BASIC ELECTRICAL ENGINEERING

LECTURE NOTES

Department of Electrical Engineering

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CONTENT

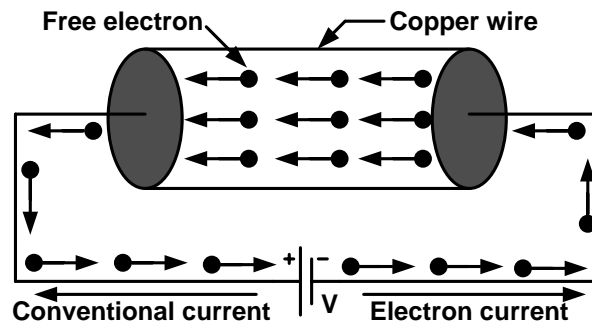## 1.1. Define following terms

(a) Current

Figure 1.1Concept of electric current

- Flow of electron in closed circuit is called current.
- Amount of charge passing through the conductor in unit time also called current.
- Unit of current is charge/second or Ampere (A).

$$I = \frac{Q}{t}$$

Where, $I =$ Current

$\qquad Q =$ Charge

$\qquad t =$ Time

(b) Potential or Voltage
- The capacity of a charged body to do work is called potential.
- Unit of potential is joule/coulomb or Volt (V).

$$V = \frac{W}{Q}$$

Where, $V =$ Potential or Voltage

$\qquad W =$ Workdone
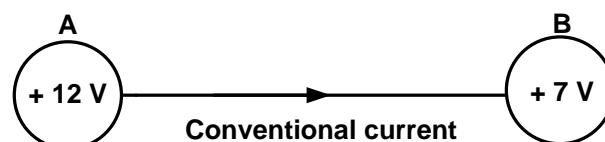
(c) Potential difference

Figure 1. 1Potential differences

- The difference of electrical potential between two charged bodies is called potential difference.
- Unit of Potential Difference is Volt (V).
- If potential of body A is +12V and potential of body B is +7V then potential difference is +5V.
  i.e. (+12V) - (+7V) = +5V

(d) **Electro Motive Force (emf)**
- The force is required to move electron from negative terminal to positive terminal of electrical source in electrical circuit is called emf.
- Unit of emf is volt (V).
- Emf is denoted as ε.

(e) **Energy**
- Ability to do work is called energy.
- Unit of energy is Joule or Watt-sec or Kilowatt-hour (KWh).
- 1KWh is equal to 1 Unit.

$$W = P \times t = VIt = I^2 Rt = \frac{V^2 t}{R}$$

Where, W = Energy
P = Power
t = Time

(f) **Power**
- Energy per unit in time is called power.
- Unit of Power is Joule/Second or Watt (W).

$$P = \frac{W}{t}$$

(g) **Resistance**
- Property of a material that opposes the flow of electron is called resistance.
- Unit of resistance is Ohm (Ω).

$$R = \frac{V}{I}$$

Where, R = Resistance

(h) **Conductance**
- Property of a material that allows flow of electron.
- It is reciprocal of resistance.
- Unit of conductance is (Ω^{-1}) or mho or Siemens(S).

$$G = \frac{1}{R}$$

Where, G = Conductance

(i) **Resistivity or Specific Resistance**
- Amount of resistance offered by 1m length of wire of 1m^2 cross-sectional area.
- Resistivity is denoted as a ρ.
- Unit of Resistivity is Ohm-meter (Ω-m).

$$R \propto \frac{l}{a}$$

$$R = \rho \frac{l}{a}$$

$$\rho = \frac{Ra}{l}$$

Where, $R =$ Resistance

$\rho =$ Resistivity

$l =$ Length of wire

$a =$ Cross section area of wire

(j) Conductivity

- Ability of a material to allow flow of electron of a given material for 1 m length & 1 m^{2}cross-sectional area is called conductivity. Unit of conductivity is$\Omega^{-1}m^{-1}$ or Siemens m^{-1}.

$$\sigma = \frac{1}{\rho}$$

Where, $\sigma =$ Conductivity

1.2. Explain types of electrical energysource

- Electrical source is an element which supplies energy to networks. There are two types of electrical sources.
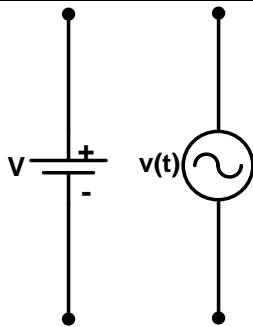
(a) Independent sources

Independent voltage source	Independent current source

Figure 1. 2Independent voltage source

Figure 1. 3Independent current source

- It is a two terminal element that provide a specific voltage across its terminal.
- The value of this voltage at any instant is independent of value or direction of the current that flow through it.
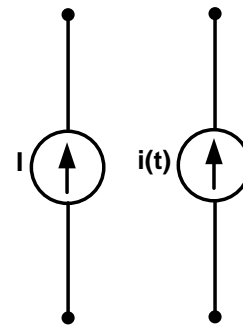
- It is two-terminal elements that provide a specific current across its terminal.
- The value and direction of this current at any instant is independent of value or direction of the voltage that appears across the terminal of source

1.3. Explain source conversion

- A voltage source with a series resistor can be converted into an equivalent current source with a parallel resistor. Conversely, a current source with a parallel resistor can be converted into a voltage source with a series resistor.
- Open circuit voltages in both the circuits are equal and short circuit currents in both the circuit are equal.Source transformation can be applied to dependent source as well.
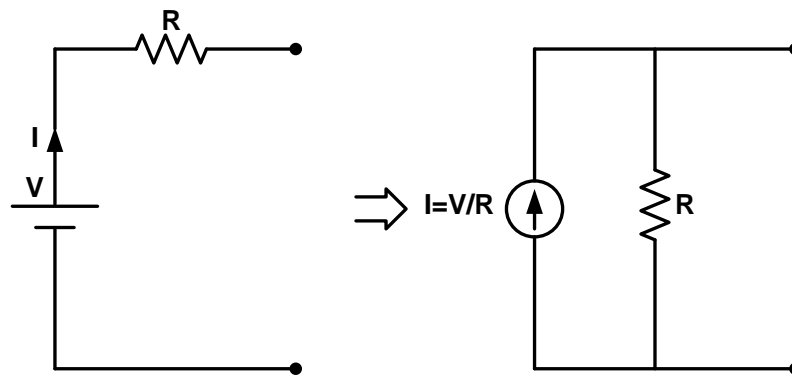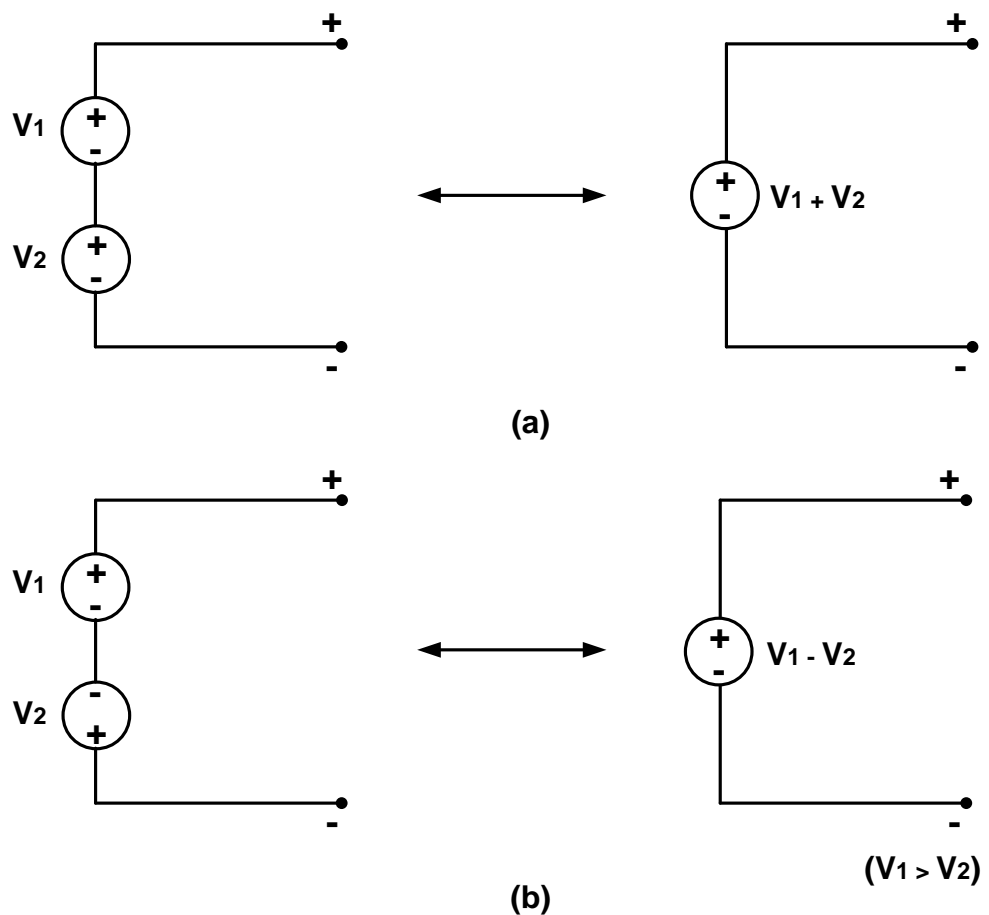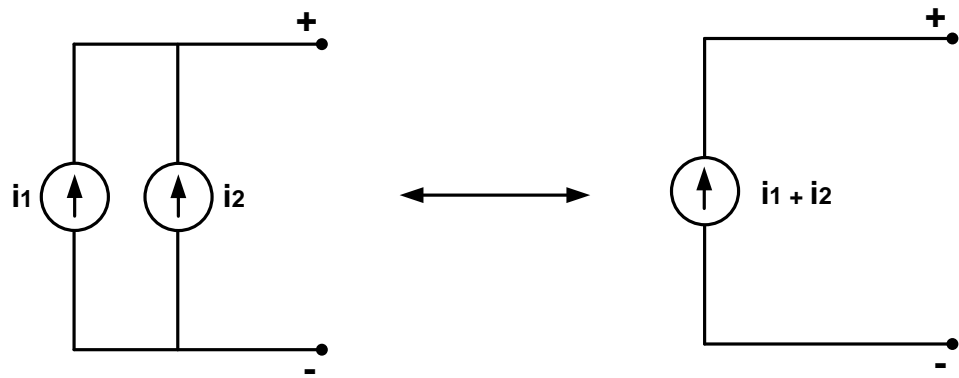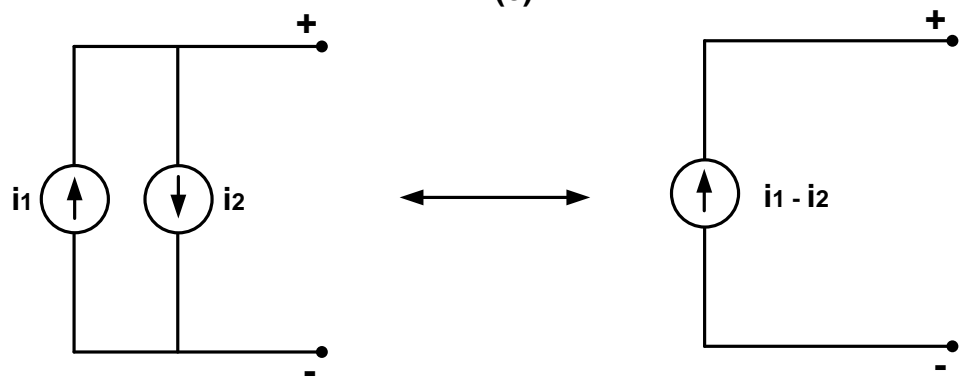

Figure 1. 9Source conversion

Network simplification techniques

(a)

(b)

(c)

$(i_1 > i_2)$

(d)

(e)

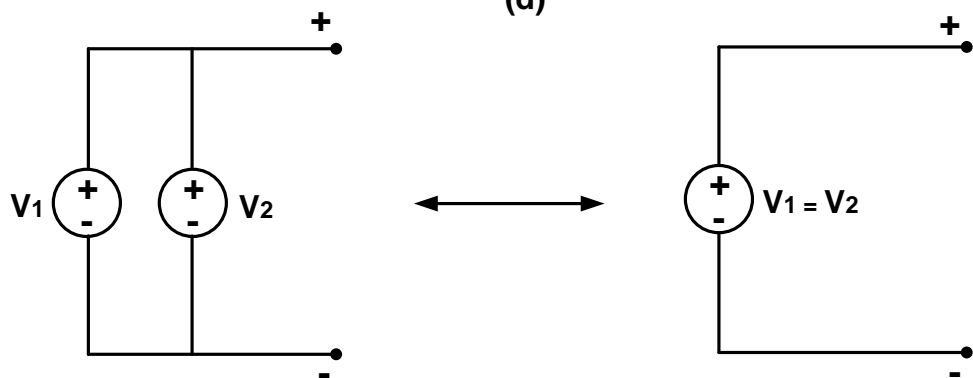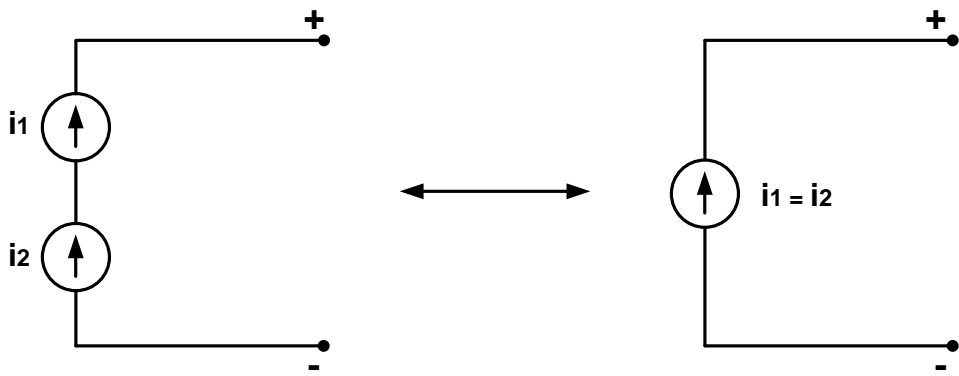**(f)**

(g)

(h)
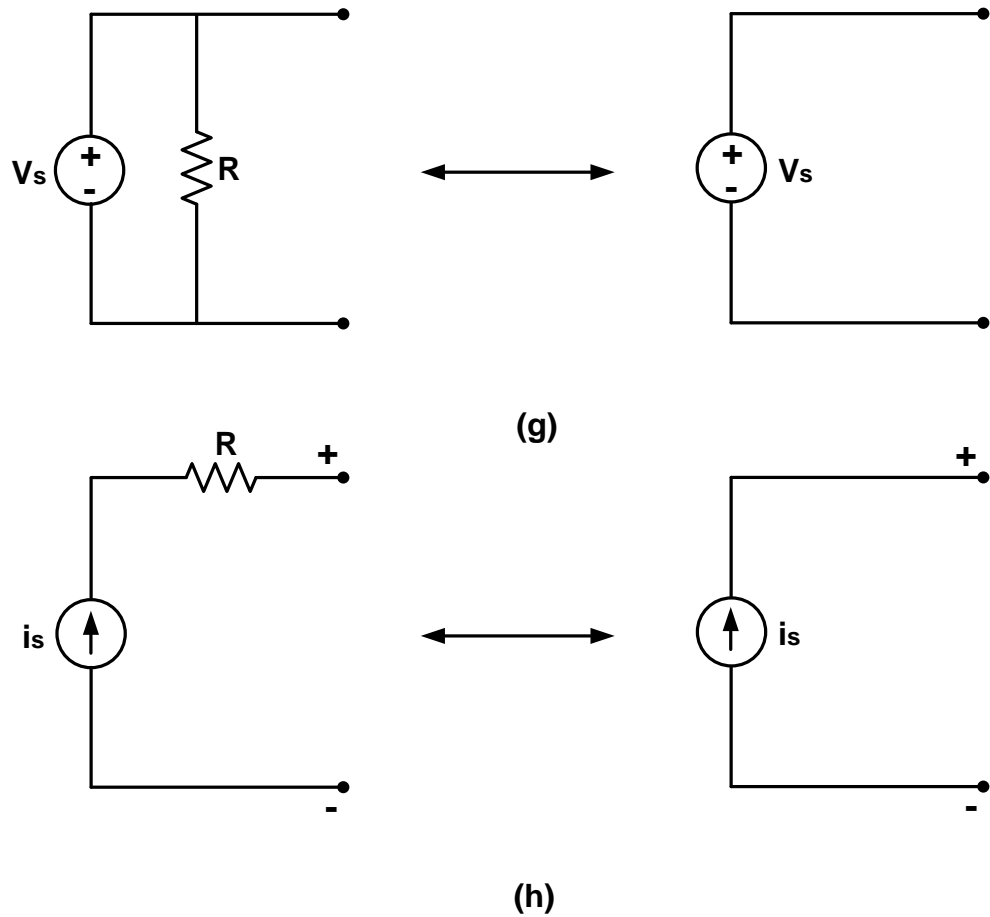
Figure 1.10Rules under which source may be combined and separated

1.4. Explain ideal electrical circuit element.

- There are major three electrical circuit elements which are discussed below.

(a)   Resistor

- Resistor is element which opposes the flow of current.

Figure 1.11Resistor   *Figure 1.12Conductor*

- Resistance is property of material which opposes the flow current. It is measured in Ohms (Ω).
- Value of resistance of conductor is
    - ✓ Proportional to its length.
    - ✓ Inversely proportional to the area of cross section.
    - ✓ Depends on nature of material.
    - ✓ Depends on temperature of conductor.

$$R \propto \frac{l}{a}$$

$$R = \frac{\rho l}{a}$$

(b) **Inductor**
- An inductor is element which store energy in form of magnetic field.
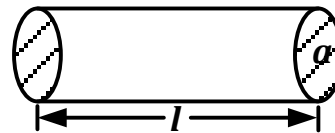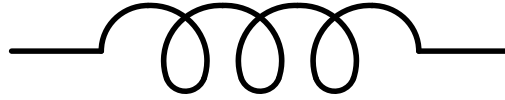- The property of the coil of inducing emf due to the changing flux linked with it is known as inductance of the coil.
- Inductance is denoted by L and it is measured in Henry (H).

1.13Inductor

- Value of inductance of coil is
  - ✓ Directly proportional to the square of number of turns.
  - ✓ Directly proportional to the area of cross section.
  - ✓ Inversely proportional to the length.
  - ✓ Depends on absolute permeability of magnetic material.

$$\Phi = \frac{F}{S} = \frac{NI}{S} = \frac{NI}{\dfrac{l}{\mu_0 \mu_r A}} = \frac{NI\mu_0 \mu_r A}{l}$$

$$Now, L = \frac{N\Phi}{I} = \frac{N\left(\dfrac{NI\mu_0 \mu_r A}{l}\right)}{I} = \frac{N^2 \mu_0 \mu_r A}{l}$$

Where, L =Inductance of coil

   N= Number of turns of coil

   Φ = Flux link in coil

   F= Magneto motive force(MMF)

   I = Current in the coil

   l = Mean length of coil

   μ_0= Permiability of free space

   μ_r= Relative permiability of magnetic material

   A = Cross sectional area of magnetic material

(c) **Capacitor**
- Capacitor is an element which stored energy in form of charge.
- Capacitance is the capacity of capacitor to store electric charge.
- It is denoted by C and measured in Farad (F).
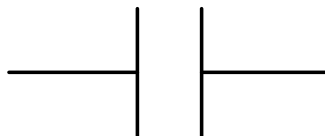

Figure 1.14Capacitor

- Value of capacitance is
  - ✓ Directly proportional to the area of plate.
  - ✓ Inversely proportional to distance between two plates.
  - ✓ Depends on absolute permittivity of medium between the plates.

$$C \propto \frac{A}{d}$$

$$C = \frac{\varepsilon A}{d}$$

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

Where,C=Capacitance of capacitor

       A =Cross sectional area of plates

       d =Distance between two plates

       ε = Abolute Permittivity

       ε_0 = Permittivity of free space

       ε_r = Relative permittivity of dielectric material

1.5. Explain Ohm's law and its limitations.

- Current flowing through the conductor is directly proportional to the potential difference applied to the conductor, provided that no change in temperature.
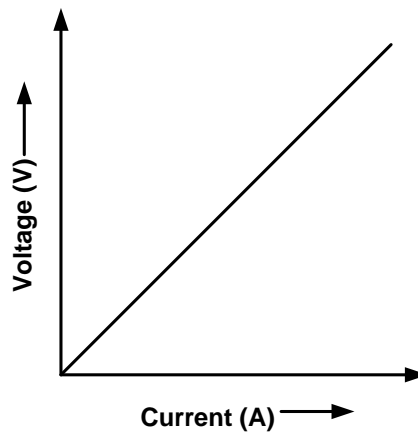
Figure 1.15Change in current w.r.t change in voltage for conducting material

$$V \propto I$$

$$\therefore V = IR$$

- Where R is constant which is called resistance of the conductor.

$$\therefore R = \frac{V}{I}$$

- Limitations of Ohm's Law:
    - ✓ It cannot be applied to non-linear device e.g. Diode, Zener diode etc.
    - ✓ It cannot be applied to non-metallic conductor e.g. Graphite, Conducting polymers
    - ✓ It can only be applied in the constant temperature condition.

1.6. State and explain the Kirchhoff's current and voltage laws

(a) Kirchhoff's current law (KCL)

- **Statement**:

"Algebraic sum of all current meeting at a junction is zero"

- Let, Suppose

- ✓ Branches are meeting at a junction 'J'
- ✓ Incoming current are denoted with (+ve) sign
- ✓ Outgoing currents are denoted with (-ve) sign

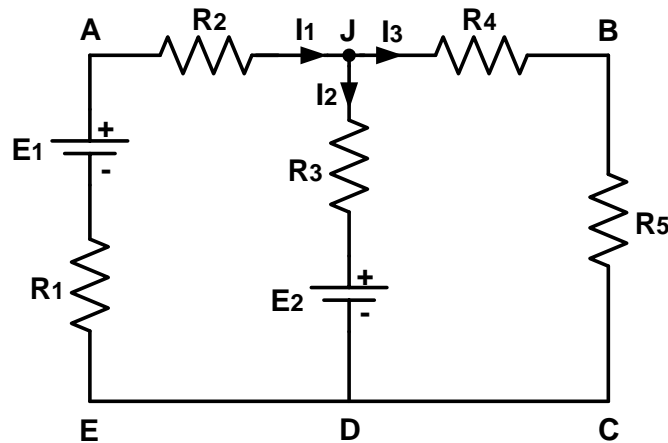

Figure 1.16Kirchhoff's law diagram

- Then,

$$\sum I = 0$$

$$(+I_1) + (-I_2) + (-I_3) = 0$$

$$I_1 - I_2 - I_3 = 0$$

$$I_1 = I_2 + I_3$$

$$\therefore Incoming\ current\ =\ Outgoing\ current$$

(b) Kirchhoff's voltage law (KVL)

- **Statement**:
  "Algebraic sum of all voltage drops and all emf sources in any closed path is zero"
- Let, Suppose
  - ✓ Loop current in clockwise or anticlockwise direction
  - ✓ Circuit current and loop current are in same direction than voltage drop is denoted by (-ve) sign.
  - ✓ Circuit current and loop current are in opposite direction than voltage drop is denoted by (+ve) sign.
  - ✓ Loop current move through (+ve) to (-ve) terminal of source than direction of emf is (-ve).
  - ✓ If Loop current move through (-ve) to (+ve) terminal of source than direction of emf is (+ve).
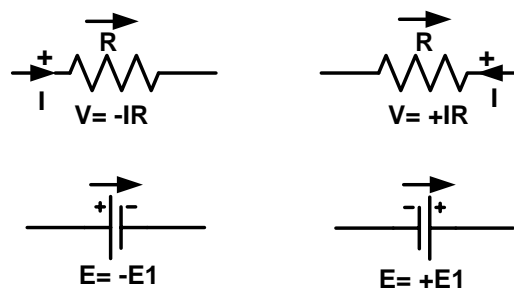

Figure 1.17Sign convention for Kirchhoff's voltage law

$\therefore \sum IR + \sum E = 0$

KVL to loop AJDEA

$-I_1 R_2 - I_2 R_3 - E_2 - I_1 R_1 + E_1 = 0$

KVL to loop JBCDJ

$-I_3 R_4 - I_3 R_5 + E_2 + I_2 R_3 = 0$

1.7. Explain series and parallel combination of resistor
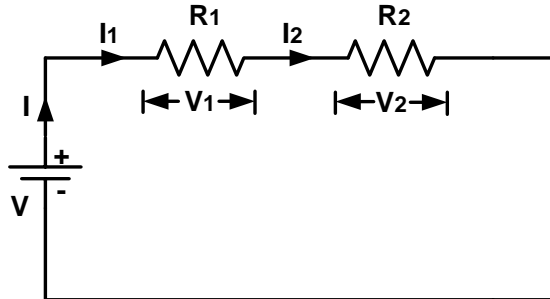
Series combination of resistor	Parallel combination of resistor

Figure 1.18Series combination of resistors

Figure 1.19Parallel combinations of resistors

Here, $I_1 = I_2 = I$

As per KVL,

$V = V_1 + V_2$

$V = IR_1 + IR_2$

$V = I(R_1 + R_2)$

$\dfrac{V}{I} = (R_1 + R_2)$

$R_{eq} = R_1 + R_2$

For n resistor are connected in series

$R_{eq} = R_1 + R_2 + R_3 + \ldots\ldots + R_n$

Here, $V_1 = V_2 = V$

As per KCL,

$I = I_1 + I_2$

$I = \dfrac{V}{R_1} + \dfrac{V}{R_2}$

$I = V\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$

$\dfrac{I}{V} = \left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$

$\dfrac{1}{R_{eq}} = \left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$

For n resistor are connected in Parallel

$\dfrac{1}{R_{eq}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \ldots\ldots + \dfrac{1}{R_n}$

- Value of equivalent resistance of series circuit is bigger than the biggest value of individual resistance of circuit.
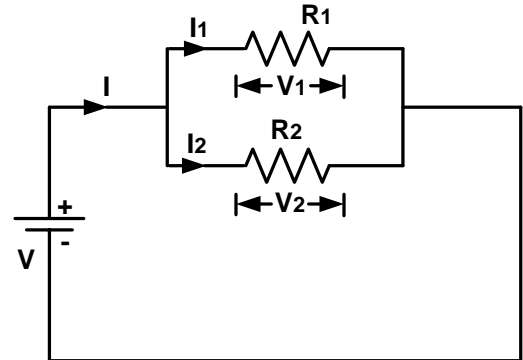
- Value of equivalent resistance of parallel circuit is smaller than the smallest value of individual resistance of circuit.

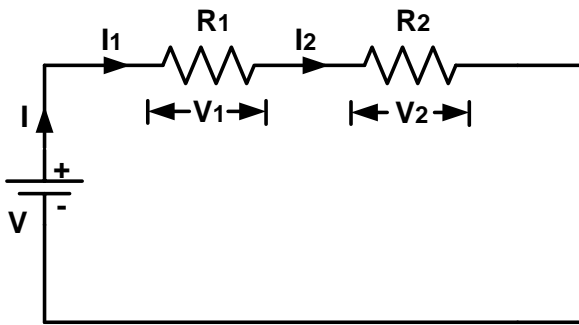## 1.8. Explain Voltage divider law and current divider Law.

Voltage Divider Law	Current Divider Law
Figure 1.20Voltage divider circuit	*Figure 1.21Current divider circuit*

Voltage Divider Law

$Here, I_1 = I_2 = I$

$As\ per\ KVL,$

$V = V_1 + V_2$

$V = I_1 R_1 + I_2 R_2$

$V = IR_1 + IR_2$

$V = I(R_1 + R_2)$

$I = I_1 = I_2 = \dfrac{V}{(R_1 + R_2)}$

$Now, V_1 = I_1 R_1$

$V_1 = \dfrac{V}{R_1 + R_2} R_1$

$V_1 = V\left(\dfrac{R_1}{R_1 + R_2}\right)$

$Now, V_2 = I_2 R_2$

$V_2 = \dfrac{V}{R_1 + R_2} R_2$

$V_2 = V\left(\dfrac{R_2}{R_1 + R_2}\right)$

Current Divider Law

$Here, V_1 = V_2 = V$

$As\ per\ KCL,$

$I = I_1 + I_2$

$I = \dfrac{V_1}{R_1} + \dfrac{V_2}{R_2}$

$I = \dfrac{V}{R_1} + \dfrac{V}{R_2}$

$I = V\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$

$\dfrac{I}{V} = \left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$

$V = V_1 = V_2 = I\left(\dfrac{R_1 R_2}{R_1 + R_2}\right)$

$Now, I_1 = \dfrac{V_1}{R_1}$

$I_1 = \dfrac{I\left(\dfrac{R_1 R_2}{R_1 + R_2}\right)}{R_1}$

$I_1 = I\left(\dfrac{R_2}{R_1 + R_2}\right)$

$Now, I_2 = \dfrac{V_2}{R_2}$

$I_2 = \dfrac{I\left(\dfrac{R_1 R_2}{R_1 + R_2}\right)}{R_2}$

$I_2 = I\left(\dfrac{R_1}{R_1 + R_2}\right)$

CHAPTER-2 AC THEORY

ALTERNATING CURRENT THEORY

what is D.C.

1. The Direct current or D.C. always flows in one direction & its magnitude remains unchanged

2. Here you see the voltage value is V volts & Current value is I amperes for all time to come i.e. as the time progresses.

[Figure (a)]
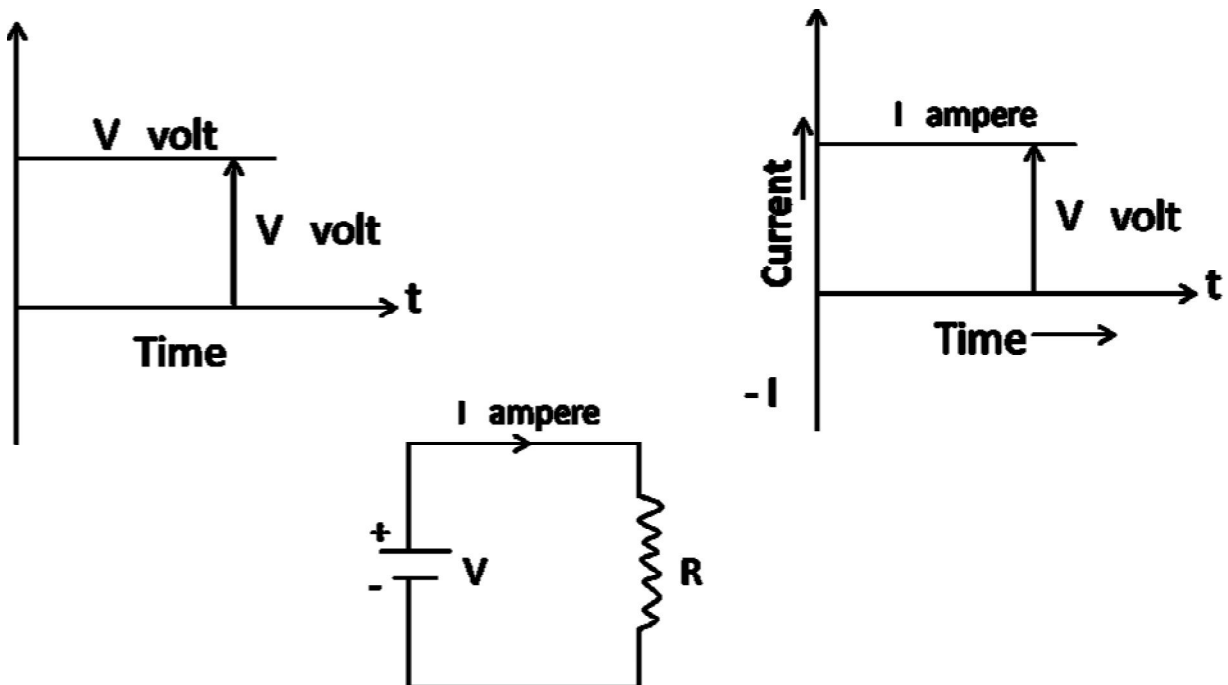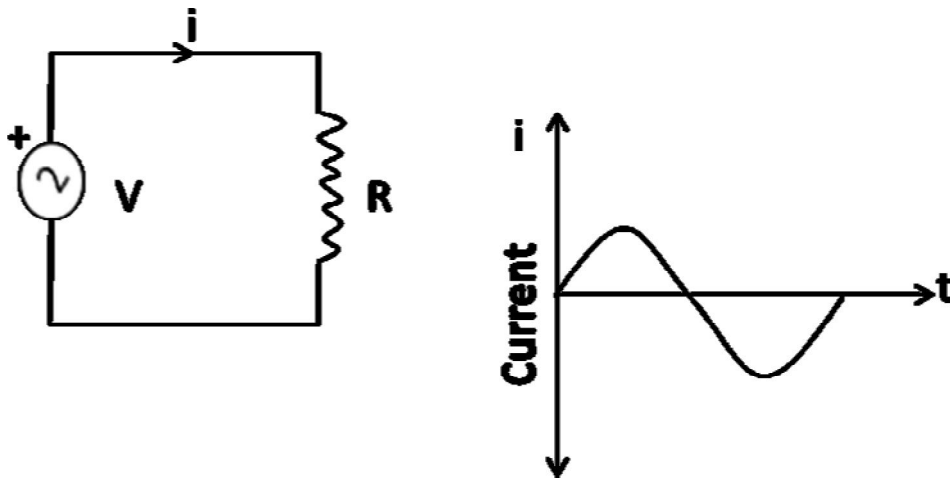
what is A.C

1. The Alternating current or A.C. is one which changes both in its direction & its magnitude .

[Figure(b)]

The AC current shown in the above circuit reverses it direction after some time as you see in the wave form diagram.

AC waveforms can also be other than like a sine wave that will be discussed later on.

HOW A.C. IS DIFFERENT FROM D.C

Alternating Current	Direct Current
1.The magnitude and direction both changes . 2. By using transformers, A.C. voltages can be increased or decreased as desired. 3. A.C. circuit current can be decreased by using choke or capacitor without any appreciable power loss. 4. A.C. can be converted into D.C. by using a device, called convertor (rectification circuit) 5. A.C. cannot be used directly for electroplating, electrotyping, etc.	1.Both magnitude & Direction remain constant. 2. No such provision can be made. 3.For decreasing D.C. circuit current, a resistance has to be used, whose power dissipation factor (I^2R) is large. 4. D.C. can be converted to A.C. by using choppers (inverters). 5. D.C. can be used directly for carrying out such operations.

Faradays laws of Electromagnetic Induction.

First Law- Whenever a coil cuts the magnetic lines of flux (φ) Electro-Magnetic Force(e.m.f) is induced in the coil i.e.

EMF Induced in a coil of N turns = e= - N dφ/dt

<u>Second Law-</u> The magnitude of e.m.f induced is directly proportional to the

rate of change of Magnetic Flux cut by the coil i.e. $e = -N \, d\varphi/dt$

Generation of Alternating E.M.F.
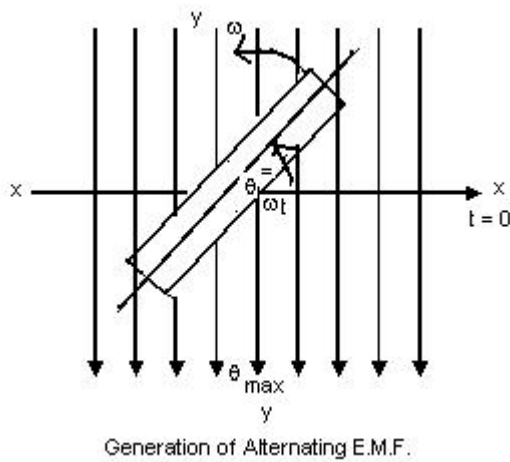
GENERATION OF ALTERNATING EMF

Let there be a rectangular coil of N turns and is made free to rotate in a counter clockwise direction and is positioned inside the magnetic field produced by a north-south pole magnet as shown in the figure below.

Fig. 5. Generation of alternating emf.
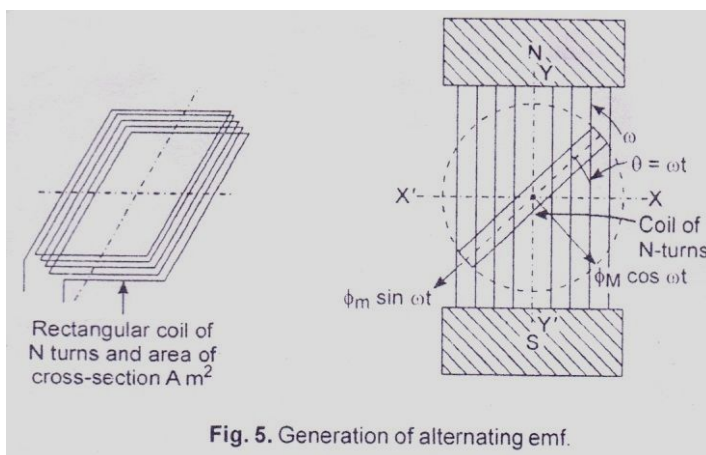
If the coil rotates at an angular velocity of ω radians per second then after a time of t seconds the coil will make an angle of $\theta = \omega t$ degrees with the horizontal i.e. starting position.

Component of flux perpendicular to the plane of the coil is : -

$$\Phi = \Phi_M \cos\omega t$$

Angle subtended by the coil in time t is

$$\theta = \omega t$$

So $\qquad \omega = \dfrac{\theta}{t}$

Magnetic Flux=Ø = Øm Coswt
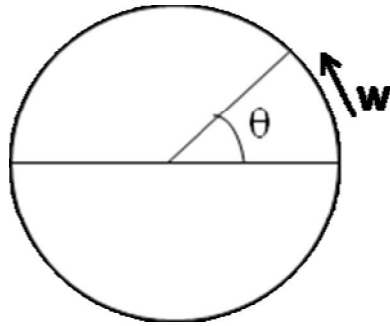
For N turns NØ = N Øm Coswt

Induced emf in the coil according to Faradays Law =

e = -d(NØ)/dt volt =- d{(N Øm Coswt)}/dt volts

   = - NØm d (Coswt)/dt volts = ⲰNØm Sinwt volt

 e = Em Sinwt (Em = ⲰNØm)
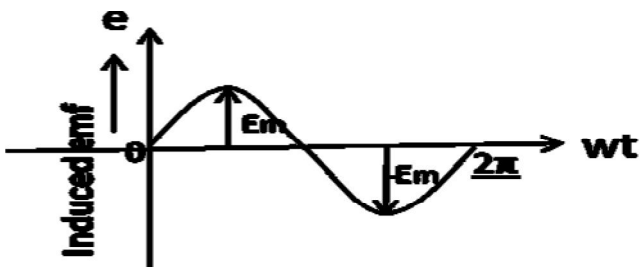
Questions/Answers

1. Is this wave forms   AC?
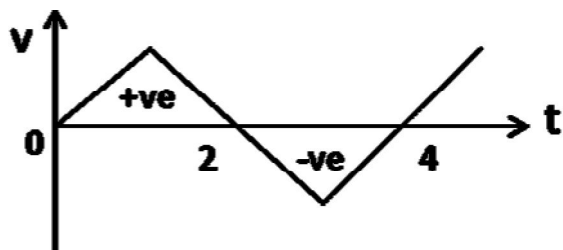
2. What is the period of sinusoidal A.C. wave form shown below?
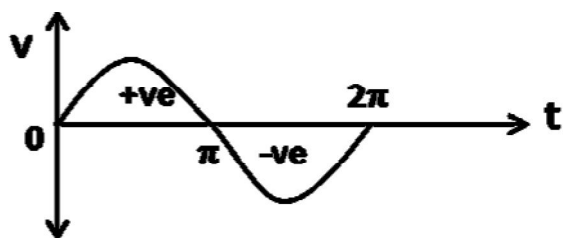
3. What is happening in a Generator or a Cell.

(D.C. GENERATOR)   (LEAD-ACID CELL)   (A.C. GENERATOR)
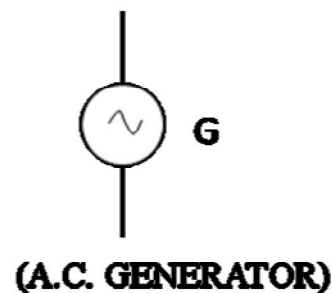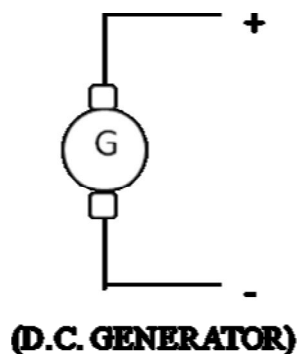
VARIOUS A.C. TERMS

AMPLITUDE: The maximum value (positive or negative) attained by an alternating quantity is called its

Amplitude or Peak value.
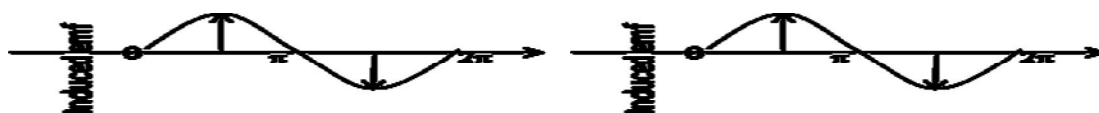
CYCLE: One complete set of positive and negative values of an alternating quantity is known as cycle.

TIME PERIOD (T): The time period taken in seconds to complete one cycle of an alternating quantity is called its time period.

FREQUENCY (f): The number of cycles that occur in one second is called the frequency (f) of the alternating quantity.

ALTERNATION: Alternation is one-half of the cycle of an alternating quantity.

PHASE: Phase of an alternating quantity is the fraction of the time period or cycle that has elapsed since it last passed from the chosen zero position on origin.

PHASE DIFFERENCE: Phase difference between two alternating quantities is the fractional part of a period through which time of one alternating quantity has advanced over another alternating quantity.
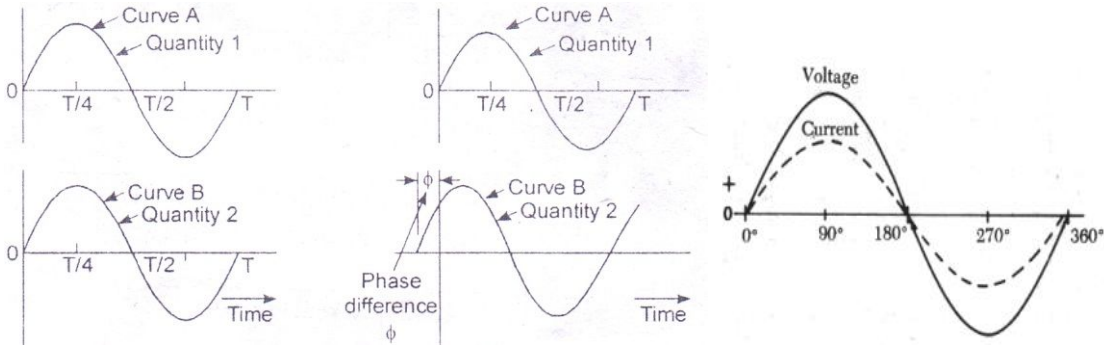
INSTANTANEOUS VALUE: The value of an alternating quantity at any instant is called its instantaneous value.

AVERAGE VALUE

Average value of a.c. is that value of steady current (d.c.) which when flowing through a circuit transfers same amount of charge as is done by a.c. through the same circuit in same time.

$$I_{av} = \frac{1}{T}\int_0^T i(t)dt \ \text{or,} \ I_{av} = \frac{1}{2\pi}\int_0^{2\pi} i\,d\theta$$

RMS / EFFECTIVE VALUE

The effective or r.m.s. value of an alternating current is that steady current (d.c.) which when flowing through a given resistance for a given time produces the same amount of heat as produced by the alternating current when flowing through the same resistance for the same time.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2 dt} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2 d\theta}$$

Graphical Method
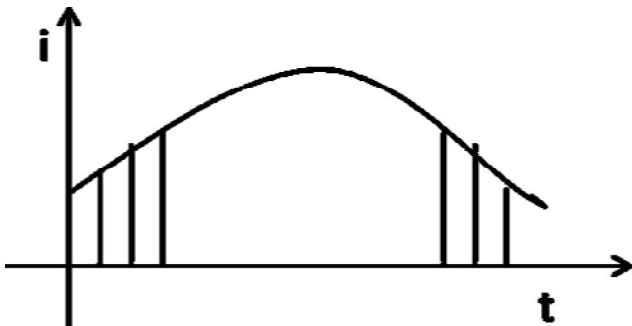
$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}}$$

Amplitude factor (peak factor)

The ratio of peak value or maximum value to r.m.s. value of an a.c. quantity is called Amplitude factor.

$$Amplitude\ factor\ (peak\ factor) = \frac{Maximum\ value}{R.M.S.value}$$

Form factor:

The ratio of R.M.S. value to average value of an a.c. quantity is called form factor.

$$Form\ factor\ = \frac{R.M.S.value}{Average\ value}$$

Assignments / Discussion:-

1. Determine the following for the a.c. waveform given by V = 141.4 sin (628t)
a. Maximum value
b. R.M.S. value
c. Average value
d. Amplitude factor
e. Form factor
f. Frequency
g. Time period
h. Determine the time taken to attain 100 volt after reaching maximum value and decreasing there after.

Solution

Do YOU KNOW

$$2\pi f = 628$$

100 = 141.4 sin 628 t

Sin 628t $= (100/141.4) = (1/\sqrt{2}) = $ Sin 45, 135 $=$ Sin ($\pi/4$) , ($3\pi/4$)

Hence 628t = ($3\pi/4$) (Think why not $\pi/4$)

t = [$3\pi/(4 \times 628)$] = ?

PHASOR REPRESENTATION OF ALTERNATING QUANTITY

A phasor is a vector rotating at a constant angular velocity in Counter-clockwise Direction.

At t_1, $e_1 = E_m \sin \omega t_1 = OA \sin \omega t_1$
At t_2, $e_2 = E_m \sin \omega t_2 = OA \sin \omega t_2$
At t_3, $e_3 = E_m \sin \omega t_3 = OA \sin \omega t_3$
At t_4, $e_4 = E_m \sin \omega t_4 = OA \sin \omega t_4$
At t_5, $e_5 = E_m \sin \omega t_5 = OA \sin \omega t_5$

and so on.
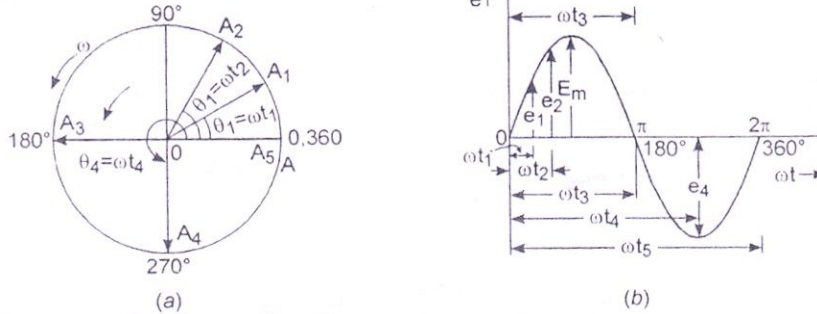
Fig. 7. Phasor (or vector) representation of alternating emf

Note: Instantaneous value of A.C. quantity is given by *projection of rotating vector at that instant on vertical axis.*

Phasor diagram is one in which different alternating quantities (sinusoidal) of the same frequency are represented by phasors with their correct phase relationship.

SIGNIFICANCE OF   j- OPERATOR

Multiplication of a phasor with j rotates the phasor by an angle of $\pi/2$ or 90^0 in counter clock-wise direction.

$$j = \sqrt{-1}$$
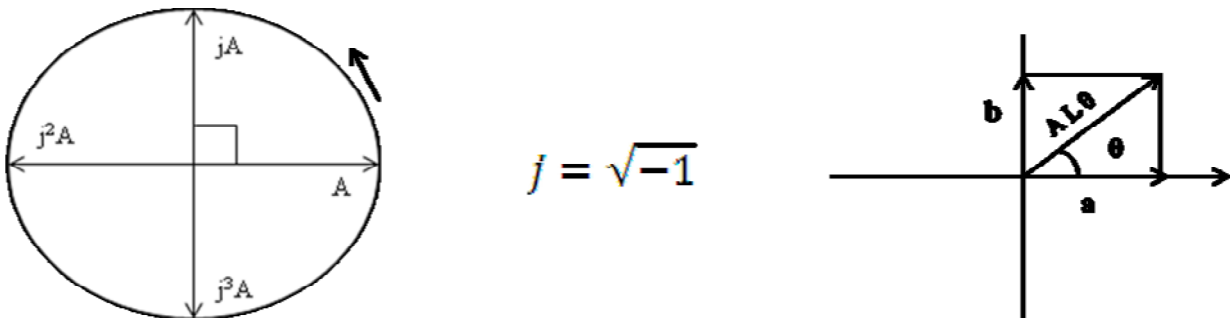
REPRESENTATION OF PHASOR IN COMPLEX PLANE

I)   Rectangular or Cartesian Form: $A = a + jb$, $\theta = \tan^{-}(b / a)$

II)   Trigonometric Form (Euler's Identity): $A = Ae^{j\theta}$ $= A (\cos \theta + j\sin \theta)$

III)   Polar Form: $A = A \angle \theta$

Discussion :

  a. Convert $7+j24$ to Polar coordinate? Modulus $=\sqrt{7^2 + 24^2} = 25$, But Argument\Angle =?

  b. Convert $5 / \underline{53.13^0}$ to Rectangular coordinate .[$5(\cos 53.13^0 + j\sin 53.13^0)$]

A.C. THROUGH PURELY RESISTIVE CIRCUIT

(a)

(b)
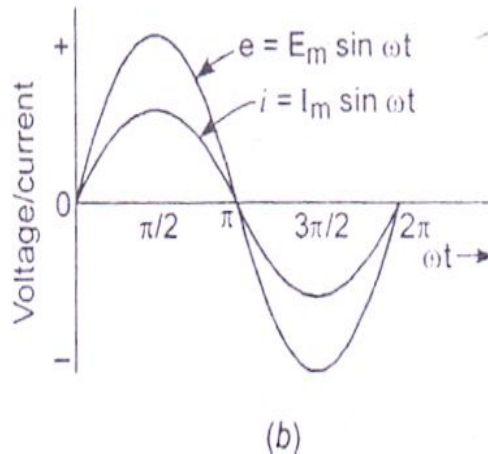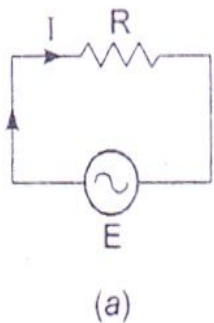
Ohm's law states

$E = iR$

E = Applied voltage

i = Instantaneous value of current

R = Ohmic resistance

Let us Find Current flowing in this circuit :

$E = E_m \, Sin \, \theta = E_m \, Sin \, wt$

Also $e = iR$ (Ohm's law)

  $iR = E_m \, Sin \, wt$

  $i = (\underline{E_m/R}) \, Sin \, wt = I_m \, Sin \, wt$ (Where $I_m = \underline{E_m/R}$)

CONCLUSION: IN A PURELY RESISTIVE CIRCUIT THE APPLIED A.C. VOLTAGE & CIRCUIT CURRENT ARE IN-PHASE.

POWER IN A PURELY RESISTIVE CIRCUIT

$P = ei = E_m . I_m \, Sin^2 \, wt = (\underline{E_m I_m}/2) \, (1 - Cos \, 2wt)$

CONCLUSION: AVERGE POWER DISSIPATION OVER COMPLETE CYCLE =

$$P = \frac{E_m I_m}{2} = \frac{E_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} = E_{rms} I_{rms}$$
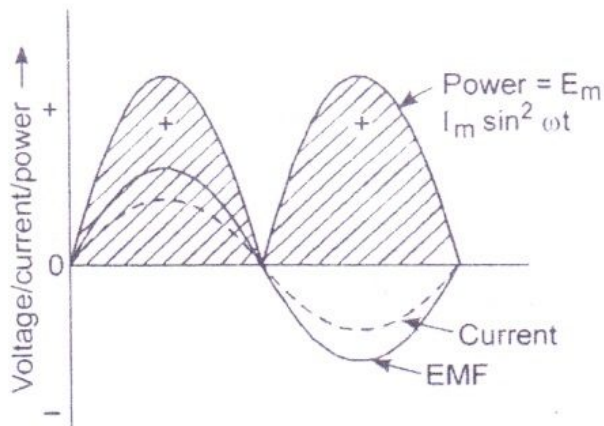
Comparison of power wave with that of
voltage, and current in a purely resistive circuit

Let us Solve

A voltage v = 141 Sin (314t + π/3) is applied to a resistance of 10 Ω. Find the R.M.S and maximum value of current

i = V /R = (141/10) Sin (314t + π / 3)

   = 14.1Sin (314t + π / 3)

Maximum value = ?

R.M.S value = Maximum value / √2 = ?

A.C. THROUGH PURELY INDUCTIVE CIRCUIT

Induced emf = e_{in} = - L $\frac{di}{dt}$

e = Applied voltage = - e_{in}

e = L di / dt = E_m Sin wt

   di = (E_m /L)Sin wt .dt

On integration

i = E_m / L ∫ Sin wt . dt = E_m / wL (-Cos wt) = (E_m / wL) Sin (wt - π/ 2)

                    (where I_m = E_m / wL)

wL = 2 π fL = X_L = INDUCTIVE REACTANCE
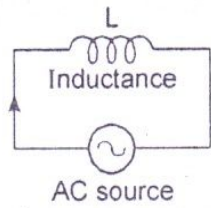
(a)
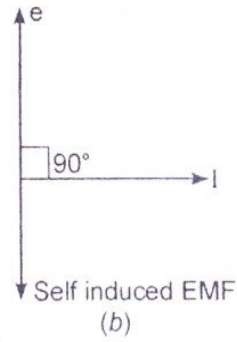
(b)

A.C. circuit with inductance only.

CONCLUSION:

IN A PURELY INDUCTIVE CIRCUIT THE CIRCUIT CURRENT (I) LAGS BEHIND THE APPLIED A.C. VOLTAGE (e) BY AN ANGLE OF $\pi / 2$ OR 90^0.

POWER IN A PURELY INDUCTIVE CIRCUIT

$p = ei = E_m . I_m$ Sin wt . Sin (wt - $\pi / 2$)

$= - E_m I_m$ Sin wt . Cos wt $= - (E_m I_m / 2)$ Sin 2wt

Power in complete cycle , $P = - (E_m I_m / 2) \int$ Sin 2wt $= 0$
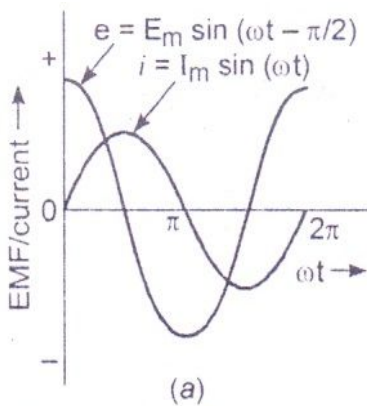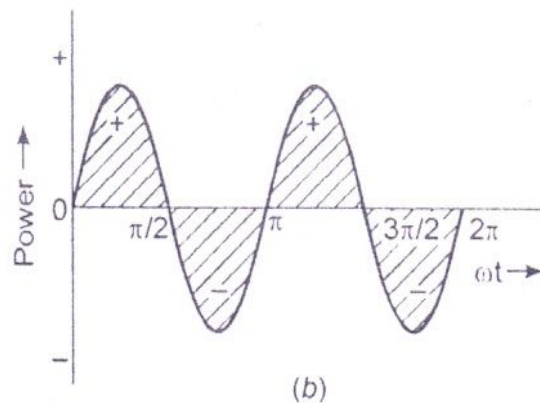
Graphs for A.C. circuit containing inductance only for : (a) voltage, and current ; (b) power

CONCLUSION:

AVERGE POWER DISSIPATION BY A PURELY INDUCTIVE A.C. CIRCUIT IS ZERO.

A voltage V = 141 Sin (314t + π / 3) is applied to a inductance of 0.1 H. Find X_L , i , I_{MAX}

Solution :

wL = 2 π fL

i.e., X_L = INDUCTIVE REACTANCE = 314 x 0.1 = WHAT

i = V_m / X_L = Sin (314t + (π / 3) – (π / 2))

= 141 / 31.4 Sin (314t - π / 6)

= 4.49 Sin (314t - π / 6)

Maximum value of current I_{MAX} = **FIND**

A.C. THROUGH PURELY CAPACITIVE CIRCUIT
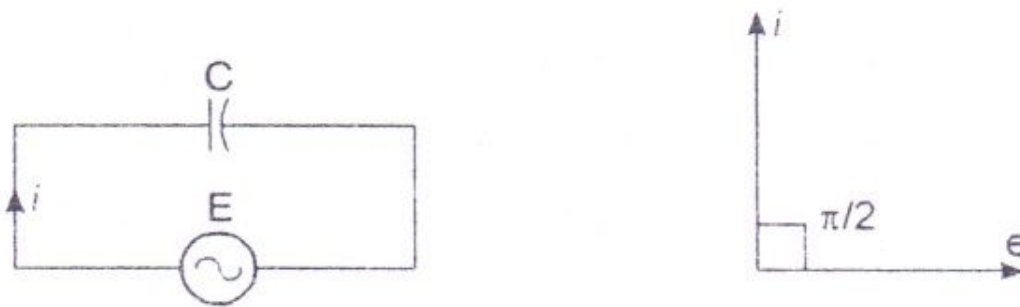
A.C. through purely capacitive circuit

For a capacitor : C = q / v = q / e

q = C.e = C. E_m Sin ωt

(putting e=E_m Sin ωt)

i = dq / dt $= \dfrac{d(CE_m \sin \omega t)}{dt}$

$\qquad$ = ω.C. E_m Cos ωt

$\qquad = \dfrac{E_m}{\frac{1}{\omega c}}$ Sin (wt+ π / 2) $= \dfrac{E_m}{X_C}$ Sin (wt+ π / 2)

$\qquad$ = I_m Sin (wt+ π / 2) (where $I_m = \dfrac{E_m}{X_C}$)

Where , $Xc = \dfrac{1}{\omega c} = \dfrac{1}{2\pi fc}$ = Capacitive Reactance

CONCLUSION: IN A PURELY CAPACITIVE CIRCUIT THE CIRCUIT CURRENT (I) LEADS THE APPLIED VOLTAGE (e) BY AN ANGLE OF π / 2 OR 90^0.

POWER IN A PURELY CAPACITIVE CIRCUIT

$P = ei = E_m \cdot I_m \sin wt \cdot \sin(wt + \pi/2)$

$= E_m I_m \sin wt \cdot \cos wt = \frac{1}{2} \cdot E_m I_m \sin 2wt$
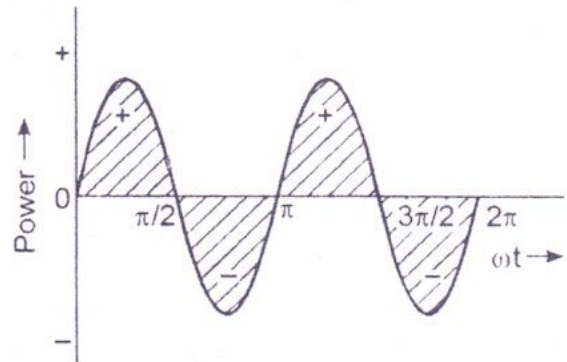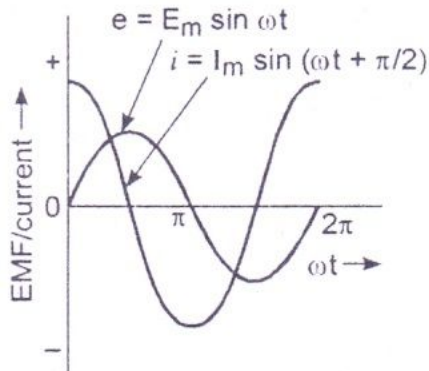
Graphs of purely capacitive A.C. circuit for EMF, and current

CONCLUSION:

THE POWER DISSIPATION OVER A COMPLETE A.C. CYCLE IN A PURELY CAPACITIVE CIRCUIT IS ZERO.

Solve Yourself

A voltage $V = 141 \sin(314t + \pi/3)$ is applied to a 10 µf capacity. Find X_C, i, I_{rms}, I_{MAX}

SOLUTION:

$X_C = 1/wc = 1/314 \times 10 \times 10^{-6}$ =v318.47 Ω

$i = (141/318.47) \sin(314t + (\pi/3) + (\pi/2))$

$= 0.443 \sin(314t + 5\pi/6)$

Maximum value of current $I_{MAX} = 0.443$ Amp

$I_{rms} = 0.443 / 2 = 0.313$ Amp

A.C. THROUGH SERIES R-L CIRCUIT
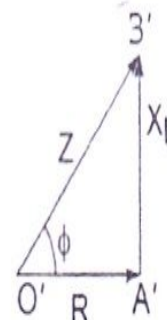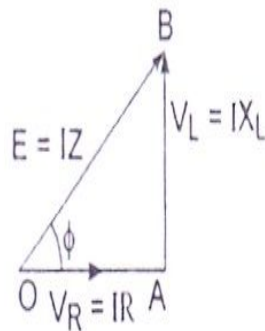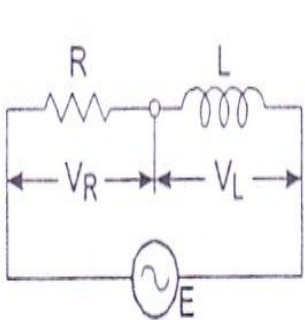
(a) R - L series A.C. circuit ; (b) voltage triangle ; (c) impedance triangle.

Voltage across resistance = $V_R = IR$

Voltage across Inductance = $V_L = IX_L$

Supply voltage := $E = \sqrt{[V_R^2 + V_L^2]}$

$\qquad = \sqrt{[(IR)^2 + (IX_L)^2]}$

$\qquad = I\sqrt{[R^2 + X_L^2]}$

$\quad I = E / \sqrt{[R^2 + X_L^2]}$

$\qquad = E / Z$

Where , Z = IMPEDANCE = $\sqrt{[R^2 + X_L^2]}$

$\llcorner Z = \tan^-(X_L / R)$

CONCLUSION:

IN A SERIES R-L CIRCUIT CONNETED TO A.C. SUPPLY, THE APPLIED VOLTAGE (E) LEADS THE CIRCUIT CURRENT (I) BY AN ANGLE ϕ CALLED THE POWER FACTOR ANGLE.

POWER FACTOR IS COSINE OF THE ANGLE OF LEAD / LAG BETWEEN APPLIED VOLTAGE & CURRENT IN AN A.C. CURRENT.

P.F. = $\cos \varphi = (R / Z)$

$P = V.I. \cos \varphi = IZ.I.(R / Z) = I^2 R$ (ACTIVE POWER)

$Q = V.I. \sin \varphi = IZ.I.(X_L / Z) = I^2 X_L$ (REACTIVE POWER)

$S = V.I = IZ.I = I^2 Z$ (APPARENT POWER)

$S = \sqrt{(P^2 + Q^2)}$ & $\llcorner S = \tan^-(Q / P)$
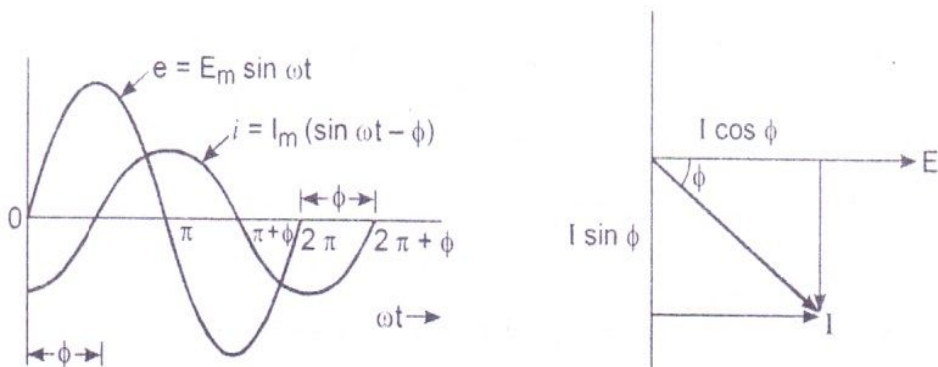
Voltage, and current waves in R-L series A.C. circuit.

PROBLEM-

An inductive coil takes 10 Amp when connected to 250v, 50hz mains. The power consumed is 1000 watt. Find (a) Z, R, X_L L (b) Power factor, (c) App power and reactive power (d) Phase angle between V & I.

SOLUTION:

(a) $Z = (V / I) = 250 / 10 = 25$ Ω

$P = VI \cos \theta$

$\cos \theta = (P / VI) = (1000 / (250 \times 10)) = 0.4$

$\sin \theta$ 0.917

$R = Z \cos \theta = 25 \times 0.4 = 10$ Ω

$X_L = Z \sin \theta = 25 \times 0.917 = 22.93$ Ω

$L = (X_L / W) = (22.93 / (2 \pi \times 50)) = 0.073$ H

(b) Power factor $= \cos \theta = 0.4$ lagging

(c) App Power $= S = VI = 2500$ VA

Reactive power $= \theta = VI \sin \theta = 2500 \times 0.917 = 2292.5$ Vars

(d) $\cos \theta = 0.4$

$\theta = 66.42^0$

Current phasor lags voltage phasor by 66.42^0

A.C. THROUGH SERIES R-C CIRCUIT
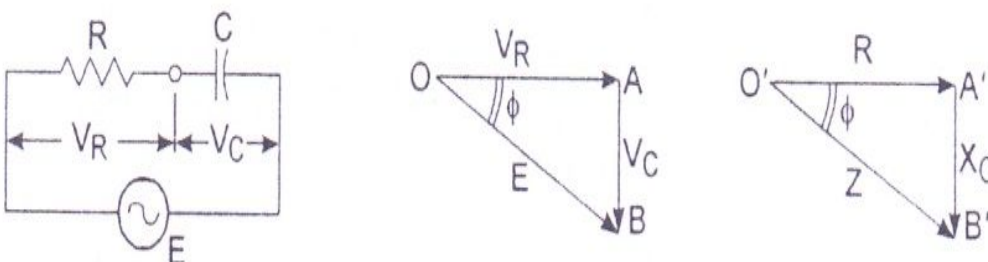
(a) Series R-C A.C. circuit ; (b) voltage triangle ; (c) impedance triangle.

Voltage across resistance $= V_R = IR$

Voltage across capacitance $= V_c = IX_c$

Supply voltage $:= E = \sqrt{[V_R^2 + V_c^2]}$

$V_R = IR$

$V_C = IX_C$

$E = \sqrt{[V_R^2 + V_C^2}$

$\quad = \sqrt{[(IR)^2 + (IX_C)^2]}$

$\quad = I \sqrt{[R^2 + X_C^2}$

$I = E / \sqrt{[R^2 + X_C^2} = E / Z$

$Z = \text{IMPEDANCE} = \sqrt{[R^2 + X_C^2}$

$\llcorner Z = \tan^- (X_C / R)$

CONCLUSION:

IN A SERIES R-C CIRCUIT CONNETED TO A.C. SUPPLY, THE APPLIED VOLTAGE (E) LAGS THE CIRCUIT CURRENT (I) BY AN ANGLE φ CALLED THE POWER FACTOR ANGLE.

P.F. $= \cos \varphi = (R / Z)$

$P = V.I. \cos \varphi = IZ.I.(R / Z) = I^2 R$ (ACTIVE POWER)

$Q = V.I. \sin \varphi = IZ.I.(X_C / Z) = I^2 X_C$ (REACTIVE POWER)

$S = V.I = IZ.I = I^2 Z$ (APPARENT POWER)

$S = \sqrt{P^2 + Q^2}$ & $\llcorner S = \tan^- (Q / P)$
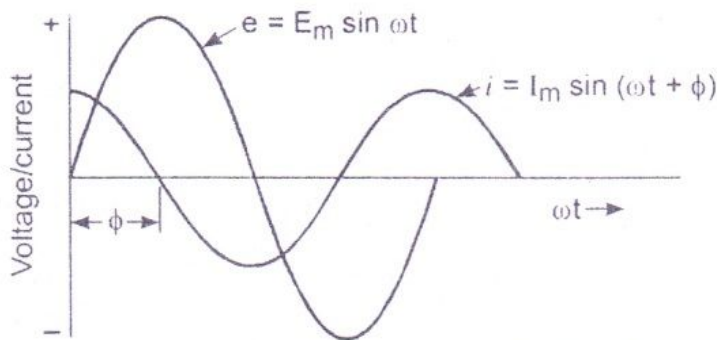
Voltage, and current waves in series R-C A.C. circuit.

PROBLEM-

A voltage V = V2 (230) Sinwt is applied to a series RC Circuit having R = 20 Ω and C = 100 μF.

Find (a) X_C , Z, (b) Y, B, G, (C) Current and power factor (d) S, P, Q (e) Write expression for instantaneous current.

SOLUTION: $V = 230 \llcorner 0^0$

(a) $X_C = (1 / wc) = (1 / 2 \pi \times 50 \times 100 \times 100 \times 10^{-6}) = 31.83 \ \Omega$

$Z = R - jX_C = 20 - j31.83 \ \Omega = 37.59 \ \angle -57.86 \ \Omega$

(b) $Y = (1 / Z) =$ Admittance $= (1 / 37.59 \ \angle -57.86 = 0.0266 \angle 57.86^0$

$= 0.01415 + j \ 0.0225$ Siemens

$Y = G + jB$

So $G = 0.01415$ Siemens & $B = 0.0225$ Siemens

(c) $I = (V / Z) = (230 \angle 0^0 / 37.59 \angle -57.86^0 = 6.12 \ \angle 57.86^0$ Amp

Power factor $= \cos (57.86^0) = 0.522$ leading

(d) App Power $= S = VI = 230 \times 6.12 = 1407.6$ VA

Active power $= P = VI \cos \theta = (1407.6 \times 0.532) = 748.84$ watt

Reactive power $= Q = - VI \sin \theta = (- 1407.6 \times \sin 57.86^0) = - 1191.9$ Vars

(e) Instantaneous value $= 2 \times 6.12 \sin (wt + 57.86^0) = 8.65 \sin (wt + 57.86^0)$

A.C. THROUGH SERIES R-L-C CIRCUIT
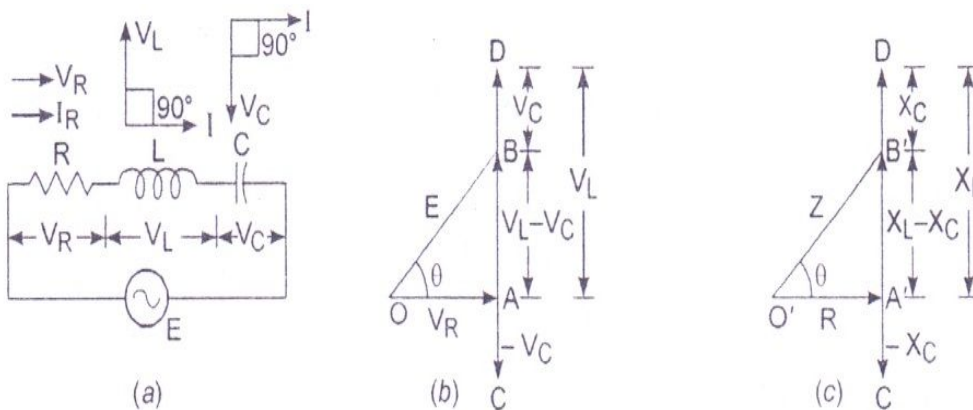
(a) Series R-L-C A C circuit ; (b) voltage triangle ; (c) impedance triangle.

Voltage across resistance $= V_R = IR$

Voltage across Inductance $= V_L = IX_L$

Voltage across capacitance $= V_c = IX_c$

Supply Voltage $= E = \sqrt{[V_R^2 + (V_L - V_C)^2]} = \sqrt{[(IR)^2 + (IX_L - IX_C)^2]}$

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

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

$Z =$ IMPEDANCE $= \sqrt{[R^2 + (X_L - X_C)^2]}$

$\angle Z = \tan^{-} (X_L - X_C) / R$

IN A SERIES R-L-C CIRCUIT CONNETED TO A.C. SUPPLY, THE APPLIED VOLTAGE (E) LEADS THE CIRCUIT CURRENT (I) IF $X_L > X_C$ & LAGS BEHIND CIRCUIT CURRENT IF $X_L < X_C$ & REMAIN IN-PHASE IF $X_L = X_C$.

P.F. $= \text{Cos } \varphi = (R / Z) = R / \sqrt{R^2 + (X_L - X_C)^2}$

$P = \text{V.I. Cos } \varphi = IZ.I.(R / Z) = I^2 R$ (ACTIVE POWER)

$Q = \text{V.I. Sin } \varphi = IZ.I. ((X_L - X_C) / Z) = I^2 [X_L - X_C]$ (REACTIVE POWER)

$S = \text{V.I} = IZ.I = I^2 Z$ (APPARENT POWER)

$S = \sqrt{P^2 + Q^2}$ & $\angle S = \tan^- ((X_L - X_C) / R)$

PROBLEM-

A resistance of 10 Ω, inductance of 0.1 H & capacitance 50 micro farad are connected in series across a 230v, 50Hz supply. Find (a) X_L , X_C & Z, (b) I & Power factor (C) Active, reactive and apparent power

SOLUTION: $V = 230 \angle 0^0$

(a) $wL = 2 \pi fL = X_L =$ INDUCTIVE REACTANCE

$2 \pi fL = 2 \pi 50 \times 0.1 = 31.41 \, \Omega$

$X_C = (1 / wc) = (1 / 2 \pi 50 \times 50 \times 10^{-6}) = 63.66 \, \Omega$

$Z = R + j (X_L - X_C) = 10 + j (31.41 - 63.66) = 10 - j32.25 = 33.76 \angle -72.77^0$

(b) $I = $ CURRENT $= (V / Z) = (230 \angle 0^0 / 33.76 \angle -72.77^0 = 6.8 \angle 72.77^0$ Amp

Power factor $= \text{Cos } (72.77^0) = 0.296$ leading

(c) App Power $= S = VI = 230 \times 6.8 = 1564$ VA

Active power $= P = VI \text{ Cos } \theta = (1564 \times 0.296) = 462.9$ watt

Reactive power $= Q = VI \text{ Sin } \theta = (1564 \times \text{Sin } -72.77^0) = -1496.80$ Vars

………………xxx……………………………

CHAPTER-3

GENERATION OF

ELECTRICAL POWER

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

STEAM POWER STATION (THERMAL STATION

CHOICE OF SITE

1. SUPPLY OF FUEL :- The steam power station should be located near coal mines so that transportation cost of fuel is minimum.

2. AVAILABILITY OF WATER:- A huge amount of water is required for the condenser for which it is it is essential that the plant should be located at the bank of a river or near a canal to ensure continuous supply of water.

3. TRANSPORTATION FACILITIES:- : A modern steam power station often requires the transportation of material and machinery. Therefore adequate transportation facilities by rail or Road should exist.

4. COST AND TYPE OF LAND:- The steam power station should be located at a place where land is cheap and further extension if necessary is possible.

5. NEARNESS TO LOAD CENTRES:- In order to reduce transmission cost the plant should be located near the center of load.

6. DISTANCE FROM POPULATED AREA :- As huge amount of coal is burnt in a steam power Plant due to which smoke and fumes pollutes the surrounding area.This necessitates that plant should be locate at a considerable distance from the populated areas.

MAIN UNITS OF PLANT

1. COAL STORAGE PLANT :- Coal is transported to the power station by road or rail and is stored in coal storage plant.

2. COAL HANDLING PLANT:- : From the coal storage plant coal is delivered to the coal handling plant where it is pulverized for rapid combustion with out using excess amount of air.

3. ASH STORAGE PLANT:- The coal is burnt in the boiler & the ash produced after the complete combustion of coal is removed to the ash handling plant.

4. ASH HANDLING PLANT:- the ash from ash handling plant is then delivered to the ash storage plant for subsequent use as fertilizer etc.

5. BOILER:- The heat of combustion of coal in the boiler is utilized to convert water into steam at very high temperature and pressure.The flue gases from the boiler makes their journey through superheater,economizer, air pre-heater & are finally exhausted to the atmosphere through the chimney.

6. SUPERHEATER:- The steam produced in the boiler is wet and is passed through super heater where it is dried and super heated.

7. ECONOMISER:- An economizer is essentially a feed water heater & derives heat from the flue gases for the purpose.

8. AIR PREHEATER:- Air pre-heater increases the temperature of the air supplied for coal burning by deriving heat from flue gases.

9. FORCED DRAUGHT FAN :-It draws air from atomosphere which is supplied to the boiler for effective combustion.

10. INDUCED DRAUGHT FAN : it draws the flue gas and sends to chimney.

11. CHIMNEY:- The hot flue gases go to the atmosphere though chimney.

12. STEAM TURBINE:- The dry and super heated steam from the super heater is fed to the steam turbine which converts the heat energy of steam tto mechanical energy.

13. ALTERNATOR:- The alternator converts the mechanical energy of steam turbine to electrical energy.

14. CONDENSER :- In order to improve the efficiency of the plant the steam exhausted from the turbine is condensed by means of a condenser. The condensate from the condenser is used as feed water to the boiler.

15. COOLING TOWER : The cooling tower provides a cooling arrangement for the feed water to be reused in boiler.

SCHEMATIC ARRANGEMENT OF STEAM POWER STATION
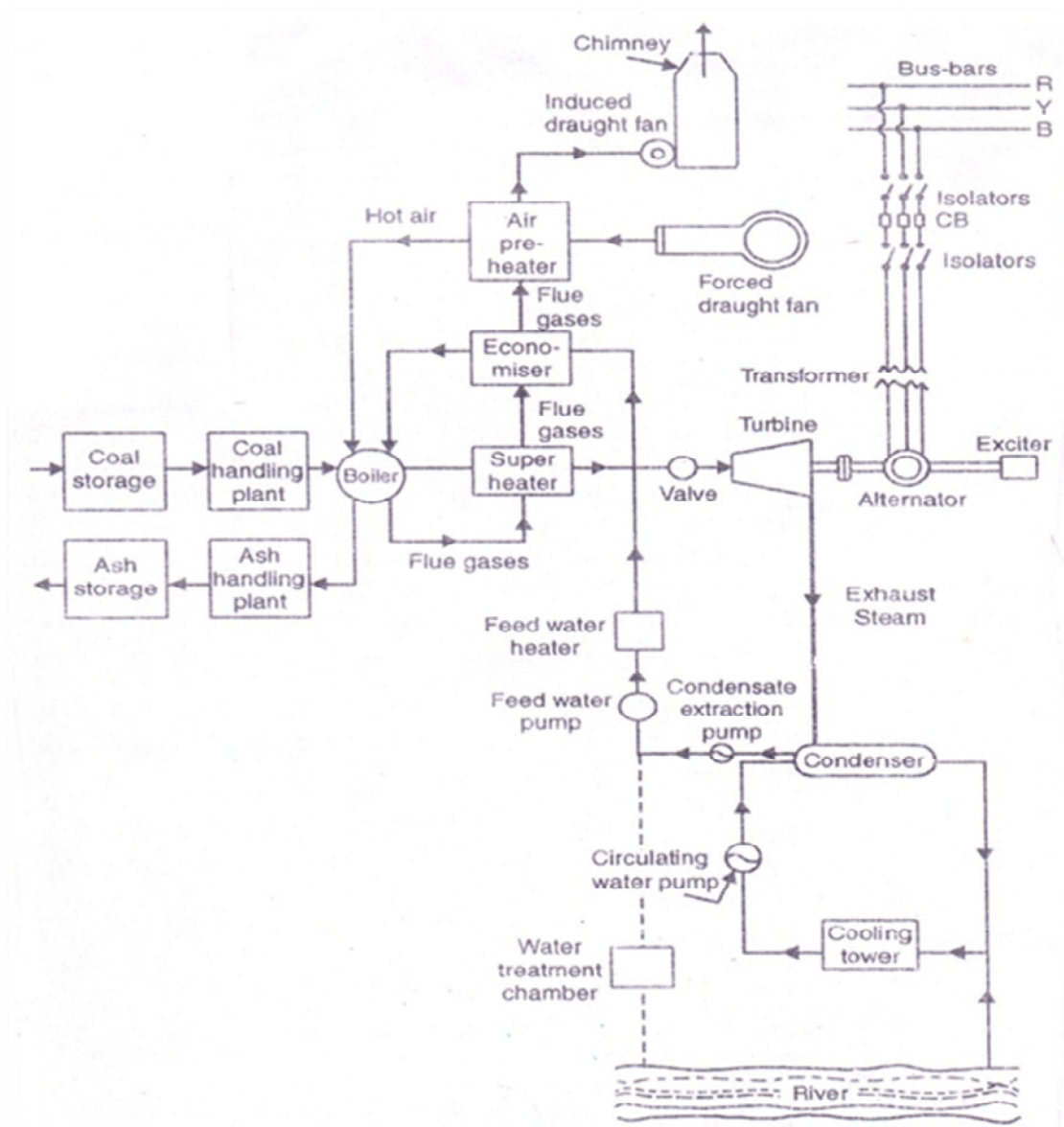
<u>Working of Thermal power Plant :</u> When the water from condenser is fed to the Boiler through Economiser it remains a little hot .The Boiler is a extremely heated chamber because of a continuous burning of Coal in presence of air injected by F.D fan through pre-heater.

So, ,the water gets converted to steam with very high temperature and pressure and reaches the Steam Turbine through Super-Heater. The Internal Energy of Steam gets converted to Mechanical Energy by Turbine and the Alternator converts the mechanical Energy of Turbine output to Electrical Energy .The Electrical Energy thus produced is supplied to the Bus-Bar for Power use.

Assignments / Discussion:-

➢ What are the Advantages / Disadvantages of a Steam Power Station ?

ADVANTAGES

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

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

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

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

DISADVANTAGES

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

ii)   Running cost is higher than hydro power plant.

HYDRO-ELECTRIC POWER STATION

CHOICE OF SITE

1. AVAILABILITY OF WATER:- Since the primary requirement of a hydro-electric power station is the availability of huge quantity of water at a good head this requirement is very essential.

2. STORAGE OF WATER:-There are wide variations in water supply from a river or canal during the year.This makes it necessaryto store water by constructing a Dam in order to ensure the generation of power throughout the year.

3. COST & TYPE OF LAND :-The land for the construction of Plant should be available at a reasonable price. Further the bearing capacity of the ground should be adequate to withstand the weight of heavy equipment to be installed.

4. TRANSPORTATION FACILITY :The site selected should be accessible by Rail and Road so that necessary equipment and machineries be easily transported.

MAIN CONSTITUENTS OF PLANT

1. DAM :- A Dam is a barrier which stores water & creates water head.Dams are built of concrete or stone masonary,earth or rock fill.

2. **SPILWAYS** :- There are times when the river flow exceeds the storage capacity of the reservoir.In order to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam, spill ways are used.

3. **HEAD WORKS** :-The head works consists of the diversion structures at the head of an intake.They generally include booms and racks for diverting floating debris,sluices for by-passing debris,sediments and valves for controlling the flow of water to the turbine.

4. **SURGE TANK** :-For close conduits abnormal pressure may cause damage to the conduit leading from head works to penstock.Surge tank acts as a protection for such situation.

5. **PENSTOCKS** :-Penstocks are open or close conduits which carry water to the turbines.They are generally made of reinforced concrete or steel.

6. **WATER TURBINES** :- Water turbines are used to convert the energy of falling water into mechanical energy.

7. **ALTERNATOR** :- The alternator converts the mechanical energy of turbine to electrical energy.

Various penstock protective devices

Schematic arrangement of a Hydro-electric plant
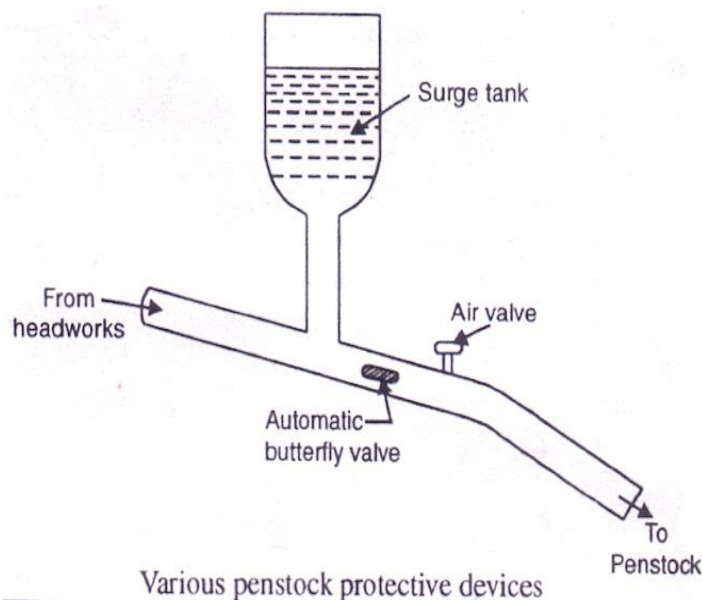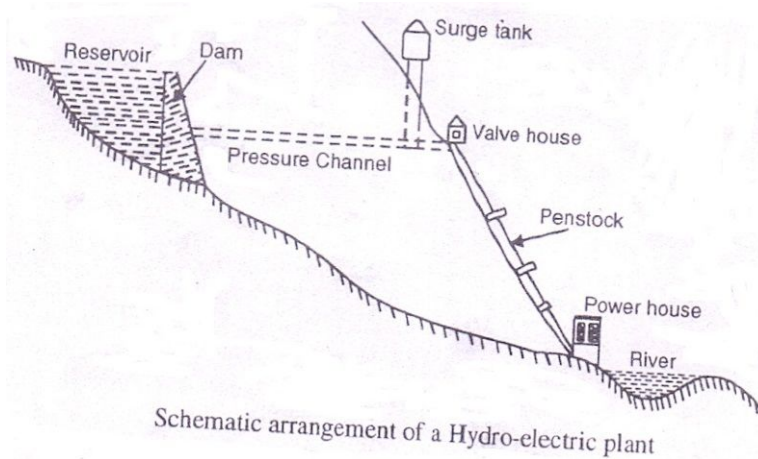
Working of Hydro-Electric Power Plant : When the water from Reservoir is allowed to get released through pressure channel, it reaches the Valve house. The surge tank is provided in order to safe guard the extra back-thrust of water causing heavy damage to Penstock.The valve house controls the amount of water that will flow to the power house turbines through the Large sized Pen-stocks. Inside the power house the water Turbine convert the potential energy of water with sufficient head to Kinetic energy i.e. mechanical Energy which in turn acts as a prime-mover for the Alternator as before and generates Electrical Energy.

ADVANTAGES

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

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

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

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

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

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

DISADVANTAGES

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

ii)   Generation depends on average rainfall round the year.

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

NUCLEAR POWER STATION

CHOICE OF SITE

1.AVAILABILITY OF WATER :- A huge amount of water is required for the condenser for which it is it is essential that the plant should be located at the bank of a river or near a canal to ensure continuous supply of water.

2. DISPOSAL OF WASTE :- The waste produced by fission in a nuclear power station is generally radio-active which must be disposed off properly to avoid health hazards for which it must be buried in deep trench.

3. DISTANCE FROM POPULATED AREA:- The site for setting up a nuclear power station should be quite away from populated areas.

4. TRANSPORTATION FACILITY:- The site selected for a nuclear power station should have adequate facilities in order to transport the heavy equipment during erection.

NUCLEAR FUEL

1. URANIUM(U^{235})

2. PLUTONIUM(Pu^{239})

3. THORIUM(Th^{232})

FISSION & CHAIN REACTION

When a U-235 atom is struck by a slow neutron ,it will split into two or more fragments.This is called a nuclear fission .This splitting(fission) is accompanied by release of thermal energy in large quantity and two or three fast neutrons. These fast moving neutrons are slowed down by moderators so that they have high probability to hit other u-235 atoms which in turn get fissioned and release heat and neutrons.This continuous self sustaining sequence of nuclear fissions is called CHAIN REACTION.

MAIN UNITS OF PLANT

1. NUCLEAR REACTOR :- It is an apparatus in which the nuclear fuel(U^{235}) is subjected to nuclear fission.

2. HEAT EXCHANGER :-The coolant gives up heat to the heat exchanger which is utilized in raising the steam & after giving up heat the coolant is again fed to the reactor.

3. **STEAM TURBINE**:- The dry and super heated steam from the super heater is fed to the steam turbine which converts the heat energy of steam to mechanical energy.

4. **ALTERNATOR**:- The alternator converts the mechanical energy of turbine to Electrical Energy.

(i) Nuclear reactor   (ii) Heat exchanger   (iii) Steam turbine   (iv) Alternator.
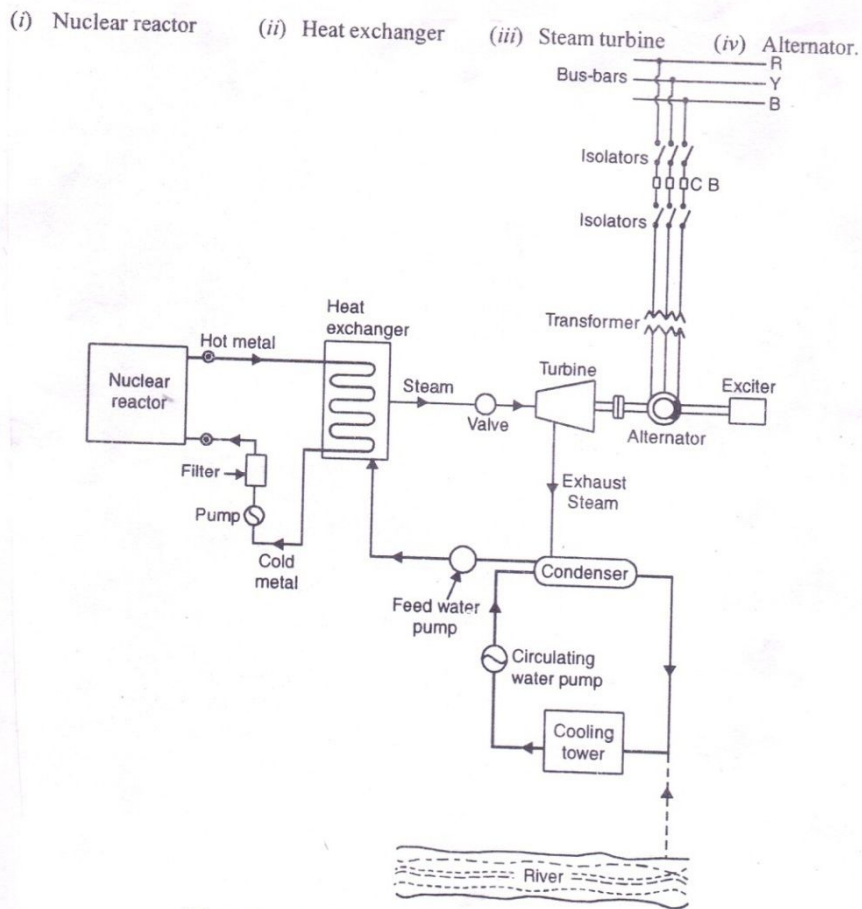
Schematic arrangement of Nuclear Power Station
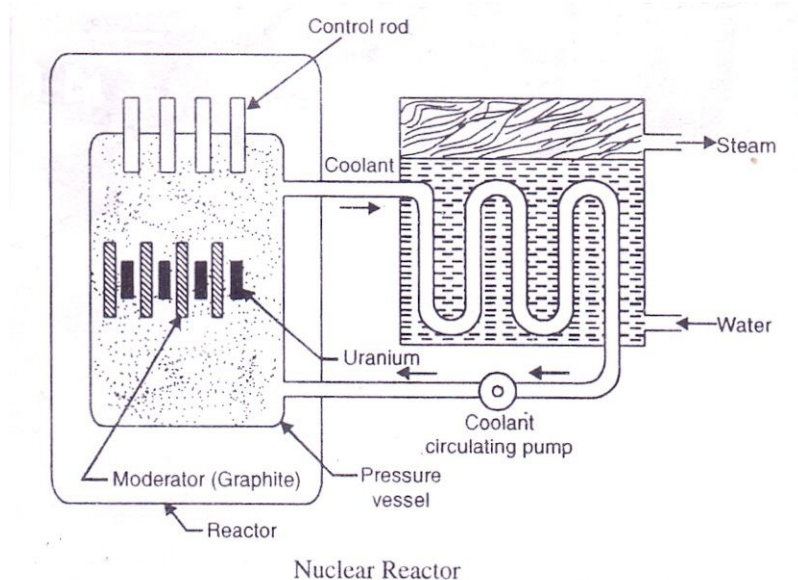
Nuclear Reactor

Working of Nuclear Power Plant : As discussed earlier, the chain reaction produces a huge amount of heat inside the Nuclear Reactor and requires a lot of care to control this reaction. The heat of the Reactor is carried to Heat-Exchanger by molten sodium which also heats the water injected into this Heat Exchanger chamber. After the water gets converted to steam with very high temperature and high pressure ,the Turbine converts the internal Energy of steam to Mechanical Energy and this is converted to Electrical Energy by Alternator as before.

ADVANTAGES

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

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

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

DISADVANTAGES

i) Fuel is expensive and difficult to recover.

ii) Capital lost is higher than other plants.

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

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

The disposal of by-product is big problem.

………………………………………………………………….xxxx…………………………………………………………

CONVERSION OF ELECTRICAL ENERGY

INTRODUCTION:-

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

PARTS OF DC MACHINE:-

The construction of the DC machine can be done using some of the essential parts like Yoke, Pole core & pole shoes, Pole coil & field coil, Armature core, Armature winding otherwise conductor, commutator, brushes & bearings.
Some of the parts of the DC machine is discussed below.
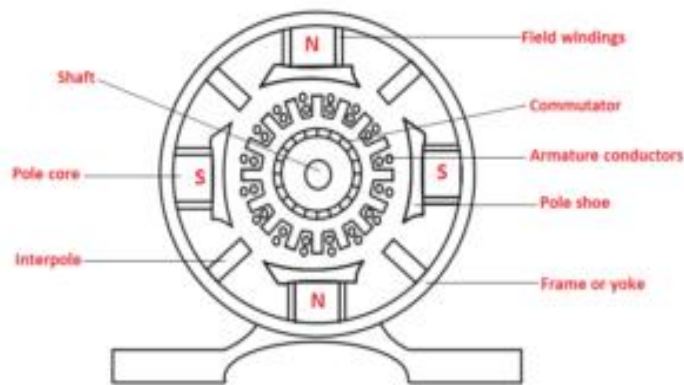
Magnetic frame or Yoke: - Purpose of Yoke is:
(a) It acts as a protecting cover for whole machine.
(b) It also provides mechanical support for poles.
(c) It carries the magnetic flux produced by poles

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

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

Armature Core: - Armature core is cylindrical in shape mounted on the shaft. It is made up of laminated construction to keep eddy current loss as low as possible. Function of armature core is
1. Armature core provides house for armature winding i.e., armature conductors.
2. To provide a path of low reluctance path to the flux it is made up of magnetic material like cast iron or cast steel.

Armature Windings or Conductors: - Armature winding is the inter connection of the armature conductors, placed in the slots provided on the armature core. Function of armature conductor is:

1. Generation of emf takes place in the armature winding in case of generators.
2. To carry the current supplied in case of dc motors.
3. To do the useful work it the external circuit.

Commutator: - The function of Commutator is to facilitate collection of current from the armature conductors and converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit. The commutator is made up of insulated copper segments.

Brushes and Bearings: - Brushes are normally made up of soft material like carbon. Brushes are used to collect current from commutator and make it available to the stationary external circuit. Bearings are used for smooth running of the machine.

CLASSIFICATION OF DC GENERATOR/MOTOR:-

DC generators/motors are usually classified according to the way in which their fields are excited.

DC generators/motors may be divided into

(a) Separately excited DC generators/motors
(b) Self-excited DC generators/motors

a) Separately excited DC generators/motors: - Separately excited generators/motors are those whose field magnets are energized from an independent external source of dc current.

b) Self-excited DC generators/motors: - Self excited generators/motors are those whose field magnets are energized by the current produced by the generators/motors themselves.

There are three types of self-excited dc generators/motors named according to the manner in which their field coils (or windings) are connected to the armature.

(i) Shunt wound DC generator/motor: - In shunt the two windings, field and armature are in parallel.

(ii) Series wound DC generator/motor: - In series type both field and armature winding are in series.

(iii) Compound wound DC generator/motor: - There are two types of compound wound DC generator/motor.

(a) Long shunt compound DC generator/motor: - The shunt field winding is parallel with both armature and series field winding.

(b) Short shunt compound DC generator/motor: - The shunt field winding is in parallel with armature winding only.

Types of DC Generators

Classification of DC Motor
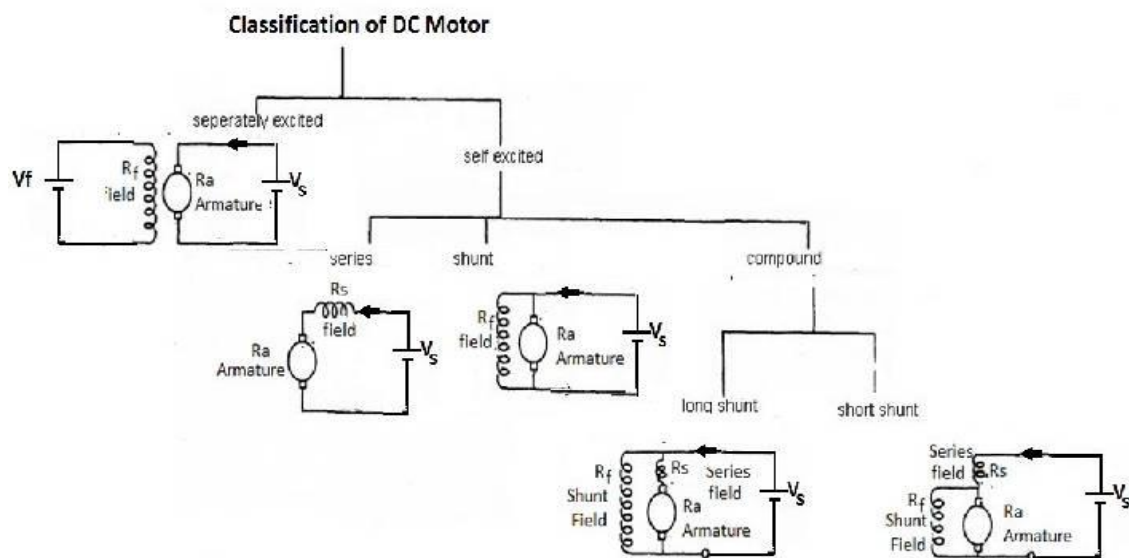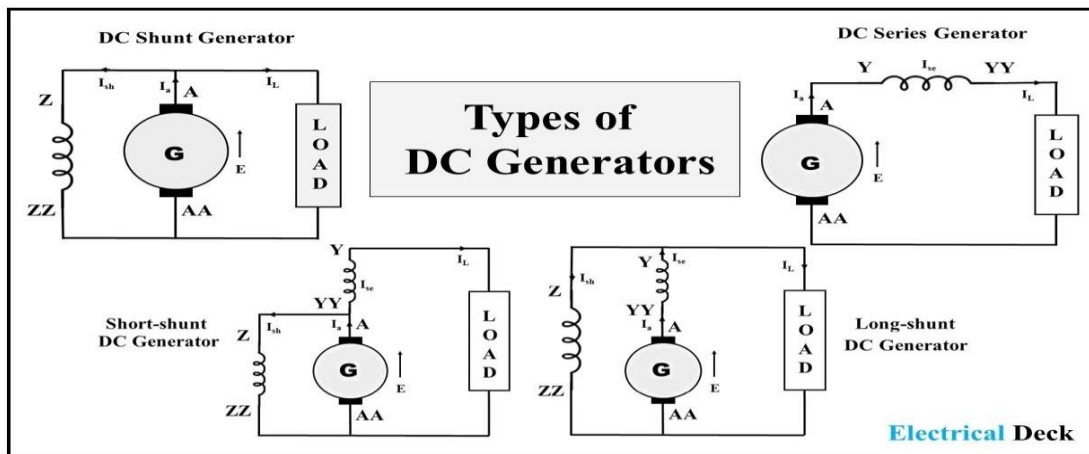
USES OF D.C. GENERATORS:-

(1) **Shunt Generator**
(i) Lighting and Power Supply
(ii) Charging batteries.
(2) **Series Generator**
(i) Boosters.

(3) **Compound Generator**
(i) Large range load
(ii) Power Supply

USES OF D.C. MOTORS:-

(1) **Shunt Motor**
(i) Constant speed drive
(ii) Drilling machine, lathes, elevators, water pump, cutting machine.

(2) **Series Motor**
(i) Electric Cranes

(ii) Electric Trains
(iii) Hoists

(3) **Compound Motor**
(i) Heavy tool machines
(ii) Printing machines

CONCEPT OF LUMEN:-

It is the unit of luminous flux. It is defined as the luminous flux emitted by a source of one candle power per unit solid angle in all directions.

Lumen = candle power of source × solid angle.

Lumen = CP × ω

Total flux emitted by a source of one candle power is 4π lumens.

DIFFERENT TYPES OF LAMPS:-

(a) Filament Lamp:-

Construction

• It consists of an evacuated glass bulb and an aluminum or brass cap is provided with two pins to insert the bulb into the socket.

• The inner side of the bulb consists of a tungsten filament and the support wires are made of molybdenum to hold the filament in proper position.

• A glass button is provided in which the support wires are inserted.

• A stem tube forms an air-tight seal around the filament whenever the glass is melted.
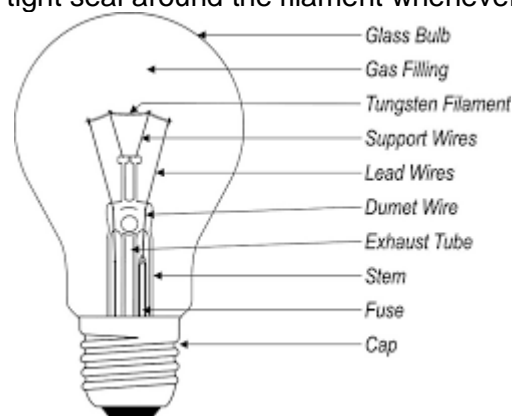
Principle

• When electric current is made to flow through the fine metallic tungsten filament, its temperature increases. At very high temperature, the filament emits both heat and light radiations, which fall in the visible region.

• The tungsten filament lamps can be operated efficiently beyond 2,000°C, it can be attained by inserting a small quantity of inert gas nitrogen with small quantity of argon.

(b) Fluorescent Lamp:-

Fluorescent lamp is a hot cathode low-pressure mercury vapor lamp.

Construction

• It consists of a long horizontal tube, due to low pressure maintained inside of the bulb; it is made in the form of a long tube.

• The tube consists of two spiral tungsten electrode coated with electron emissive material and are placed at the two edges of long tube.

• The tube contains small quantity of argon gas and certain amount of mercury, at a pressure of 2.5 mm of mercury.

• Normally, low-pressure mercury vapor lamps suffer from low efficiency and they produce an objectionable colored light. Such drawback is overcome by coating the inside of the tube with fluorescent powders. They are in the form of solids, which are usually knows as phosphors.

• A glow starter switch contains small quantity of argon gas, having a small cathode glow lamp with bimetallic strip is connected in series with the electrodes, which puts the electrodes directly across the supply at the time of starting.

- A choke is connected in series that acts as ballast when the lamp is running, and it provides a voltage impulse for starting. A capacitor of 4µF is connected across the starter in order to improve the power factor.

Fluorescent lamp starter
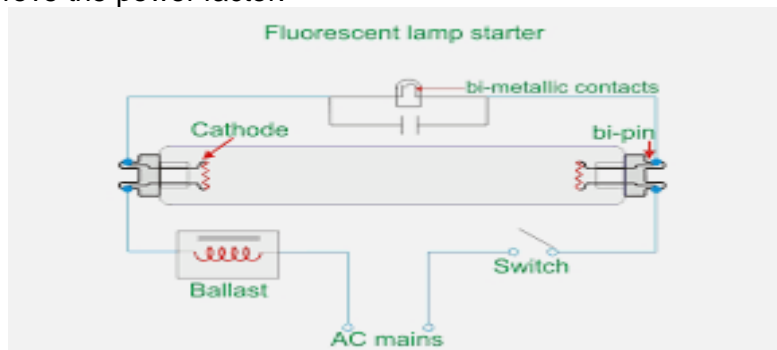
Principle

• At the time of starting, when both the lamp and the glow starters are cold, the mercury is in the form of globules.

• When supply is switched on, the glow starter terminals are open circuited and full supply voltage appeared across these terminals, due to low resistance of electrodes and choke coil.

• The small quantity of argon gas gets ionized, which establishes an arc with a starting glow.

• This glow warms up the bimetallic strip thus glow starts gets short circuited. Hence, the two electrodes come in series and are connected across the supply voltage.

• Now, the two electrodes get heated and start emitting electrons due to the flow of current through them.

• These electrons collide with the argon atoms present in the long tube discharge that takes place through the argon gas. So, in the beginning, the lamp starts conduction with argon gas as the temperature increases, the mercury changes into vapor form and takes over the conduction of current.

• In the meantime, the starter potential reaches to zero and the bimetallic strip gets cooling down. As a result, the starter terminals will open. This results breaking of the series circuit.

• A very high voltage around 1,000 V is induced, because of the sudden opening of starter terminals in the series circuit. But in the long tube, electrons are already present; this induced voltage is quite sufficient to break down the long gap. Thus, more number of electrons collides with argon and mercury vapour atoms.

• The excited atom of mercury gives UV radiation, which will not fall in the visible region. Meanwhile, these UV rays are made to strike phosphor material; it causes the re-emission of light of different wavelengths producing illumination. The phenomenon of the emission is called as luminescence.

(c) LED Lamp:-

• A Light emitting diode bulb consists of two semiconducting material i.e. p-type material and n-type material. A p-n junction is formed, by connecting these two types of materials.

• When the p-n junction is forward biased, the majority carriers; either electrons or holes; start moving across the junction.
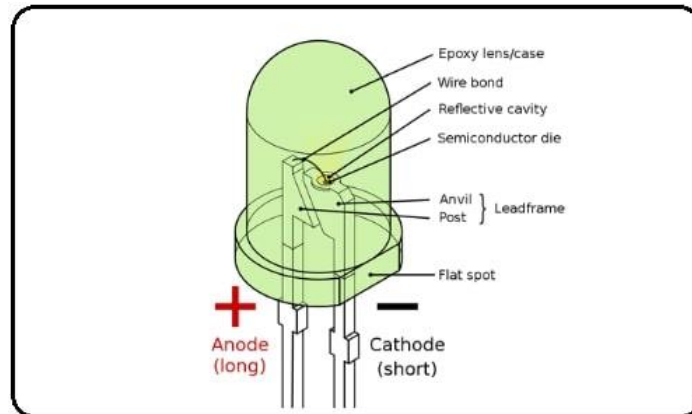
- As shown in the figure above, electrons start moving from n-region and holes start moving from p-region. When they moved from their regions they start to recombine across the depletion region. Free electrons will remain in the conduction band of energy level while holes remain in the valence band of energy level.

• The Energy level of the electrons is high than holes because electrons are more mobile than holes i.e. current conduction due to electrons are more. During the recombination of electrons and holes, some portion of energy must be dissipated or emitted in the form of heat and light.

• The phenomenon into which light emits from the semiconductor under the influence of the electric field is known as electroluminescence.

• Always remember that the majority of light is produced from the junction nearer to the p-type region. So diode is designed in such a way that this area is kept close to the surface of the device to ensure that the minimum amount of light is absorbed.

• The electrons dissipate energy in different forms depending on the nature of the diode used. Like for silicon and germanium diodes, it dissipates energy in the form of heat while for gallium phosphide (GaP) and gallium arsenide phosphide (GaAsP) semiconductors, it dissipates energy by emitting photons.

• For the emission of different colours, different semiconductors are used. For example; phosphorus is used for a red light, gallium phosphide for the green light and aluminum indium gallium phosphide for yellow and orange light.

STAR RATING OF HOME APPLIANCES:-

Terminology
BEE - Bureau of Energy Efficiency
EER - Energy Efficiency Ratio
BTU - British thermal unit

Energy Efficiency
It is defined as energy service per unit of energy consumption.

Star Rating

• An energy efficiency rating scheme for Electrical appliances is known as Star labelling.

• Star Rating is the average amount of electricity used by the equipment in a year i.e kWh/year or unit/year under standard test conditions.

• Star ratings are provided to all the major kind of appliances in the form of labels. These star ratings are given out of 5 and they provide a basic sense of how energy efficient each product is.
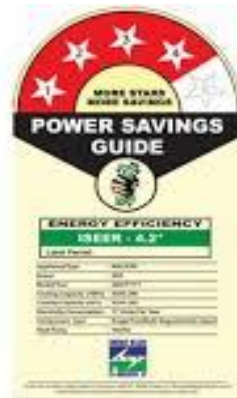
TYPES OF SINGLE PHASE INDUCTION MOTOR:-

(1) Split phase motor
(2) Capacitor start motor
(3) Capacitor start – Capacitor run single phase Induction Motor.
(4) Shaded Pole Motor
(5) Repulsion Motor

USES:

(1) Split phase motor:
(i) Small Pumps
(ii) Grinders
(2) Capacitor start motor
(i) Compressor
(ii) Pumps
(3) Capacitor start capacitor Run Motor
(i) Compressor of Air-conditioner
(ii) Water Cooler
(4) Shaded Pole Motor
(i) Small fans
(5) Repulsion Motor
(i) Mixing Machine
(ii) Blowers

CHAPTER-5
WIRING AND POWER BILLING

ELECTRICAL WIRING:-

A network of cables connecting various electrical accessories for distribution of electrical energy from the supplier meter board to the various electrical energy consuming devices such as lamps, fans, radio, TV and other domestic appliances through controlling and safety devices is known as wiring system.

TYPES OF WIRING FOR DOMESTIC INSTALLATIONS:-
Electrical wiring system is classified into five categories

• Cleat wiring
• Wooden casing and capping wiring
• CTS or TRS or PVC sheath wiring
• Lead sheathed or metal sheathed wiring
• Conduit wiring (Concealed or underground type Conduit)

Cleat Wiring

In this system of wiring cables are supported and gripped between porcelain cleats above the wall or roof.
• The porcelain cleats are made in two halves. The main part is base, which is grooved to accommodate the cables; the other part is the cap which is put over the base
• The lower cleat (base) and upper cover (cap), after placing cables between them are then screwed on wooden gutties.

Advantages:
• It is the cheapest system.
• Installation and dismantling is easy.
• Less skilled persons are required.

Disadvantages:
• It is purely temporary wiring system.
• Appearance is not good.
• Cables are exposed to atmosphere and there is a possibility of mechanical injury.
• This system should not be used in damp places otherwise insulation gets damaged.

Casing and capping wiring

• It consists of rectangular blocks made from seasoned and knots free wood or PVC.
• The casing has usually two (or three) „U" shaped grooves, (two in number) into which the VIR or PVC cables are laid in such a way that the opposite polarity cables are laid in different grooves.
• The casing is covered by means of a rectangular strip of the same width as that of casing known as capping and is screwed to it.

Advantages:
• It provides good mechanical strength.
• Easy to inspect by opening the capping.
• It is cheap wiring system as compared to sheath and conduit wiring systems.

Disadvantages:

• Difficulty in finding any fault caused in the wire.

• There is a high risk of fire in casing & capping wiring system.

• Not suitable in the acidic, alkalis and humidity conditions

• Costly repairing and need more material.

Batten Wiring (CTS or TRS)

• The cables are run or carried on well-seasoned, perfectly straight and well varnished (on all four sides) teak wood batten of thickness 10 mm. at least.

• The width of the batten depends upon the number and size of cables to be carried by it..

• The wooden battens are fixed to the walls or ceilings by means of PVC gutties or wooden plugs with flat head wooden screws, the wooden screws should be fixed on the batten at an interval not exceeding **75cm**.

Advantages:

• Wiring installation is simple and easy

• Cheap as compared to other electrical wiring systems

• Repairing is easy

Disadvantages:

• Not suitable for outdoor wiring

• Humidity, smoke, steam etc. directly affect on wires.

• Heavy wires are not recommended for this wiring scheme.

Lead Sheathed Wiring

• The type of wiring employs conductors that are insulated with VIR and covered with an outer sheath of lead aluminum alloy containing about 95% of lead.

• The metal sheath given protection to cables from mechanical damage, moisture and atmospheric corrosion.

• The cables are run on wooden batten and fixed by means of link clips just as in TRS wiring.

Advantages:

• Provides protection against mechanical injury better than TRS wiring.

• Easy to fix and looks nice

• Can be used in damp situation and in situation exposed to rain & sun.

Disadvantages:

• Costlier than TRS wiring

• Not suitable for chemical corrosion.

• In case of damage of insulation the metal sheath becomes alive & gives shock.

Conduit Wiring

• If the conduit is hidden inside the wall slots with the help of plastering, it is called concealed conduit wiring. In other words, the electrical wiring system inside wall, roof or floor with the help of plastic or metallic piping is called concealed conduit wiring. obliviously,

• It is the most popular, beautiful, stronger and common electrical wiring system nowadays.
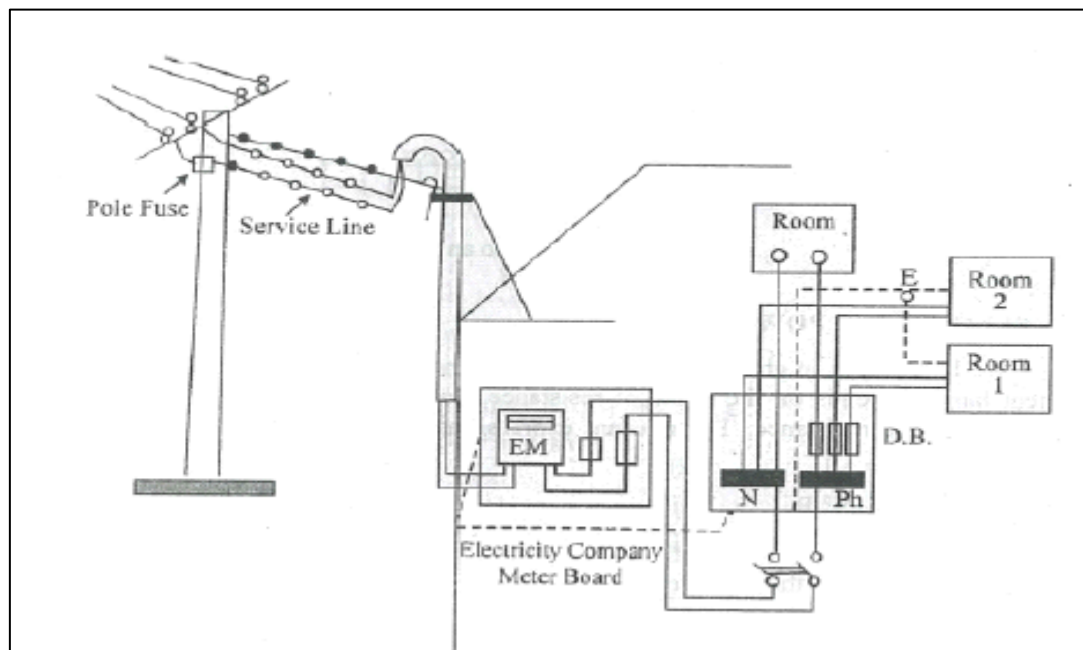
Advantages:

• The safest wiring

• Appearance is better

• No risk of fire or mechanical wear and tear.

• No risk of damage of cable insulation

• Safe from humidity, smoke, steam etc.

Disadvantages:
• Very expensive

• Installation is not easy

• Not easy to customize for future

• Hard to detect the faults.

Layout Of Household Electrical Wiring:-

BASIC PROTECTIVE DEVICES USED IN HOUSE HOLD WIRING:-

• Fuse

• MCB (Miniature Circuit Breaker)

• Earthing Wire

ELECTRICAL ENERGY:-

☐ Energy is the capacity to do work, and is measured in joules (J).

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

Example 1. A building has the following electrical appliances
(i) A 1 HP motor running for 5 hrs in a day.
(ii) Three fans each of 80W running for 10 hrs. in a day.
(iii) Four tube lights of 40W running for 15 hrs. per day.
Find the monthly bill for the month of November if unit cost of bill is Rs.2.50.

Solution:

Sl.No.	Name of Appliances	Quantity	Power Rating in KW	Working Hrs in a day	Energy consumed in KWH
01	Motor	1No.	1HP = 746W=0.746KW	5	1×0.746×5=3.73
02	Fans	3Nos	80W = 0.08KW	10	3×0.08×10=2.4
03	Tubelight	4Nos	40W = 0.04KW	15	4×0.04×15=2.4

Total Energy consumed   = 3.73+2.4+2.4=8.53

As we know 1KWH = 1unit
So, 8.53 KWH = 8.53 units.
In the month of November total Electrical Energy Consumed = 8.53 X 30 = 255.9 units.
Monthly bill = 255.9 X Rs.2.5 = Rs. 639.75

INTRODUCTION TO MEASURING INSTRUMENTS

Definition of instruments

An instrument is a device in which we can determine the magnitude or value of the quantity to be measured. The measuring quantity can be voltage, current, power and energy etc. Generally instruments are classified in to two categories.
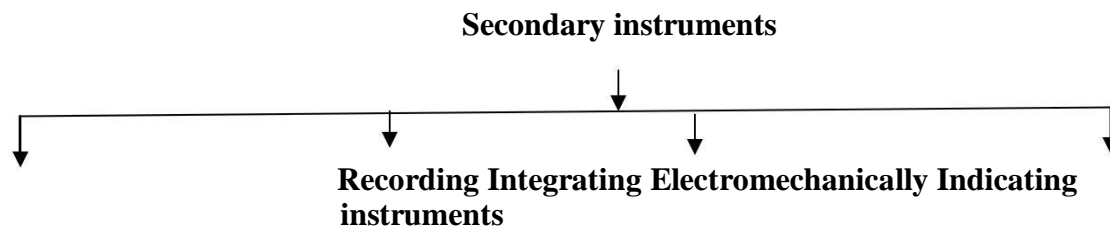
Instrument

Absolute Instrument   **Secondary Instrument**
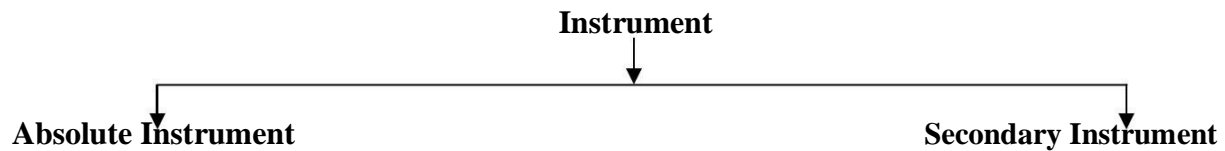
Absolute instrument

An absolute instrument determines the magnitude of the quantity to be measured in terms of the instrument parameter. This instrument is really used, because each time the value of the measuring quantities varies. So we have to calculate the magnitude of the measuring quantity, analytically which is time consuming. These types of instruments are suitable for laboratory use. Example: Tangent galvanometer.

Secondary instrument

This instrument determines the value of the quantity to be measured directly. Generally these instruments are calibrated by comparing with another standard secondary instrument.

Examples of such instruments are voltmeter, ammeter and wattmeter etc. Practically secondary instruments are suitable for measurement.

Secondary instruments

Recording Integrating Electromechanically Indicating instruments

1 Indicating instrument

This instrument uses a dial and pointer to determine the value of measuring quantity. The pointer indication gives the magnitude of measuring quantity.

2 Recording instrument

This type of instruments records the magnitude of the quantity to be measured continuously over a specified period of time.

3 Integrating instrument

This type of instrument gives the total amount of the quantity to be measured over a specified period of time.

4 Electromechanical indicating instrument

For satisfactory operation electromechanical indicating instrument, three forces are necessary. They are

(a) Deflecting force

(b) Controlling force

(c)Damping force

Deflecting force

When there is no input signal to the instrument, the pointer will be at its zero position. To deflect the pointer from its zero position, a force is necessary which is known as deflecting force. A system which produces the deflecting force is known as a deflecting system. Generally a deflecting system converts an electrical signal to a mechanical force.
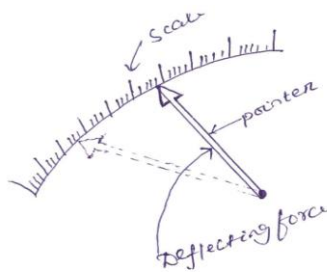

Pointer scale

1 Magnitude effect

When a current passes through the coil   , it produces a imaginary bar magnet. When a soft-iron piece is brought near this coil it is magnetized. Depending upon the current direction the poles are produced in such a way that there will be a force of attraction between the coil and the soft iron piece. This principle is used in moving iron attraction type instrument.
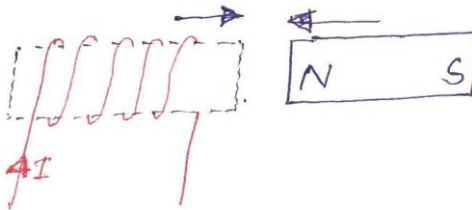
If two soft iron pieces are place near a current carrying coil there will be a force of repulsion between the two soft iron pieces. This principle is utilized in the moving iron repulsion type instrument.

2 Force between a permanent magnet and a current carrying coil

When a current carrying coil is placed under the influence of magnetic field produced by a permanent magnet and a force is produced between them. This principle is utilized in the moving coil type instrument.
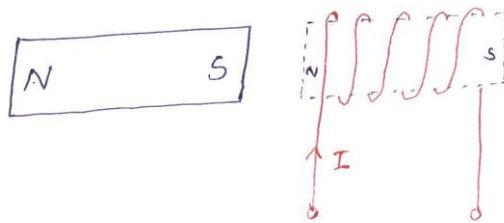
3 Force between two current carrying coil

When two current carrying coils are placed closer to each other there will be a force of repulsion between them. If one coil is movable and other is fixed, the movable coil will move away from the fixed one. This principle is utilized in electrodynamometer type instrument.
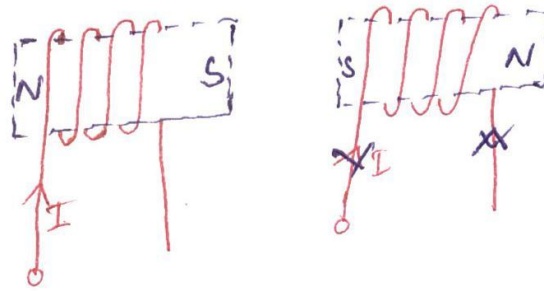
Controlling force

To make the measurement indicated by the pointer definite (constant) a force is necessary which will be acting in the opposite direction to the deflecting force. This force is known as controlling force. A system which produces this force is known as a controlled system. When the external signal to be measured by the instrument is removed, the pointer should return back to the zero position. This is possibly due to the controlling force and the pointer will be indicating a steady value when the deflecting torque is equal to controlling torque.

$$T_d = T_c \tag{1.1}$$

1 Spring control

Two springs are attached on either end of spindle (Fig. 1.5).The spindle is placed in jewelled bearing, so that the frictional force between the pivot and spindle will be minimum. Two springs are provided in opposite direction to compensate the temperature error. The spring is made of phosphorous bronze.

When a current is supply, the pointer deflects due to rotation of the spindle. While spindle is rotate, the spring attached with the spindle will oppose the movements of the pointer. The torque produced by the spring is directly proportional to the pointer deflection θ.

$$T_C \propto \theta \tag{1.2}$$

The deflecting torque produced T_d proportional to 'I'. When $T_C = T_d$, the pointer will come to a steady position. Therefore

$$\theta \propto I \tag{1.3}$$
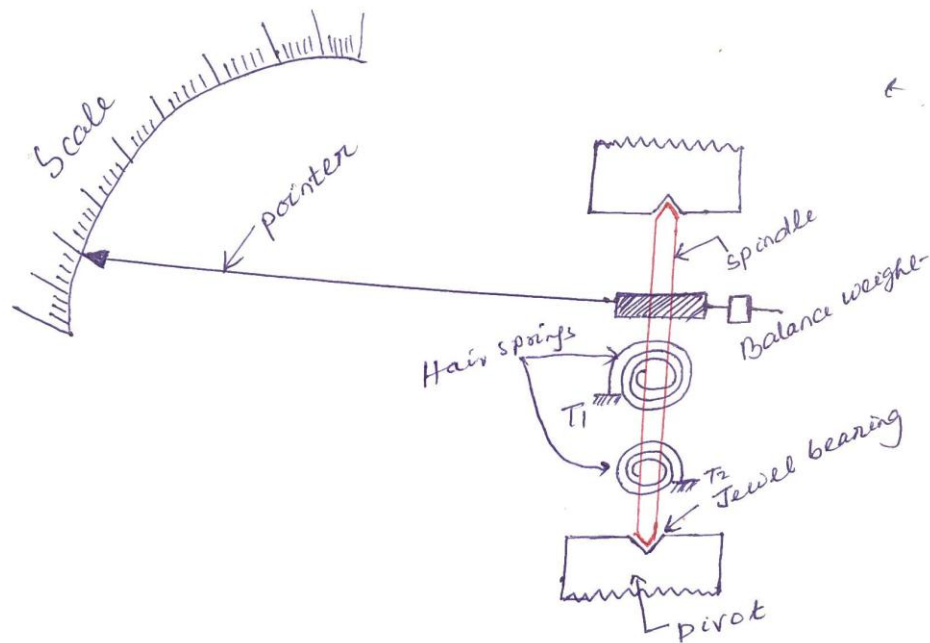
Since, θ and I are directly proportional to the scale of such instrument which uses spring controlled is uniform.

Damping force

The deflection torque and controlling torque produced by systems are electro mechanical. Due to inertia produced by this system, the pointer oscillates about it final steady position before coming to rest. The time required to take the measurement is more. To damp out the oscillation is quickly, a damping force is necessary. This force is produced by different systems.

(a) Air friction damping
(b) Fluid friction damping
(c) Eddy current damping

1 Air friction damping

The piston is mechanically connected to a spindle through the connecting rod (Fig. 1.6). The pointer is fixed to the spindle moves over a calibrated dial. When the pointer oscillates in clockwise direction, the piston goes inside and the cylinder gets compressed. The air pushes the piston upwards and the pointer tends to move in anticlockwise direction.
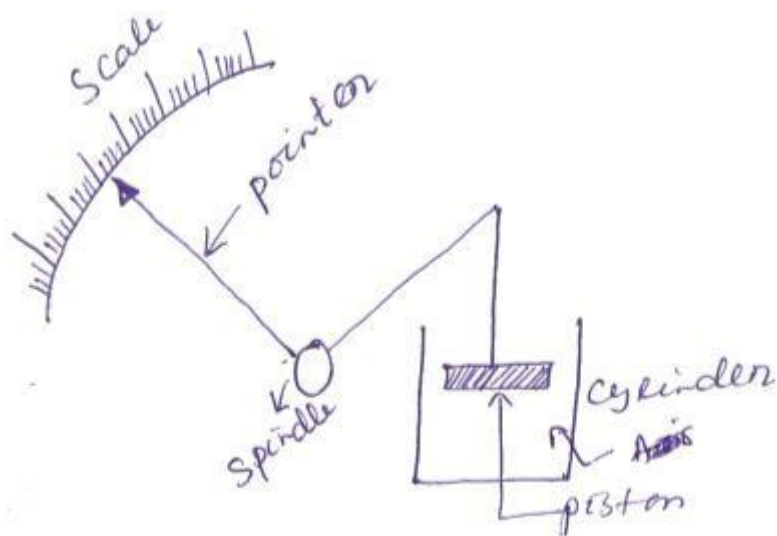
If the pointer oscillates in anticlockwise direction the piston moves away and the pressure of the air inside cylinder gets reduced. The external pressure is more than that of the internal pressure. Therefore the piston moves down wards. The pointer tends to move in clock wise direction.

## 2 Eddy current damping
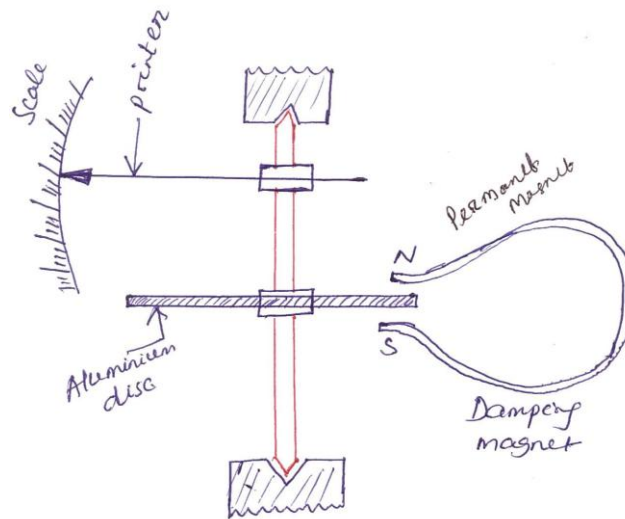
Disc type

An aluminum circular disc is fixed to the spindle   . This disc is made to move in the magnetic field produced by a permanent magnet.

When the disc oscillates it cuts the magnetic flux produced by damping magnet. An emf is induced in the circular disc by faradays law. Eddy currents are established in the disc since it has several closed paths. By Lenz's law, the current carrying disc produced a force in a direction opposite to oscillating force. The damping force can be varied by varying the projection of the magnet over the circular disc.
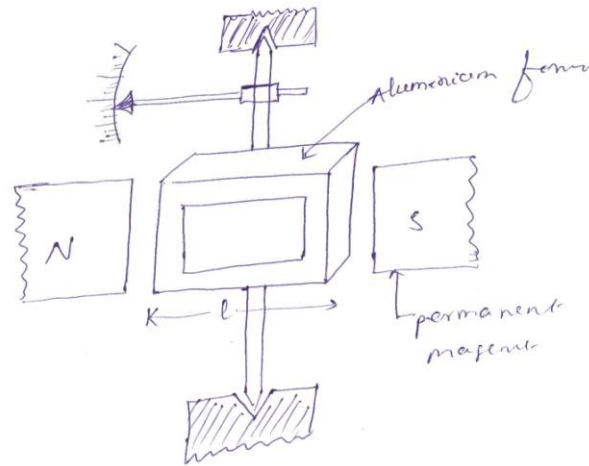
Rectangular type

DIFFERENT USES OF PMMC TYPES INSTRUMENT:-

(i) Ammeter: - When PMMC used as an ammeter, except for a very small current range, the moving coil is connected across a suitable low resistance shunt, so that only small part of the main current flows through the coil.

(ii) Voltmeter: - When PMMC used as voltmeter, the coil is connected in series with high resistance. The same PMMC instrument can be used as voltmeter or ammeter

(iii) Galvanometer: - It is used to measure a small value of current along with its direction and strength.

(iv) Ohm meter: - It is used to measure the resistance of the electric circuit by applying a voltage to a resistance with the help of battery.
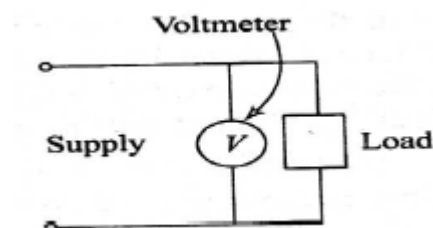
DIFFERENT USES OF MI TYPES INSTRUMENT:-

● They are suitable for measurement of current, voltage and power factor in electrical circuit.

● They are used for DC as well as low frequency AC in high power circuits.

● MI ammeter can be designed for full scale deflection current of 0.1Amp to 30Amp without use of shunt

● MI voltmeter of ranges over 50V without series resistance is in common use.
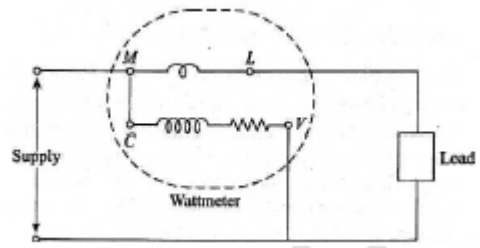
CONNECTION DIAGRAM:-

(i) Ammeter:
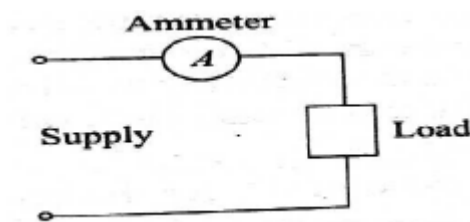
(ii) Voltmeter:

(iii) Wattmeter

Wattmeter

(iv) Energy meter

From supply — To load