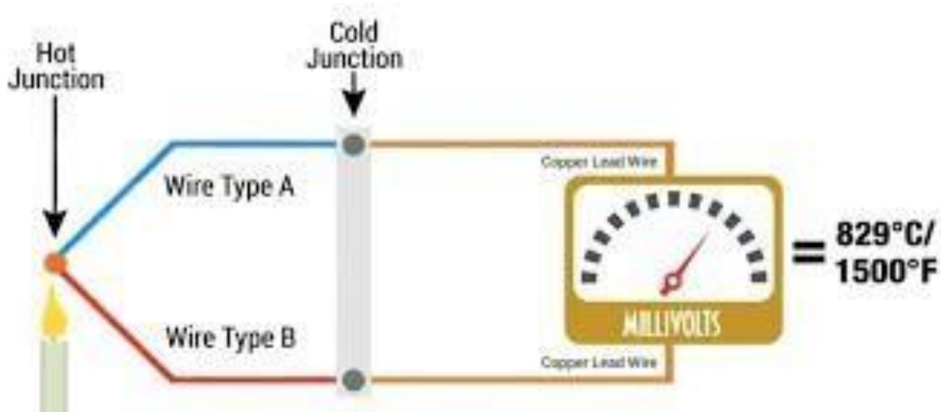
The figure below shows the general arrangement of a thermocouple having two different metals.

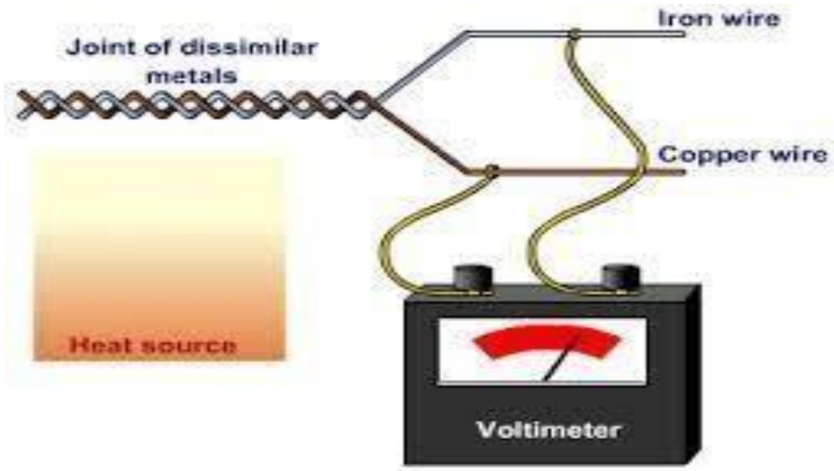


Seebeck effect states that when two wires of dissimilar metals form an electric circuit on joining, then current flows through that circuit if there exists a temperature difference between the two junctions.

It is to be noted here that no any current will flow through the circuit when the temperature difference of the circuit becomes equal.

Any rapid change in the circuit is efficiently measured by a thermocouple thus it is widely used for temperature measurement.





b) Passive transducers

Passive transducers are those transducers which convert a form of energy into another (electrical) by making use of an external source of power.

This transducer induces variation in the parameters associated with the electrical circuits, with the variation in the applied input signal.

Passive transducers are also known as externally energized transducers.

Passive transducer requires external power supply.

In these type of transducers, changes in voltage, current or frequency are noticed when electrical parameters such as inductance, capacitance or resistance associated with the circuit changes.

A passive transducer sometimes may draw energy from the measuring system itself.

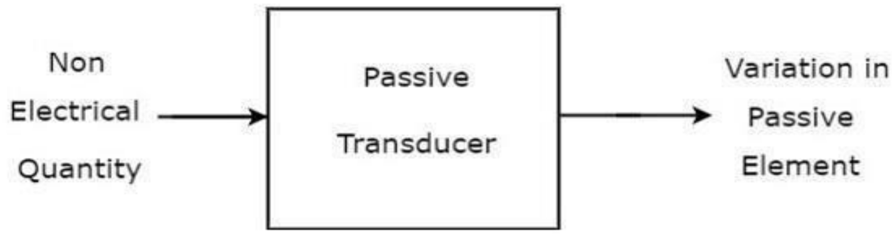
The output of a passive transducer is not that much low so further amplification is not needed. However, sometimes amplifiers are employed in such transducers also.

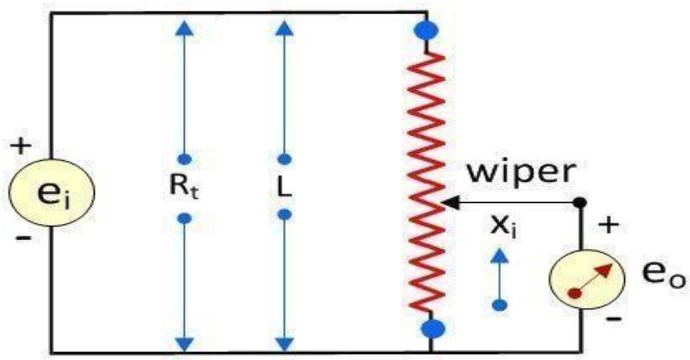
Following are the examples of passive transducers.

- Potentiometer It is a device that converts displacement into voltage.
- Thermistor

  These produce voltage with change in temperature

The block diagram of passive transducer is shown in below figure.





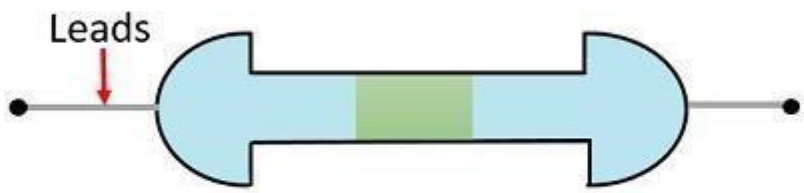
Linear Potentiometer (Pot), a passive transducer

THERMISTOR:-

Thermistor, a semiconductor device is a type of passive transducer in which variation in temperature causes a corresponding change in resistance.

Thus, variation in temperature produces an analogue voltage. As these are thermally sensitive resistors thus also termed as thermal resistors.

The figure below shows the rod form of a Thermistor



Rod form of thermistor

Due to their temperature sensitive nature, thermistors have various applications in temperature measurement field.

It can be a positive temperature coefficient thermistor or negative temperature coefficient thermistor depending on the variation of resistance with respect to temperature.

An extremely non-linear characteristic is exhibited by the thermistor for resistance versus temperature curve. As it is inexpensive and highly sensitive device thus has numerous applications.

DIFFERENCE BETWEEN ACTIVE AND PASSIVE TRANSDUCER:-

COMPARISON **ACTIVE TRANSDUCER** **PASSIVE TRANSDUCER**

What is it? Active transducers are those Passive transducers are those which
convert one form of transducers which convert a energy into another
form form of energy into another
(electrical) without requiring (electrical) by making use of an any external
source of power. external source of power.

.

Operating Operational energy is derived Operational energy is taken from from quantity
principle being measured external power source.

Active transducers are also Passive transducers are also
Alternatively known as self-generating known as externally energized known as
transducers. transducers.

Variation in quantity associated
Output
Electrical current or voltage. with passive elements is generated observed.

External
Not required Required
Energy

The output obtained from The output of a passive

	Further these transducers are very small so further amplification is needed.	transducer is not that much low Amplification so further amplification is not needed.
Design	simple	complicated
Examples	Thermocouple, photovoltaiccell, Tachogenerator, Differential Transformer.	Thermistor, potentiometer piezoelectric crystal.

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

- Analog transducer
- Digital transducer

4. Based on the electrical phenomenon

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

5. Based on the non-electrical phenomenon

- Linear displacement
- Rotary displacement

6. Based on the transduction phenomenon

- Transducer
- Inverse transducer.

FACTORS TO BE CONSIDERED WHILE SELECTING TRANSDUCER:-

- It should have high input impedance and low output impedance, to avoid loading effect.
- It should have good resolution over entire selected range.
- It must be highly sensitive to desired signal and insensitive to unwanted signal.
- Preferably small in size.
- It should be able to work in corrosive environment.
- It should be able to withstand pressure, shocks, vibrations etc.
- It must have high degree of accuracy and repeatability.
- Selected transducer must be free from errors.

REQUIREMENTS OF GOOD TRANSDUCERS:-

- Smaller in size and weight.
- High sensitivity.
- Ability to withstand environmental conditions.
- Low cost.

Sensor

A sensor is a physical device that senses a physical quantity and then converts it into signals which can be read by an instrument or the user.

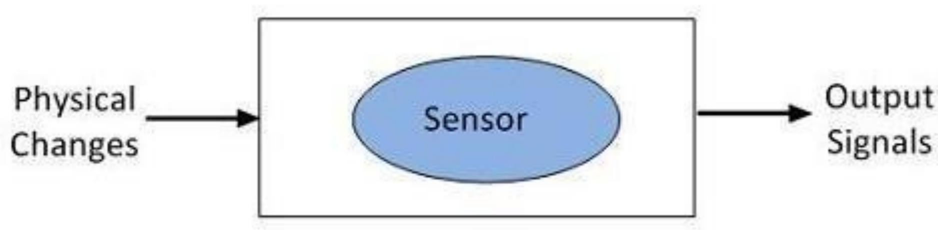
The specific input could be light, heat, motion, moisture, pressure etc.

The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing.

Sensors are sophisticated devices that are frequently used to detect and respond to electrical or optical signals.

A Sensor converts the physical parameter (for example: temperature, blood pressure, humidity, speed, etc.) into a signal which can be measured electrically.

Both the input and output quantities of a Sensor are Physical i.e. non-electrical in nature.



Sensor

The sensors have many applications in the electronics equipment. The few of them are explained below:-

1. The motion sensors are used in the home security system and the automation door system.
2. The photo sensor senses the infrared or ultraviolet light.
3. The accelerometer sensor used in mobile for detecting the screen rotations.

CLASSIFICATION OF SENSORS:-

Based on the applications of sensors, their classification can be made as follows.

I. Displacement, Position and Proximity Sensors

1. Resistive Element or Potentiometer
2. Capacitive Elements
3. Strain Gauged Element
4. Inductive Proximity Sensors
5. Eddy Current Proximity Sensors
6. Differential Transformers
7. Optical Encoders
8. Hall Effect Sensors
9. Pneumatic Sensors
10. Proximity Switches
11. Rotary Encoders

II. Temperature Sensors

1. Thermistors
2. Thermocouple
3. Bimetallic Strips
4. Resistance Temperature Detectors
5. Thermostat

III. Light Sensors

1. Photo Diode
2. Phototransistor
3. Light Dependent Resistor

IV. Velocity and Motion

1. Pyroelectric Sensors
2. Tachogenerator
3. Incremental encoder

V. Fluid Pressure

1. Diaphragm Pressure Gauge
2. Tactile Sensor
3. Piezoelectric Sensors
4. Capsules, Bellows, Pressure Tubes

VI. Liquid Flow and Level

1. Turbine Meter
2. Orifice Plate and Venturi Tube

VII. IR Sensor

1.Infrared Transmitter and Receiver Pair

VIII. Force

1. Strain Gauge
2. Load Cell

IX. Touch Sensors

1. Resistive Touch Sensor
2. Capacitive Touch Sensors

X. UV Sensors

1. Ultraviolet Light Detector
2. Photo Stability Sensors
3. UV Photo Tubes
4. Germicidal UV Detectors

COMMONLY USED SENSORS AND TRANSDUCERS:-

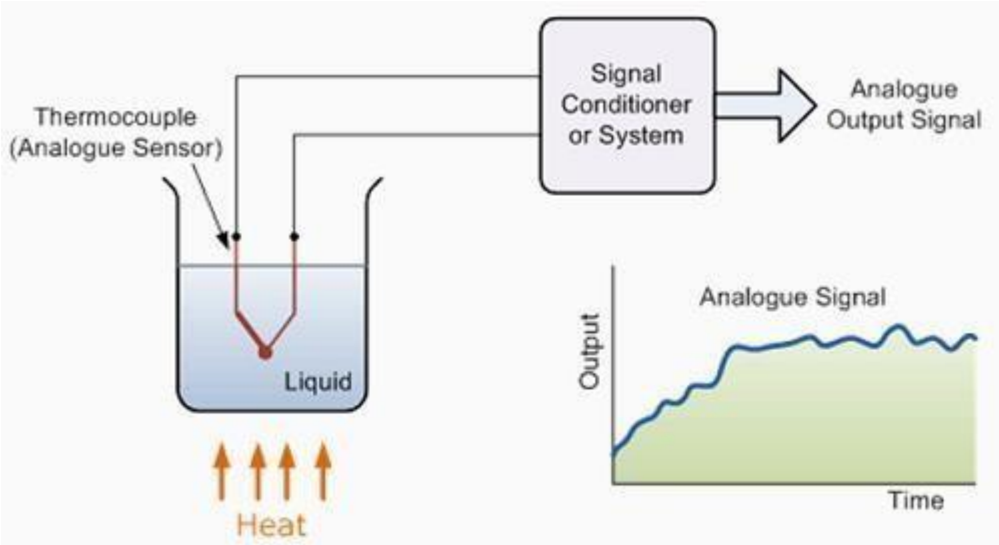
Some of the most commonly used sensors and transducers for different stimuli (the quantity to be measured) are

1. For sensing light, the input devices or sensors are photo diode, photo transistor, light dependent resistor and solar cells. The output devices or actuators are LEDs, displays, lamps and fiber optics.
2. For sensing temperature, the sensors are thermistor, thermocouple, resistance temperature detectors and thermostat. The actuators are heaters.
3. For sensing position, the input devices are potentiometer, proximity sensor, and differential transformer. The output devices are motor and panel meter.
4. For sensing pressure, the sensors are strain gauge and load cell. The actuators are lifts and jacks and electromagnetic vibrations.
5. For sensing sound, the input devices are microphones and output devices are loudspeakers and buzzers.
6. For sensing speed, the sensors used are Tachogenerator and Doppler Effect sensors. The actuators are motors and brakes.

<u>ANALOGUE SENSORS</u>

An analogue sensor produces continuously varying output signals over a range of values. Usually the output signal is voltage and this output signal is proportional to the measurand.

The quantity that is being measured like speed, temperature, pressure, strain, etc. are all continuous in nature and hence they are analogue quantities.



A thermocouple or a thermometer is an analog sensor. The following setup is used to measure the temperature of the liquid in the container using a thermocouple.

The output of an analogue sensor tends to change smoothly and continuously over time.

Hence the response time and accuracy of circuits employing analogue sensors is slow and less.

In order to use these signals in a microcontroller based system, Analog to Digital converters can be used.

Analogue sensors generally require an external power supply and amplification of some form to produce appropriate output signals.

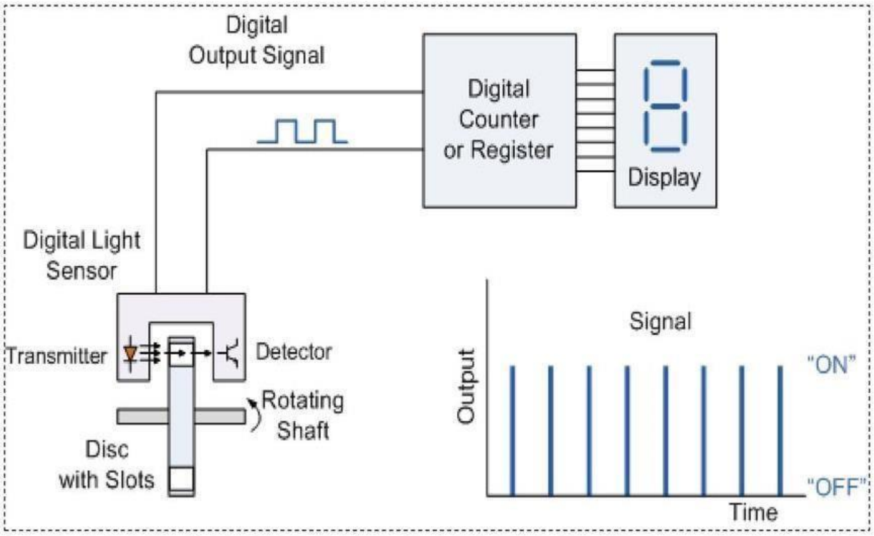
Op Amps are very useful in providing amplification and filtering.

DIGITAL SENSORS

A digital sensor produces discrete digital signals.

The output of a digital sensor has only two states, namely 'ON' and 'OFF'. ON is logic 1 and OFF is logic 0.

A push button switch is the best example of a digital sensor. In this case, the switch has only two possible states: either it is ON when pushed or it is OFF when released or not pushed.



The following setup uses a light sensor to measure the speed and produces a digital signal. In the above setup, the rotating disc is connected to the shaft of a motor and has number of transparent slots.

The light sensor captures the presence or absence of the light and sends logic 1 or logic 0 signal accordingly to the counter. The counter displays the speed of the disc.

The accuracy can be increased by increasing the transparent slots on the disc as it allows more counts over the same amount of time.

In general, the accuracy of a digital sensor is high when compared to an analogue sensor. The accuracy depends on the number of bits that are used to represent the measurand. Higher the number of bits, the greater is the accuracy.

Here are a few examples of the many different types of sensors:

a) In a mercury-based glass thermometer, the input is temperature. The liquid contained expands and contracts in response, causing the level to be higher or lower on the marked gauge, which is human-readable.

b) Motion sensors in various systems including home security lights, automatic doors and bathroom fixtures typically send out some type of energy, such asmicrowaves,ultrasonic wavesor light beams and detect when the flow of energy is interrupted by something entering its path.

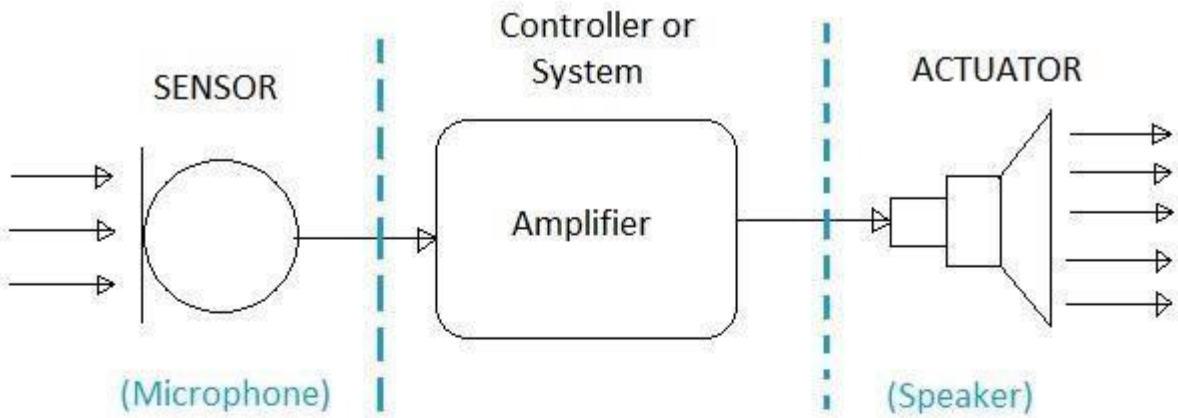
c) Aphoto sensordetects the presence of visible light,infrared transmission(IR), and/or ultraviolet (UV) energy.

A Transducer uses the principle of Transduction to convert the measurand into a usable output.

A Piezoelectric Crystal is the Sensor whereas a Piezoelectric Crystal with electrodes and some sort of input/output mechanism attached to it makes it a Transducer. Sensors are those devices that respond to a physical quantity with a signal and Actuators are those devices that respond to signals with physical movement (or similar action). Both sensors and transducers can be considered as transducers.

For example, a Microphone is a Sensor, which converts sound waves into electrical signals and a Loudspeaker is an Actuator, which converts electrical signals into audio signals.

Both Microphone and Loudspeaker are Transducers in the sense that a microphone converts sound energy into electrical energy and a loud speaker converts electrical energy into sound energy.

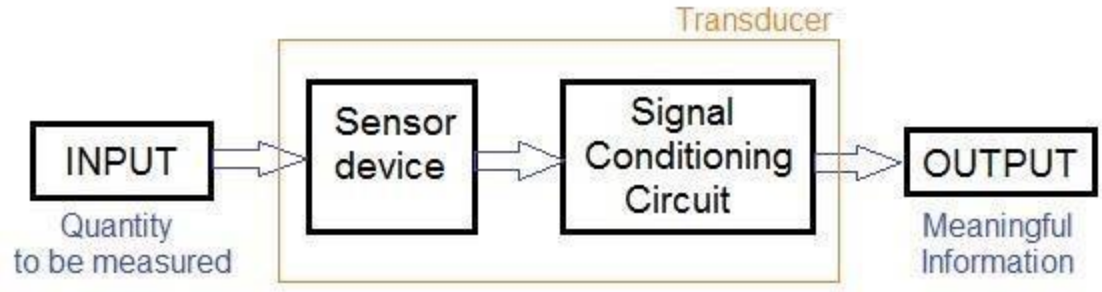


Measuring instruments:-

A measuring instrument is a device used for measuring a physical quantity.

In this block diagram of a simple measuring system, there are three basic elements:

- Sensor
- Signal Conditioning Unit
- Data Representing Device



Sensor

A Sensor is a device that is used to detect changes in any physical quantity like Temperature, Speed, Flow, Level, Pressure, etc.
Any changes in the input quantity will be detected by a Sensor and reflected as changes in output quantity.

Signal Conditioning Unit

The non-electrical output quantity of the Sensor makes it inconvenient to further process it.
Hence, the Signal Conditioning Unit is used to convert the physical output (or non-electrical output) of the sensor to an electrical quantity. Some of the best known Signal conditioning units are:

- Analog to Digital Converters
- Amplifiers
- Filters
- Rectifiers
- Modulators

Data Representation Device

A Data representation device is used to present the measured output to the observer.
This can be anything like

- A Scale
- An LCD Display
- A Signal Recorder

PHOTOELECTRIC TRANSDUCER:-

The photoelectric transducer converts the light energy into electrical energy.
It is made up of semiconductor material.

It uses a photosensitive element which emits electrons when it absorbs a beam of light.

This discharge of electron changes the photosensitive element property. Thus, current is induced in the devices.

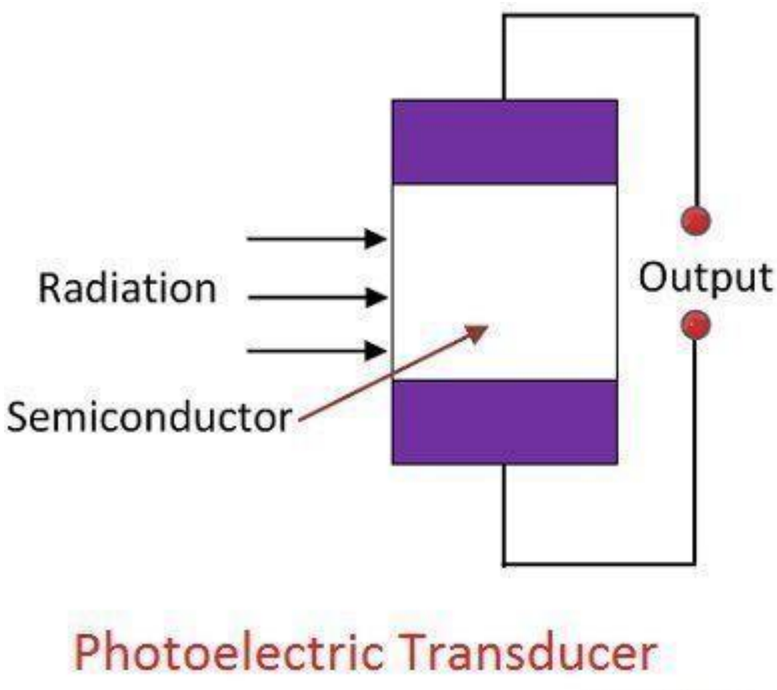
The magnitude of current is equal to the total light absorbed by the photosensitive element.

The photoelectric transducer absorbs the radiation of light which falls on theirsemiconductor material.

The absorption of light energizes the electrons of the material, and hence the electrons start moving.

The mobility of electrons produces one of the three effects.

- The resistance of the material changes.
- The output current of the semiconductor changes.
- The output voltage of the semiconductor changes.



Photoelectric transducers are classified into two types. They are:-

a) Active transducer

Photo voltaic

b) Passive transducer Photo emissive

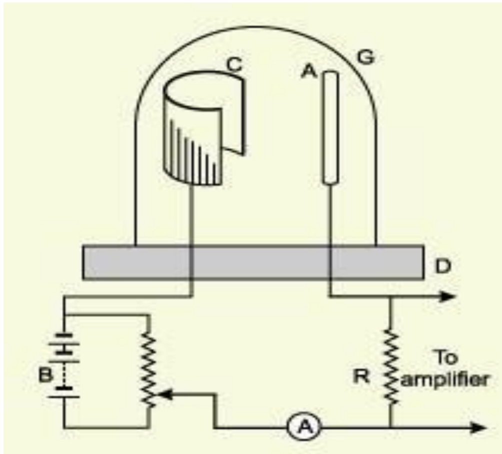
Photo conductive

PHOTO EMISSIVE CELL:-

The Photoemissive cell converts the photons into electric energy.

A photo emissive cell consists of an Anode, cathode, glass envelope and connecting pins.

The anode is a rod and the cathode is a curved plate coated with a photo emissive material like Cesium antimony. Current is produced across anode and cathode. Both anode and cathode are sealed within an evacuated envelope.

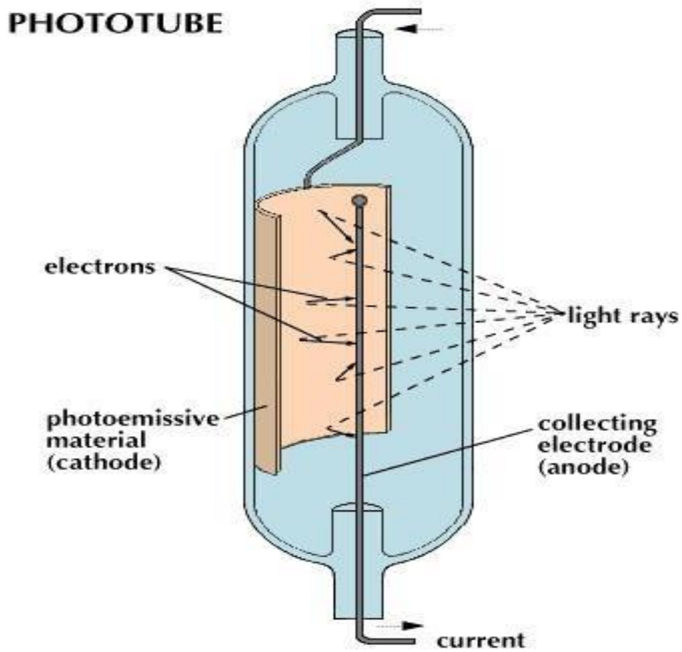


When a beam of light falls on the cathode, electrons are released from it, which are drawn towards the anode.

The anode is maintained at certain positive potential. This gives rise to a photoelectric current.

The current produced across the anode and cathode is proportional to the intensity of the incident light on the cathode.

To increase the sensitivity a large number of resistors are employed. eg: photomultiplier.



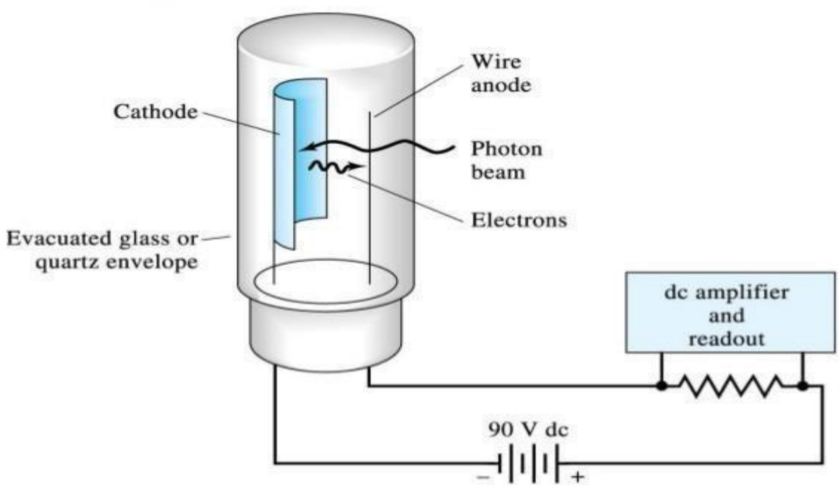
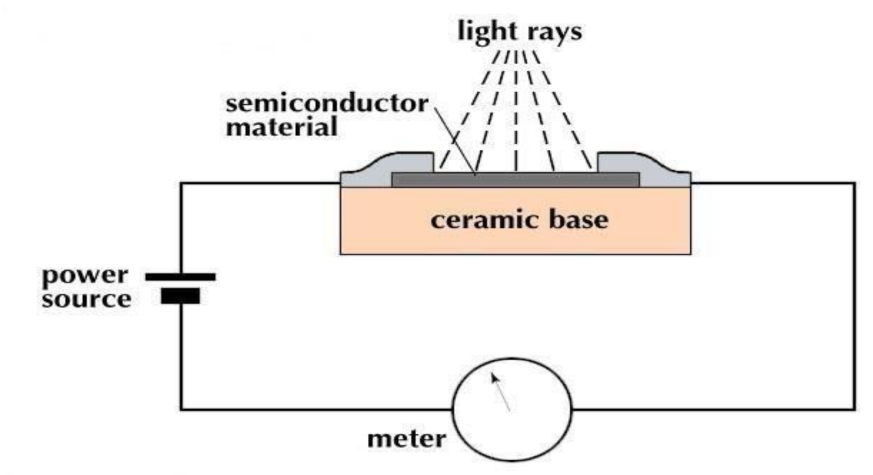


PHOTO CONDUCTIVE CELL:-

Photoconductive cell converts solar radiation into electric current.



The resistance of the photoconductive material change when a beam of light is incident on it.

Basically, the semiconductor materials are made up of Ge, Si, and Cadmium Selenide.

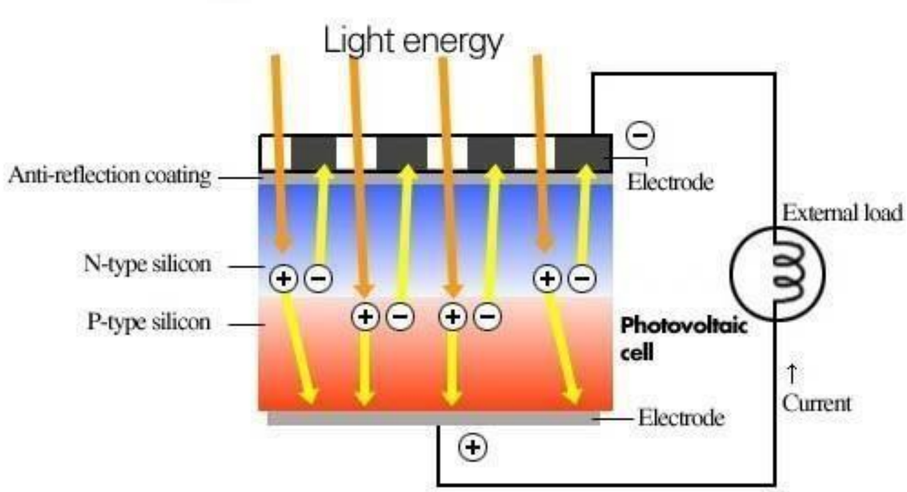
When the beam of light falls on the semiconductor material, their conductivity increases and the material works like a closed switch. If there is no light then the cell works as an open switch.

The current starts flowing through the material and deflects the pointer of the meter.

PHOTOVOLTAIC CELL:-

A photovoltaic cell or solar cell is an active transducer, which converts the light into electrical energy.

The current starts flowing through the photovoltaic cell when the load is connected to it.



A P-type silicon and N-type material are diffused to form a photovoltaic cell.

Silicon and selenium are used as a semiconductor material.

The anti-reflective coating is made up of silver nitrate to absorb maximum amount of light.

The N type material is heavily doped and thin so that sunlight can easily reach the depletion region. The p type material is lightly doped and thick.

It operates on the principle of photovoltaic effect.

When a semiconductor material is exposed to light, photons of the light ray are absorbed by semiconductor crystal which causes significant number of free electrons in the crystal; this phenomenon is called photovoltaic effect.

The current starts flowing into the photovoltaic cell when the load is connected to it.

The movement of electrons develops the current in the cell, and the current is known as the photoelectric current.

MULTIMETER:-

A multimeter or a multitester is also known as a VOM (volt-ohm-milliammeter).

A Multimeter is an electronic instrument, every electronic technician and engineers widely used piece of test equipment.

It is an electronicmeasuring instrumentthat combines several measurement functions in one unit.

A typical multimeter can measure voltage,current, and resistance.

It can also be used to test continuity between two points in a electrical circuit.

It is a handheld device with positive and negative indicator needle over a numeric LCD digital display.

Multimeters can be used for testing batteries, household wiring, electric motors and power supplies.

A multimeter can be a hand-held device useful for basic faultfinding and field service work, or a bench instrument which can measure to a very high degree of accuracy.

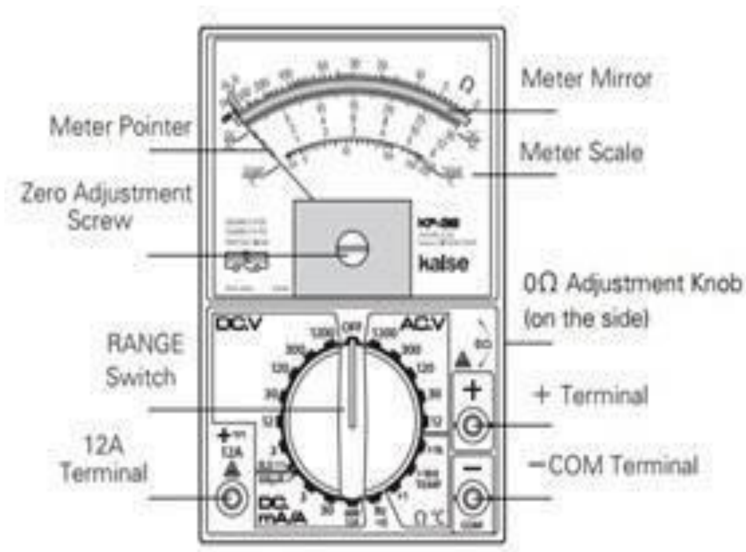
Multimeters are available in a wider range of features and prices.

Multimeters are of two types:-

a) Analog multimeters
b) Digital multimeters

a) **Analog multimeters:**

Analog multimeters use a microammeterwith a moving pointer to display readings.



<u>(i) MULTIMETER AS VOLTMETER</u>

Voltmeter can measure only potential difference between two points in an electrical circuit.

When a high resistance is connected in series with a galvanometer, it becomes a voltmeter.

The above figure shows a high resistance R connected in series with the galvanometer of resistance G.

For maximum accuracy, a multimeter is always provided with a number of voltage ranges.

This is achieved by providing a number of high resistances in the multimeter as shown in the figure below.

Each resistance corresponds to one voltage range.

With the help of selector switch S, we can select any resistance.

When D.C voltages are to be measured, the multimeter switch is turned on to d.c position.

By throwing the range selector switch S to a suitable position, the given dc voltage can be measured.

The multimeter can also measure A.C voltages.

In order to perform this function, a full wave rectifier is used. The rectifier converts ac into dc before it is fed to galvanometer.

The desired ac voltage range can be selected by the switch S.

When ac voltage is to be measured, the multimeter switch is thrown to ac position.

(ii) MULTIMETER AS AMMETER:-

When low resistance is connected in parallel with a galvanometer, it becomes an ammeter.

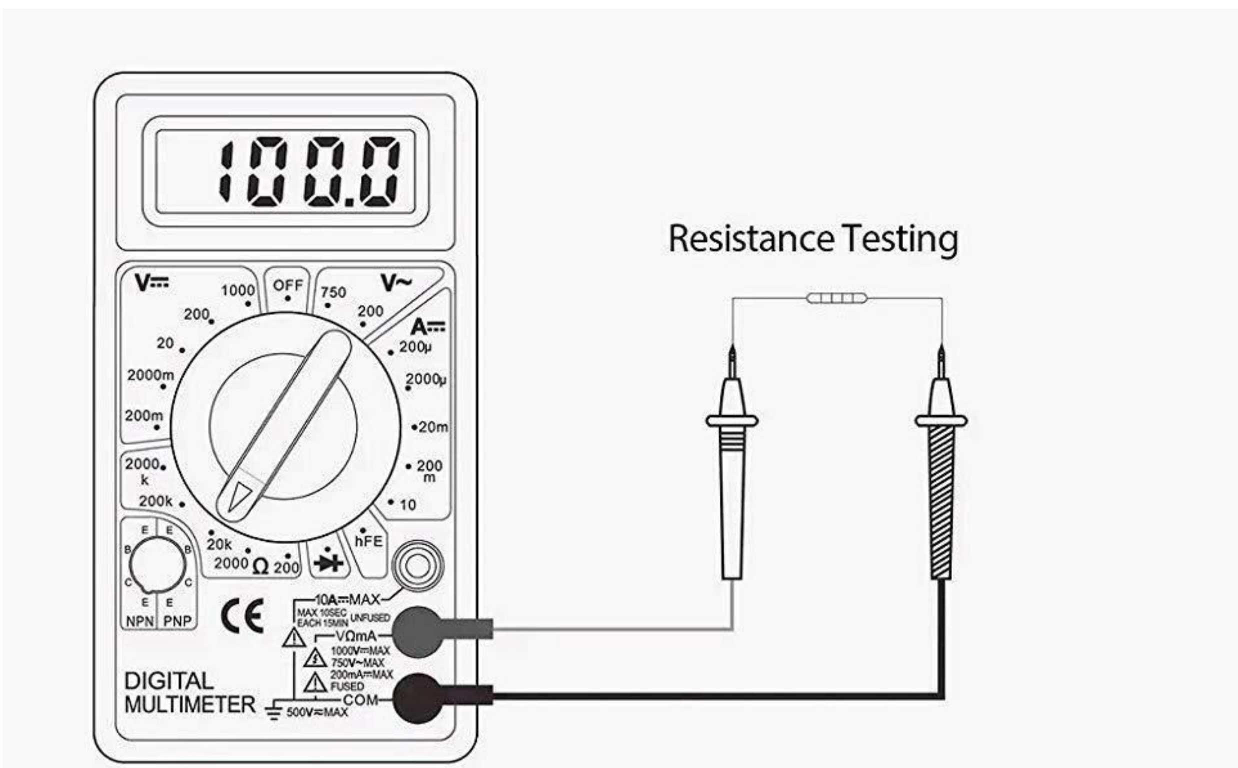
The above figure shows a low resistance S (generally called shunt) connected in parallel with the galvanometer of resistance G.

A number of low resistances are connected in parallel with the galvanometer to provide a number of current ranges.

When dc current is to be measured, the multimeter switch is turned on to dc position.

By throwing

(iii) MULTIMETER AS OHMMETER:-



b) Digital multimeters

Digital multimeters (DMM, DVOM) have a numeric display, and may also show a graphical bar representing the measured value.

Digital multimeters are now far more common due to their lower cost and greater precision, but analog multimeters are still preferable in some cases, for example when monitoring a rapidly varying value. The Digital Multimeter basically consists of

- a LCD display
- A knob to select various ranges of the three electrical characteristics.
- An internal circuitry consisting of a signal conditioning circuitry. An
- analog to digital converter.

It has two probes positive and negative indicated with black and red color.

The black probe is connected to COM JACK and red probe is connected by user requirement to measure ohm, volt or amperes. The COM port stands for "common" and the black probe will always plug into this port.

The VΩmA (sometimes denoted as mAVΩ) is simply an acronym for voltage, resistance and current (in mA). This is where the red probe will plug into if we have to measure voltage, current less than 200mA, resistance and continuity.

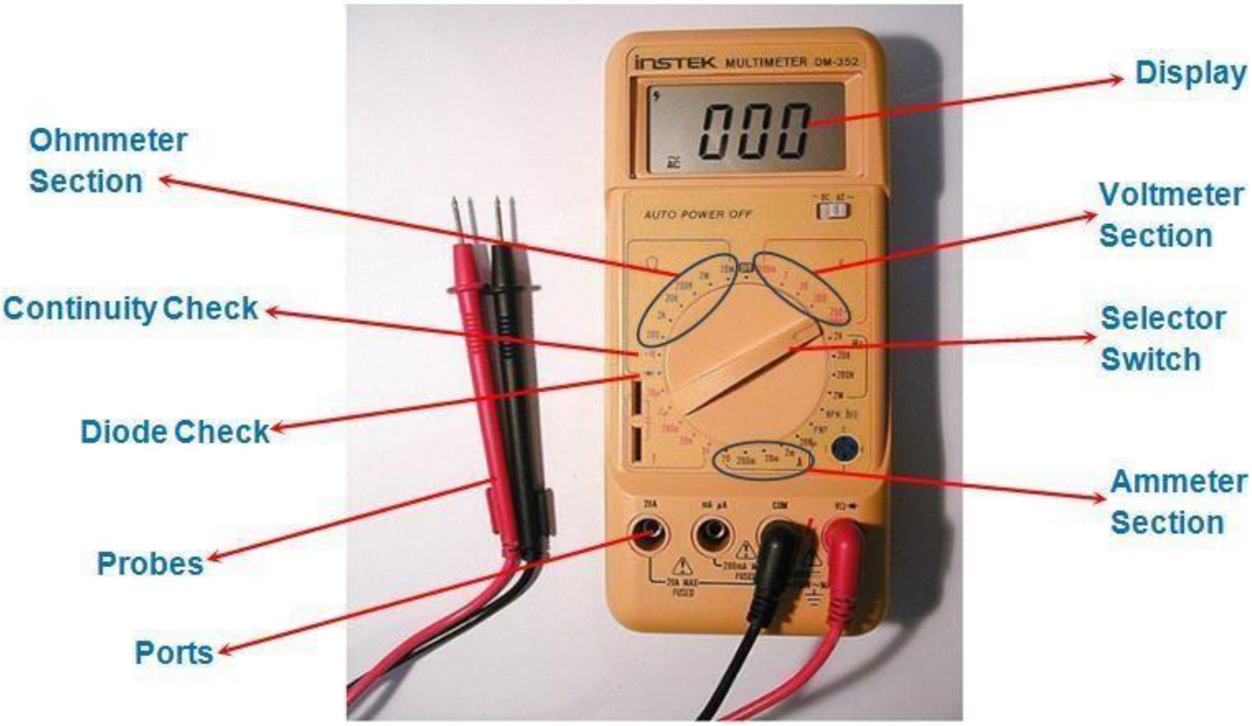
The 10ADC port (sometimes denoted as 10A) is used whenever we have to measure current more than 200mA

To measure the resistance, current flows from a constant current source through the unknown resistor and the voltage across the resistor is amplified and fed to a Analog to Digital Converter and the resultant output in form of resistance is displayed on the digital display.

To measure an unknown AC voltage, the voltage is first attenuated to get the suitable range and then rectified to DC signal and the analog DC signal is fed to A/D converter to get the display, which indicates the RMS value of the AC signal.

Similarly to measure an AC or DC current, the unknown input is first converted to voltage signal and then fed to analog to digital converter to get the desired output(with rectification in case of AC signal).

Advantages of a Digital Multimeter are its output display which directly shows the measured value, high accuracy, and ability to read both positive and negative values.



A Typical Digital Multimeter

DIFFERENCE BETWEEN ANALOG AND DIGITAL MULTIMETER:-

CHARACTERISTICS	ANALOG MULTIMETER	DIGITAL MULTIMETER
Purpose	The analog multimeters provide measurement in analog form.	The digital multimeters provide measurement in digital form.
Accuracy	Prone to error because of wrong pointer based reading	Measures with great accuracy
Reading	Provides reading on a scale against pointer	Provides reading in numeric form appeared on a LCD

Calibration	Calibration is done manually	They are calibrated automatically before taking any measurement
Range	Have to set a range of measurement manually	Mostly, they have autoranging feature but costlier than their counter-parts
Measuring parameters	Usually it measures current, voltage, and resistance	Measures current, voltage, resistance, capacitance, and inductance as well
ADC Requirement	Does not require analogto-digital converter (ADC) to display reading	Requires ADC in order to display the reading on LCD
AC Frequency	Highest AC Frequency which can be measured is lower	Highest AC Frequency which can be measured is higher than analog multimeter
Construction	Construction is easy and simple	Complicated construction because of several electronic and logic components involvement
Power supply	Is not required	Is required in these types of meters
Noise	Suffer less from electric noise	Suffer more from electric noise

CHARACTERISTICS	ANALOG MULTIMETER	DIGITAL MULTIMETER
		It is able to accept multiple inputs and has

Input signals	Displays only one input signal value	adjustable displays which allow user to choose between the input signals.
Size	Bigger in size	Very small like hand-held devices
Cost	Less costly as they offer very few features	Expensive as they offer wide range of features

CATHODE RAY OSCILLOSCOPE (CRO):-

CRO stands for cathode ray oscilloscope.

The **cathode ray oscilloscope** is an instrument which generates the waveform of any electrical quantity.

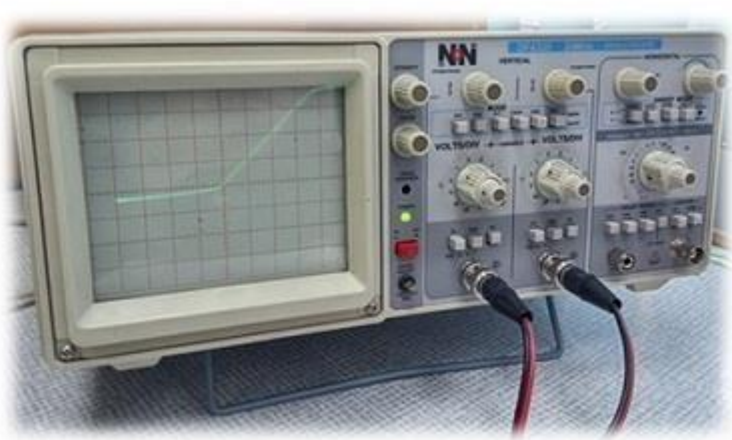
It is a laboratory instrument commonly used to display and analyze the waveform of electronic signals.

The waveform is generated in such a way that the amplitude of the signal is represented along Y-axis and the variation in the time is represented along X-axis.

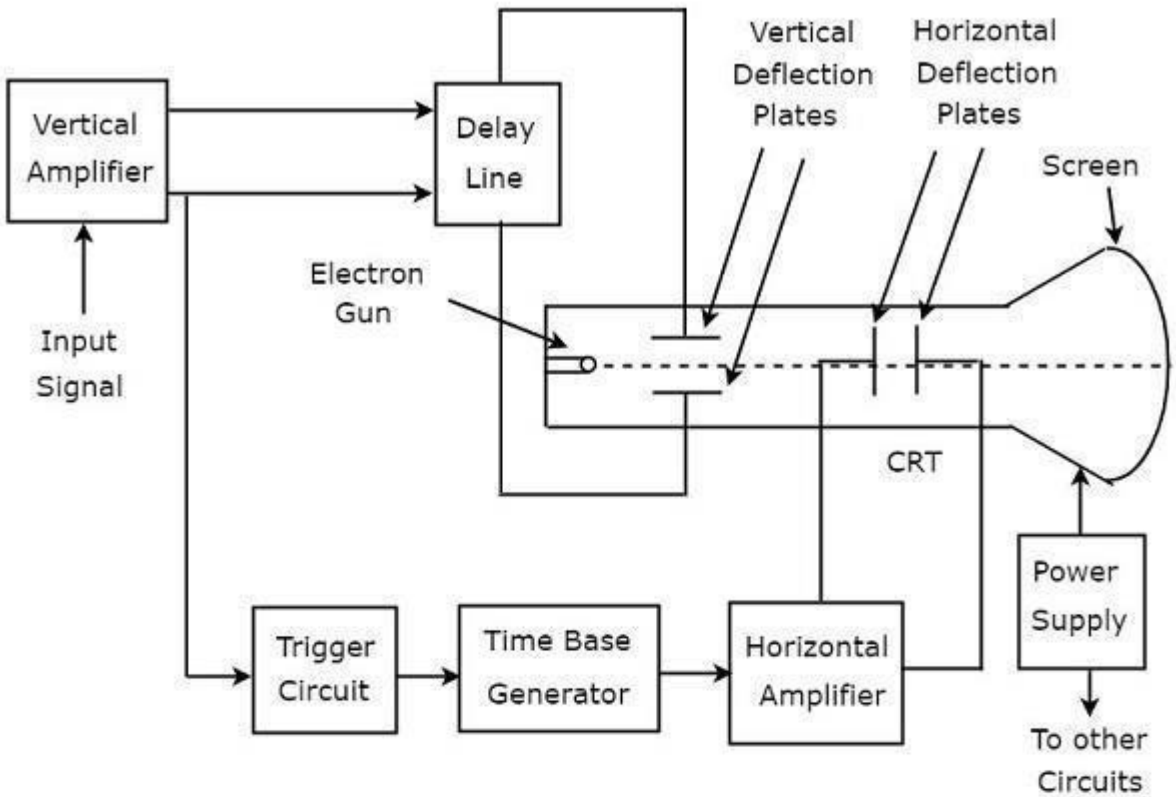
A cathode ray oscilloscope is a very fast X-Y (2 dimensional) plotter that can display an input signal versus time or other signal.

The screen of a CRO has a reference grid with usually 8 vertical and 10 horizontal divisions.

Each resulting square has 5 further subdivisions per axis useful to better readings.



A basic block diagram of a general purpose oscilloscope is shown in figure.



An oscilloscope consists of the following parts:

1. Cathode ray tube
2. Vertical amplifier
3. Delay line
4. Trigger circuit
5. Time base generator
6. Horizontal amplifier
7. Power supply

1. CATHODE RAY TUBE:

It is the heart of the oscilloscope.

It generates the electron beam, accelerates the beam to a high velocity, deflects the beam to create the image, and contains a phosphor screen where the electron beam eventually becomes visible.

When the electrons emitted by the electron gun strikes the phosphor screen, a visual signal is displayed on the CRT.

It 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.

2. VERTICAL AMPLIFIER

The vertical amplifier receives the input from the signal which is to be measured.

The vertical amplifier receives the input signal and then amplifies it so that the signal of high intensity is supplied to the vertical deflection plate.

If a low-intensity signal strikes the vertical deflection plate, the electron beam will not be deflected effectively to create the bright spots on desired points on the screen.

It amplifies the input signals, which is to be displayed on the screen of CRT.

The vertical amplifier is a wide band amplifier which passes the entire band of frequencies.

3. DELAY LINE

This circuit is used to delay the signal for a period of time in the vertical section of CRT.

When the signal from the vertical amplifier is fed to the delay line, then some part of the amplified signal is supplied to the time base generator.

This trigger pulse generated from the time-based generator is amplified with the help of the horizontal amplifier.

After this, it is fed to horizontal deflection plates. This process requires approximately **100ns**. Thus, it is crucial to delay the signal generated by the vertical amplifier too in order to maintain synchronization.

The delay line is essential because there is the delay when any electronic signal passes through the electronic circuitry.

Therefore, the input signal is delayed by a period of time.

4. TRIGGER CIRCUIT-

Trigger circuit is used to make the trace of the screen ‘STEADY’.

Some part of the amplified signal is supplied to the triggering circuit.

It produces a triggering signal in order to synchronize both horizontal and vertical deflections of electron beam.

The trigger control enables user to stabilize repetitive waveforms as well as capture single- shot waveforms.

5. TIME BASE GENERATOR-

Time base generator is a special type of function generator.

Time base circuit uses a uni-junction transistor, which is used to produce the sweep.

Time base generators generates high frequency saw tooth waves specially designed to deflect the beam in CRT smoothly across the face of the tube and then return to its starting position.

The saw tooth voltage produced by the time base circuit is required to deflect the beam in the horizontal direction.

The spot is deflected by the saw tooth voltage at a constant time dependent rate.

6. HORIZONTAL AMPLIFIER-

The saw tooth voltage produced by the time base circuit is amplified by the horizontal amplifier before it is applied to horizontal deflection plates.

7. POWER SUPPLY-

The voltage required by CRT, horizontal amplifier and vertical amplifier are provided by the power supply block .It is classified into two types-

1. Negative high voltage supply
2. Positive low voltage supply

The voltage of negative high voltage supply is from -1000V to -1500V. The range of positive voltage supply is from 300V to 400V.

Working of Cathode Ray Oscilloscope

The electron gun generates the beam of electrons.

These electron beams consists of several electrons moving towards phosphor screen.

The control grids are also used in **CRT (Cathode Ray Tube)** to control the intensity of electrons.

The accelerating anodes are used to increase the velocity of electrons so that they strike the phosphor screen with high speed and thus form a bright spot.

The beam creates the luminous spot at the different points on the screen. This becomes easy with the help of deflection plates which deflects the electron beam through various angles.

For accomplishing these tasks various electrical signals and voltages are required, which are provided by the power supply circuit of the oscilloscope.

Low voltage supply is required for the heater of the electron gun for generation of electron beam

High voltage, of the order of few thousand volts, is required for cathode ray tube to accelerate the beam.

Normal voltage supply, say a few hundred volts, is required for other control circuits of the oscilloscope.

Horizontal and vertical deflection plates are fitted between electron gun and screen to deflect the beam according to input signal.

Electron beam strikes the screen and creates a visible spot.

This spot is deflected on the screen in horizontal direction (X-axis) with constant time dependent rate. This is accomplished by a time base circuit provided in the oscilloscope.

The signal to be viewed is supplied to the vertical deflection plates through the vertical amplifier, which raises the potential of the input signal to a level that will provide usable deflection of the electron beam.

Now electron beam deflects in two directions, horizontal on X-axis and vertical on Yaxis.

A triggering circuit is provided for synchronizing two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps.

Applications of Oscilloscope

An oscilloscope is used for voltage measurement, current measurement, measurement of other physical quantities after conversion to electrical form.

Cathode ray oscilloscope is also used in the laboratory to study the output waveforms of various signals. Besides, it can also be used to measure their phase and frequency.