Date..................

BEE101 / BEE201 : Fundamentals of Electrical Engineering.

Unit-1 DC Circuits

Electrical circuit Elements (R, L & C), Concept of active and passive elements, voltage and current source, concept of linearity, unilateral and bilateral elements.

Kirchoff's voltage & current law.

Unit-2 Steady state analysis of single phase A.C. circuit

Representation of sinusoidal waveforms – Average and effective values, form and peak factors.
Analysis of 1 phase A.C circuit consisting R-L-C combination (Series and Parallel) Apparent, active & reactive power, Power factor, Concept of Resonance in series and parallel circuits, bandwidth and quality factor.

Three phase balanced circuits, voltage and current relations in star and delta connections.

Unit-3 Transformers.

Magnetic circuits, ideal and practical transformer, equivalent circuit, losses in transformers, regulation and efficiency.

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Unit-4 :- Electrical Machines.

DC Machines :, Three phase induction motors, Single phase induction motor, Three phase synchronous machines.

Unit-5 :- Electrical Installations.

Introduction of switch fuse unit (SFU), MCB, ELCB, MCCB, ACB Types of Wires Cables and Bus Bars, Fundamentals of Earthing and lightning problem. Types of Batteries.

Formulas

$V_S = IZ$

$V_R = IR$

$V_L = IX_L$

$V_C = IX_C$

$X_L = 2\pi f L$

$X_C = 1/2\pi f C$

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

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

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

$\cos\phi = \frac{R}{Z}$

$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ (for series)

$P = VI\cos\phi$

$Q = VI\sin\phi$

$S = VI$

$\sin\phi = \frac{X_L}{Z}$ [RL]

$\sin\phi = \frac{X_C}{Z}$ [RC]

$\tan\phi = \frac{X_L}{R}$ [RL]

$\tan\phi = \frac{X_C}{R}$ [RC]

1. in pure R circuit $(V - I) = 0°$
2. in pure L " $(V - I) = 90°$
3. in pure C " $(I - V) = 90°$
4. in RL, RC, RLC circuit : $(V - I) = \phi$

$\phi = [0 - 90°]$

For star

$\sqrt{3} V_{ph} = V_L$

$I_{ph} = I_L$

For Delta = $\sqrt{3} I_{ph} = I_L$

$V_{ph} = V_L$

Unit - 01

D.C Circuit

Current → The rate of tranfer of electric charge per unit time is called the "current". The unit of current is "Ampere". It is denoted by 'I'. and is given by

$$\boxed{I = \frac{dq}{dt}}$$

EMF (Electro motive Force) → The full form of EMF is electro motive Force. The EMF is the force that causes the current to flow in a circuit. It is denoted by 'E' or 'V' and its unit is 'volt'.

Potential difference → It is diffiend as the difference of the Potentials b/w two points which tend to causes the electric current b/w them. It is also denoted by E or V and its unit is also 'Volt'.

Volt → The volt is the unit of Potential difference and EMF. It is diffiend as the Potential difference b/w two points of a conductor carrying a current of One Amphere when the power dissipated b/w these points is 'One watt'.

$$P = VI$$

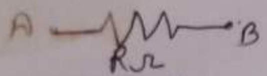
when $P = 1$ Watt

$I = 1$ Ampere

then putting value, we get

$$\boxed{\frac{P}{I} = V} \quad \boxed{V = 1} \quad [= 1V]$$

Resistance → The Resistance of a conducting matterial is the properdy to oppose the electric current. It is denoted by 'R'. and its Unit is 'ohm' (Ω). It is ~~repreoter~~ ~~represted~~ represented



• The Resistance dependes upon

1). It is directly ~~propatral~~ proportional to the length of the conductor

$$R \propto l \quad \text{—(i)}$$

2). It is Inversly proportional to area of cross section of the matterial

$$R \propto \frac{1}{A} \quad \text{—(ii)}$$

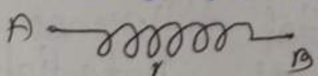
From equⁿ (i) & (ii) are is proportional to $\frac{l}{A}$

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

$$\boxed{R = \rho \frac{l}{A}}$$

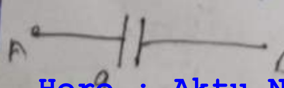
where. ρ = resistivity

Inductor → The inductor is an element which stores the electrical energy in the form of magnetic field. Its is denoted by 'L'. and Its unit is 'Henry'. It is represented by



$$\boxed{V = L\frac{di}{dt}}$$

Capacitor → The capacitor is an element that has the capacity of storing the electrical energy in the form of electrostatic field. It is denoted by 'C' & its unit is Farad. It's represented by



$$\boxed{q = CV}$$

Ohm's law → At normal physical conditions lie temprature and pressure, the current flowing in a conductor is directly praportional to the voltage applied at both its ends. Mathmaticaly,

$$I \propto V$$

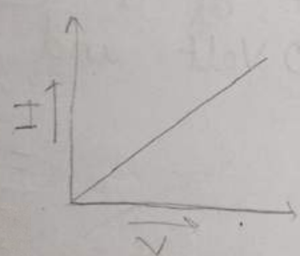
solving it we get,

$$I = GV$$

$$I = \frac{1}{R} \times V$$

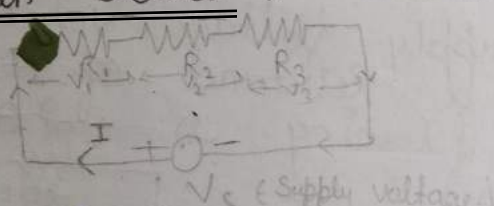
$$\boxed{IR = V}$$

where, V is equal to voltage applied in volt.
I is equal to current in ampere
G is equal to conductance in ohm^{-1} or mho
R is equal to Resistance in ohm



II. Connection of Resistance

① Resistance in series →



$$+V_s - V_1 - V_2 - V_3 = 0$$

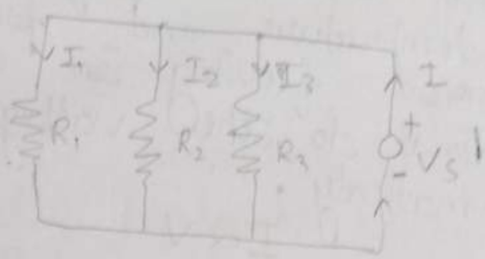
$$V_s = V_1 + V_2 + V_3$$

$$(IR_{total}) = (IR_1) + (IR_2) + (IR_3)$$

$$(\cancel{I}R_{total}) = \cancel{I}(R_1 + R_2 + R_3)$$

$$\boxed{R_{total} = R_1 + R_2 + R_3}$$

(2) Resistance in Parallel :-



$$I_{total} = I_1 + I_2 + I_3$$

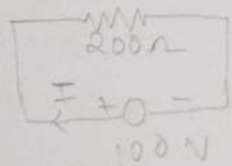
$$\frac{V_s}{R_{total}} = \frac{V_s}{R_1} + \frac{V_s}{R_2} + \frac{V_s}{R_3}$$

$$\frac{V_s}{R_{total}} = V_s\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

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

Numerical

(1) Find the total current of a circuit with a supply voltage of 100 Volt and a Resistance of 200 ohm.



V = 100 Volt

R = 200 ohm

$I = ?$

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

$$= \frac{100}{200}$$

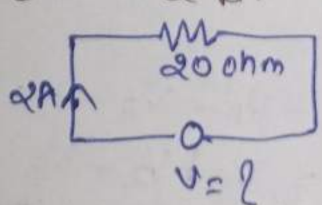
$$\boxed{I = 0.5} \text{ Ampere}$$

(2) Find the supply voltage (Vo) of a circuit consisting of a Resistance of 20 ohm and the current flowing is 2 Amp.

I = 2A

R = 20 ohm

V = ?

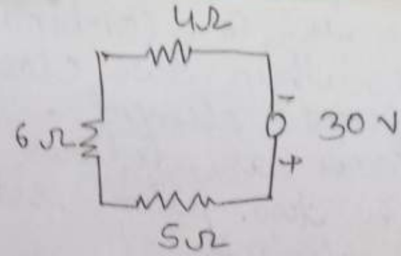


$$V = IR$$

$$V = 2 \times 20$$

$$\boxed{V = 40 \text{ volt}}$$

Q Find the total resistance of the circuit and hence find the current induce



~~V = IR~~

~~30 = I (~~

(Total Resistance) $R = R_1 + R_2 + R_3$

$= 4 + 6 + 5$

$= 15$

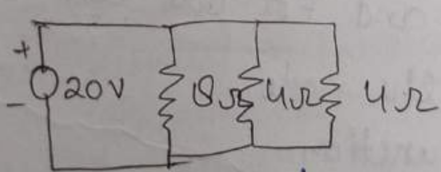
$V = IR$

$30 = I \times 15$

$I = \frac{30}{15} = 2$

I = 2 Amp

Q, R = ?, I_{total} = ?



$\frac{1}{R} = \frac{1}{8} + \frac{1}{4} + \frac{1}{4}$

$\frac{1}{R} = \frac{1+2+2}{8}$

$\frac{1}{R} = \frac{5}{8}$

$R = \frac{8}{5}$

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

$= \frac{20}{1} = 20$

$I = 20$

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

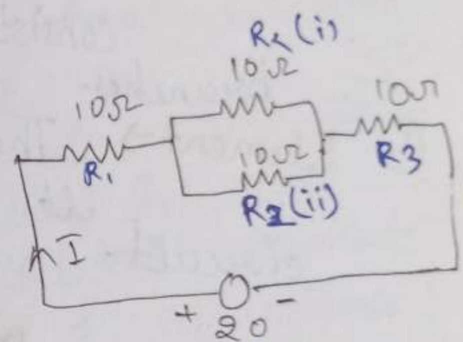
$= \frac{20}{\frac{8}{5}}$

$= \frac{20 \times 5}{8}$ 25

$= \frac{100}{8}$

$\frac{25}{2}$

Q



$\frac{1}{R} = \frac{1}{10} + \frac{1}{10}$

$\frac{1}{R} = \frac{1+1}{10}$

$\frac{1}{R} = \frac{2}{10}$ 5

$R_2 = 5$

$R_{tot} = R_1 + R_2 + R_3$

$= 10 + 5 + 10$

$R_{tot} = 25$

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

$I = \frac{20}{25} = \frac{4}{5}$ 0.8

I = 0.8

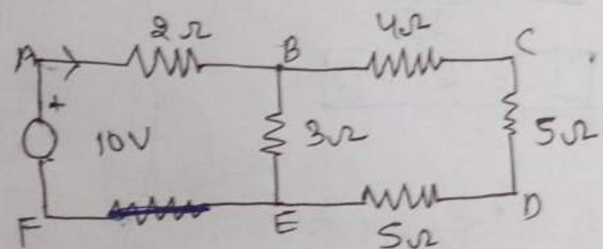
Circuit → The circuit is a combination of two or more than two closed paths consisting of different element. The different parts of circuit are as follows

① Branch → Branch is two point set up which consist of any element.

② Node → The node is a point which consists of two or more than two branches.

③ Junction → The junction is a point which consist of three or more than three branches.

④ Element → The element is the one which circulate or oppose the current in the circuit.



- ABCDEFA is a circuit
- AB, BC, CD, DE, EF and FA are the different branches.
- A, B, C, D, E, F are the node
- B and E are the junction
- 10V, 2Ω, 4Ω, 5Ω, 5Ω & 3Ω are the elements

The circuit can be divided into different parts on the bases.

(a) On the basis of current deliver :- On this basis the circuit element can be divided into two part

(i) Active element → The element which deliver the current in the circuit are called active element. Example → Voltage source & current source

(ii) Passive element → The elements which absorbe the current in the circuit are called Passive element.
Example → Resistance, Inductance & capacitance.

(b) On the basis of direction of current :-

On this basis the circuit element can be divided into two parts which are -

(i) Unilateral elements → The elements which allow the current to flow in only one direction are called Unilateral elements
Example → Diode & transisters

(ii) Bilateral elements → The elements which allow the current to flow in Both the direction are called Bilateral elements.
Example → Resistance, Inductance & capacitance.

(c) On the basis of obeying ohm's law :-

On this basis the circuit can be linear and non-linear :

(i) Linear circuit → The circuit which consiste of linear element (obeying ohm's law) are called linear circuit
Example - A circuit consists of resistance

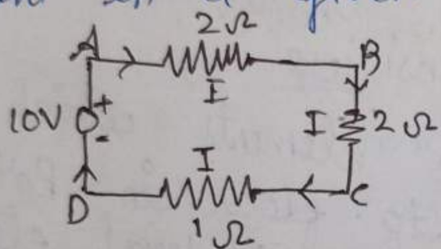
(ii) Non-linear circuit → The circuit which does not obey ohm's law are called Non-linear circuit
Example → The circuit consists of Diode & transisters.

physical seperable → Lumped

Kirchoff's law

are two laws given by Kirchoff, which are current law + Voltage law.

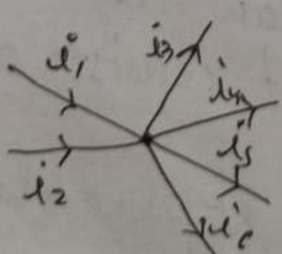
i) **Kirchoff's Voltage law or loop law** :- This law states that the algebraic sum of all the Voltage in a closed path is zero (0). The application of KVL is Mesh analysis by which we can calculate the current in a given resistance



$$10 - 2I - 2I - I = 0$$
$$10 = 2I + 2I + I$$
$$10 = I(2+2+1)$$
$$10 = I5$$
$$I = \frac{10}{5}$$
$$\boxed{I = 2}$$

ii) **Kirchoff's Current law** :- This law states that the algebraic sum of all the current in a node is zero (0). In other words, the incoming current at a node is equal to the outgoing current.

The application of KCL is Nodal analysis by which we can calculate the current in a given branch or resistance



$$-i_1 - i_2 + i_3 + i_4 + i_5 + i_6 = 0$$

or $\boxed{i_1 + i_2 = -i_3 - i_4 - i_5 - i_6}$

11. **Source →** The Source is also called active element of the circuit.

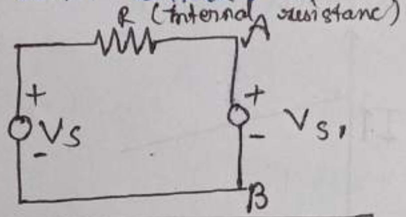
There are two types of sources which are voltage source & current source.

1) **Voltage Source →** The voltage source deliver the current in the circuit.

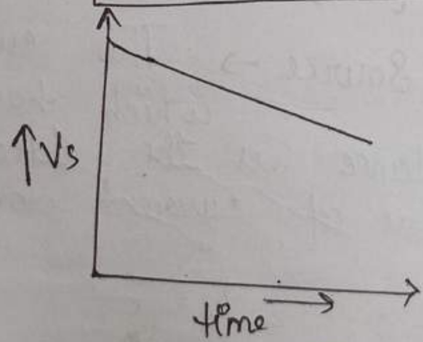
For example → Battery

There are two type of voltage source which are Practical & Ideal voltage source.

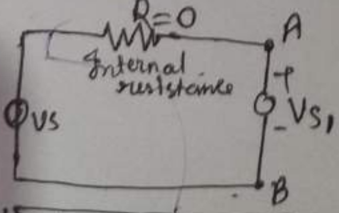
i) **Practical voltage source →** The voltage source having some internal resistance are called Practical Voltage source. So, their value decreases with time.

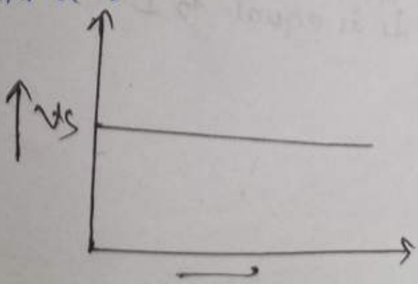


V_{s1} is less than V_s



ii) **Ideal Voltage source →** The voltage source having no internal ~~sour~~ resistance are called Ideal Voltage source. So, their value remaine same with time.

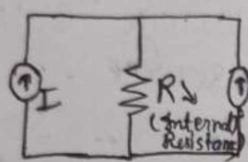




V_{s1} is equal to V_s

Current Source → The current Source is an element which gives the current to the circuit. There are two types of current Source which are explained below

(i) **Practical current Source →** The Practical current Source is the one which has its Internal resistance. This internal resistance is connected in Parallel to it.



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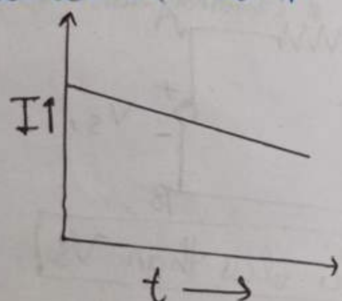
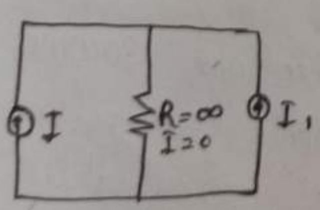
In this case I_1 is less than I

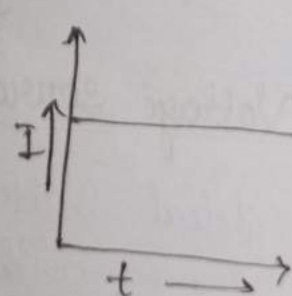
Due to this, In practical source the value of current is decreased with time.



(ii) **Ideal current Source →** The current source which have infinite value of Internal resistance is the Ideal current Source. In this case value of current does not decrease with time.



In this case I_1 is equal to I



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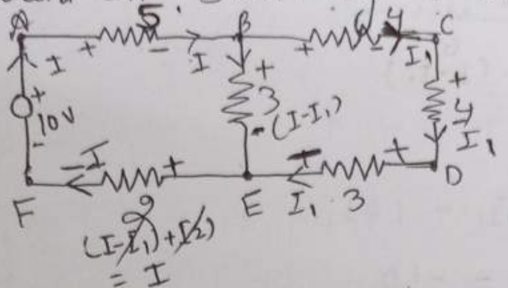
Mesh analysis →

Q Find the current in 5 ohm by Mesh analysis ?



$$-10 + 5I + 3(I - I_1) + 2I = 0 \quad - \text{equ}^n \text{ (1)}$$

$$-10I + 3I_1 = -10 \quad - \text{(1)}$$

$$4I_1 + 5I_1 + 3I_1 - 3(I - I_1) = 0 \quad - \text{(2)}$$

$$3I - 14I_1 = 0$$

$$x = 1.06\,A - I$$

$$y = 0.22 = I_1$$

The current flowing across 5 ohm is 1.06A

Q. $4I - 5I_1 = 8$

$3I + 10I_1 = 12$

$x = 2.5$

$y = 0.436$

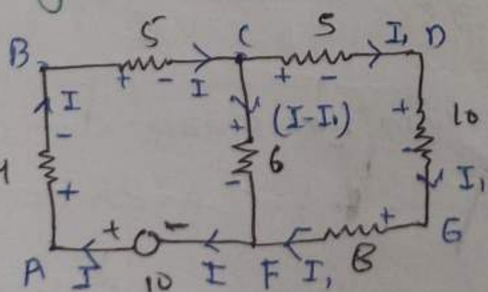
Q. $14I - 16I_1 = 0$

$I_1 - 4I = 0$

$x = 0$

$y = 0$

Q.



Find the current in 6 Ohm ?

First equ^n

$$-10 + 4I + 5I + 6(I - I_1) = 0$$

$$4I + 5I + 6I - 6I_1 = 10$$

$$15I - 6I_1 = 10 \quad - \text{(1)}$$

Second equ^n

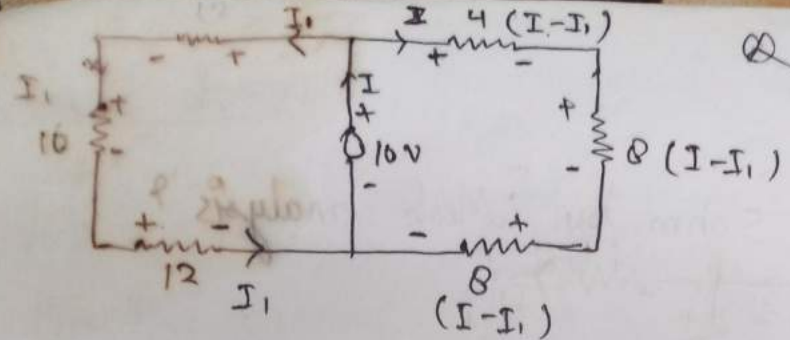
$$5I_1 + 10I_1 + 8I_1 - 6(I - I_1) = 0$$

$$5I_1 + 10I_1 + 8I_1 - 6I + 6I_1 = 0$$

$$29I_1 - 6I = 0 \quad - \text{(2)}$$

$x = 0.726$

$y = 0.150$



Q Find the current in 4 ohm ?

loop One

$10 - 12I_1 - 16I_1 - 12I_1 = 0$

$-40 I_1 = -10$

$I_1 = \frac{10}{40}$

$\boxed{I_1 = 0.25A}$ — (i)

Second loop -

$10 - 4(I-I_1) - 8(I-I_1) - 8(I-I_1) = 0$

$20(I-I_1) = 10$

$I - I_1 = \frac{10}{20}$

$I - I_1 = 0.5$ — (2)

Put the value of I_1 in above equⁿ

$I - 0.25 = 0.5$

$I = 0.5 + 0.25$

$\boxed{I = 0.75}$

The current flow in a 4 ohm resistance

$0.75 - 0.25$

$= 0.5A$

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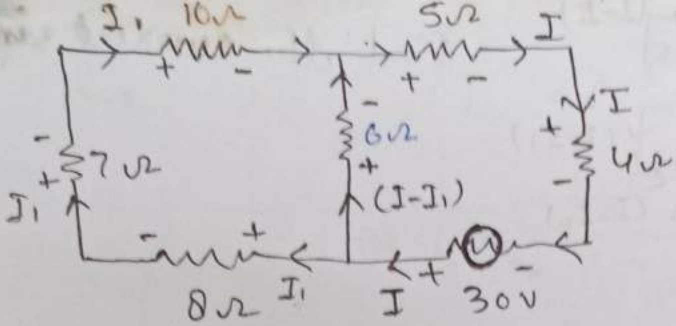
Q Calculate the current in 4 ohm



First loop –

$30 - 6(I - I_1) - 5I - 4I = 0$

$-15I + 6I_1 = -30$ —(i)

Second loop

$-8I_1 - 7I_1 - 10I_1 + 6(I - I_1) = 0$

$6I - 31I_1 = 0$

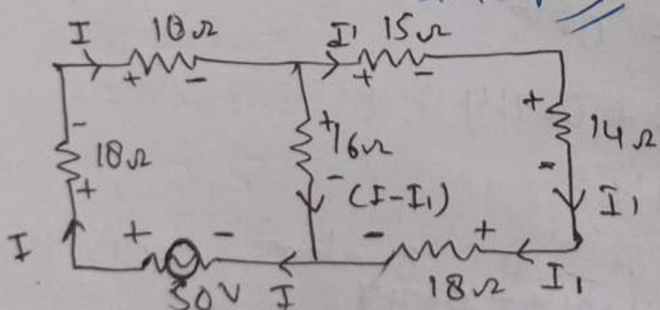
$I = 2.16A$

$I_1 = 0.41A$

The current flow in 4ohm resistance is –

$I = 2.16A$

Q.



First loop

$50 - 18I - 10I - 16(I - I_1) = 0$

$-44I + 16I_1 = -50$ —(1)

Second loop

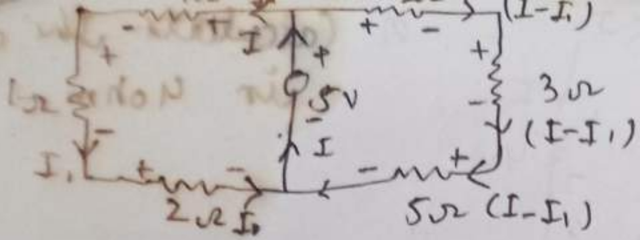
$-15I_1 - 14I_1 - 18I_1 + 16(I - I_1) = 0$

$-63I_1 + 16I = 0$ —(2)

I_1 0.0198

$= I = -1.1435$

0.94A



Find the current in 3Ω.

First loop

$-5 + 4I_1 + 1I_1 + 2I_1 = 0$

$7I_1 = 5$

$I_1 = \frac{5}{7}$

$I_1 = 0.714$ A

Second loop

$-5 + 2(I - I_1) + 3(I - I_1) + 5(I - I_1) = 0$

$10(I - I_1) = 5$

$I - I_1 = \frac{5}{10}$

$I - I_1 = 0.5$

Put the value of I_1 in above eqn

$I - 0.714 = 0.5$

$I = 0.5 + 0.714$

$I = 1.214$

The current flow in 3 ohm resistor

$I - I_1 = 1.214 - 0.714$

~~$I - I_1 = 1.21$~~ ~~$0.714 - 1.214$~~

$I - I_1 = +0.5$

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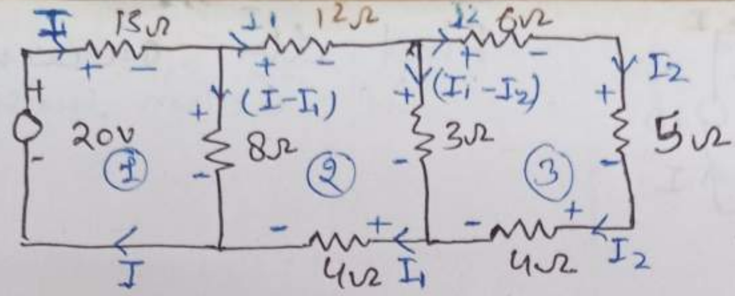
Q.



First loop

$$-20+15I+8(I-I_1)=0$$

$$\boxed{23I-8I_1=20}$$

Second loop

$$12I_1+3(I_1-I_2)+4I_1-8(I_1-I_2)=0$$

$$12I_1+3I_1-3I_2+4I_1-8I_1+8I=0$$

$$\boxed{27I_1-3I_2-8I=0}$$

Third loop

$$6I_2+5I_2+4I_2-3(I_1-I_2)=0$$

$$6I_2+5I_2+4I_2-3I_1+3I_2=0$$

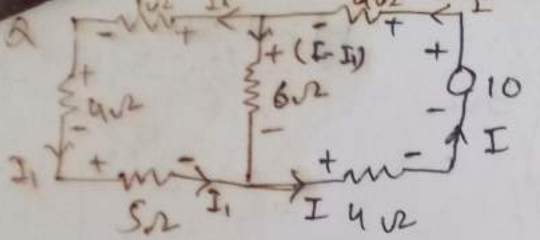
$$\boxed{18I_2-3I_1=0}$$

$x=0$
$y=0$

$$I=0.95$$
$$I_1=0.29$$
$$I_2=0.04$$

The current flowing in 3 ohm resistance is

$$I_1-I_2=0.29-0.04$$
$$=0.25\text{ A}$$

Q 

Find the current in 6 ohm resistance?

First loop

$$-10 + 4I + 6(I - I_1) + 4I = 0$$

$$4I + 6I - 6I_1 + 4I = 10$$

$$\boxed{14I - 6I_1 = 10}$$

Second loop

$$1I_1 + 4I_1 + 5I_1 - 6(I - I_1) = 0$$

$$1I_1 + 4I_1 + 5I_1 - 6I + 6I_1 = 0$$

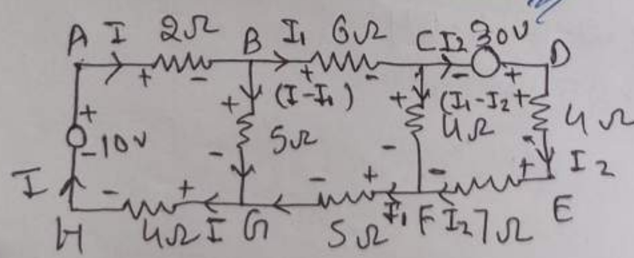
$$\boxed{16I_1 - 6I = 0}$$

$$x = 0.851 \quad I_1$$
$$y = 0.319 \quad I_2$$

The current flow in 6ohm resistance is

$$I - I_1 = 0.851 - 0.319$$

$$\boxed{I - I_1 = 0.532}\, A$$

Q 

Find the current in branch CF?

First loop

$$-10 + 2I + 5(I - I_1) + 4I = 0$$

$$11I - 5I_1 = 10$$

second loop

$$6I_1 + 4(I_1 - I_2) + 5I_1 - 5(I - I_1) = 0$$

$$-5I + 20I_1 - 4I_2 = 0$$

2.200
0.753
1.447

Third loop

$$-30 + 4I_2 + 7I_2 - 4(I_1 - I_2) = 0$$

$$15I_2 - 4I_1 = 30$$

$x = 1.251$ I

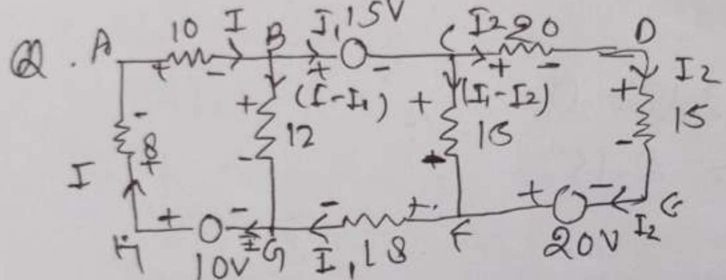
$y = 0.753$ I_1

$z = 2.200$ I_2

The current flow in CF branch

$$I_1 - I_2 = 0.753 - 2.200$$

$$\boxed{I_1 - I_2 = +1.447}\ A$$

Q. 

Find the current in branch BG ?

first loop

$$-10 + 8I + 10I + 12(I - I_1) = 0$$

$$30I - 12I_1 = 10$$

Second loop

$$-15 + 15(I_1 - I_2) + 18I_1 - 12(I - I_1) = 0$$

$$-12I + 45I_1 - 15I_2 = 15$$

Third loop

$$20I_2 + 15I_2 - 20 - 15(I_1 - I_2) = 0$$

$$50I_2 - 15I_1 = 20$$

$x = 0.613$

$y = 0.700$

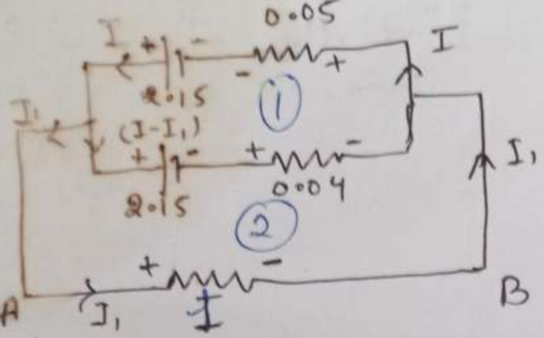
$z = 0.610$

The current flow in BG Branch

$$(I - I_1) = 0.613 - 0.700$$

$$= 0.087$$

Q



Find the current in AB Branch?

First loop

$-2.15 + 2.15 + 0.04(I-I_1) + 0.05I = 0$

$0.09I - 0.04I_1 = 0$

Second loop

$1I_1 - 0.04(I-I_1) - 2.15 = 0$

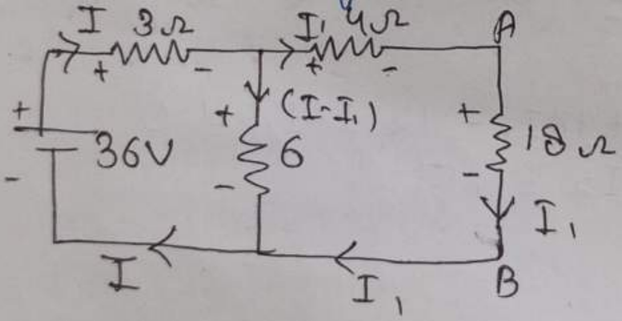
$1.04I_1 - 0.04 = 2.15$

$I = x = 0.934$

$I_1 = y = 2.103$

The current flow in AB Branch is 2.10A

Q



Find the current in AB branch?

First loop

$-36 + 3I + 6(I-I_1) = 0$

$9I - 6I_1 = 36$

Second loop

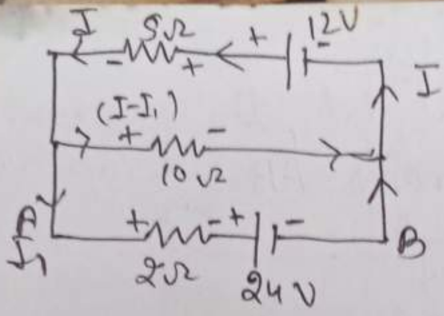
$4I_1 + 18I_1 - 6(I-I_1) = 0$

$28I_1 - 6I = 0$

$I = x = 4.66$

$I_1 = y = 1$

The current flow in AB Branch is 1 A

Q 

Find the current in Branch AB ?

First loop

$-12 + 5I + 10(I - I_1) = 0$

$15I - 10I_1 = 12$ —(i)

Second loop

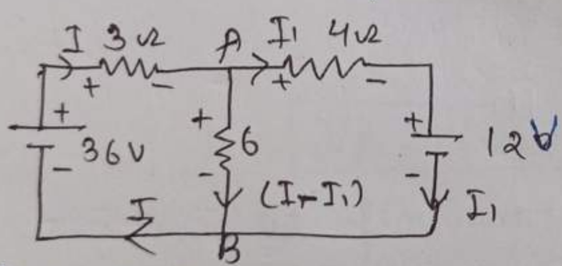
$2I_1 + 24 - 10(I - I_1) = 0$

$12I_1 - 10I = -24$ —(ii)

$I = x = 2.8$

$I_1 = y = 3.$

The current flow in AB Branch is 3A

Q 

Find the current in Branch AB ?

First loop

$-36 + 3I + 6(I - I_1) = 0$

$9I - 6I_1 = 36$ —(i)

Second loop

$4I_1 + 12 - 6(I - I_1) = 0$

$10I_1 - 6I = -12$. —(ii)

$I = x = 5.33$

$I_1 = y = 2.00$

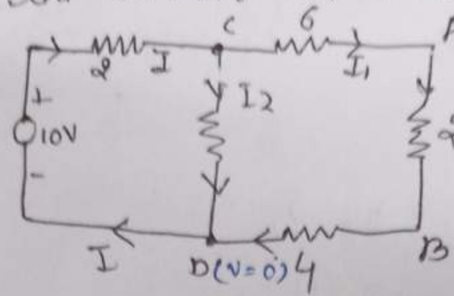
The current flow in AB Branch is

$(I - I_1) = 5.33 - 2.00$

$I - I_1 = 3.33\ A$

Nodal Analysis

Q1) Find out the current in Branch AB



(C) $I = I_1 + I_2$ (Node)

(D) $I_1 + I_2 = I$ (Reference node) (V = 0)

$$I = I_1 + I_2$$

$$\left(\frac{10 - V_c}{2}\right) = \left(\frac{V_c - 0}{12}\right) + \left(\frac{V_c - 0}{2}\right)$$

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

$$\frac{10 - V_c}{2} = \frac{2V_c + 12V_c}{24}$$

$$\frac{10 - V_c}{2} = \frac{14V_c}{24}$$

$$10 - V_c = \frac{14V_c}{12}$$

$$120 - 12V_c = 14V_c$$

$$120 = 14V_c + 12V_c$$

$$120 = 26V_c$$

$$4.61 \; \frac{120}{26} = V_c$$

$$\boxed{V_c = 4.61} \cdot V$$

The current in Branch AB is

$$I_1 = \frac{V_c - 0}{12}$$

$$I_1 = \frac{V_c}{12}$$

$$I_1 = \frac{4.61}{12}$$

$$\boxed{I_1 = 0.38} \; A$$

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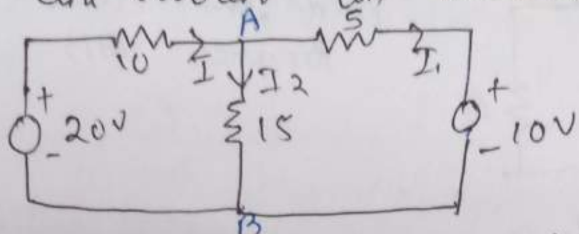
Q) Find the current in Branch AB ?



Applying KCL at node of A · considering B as reference node

$I = I_1 + I_2$

$$\left(\frac{20 - V_A}{10}\right) = \left(\frac{V_A - 10}{5}\right) + \left(\frac{V_A - 0}{15}\right)$$

$$\frac{20 - V_A}{\cancel{10}\ \cancel{5}\ 2} \times \frac{3V_A - 30 + V_A}{\cancel{15}\ 3}$$

$$60 - 3V_A = 2(4V_A - 30)$$

$$60 - 3V_A = 8V_A - 60$$

$$60 + 60 = 8V_A + 3V_A$$

$$120 = 11V_A$$

$$10.9\ \frac{\cancel{120}}{\cancel{11}} = V_A$$

$$\boxed{V_A = 10.9}\ V$$

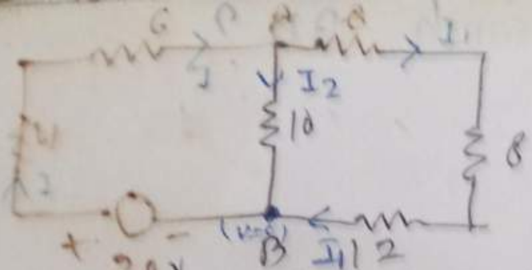
The current flow in branch AB is

$$I_2 = \frac{V_A - 0}{15}$$

$$I_2 = \frac{V_A}{15}$$

$$I_2 = \frac{10.9}{15}$$

$$\boxed{I_2 = 0.72}\ A$$



Find the current in Branch AB

applying KCL at node A

$I = I_1 + I_2$

$$\left(\frac{20 - V_A}{10}\right) = \left(\frac{V_A - 0}{28}\right) + \left(\frac{V_A - 0}{10}\right)$$

$$\frac{20 - V_A}{10} = \frac{V_A}{28} + \frac{V_A}{10}$$

$$\frac{20 - V_A}{1\cancel{0}} = \frac{10V_A + 28V_A}{28\cancel{0}}$$

$$20 - V_A = \frac{38V_A}{28}$$

$$560 - 28V_A = 38V_A$$

$$560 = 38V_A + 28V_A$$

$$560 = 66V_A$$

$$\frac{560}{66} = V_A$$

$$\boxed{8.48 = V_A}$$

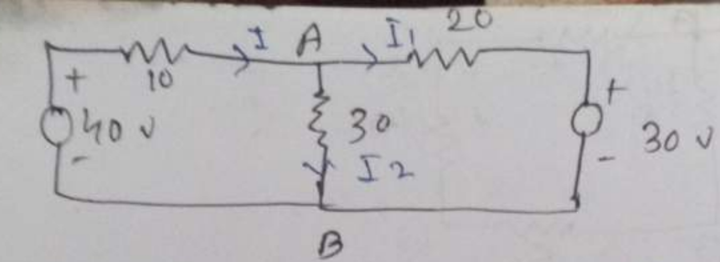
The current flow in AB Branch is

$$I_2 = \frac{V_A - 0}{10}$$

$$I_2 = \frac{8.486}{10}$$

$$\boxed{I_2 = 0.848} \text{ A}$$

a)



Applying KCL at node A

$$I = I_1 + I_2$$

$$\left(\frac{40 - V_A}{10}\right) = \left(\frac{V_A - 30}{20}\right) + \left(\frac{V_A - 0}{30}\right)$$

$$\frac{40 - V_A}{10} = \frac{30(V_A - 30) + 20V_A}{600}$$

$$40 - V_A = \frac{30V_A - 900 + 20V_A}{60}$$

$$40 - V_A = \frac{50V_A - 900}{60}$$

$$2400 - 60V_A = 50V_A - 900$$

$$2400 + 900 = 50V_A + 60V_A$$

$$3300 = 110V_A$$

$$\frac{3300}{110} = V_A$$

$$\boxed{30 = V_A}$$

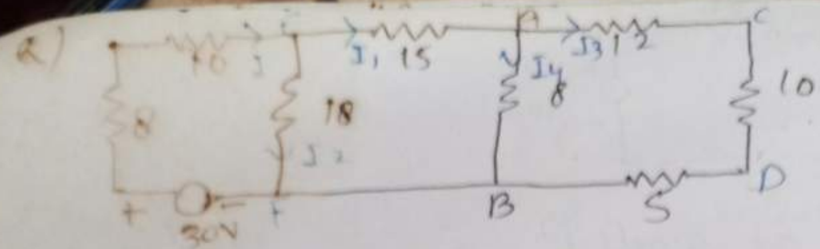
The current flow in AB Branch

$$I_2 = \frac{V_A - 0}{30}$$

$$I_2 = \frac{30}{30}$$

$$\boxed{I_2 = 1}\ A$$

2)



Applying KCL in E node

$I = I_1 + I_2$

$$\frac{30 - V_E}{18} = \frac{V_E - 0}{23} + \frac{V_E - 0}{18}$$

$$\frac{30 - V_E}{18} = \frac{18 V_E + 23 V_E}{414}$$

$$\frac{30 - V_E}{1} = \frac{41 V_E}{23}$$

$690 - 23 V_E = 41 V_E$

$690 = 41 V_E + 23 V_E$

$690 = 64 V_E$

$$\frac{690}{64} = V_E$$

$10.468 = V_E$

Applying KCL in A node

$I_1 = I_3 + I_4$

$$\frac{V_E - V_A}{15} = \left(\frac{V_A - 0}{27}\right) + \left(\frac{V_A - 0}{8}\right)$$

$$\frac{10.468 - V_A}{5} = \frac{8 V_A + 27 V_A}{72}$$

$72(10.468 - V_A) = 5 \times 35 V_A$

$753.696 - 72 V_A = 175 V_A$

$753.696 = 175 V_A + 72 V_A$

$753.696 = 247 V_A$

$$\frac{753.696}{247} = V_P$$

$$3.051 \rightarrow V_A$$

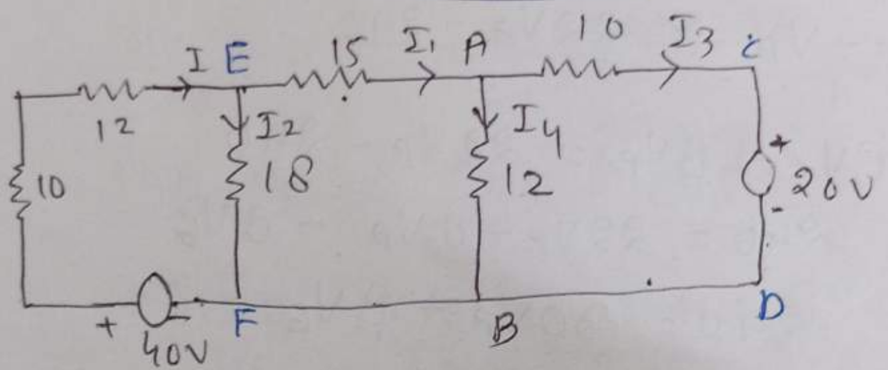
The current flow in AB Branch is

$$I_4 = \frac{V_A - 0}{8}$$

$$I_4 = \frac{3.051}{8}$$

$$\boxed{I_4 = 0.381} \ A$$

Q)



Applying KCL in E node :-

$$I = I_1 + I_2$$

$$\left(\frac{40 - V_E}{22}\right) = \left(\frac{V_E - V_A}{15}\right) + \left(\frac{V_E - 20}{18}\right)$$

$$\frac{40 - V_E}{22} = \frac{18V_E - 18V_A + 15V_E}{270}$$

$$\frac{40 - V_E}{\cancel{22}\ 11} = \frac{33V_E - 18V_A}{\cancel{270}\ 135}$$

$$5400 - 135V_E = 363V_E - 198V_A$$

$$5400 = 363 + 135V_E - 198V_A$$

$$5400 = 498V_E - 198V_A$$

$$I_1 = I_3 + I_4$$

$$\frac{V_E - V_A}{15} = \frac{V_A - 20}{10} + \frac{V_A - 0}{12}$$

$$\frac{V_E - V_A}{15} = \frac{12(V_A - 20) + (V_A)\times 10}{120}$$

$$\frac{V_E - V_A}{15} = \frac{12V_A - 240 + 10V_A}{120}$$

$$\frac{V_E - V_A}{1} = \frac{22V_A - 240}{8}$$

$$8V_E - 8V_A = 22V_A - 240$$

$$240 = 22V_A + 8V_A - 8V_E$$

$$240 = 30V_A - 8V_E$$

$$V_E = x = 15.687$$
$$V_A = y = 12.183$$

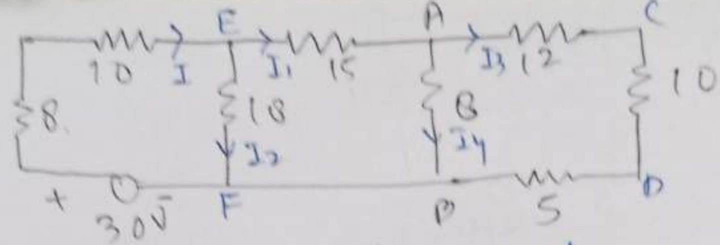
The current flow in AB Branch

$$I_4 = \frac{V_A - 0}{12}$$

$$= \frac{12.183}{12}$$

$$I_4 = 1.183$$

Q



Applying KCL in E node

$I = I_1 + I_2$

$$\frac{30 - V_E}{18} = \frac{V_E - V_A}{15} + \frac{V_E - 0}{18}$$

$$\frac{30 - V_E}{\cancel{18}} = \frac{18V_E - 18V_A + 15V_E}{\cancel{270}}$$

$$\frac{30 - V_E}{1} = \frac{33V_E - 18V_A}{15}$$

$450 - 15V_E = 33V_E - 18V_A$

$450 = 33V_E + 15V_E - 18V_A$

$450 = 48V_E - 18V_A \quad -(1)$

Applying KCL in A node

$I_1 = I_3 + I_4$

$$\frac{V_E - V_A}{15} = \frac{V_A - 0}{27} + \frac{V_A - 0}{8}$$

$$\frac{V_E - V_A}{\cancel{15}\,5} = \frac{8V_A + 27V_A}{\cancel{216}\,72}$$

$72V_E - 72V_A = 40V_A + 135V_A$

$72V_E - 72V_A = 175V_A$

$0 = 175V_A + 72V_A - 72V_E$

$0 = 247V_A - 72V_E$

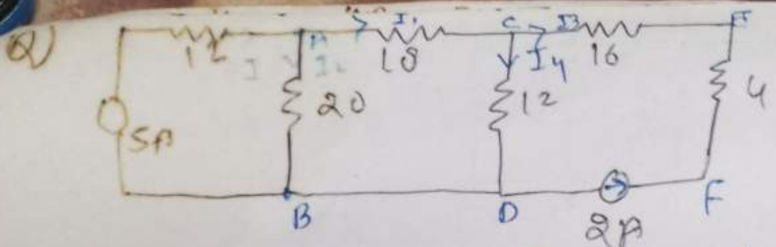
$V_E = x = 10.525$

$V_A \quad y = 3.068$

The current in AB Branch is

$I_4 = \frac{V_A - 0}{8} = \frac{3.068}{8} = 0.383$ A

Q)



applying current in A node

$$I = I_1 + I_2$$

$$5 = \frac{V_A - V_C}{18} + \frac{V_A - 0}{20}$$

$$5 = \frac{20V_A - 20V_C + 18V_A}{360}$$

$$360 \times 5 = 38V_A - 20V_C$$

$$1800 = 38V_A - 20V_C$$

Applying current in C node

$$I_1 = I_3 + I_4$$

~~$\frac{V_A - V_C}{18} = \frac{V_C - 2}{20} + \frac{V_C - 0}{12}$~~

~~$\frac{V_A - V_C}{18} = \frac{12V_C - 24 + 20V_C}{240}$~~

~~$\frac{V_A - V_C}{18} = \frac{32V_C - 24}{240}$~~ (9/3 ; 120 ; 40)

~~$40V_A - 40V_C = 96V_C - 72$~~

~~$72 = 96V_C + 40V_C - 40V_A$~~

~~$72 = 136V_C - 40V_A$~~

$V_A = x = 56.373$

$V_C = y = 17.109$

The current flow in AB Branch is

$$I_2 = \frac{V_A - 0}{20} = \frac{56.373}{20} = 2.818$$

$I_1 = I_3 + I_4$

$\frac{V_A - V_C}{18} = -2 + \frac{V_C - 0}{12}$

$\frac{V_A - V_C}{18} = \frac{-24 + V_C}{12}$

$2V_A - 2V_C = -72 + 3V_C$

$72 = 3V_C + 2V_C + 2V_A$

$72 = 5V_C - 2V_A$

$x = 69.6$

$y = 42.24$

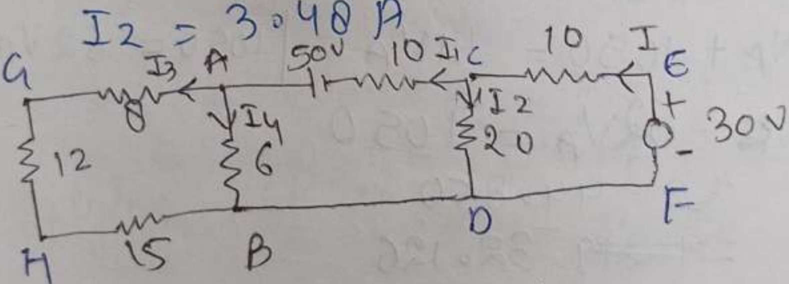
The current flow in AB Branch

$I_2 = \frac{V_A - 0}{20} = \frac{69.24}{20}$

$I_2 = \frac{69.6}{20}$

$I_2 = 3.48\ A$

Q)



Applying KCL in C Node

$I = I_1 + I_2$

$\left(\frac{30 - V_C}{10}\right) = \left(\frac{V_C + 50}{10}\right) + \left(\frac{V_C - 0}{20}\right)$

$\frac{30 - V_C}{10} = \frac{20V_C + 1000 + 10V_C}{200}$

$\frac{30 - V_C}{1} = \frac{30V_C + 1000}{20}$

$600 - 20V_C = 30V_C + 1000 - 20V_A$

$600 + 1000 = 30V_C + 20V_C - 20V_A$

$1600 = 50V_C - 20V_A$

$\frac{32\,1600}{50} = V_C$

$32 = V_C$

Applying KCL in A node

$I_1 = I_3 + I_4$

$\frac{V_C - V_A + 50}{10} = \left(\frac{V_A - 0}{35}\right) + \left(\frac{V_A - 0}{6}\right)$

$\frac{V_C - V_A + 50}{10} = \frac{6V_A + 35V_A}{210}$

$\frac{V_C - V_A + 50}{10} = \frac{41V_A}{210}$

$V_C - \frac{V_A + 50}{1} \times \frac{41V_A}{21} =$

$21V_C - 21V_A + 1050 = 41V_A$ | $1050 = 62V_A - 21V_C$

$21V_C - 62V_A = 1050$

$V_C = x = ~~32~~ \; 44.850$

$V_A = y = ~~-9.219~~ \; 32.126$

The current flow in AB Branch is

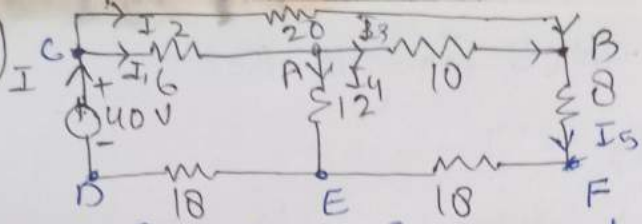
$I_4 = \left(\frac{V_A - 0}{6}\right)$

$I_4 = \frac{~~-9.219~~}{6} \quad \frac{32.126}{6}$

$\boxed{I_4 = 1.536}$ A

5.354

(Q)



Applying KCL in C node

$I = I_1 + I_2$

$\left(\frac{40 - V_C}{18}\right) = \left(\frac{V_C - V_A}{6}\right) + \left(\frac{V_C - V_B}{20}\right)$

$\frac{40 - V_C}{18} = \frac{20V_C - 20V_A + 6V_C - 6V_B}{120}$

$\frac{40 - V_C}{18} = \frac{26V_C - 20V_A - 6V_B}{120}$

$\frac{40 - V_C}{3} = \frac{26V_C - 20V_A - 6V_B}{20}$

$800 - 20V_C = 78V_C - 60V_A - 18V_B$

$800 = 78V_C + 20V_C - 60V_A - 18V_B$

$800 = 98V_C - 60V_A - 18V_B$

$2 \times 400 = 2(49V_C - 30V_A - 9V_B)$

$400 = 49V_C - 30V_A - 9V_B$ — (1)

Applying KCL in A node

$I_1 = I_3 + I_4$

$\left(\frac{V_C - V_A}{6}\right) = \left(\frac{V_A - V_B}{10}\right) + \left(\frac{V_A - 0}{12}\right)$

$\frac{V_C - V_A}{6} = \frac{12V_A - 12V_B + 10V_A}{120}$

$\frac{V_C - V_A}{1} = \frac{22V_A - 12V_B}{20}$

$20V_C - 20V_A = 22V_A - 12V_B$

$0 = 22V_A + 20V_A - 12V_B - 20V_C$

$0 = 42V_A - 12V_B - 20V_C$ — (2)

Applying KCL on B node

$I_4 + I_2 = I_5$

$$\frac{V_A - V_B}{10} + \frac{V_C - V_B}{20} = \frac{V_B - 0}{26}$$

$$\frac{20V_A - 20V_B + 10V_C - 10V_B}{200} = \frac{V_B}{26}$$

~~200~~ ~~100~~ ~~50~~ 25 ; ~~26~~ 13

$13(20V_A - 20V_B + 10V_C - 10V_B) = 100V_B$

$260V_A - 260V_B + 130V_C - 130V_B = 100V_B$

$260V_A - 390V_B + 130V_C = 100V_B$

$260V_A - 390V_B - 100V_B + 130V_C = 0$

$260V_A - 490V_B + 130V_C = 0$ — (B)

V_A x = ~~26.691~~ 10.850

V_B y = ~~17.366~~ = 10.181

V_C z = ~~16.295~~ = 16.676

the current flow in AB Branch is

$$I_S = \frac{V_A - V_B}{10}$$

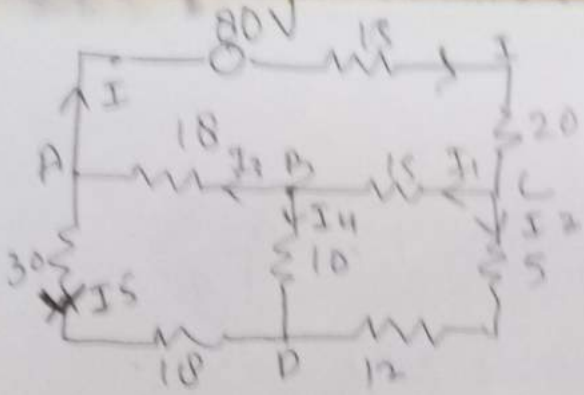
$$I_S = \frac{10.850 - 10.181}{10} = ~~\frac{17.366 - 16.295}{10} = 1.071~~$$

$$I_S = \frac{0.669}{10}$$

$I_S = 0.069$

~~$I_S = 0.1071$~~

$\frac{V_B - V_A}{10} = -0.$



applying KCL in Node C

$I = I_1 + I_2$

$$\frac{V_A - V_C + 80}{35} = \frac{V_C - V_B}{15} + \frac{V_C - 0}{17}$$

$$\frac{V_A - V_C + 80}{35_{\,7}} = \frac{17V_C - 17V_B + 15V_C}{255_{\,51}}$$

$$51V_A - 51V_C + 4080 = 119V_C - 119V_B + 105V_C$$

$$4080 = 119V_C - 119V_B + 105V_C - 51V_A + 51V_C$$

$$4080 = 224V_C - 119V_B - 51V_A + 51V_C$$

$$4080 = 275V_C - 119V_B - 51V_A$$

at Node B

$I_1 = I_3 + I_4$

$$\frac{V_C - V_B}{15} = \frac{V_B - V_A}{18} + \frac{V_B - 0}{10}$$

$$\frac{V_C - V_B}{15} = \frac{10V_B - 10V_A + 18V_B}{180_{\,12}}$$

$$12V_C - 12V_B = 28V_B - 10V_A$$

$$0 = 28V_B + 12V_B - 10V_A - 12V_C$$

$$0 = 40V_B - 10V_A - 12V_C$$

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at node A

$$I_3 = I + I_5$$

$$\frac{V_B - V_A}{18} = \frac{V_A - V_C + 80}{35} + \frac{V_A - 0}{48}$$

$$\frac{V_B - V_A}{\cancel{18}\,9} \qquad \frac{48V_A - 48V_C + 3840}{\cancel{1680}\,840}$$

$$\frac{V_B - V_A}{\cancel{18}\,9} = \frac{48V_A - 48V_C + 3840 + 35V_A}{\cancel{1680}\,840}$$

$$840V_B - 840V_A = 432V_A - 432V_C + 34560 + 315V_A$$

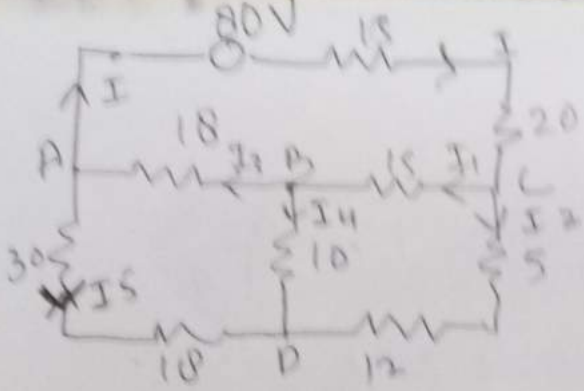
$$840V_B - 840V_A - 432V_A + 432V_C - 315V_A = 34560$$

$$840V_B - 1272V_A - 315V_A + 432V_C = 34560$$

$$840V_B - 1587V_A + 432V_C = 34560$$

$$-34560 = -840V_B + 1587V_A - 432V_C$$

$$529V_A - 280V_B - 144V_C = -11520$$



Applying KCL in Node C

$$I = I_1 + I_2$$

$$\frac{V_A - V_C + 80}{35} = \frac{V_C - V_B}{15} + \frac{V_C - 0}{17}$$

$$\frac{V_A - V_C + 80}{\cancel{35}\ 7} \Rightarrow \frac{17V_C - 17V_B + 15V_C}{\cancel{255}\ 51}$$

$$51V_A - 51V_C + 4080 = 119V_C - 119V_B + 105V_C$$

$$4080 = 119V_C - 119V_B + 105V_C - 51V_A + 51V_C$$

$$4080 = 224V_C - 119V_B - 51V_A + 51V_C$$

$$4080 = 275V_C - 119V_B - 51V_A$$

at Node B

$$I_1 = I_3 + I_4$$

$$\frac{V_C - V_B}{15} = \frac{V_B - V_A}{18} + \frac{V_B - 0}{10}$$

$$\frac{V_C - V_B}{\cancel{15}} = \frac{10V_B - 10V_A + 18V_B}{\cancel{180}\ 12}$$

$$12V_C - 12V_B = 28V_B - 10V_A$$

$$0 = 28V_B + 12V_B - 10V_A - 12V_C$$

$$0 = 40V_B - 10V_A - 12V_C$$

A

$I + I_5$

$$\frac{V_B - V_A}{18} = \frac{V_A - V_C + 80}{35} + \frac{V_A - 0}{48}$$

$$\frac{V_B - V_A}{\cancel{18}\ 9} \qquad \frac{48V_A - 48V_C + 3840}{\cancel{1680}\ 840}$$

$$\frac{V_B - V_A}{\cancel{18}\ 9} = \frac{48V_A - 48V_C + 3840}{\cancel{1680}\ 840} + 35V_A$$

$840V_B - 840V_A = 432V_A - 432V_C + 34560 + 315V_A$

$840V_B - 840V_A - 432V_A + 432V_C - 315V_A = 34560$

$840V_B - 1272V_A - 315V_A + 432V_C = 34560$

$840V_B - 1587V_A + 432V_C = 34560$

$-34560 = -840V_B + 1587V_A - 432V_C$

$529V_A - 280V_B - 144V_C = -11520$

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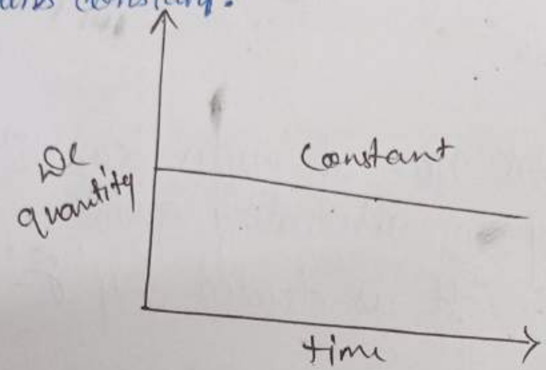
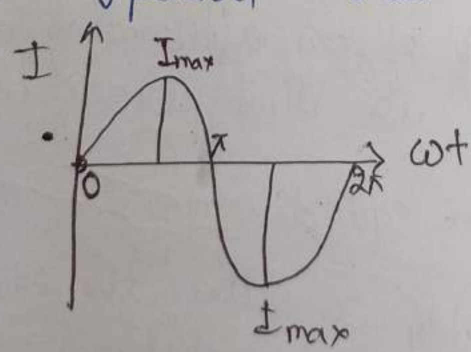
Unit 2

AC Fundamentals

1. DC Current :- The DC Current always flow in one direction and its magnitude remains constant.



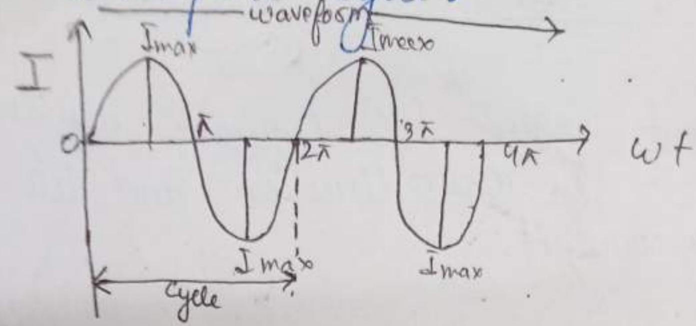
1. AC Current :- The quantity is called Alternating if reverses periodically in one direction and its magnitude undergoes are definite cycle of changes in definite interval of time. In other words the Alternating current is periodically changing current average of which over a period is Zero.



1. Terms used in AC :-

① Wave form → The shape of ~~occur~~ the curve of any alternating quantity against time is called the wave form.

When an alternating quantity goes through complete set of positive and negative values, called a complete cycle.



In India F = 50 Hz

3) **Frequency** → The total no. of cycles completed in One second by an alternating quantity is called the frequency. It is denoted by 'f' and its unit 'Hertz'

4) **Time period** → The time taken by an alternating quantity to complete in One cycle is called the time period. It is denoted by 'T' & its unit 'Second'

$$F = \frac{1}{T}$$

For example → If frequency of an alternating quantity is 10 Hz then its time period will be 0.1 sec

5) **Intentanous equ^n** → The equ^n diterming the different value of alternating quantity is called the intention.

the instention equ^n of current is

~~i = Im sin ωt~~

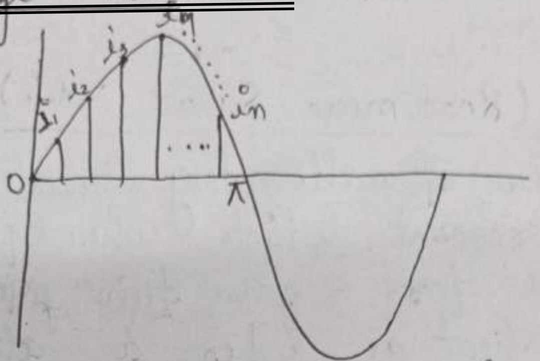
$$I = I_m \sin \omega t$$

where I = instantaneous value
I_m = maximum value
ω = angular velocity
t = time at which I is calcuted

6) Instantaneous value → The value of alternating at a given instant is intantanous value.

'I' is the Instantaneous value in the above eq.

Average value →



$$I_{avg} = \frac{i_1 + i_2 + i_3 + i_4 \cdots i_n}{n}$$

$$I_{avg} = \frac{\int_0^{\pi} I_m \sin\omega t \, d\omega t}{\pi}$$

$$I_{avg} = \frac{1}{\pi} \int_0^{\pi} I_m \sin\omega t \, d\omega t$$

$$= \frac{I_m}{\pi} \int_0^{\pi} \sin\omega t \, d\omega t$$

$$= \frac{I_m}{\pi} \left[-\cos\omega t \right]_0^{\pi}$$

applying limites

$$I_{avg} = \frac{I_m}{\pi} \left[-\cos\pi - (-\cos 0) \right]$$

$$= \frac{I_m}{\pi} \left[-(-1) - (-1) \right]$$

$$= \frac{I_m}{\pi} \left[+1 + 1 \right]$$

$$\Rightarrow \frac{I_m}{3.14} \times 2$$

$I_{avg} = 0.637 I_m$

The average value of an alternating quantity is in half cycle is 0.637 of its maximum value, The average value in full cycle is 0 (Zero)
It is diffined as the alternating current which transfers the direct current during the given time.

R.M.S Value (Root mean Square Value) →

The R.M.S value of an alternating quantity is given by that dc current which when flows for a given resistance for a given time produces the same amount of heat as when a alternating current is flowing to the same resistance for the same time. consider a circuit in which the heat develope for the time 't' is same for DC & AC show there equ^ns will –

$$H_{dc} = H_{ac}$$

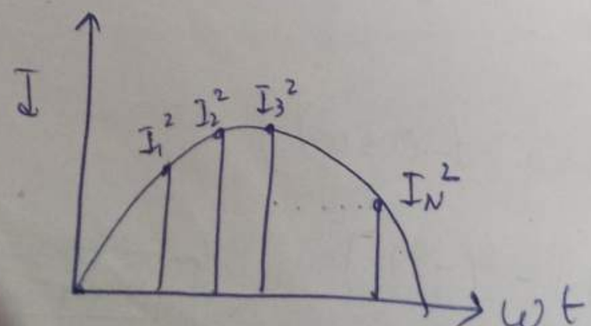
$$I^2_{dc} Rt = I^2_{ac} Rt$$

$$I^2_{dc} = I^2_{ac}$$

$$\boxed{I_{dc} = \sqrt{I^2_{ac}}}$$

For calculating RMS value

$$I_{ac}^2 = \frac{I_1^2 + I_2^2 + I_3^2 - - I_N^2}{N}$$



$$I_{ac}^2 = \frac{1}{\pi}\int_0^{\pi}(I_m \sin\omega t)^2 d\omega t$$

$$I_{ac}^2 = \frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2\omega t \, d\omega t$$

$$I_{ac}^2 = \frac{I_m^2}{\pi}\int_0^{\pi}\left(1 - \frac{\cos 2\omega t}{2}\right)d\omega t$$

$$\Rightarrow \frac{I_m^2}{\pi}\left[\frac{\omega t}{2} - \frac{\sin 2\omega t}{4}\right]_0^{\pi}$$

$$\Rightarrow \frac{I_m^2}{\pi}\left[\left(\frac{\pi}{2} - \frac{\sin 2\pi}{4}\right) - \left(\frac{0}{2} - \frac{\sin 0}{2}\right)\right]$$

$$I_{ac}^2 \Rightarrow \frac{I_m^2}{\pi}\left[\frac{\pi}{2}\right]$$

$$\boxed{I_{ac}^2 = \frac{I_m^2}{2}} \quad - (2)$$

From eqn (1) & (2)
we get

$$I_{dc} = \sqrt{\frac{I_m^2}{2}}$$

$$I_{dc} = \frac{I_m}{\sqrt{2}}$$

$$\boxed{I_{dc} = I_{Rms} = 0.707\, I_m}$$

From the above derivation we ~~conculde~~ conclude that the RMS value of an alternating quantity over half cycle is 0.707 of its maximum value.

Peak ~~Form~~ factor → The peak factor is also called crest factor. It is defined as the ratio of max. value and rms value of an alternating quantity

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It is denoted by kp and it has a constant value of 1.414 in a sinusoidal waveform

$$kp = \frac{\text{peak or max value}}{\text{rms value}} = \frac{I_m}{0.707 I_m}$$

$\sqrt{2} = 1.414$

Numerical →

① An alternating current has a instantaneous equ^n of $I = 50 \sin 377t$. Calculate ① Max. Value ② Frequency ③ time at which current occurs 30A for the I time ④ Current at $t = \frac{1}{300}$ sec.

① Comparing the both of equ^n f we get 50A

② $\omega = 377 = 2\pi f$

$377 = 2 \times 3.14 \times f$

$f = \frac{377}{2 \times 3.14} = 60.03$

⇓

60Hz

③ $i = 50 \sin 377t$

$i = 50 \sin(72.03)$

$i = 50 \times 0.95$

$i = 47.5A$

(6)

$30 = 50 \sin\left(377 \times t \frac{180}{3.14}\right)$

$\sin^{-1}\left(\frac{30}{50}\right) = \left(\frac{377 \times t \times 180}{3.14}\right)$

$36.86 = \frac{377 \times t \times 180}{3.14}$

$115.77 = 377 \times t \times 180$

$t = 1.706 \times 10^{-3}$ Sec

Form factor:- The form factor is defined as the ratio of RMS value and average value of an alternating quantity. In a sinusoidal waveform it has a constant value of 1.10 & is denoted by 'Kf'

$$K_f = \frac{\text{RMS Value}}{\text{avg. value}} = \frac{0.707 I_m}{0.637 I_m} = 1.10$$

Q. An alternating voltage has $V = 20 \sin(314t)$.
Find out (1) max. value (2) Frequency (3) Time Period (4) Average value (5) rms value (6) form factor (7) peak factor. (8) Voltage at $t = \frac{1}{500}$ sec. (9) time at which voltage reaches V = 12 Volt For the first time.

$i_m = 500$
$\omega = 314$

(1) $V_m = 20$ Volt

(2) $314 = 2\pi F$
$314 = 2 \times 3.14 F$
$\frac{314}{6.28} = f$
$F = 50$ Hz

(3) Time Period
$F = \frac{1}{T}$
$50 = \frac{1}{T}$
$T = \frac{1}{50}$
$T = 0.02$

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Average value

$I_{avg} = 0.637 I_m$

0.637×20

$I_{avg} = 12.74$

⑤ rms value

$I_{rm} = 0.707 \times I_m$

$I_{rms} = 0.707 \times 20$

$I_{rms} = 14.14$

⑥ Form factor

$K_f = \frac{\text{rms value}}{\text{Average Value}}$

$= \frac{14.14}{12.74}$

$K_f = 1.109$

⑦ peak factor

$K_p = \frac{\text{max. Value}}{\text{rms value}}$

$= \frac{20}{14.14}$

$K_p = 1.414$

⑨ Voltage at $t = \frac{1}{500}$ sec

$12 = 20 \sin(314t)$

$\sin^{-1}\left(\frac{12}{20}\right) = \frac{314 \times t \times 180}{3.14}$

$36.859 = \frac{56520\, t}{3.14}$

$36.859 \times 3.14 = 56520\, t$

$\frac{115.737}{56520} = t$

$\boxed{t = 2.047 \times 10^{-3}}$ sec

⑧ Voltage at $t = \frac{1}{500}$ sec

$V = 20 \sin\left(314 \times \frac{1}{500} \times \frac{180}{3.14}\right)$

~~$V = 20 \sin 36$~~

$V = 20 \sin\left(\frac{56520}{1570}\right)$ 36

$V = 20 \sin 36$

$V = 20 \times 0.587$

$\boxed{V = 11.74}$ Volt

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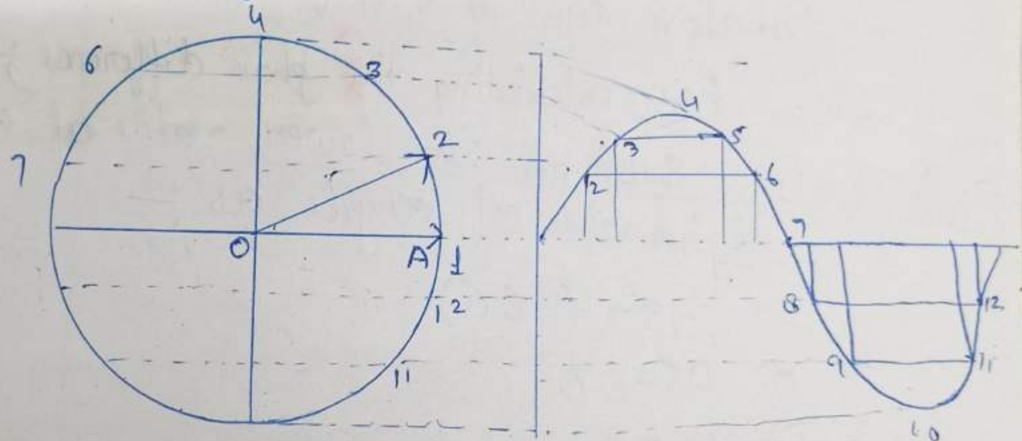
Graphical Representation of Alternating Quantity

Consider a straight line in space rotating at a speed of ω rad/sec. When this straight line completes 360° rotation in anticlock wise direction, a full cycle of a sinusoidal waveform is completed. The rotation of the straight line is analysed at every instance making a full cycle



In the above diagram, the 12 different points in circle represents the exact points in the waveform too.

Phase — The phase is defined as the fraction of the time period of any alternating quantity that has ended since the quantity has last passed through the zero position of reference.

phase angle → The angle which a phasor makes with the reference line is called phase angle

For ex → $V = V_m \sin(\omega t - 90)$
has the phase angle of 90°

Phase difference → When two or more than two have different points for their maximum values, they are said to have a phase difference. In this case, the phasor which is ahead is called leading phase and the phasor which trailing is called lagging phase.

For example → $V_1 = 10\sin(\omega t + 45)$
$V_2 = 20\sin(\omega t - 60)$

In above eqn of V_1 & V_2 both have a phase difference.

For calculating the phase difference :-

Substract the lower value of angle from higher value of angle as :-

$\Rightarrow 45^\circ - (-60^\circ)$

$\Rightarrow 45^\circ + 60^\circ$

$\Rightarrow 105^\circ$

V_1 and V_2 have a phase difference of 105°.
Also V_1 is leading phase and V_2 is lagging phase.

Zero phase difference → If two phases has their max. at exactly same points of time, they are said to be having zero phase difference or no phase difference.

For example - $V_1 = V_m\sin(\omega t + 90)$
$V_2 = V_m\sin(\omega t + 90)$

They have zero phase difference as they are in phase

phase difference $\Rightarrow 90^\circ - (+90^\circ)$

~~$90^\circ - 90^\circ$~~

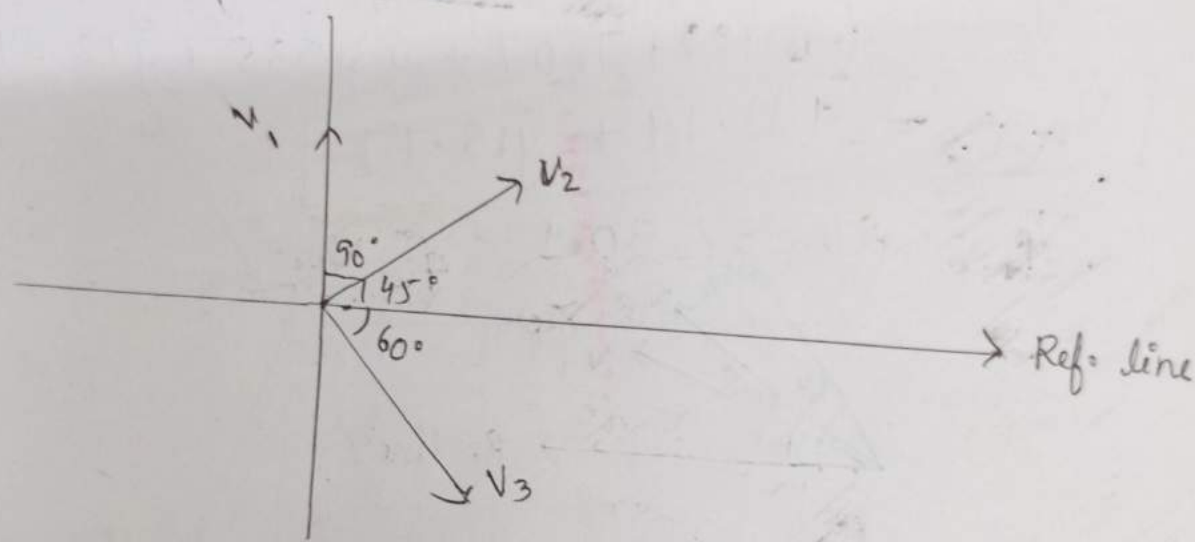
$\Rightarrow 0^\circ$

I. **Phase diagram** → The representation line considering the phase angle from reference line is phaser diagram.

For example → $V_1 = 10 \sin(\omega t + 90)$

$V_2 = 20 \sin(\omega t + 45)$

$V_3 = 30 \sin(\omega t - 60)$



II. **Representation of phasor in complex form** :–

The phasor can be represented in complex form in polar and rectangular for :–

The polar form can be written as the rms value of a phasor and its angle as :–

Polar :– $M_{rms} \angle \phi$

where M_{rms} = rms value of phasor

ϕ = phase angle.

Rectangular form can be represented in real + imaginary value of phasor :–

Rectangular :– $(a + jb)$

where, V_a = real value

Q. Determine the resultant of following

a) $V_1 = 10 \sin(\omega t + 30)$

$V_2 = 20 \sin(\omega t + 60)$

hence the phasor diagram

Polar → convert → Rectangular

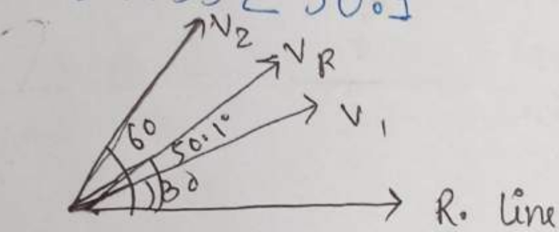
$V_1 = 7.07 \angle 30$ $\quad (6.122 + j\,3.535)$

$V_2 = 14.14 \angle 60$ $\quad (7.07 + j\,12.24)$

$V_R = (6.122 + 7.07 + j\,3.535 + j\,12.24)$

$V_{Re} = (13.19 + j\,15.77$

$V_R = 20.55 \angle 50.1$



Q. Find the Resultant and draw phasor diagram?

$V_1 = 20 \sin(\omega t - 60)$; $V_2 = 30 \sin(\omega t - 90)$

$V_3 = 100 \sin(\omega t - 45)$

Polar → convert → Rectangular

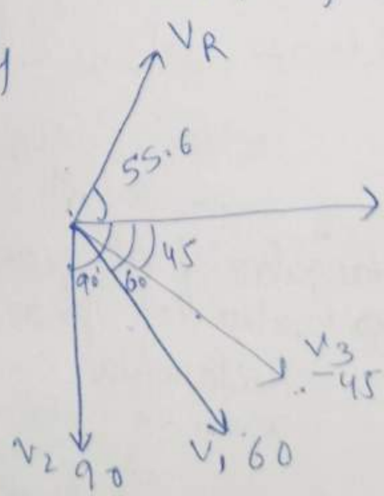
$V_1 = 14.14 \angle -60$ $\quad 7.07 + j\,12.24$

$V_2 = 21.21 \angle -90$ $\quad 0 - j\,21.21$

$V_3 = 70.07 \angle -45$ $\quad 49.99 - j\,49.99$

$V_R = 57.06 - j\,83.44$

$V_R = 101 \angle 55.6$



Q/ $I_1 = 10\sin(\omega t - 65)$; $I_2 = 25\sin(\omega t + 135)$

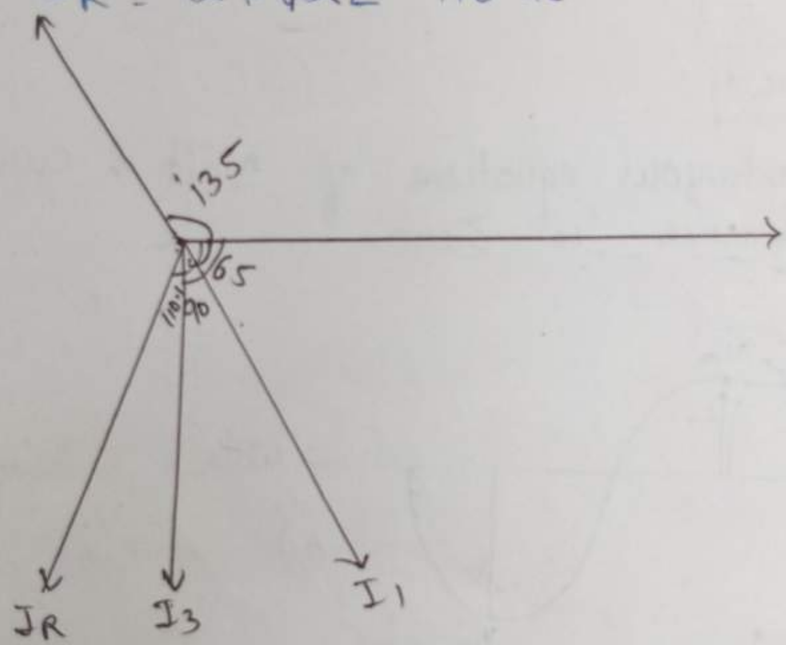
$I_3 = 45\sin(\omega t - 90)$

Polar	Rectangular
$I_1 = 7.07 \angle -65$	$2.98 - j6.40$
$I_2 = 17.67 \angle 135$	$-12.49 + j12.49$
$I_3 = 31.81 \angle -90$	$0 - j31.81$

$I_R = 2.98 - 12.49 + 0 - j6.40 + j12.49 - j31.81$

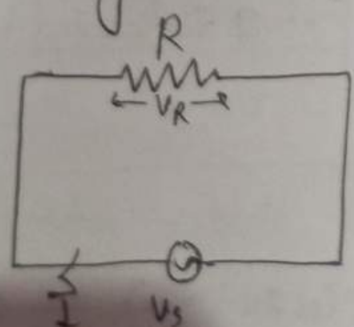
$$I_R = -9.51 - j25.72$$

$I_R = 27.42 \angle -110.2$



AC Series Circuit :-

① Purely resistive circuit →



V_s = Supply voltage (Volt)

V_R = Voltage across Resistance (Volt)

R = Resistance (ohm)

I = Current (Amp)

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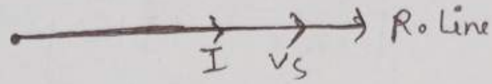
Applying KVL we get

$$V_s + V_R = 0$$

$$V_s - (IR) = 0$$

$$\boxed{V_s = IR}$$

$$V_m \sin\omega t = IR$$

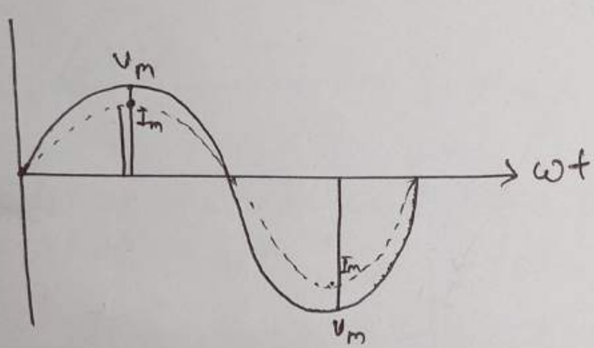


$$\frac{V_m}{R} \sin\omega t = I$$

$$I_m \sin\omega t = I$$

$$\boxed{I = I_m \sin\omega t}$$

From the instantaneous equations of Volt & current, the phase difference is Zero.



$$P = VI$$

$$P = V_m \sin\omega t \times I_m \sin\omega t$$

$$P = V_m I_m \sin^2\omega t$$

$$P = \frac{V_m I_m}{2}\left[1 - \cos 2\omega t\right] \qquad \left[\because 2\sin^2\omega t = (1 - \cos 2\omega t)\right]$$

$$P = \frac{V_m I_m}{2} - \frac{V_m I_m}{2}\cos 2\omega t$$

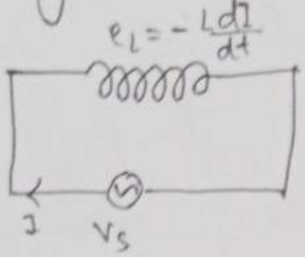
$$\boxed{P = \frac{V_m I_m}{2}}$$

{ ∵ $\cos 2\omega t$ = it has double angular velocity as that of voltage and I

$$P = \frac{V_m I_m}{\sqrt{2} \times \sqrt{2}} \Rightarrow V_{Rms} \times I_{Rms}$$

$$\boxed{P = VI}$$

Purely Inductive Circuit →



V_s = Supply voltage (Volt)
e_L = emf across coil (Volt)
L = Inductor (Henry)
I = Current (A)

Applying KVL we get

$$V_s + e_L = 0$$
$$V_s = -e_L$$
$$V_s = -\left(-L\frac{dI}{dt}\right)$$
$$V_s = L\frac{dI}{dt}$$

$$V_m \sin\omega t = L\frac{dI}{dt}$$

Integrating Both sides :-

$$\int V_m \sin\omega t = \int L\frac{dI}{dt}$$
$$V_m \int \sin\omega t = L\int\frac{dI}{dt}$$
$$-\frac{V_m}{\omega}\cos\omega t = LI$$
$$\frac{V_m}{\omega}\sin(\omega t - 90) = LI$$

$$\boxed{I = \frac{V_m}{\omega L}\sin(\omega t - 90^\circ)}$$

comparing above equ^n with equ^n of I we get

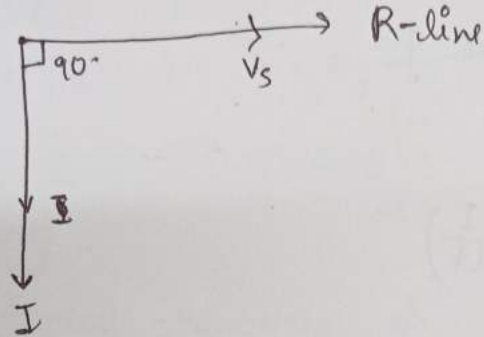
$$I_m = \frac{V_m}{\omega L}$$
$$I_m \times (\omega L) = V_m$$

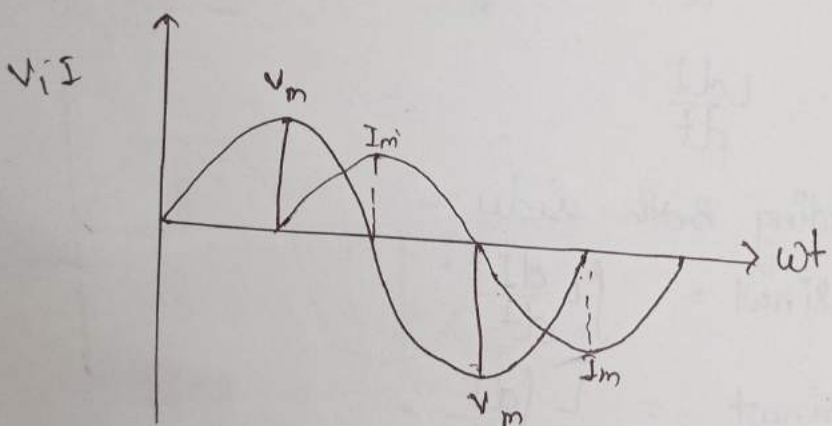
Considering above equ^n as ohm's law we get

opposition = $\omega L = 2\pi f L$

The opposition in this case is X_L which is called inductive reactance. Its unit is ohm.

$$\boxed{X_L = 2\pi f L}$$





$P = VI$

$= V_m \sin\omega t \times I_m \sin(\omega t - 90)$

$= V_m I_m \sin\omega t \times \sin(\omega t - 90^\circ)$

$= -V_m I_m \sin\omega t \cos\omega t$

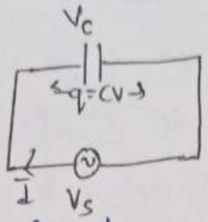
$= -\frac{V_m I_m}{2} \times 2\sin\omega t \cos\omega t$

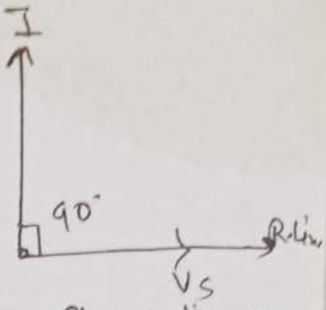
$= -\frac{V_m I_m}{2} \times \sin 2\omega t$ $\quad \{\because \sin 2\omega t \Rightarrow 2\sin\omega t \cos\omega t\}$

$$\boxed{P = 0}$$

[$\sin 2\omega t$ is the value of double angular frequency]

Purely capacitive circuit





Phasor diagram

The charge stored across the capacitor

$$q = CV \quad \text{--- (1)}$$

and from the definition of current

$$I = \frac{dq}{dt} \quad \text{--- (2)}$$

from eqn (1) & (2)

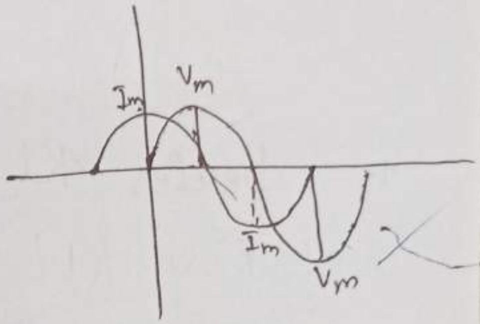
$$I = \frac{d(CV)}{dt}$$

$$I = C\frac{d(V_m \sin \omega t)}{dt}$$

$$I = CV_m \frac{d \sin \omega t}{dt}$$

$$I = CV_m\omega \cos \omega t$$

$$I = CV_m\omega \sin(\omega t + 90°)$$



wave forms

From the instantaneous eqn of Voltage and current, the current is leading the voltage by 90°.
If we compare the above eqn with the instantaneous eqn of current we get that

$$I_m = V_m \times \omega C$$

considering the above eqn ohm's law we get

$$\frac{I_m}{\omega C} = V_m \quad \text{or} \quad V_m = I_m \times \left(\frac{1}{\omega C}\right)$$

The opposition in this is X_C which is called Capacitive reactans. Its unit is ohm

$$X_C = \frac{1}{\omega C} \quad \text{or} \quad X_C = \frac{1}{2\pi f C}$$

$$P = VI$$

$$P = V_m \sin\omega t \times I_m \sin(\omega t + 90)$$

$$P = V_m I_m \sin\omega t \times \sin(\omega t + 90)$$

$$P = V_m I_m \sin\omega t \cos\omega t$$

$$P = \frac{V_m I_m}{2} \times 2 \sin\omega t \cos\omega t$$

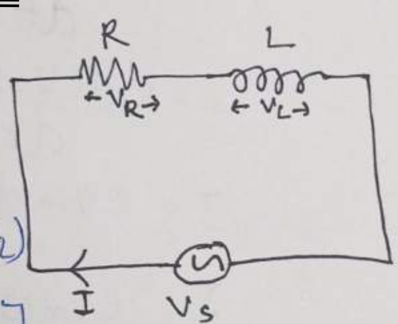
$$P = \frac{V_m I_m}{2} \times \sin 2\omega t$$

$$\boxed{P = 0}$$

∵ sin2ωt is the value of double angular frequency.

4. <u>Series RL circuit</u>

Applying KVL we get

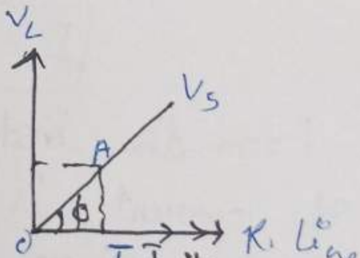


$$V_S = V_R + V_L$$

$$I \times (\text{opposition}) = (IR) + (IX_L)$$

$$I \times (\text{opposition}) = I[R + X_L]$$

$$\boxed{\text{opposition} = R + X_L}$$



In triangle OAT, using paithagoras theorem, we get

$$OA^2 = OT^2 + AT^2$$

$$V_S^2 = V_R^2 + V_L^2$$

$$I^2 \times (\text{opposition})^2 = (IR)^2 + (I \times X_L)^2$$

$$(\text{opposition})^2 = R^2 + (X_L)^2$$

$$\boxed{\text{opposition} = \sqrt{R^2 + X_L^2}}$$

= use this formula at the time of numerical the opposition in an ϕ RL circuit is called ~~the opposition~~ impediance. It is denoted by Z and its unit is 'ohm'. So the equⁿ become

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

Power calculation—

$$P = V \times I$$

$$P = V_m \sin\omega t \times I_m \sin(\omega t - \phi)$$

$$P = V_m I_m \sin\omega t \times \sin(\omega t - \phi)$$

$$P = \frac{V_m I_m}{2} \times [2\sin\omega t \sin(\omega t - \phi)]$$

$$P = \frac{V_m I_m}{2}[\cos(\omega t - \omega t + \phi) + \cos(\omega t + \omega t - \phi)]$$

$\because$ [If $\omega t = A$
$\omega t - \phi = B$ Then
$2\sin(A)\sin(B) = \cos(A-B) + \cos(A+B)$]

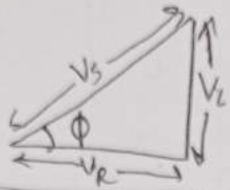
~~$P = \frac{V_m I_m}{2}[\sin\phi + \sin(2\omega t - \phi)]$~~

$$P = \frac{V_m I_m}{2}[\cos\phi + \cos(2\omega t - \phi)]$$

$$P = \frac{V_m I_m}{2}[\cos\phi]$$

$$\boxed{P = VI\cos\phi}$$

Voltage triangle :- The triangle determining the values of voltages is called the Voltage triangle.



$$\boxed{V_S^2 = V_R^2 + V_L^2}$$

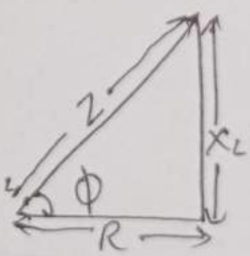
$$\sin\phi = \frac{V_L}{V_S}$$

$$\cos\phi = \frac{V_R}{V_S}$$

$$\tan\phi = \frac{V_L}{V_R}$$

Impedance triangle → The right angle triangle determining the different values of opposition is called the impedance triangle.

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



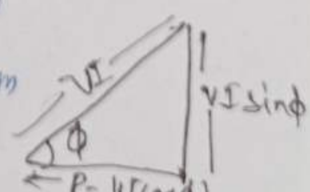
$$\sin\phi = \frac{X_L}{Z}$$

$$\cos\phi = \frac{R}{Z}$$

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

Power triangle → From the formula of power $P = VI\cos\phi$, we can write $P/VI = \cos\phi$. Using these value in the triangle we get.

It is determined using Pythagoras theorem



$$(VI)^2 = (VI\cos\phi)^2 + n^2$$

$$n^2 = VI^2 - (VI\cos\phi)^2$$

$$n^2 = VI^2[1 - \cos^2\phi)$$

$$n^2 = VI^2(\sin^2\phi)$$

$$\boxed{n = VI\sin\phi}$$

$$\sin\phi = \frac{VI\sin\phi}{VI}$$

$$\cos\phi = P/VI$$

$$\tan\phi = \frac{VI\sin\phi}{VI\cos\phi}$$

The above triangle is called [illegible] because it determines the [illegible] of power in a series circuit.

There are three types of power which can be analysied from the power triangle.

(i) **Active power** → The total useful power of the system is called the active power. it is also called Real power, true power and total power. It is denoted by 'P' and as given as.

$$P = VI\cos\phi$$

Its unit is 'Watt' or 'Kilowatt'.

(ii) **Reactive power** → The reactive power the product of voltage, current and phase angle sinϕ. It is denoted by 'Q' and its unit is volt ampere reactive or Kilovolt amphere reactive (VAR or KVAR). It is the unusefull power of the system.

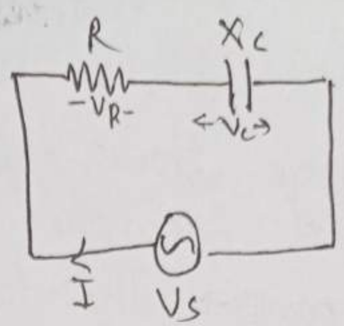
$$Q = VI\sin\phi$$

(iii) **Apperent power** → The apperent power is the sum of active & reactive power. It is denoted by 'S' & is the product of voltage & current & its unit is Volt amphere or Kilovolt amp. (VA or KVA

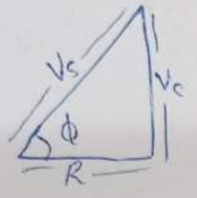
$$S = VI$$

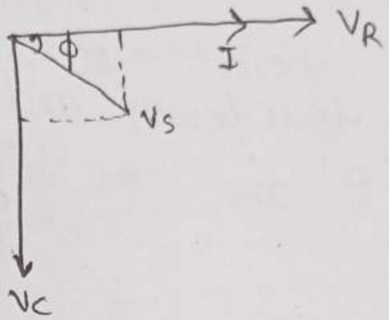
Series RC circuit :-

Diagram of circuit is above.



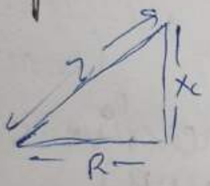
① Voltage triangle





$$V_S^2 = V_R^2 + V_C^2$$

② Impedence triangle



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

③ Power calculation :-

$$P = VI$$

$$P = V_m \sin\omega t \times I_m \sin(\omega t + \phi)$$

$$P = V_m I_m \sin\omega t \sin(\omega t + \phi)$$

$$P = \frac{V_m I_m}{2} 2\sin\omega t \sin(\omega t + \phi)$$

$$P = \frac{V_m I_m}{2}\left[\cos(\omega t - \omega t - \phi) - \cos(\omega t + \omega t + \phi)\right]$$

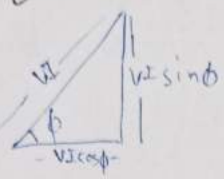
$$P = \frac{V_m I_m}{2}\left[\cos(-\phi)\right]$$

$$P = \frac{V_m I_m}{2}\left[\cos\phi\right]$$

$$P = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} \times \cos\phi$$

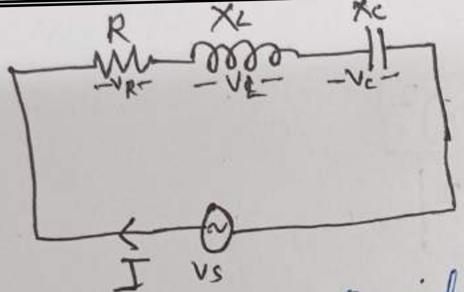
∵ if $\omega t = A$ & $(\omega t + \phi) = B$
then $2\sin A \sin B = \cos(A-B) - \cos(A+B)$

Power triangle



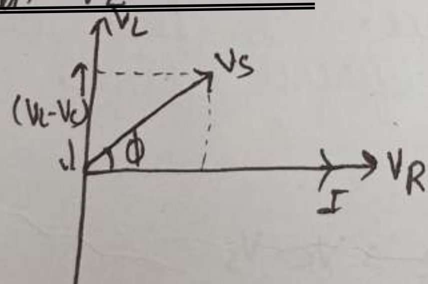
The different power in RC circuit are same as that in series RL circuit which are explained in RL circuit

Series RLC circuit



The series RLC circuit can be explained in three different types

(a) When $V_L > V_C$



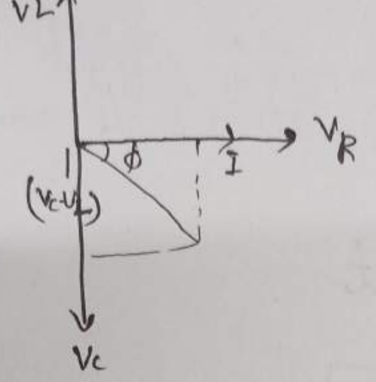
When V_L will be greater than V_C, the value of V_L will dominate the phasor and it will be drawn above the reference line.

$$V_S^2 = V_R^2 + (V_L - V_C)^2$$

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

b) When $V_L < V_C$

In this case the value of V_C will dominate the phasor of it will be drawn below the reference line.

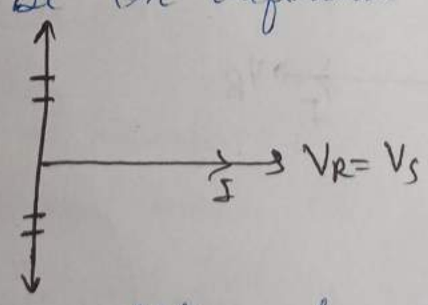


$$V_S^2 = V_R^2 + (V_C - V_L)^2$$

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

c) When $V_L = V_C$

The condition of series RLC circuit when V_L will be equal to V_C, is called the condition of resonance. In this case the phasor will be on reference line.



The different condition of resonance are as follows.

(1) At resonance the voltage across inductor is equal to the voltage across capacitor

$$V_L = V_C$$

2. The inductive reactance at resonance equal to capacitive reactance

$$X_L = X_C$$

3. The phase angle b/w voltage will be zero degree.

4. The power factor at resonance will be unity

$$\cos\phi = 1$$

5. The impedence at resonance is equal to the resistance.

6. The current at resonance is max.

Power Factor

The power factor is defined as the cosign of the angle b/w supply voltage and current. In other words, its deffined as the ratio of resistance and total impedence of the circuit.

$$\cos\phi = \frac{R}{Z}$$

The range of power factor is zero to one (0 to 1)

Resonant frequency → At resonance

$$V_L = V_C$$

$$I X_L = I X_C$$

$$X_L = X_C$$

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

$$f^2 = \frac{1}{(2\pi)^2 \times L \times C}$$

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

where f = resonant frequency
L = inductor (in henry)
C = Capacitor (in Farad)

The alternating quantity at resonant are represented as zero at there suffics.

Q// In a series circuit, $V = 100\sin(\omega t + 60°)$ & $I = 20\sin(\omega t + 15)$ determine the nature of the circuit and calculate impendence, power factor & resistance.

Since the phase angle between voltage & current is

$$\phi = 60 - 45$$

$$\phi = 45°,$$

and the voltage is leading, the nature of the circuit is RL circuit.

① When $V = 100$

$I = 20$

then

$$V = IZ$$

$$Z = \frac{100}{20}$$

$$\boxed{Z = 5\Omega}$$

② Power factor

$$\cos\phi = \cos 45°$$

$$\boxed{\cos\phi = 0.707}$$

③ Resistance

× $V = IR$

$$R = \frac{V}{I} = \frac{100}{20}$$

$$\boxed{R = 5\Omega}$$

✓ $$\cos\phi = \frac{R}{Z}$$

$$R = 0.707 \times 5$$

[illegible]

$$\boxed{R = 3.535\Omega}$$

Q (The values) of voltage and current in a series circuit are $V = 80\sin(\omega t - 45°)$ &
$I = 10\sin(\omega t - 30)$.
Calculate the value of impendence, resistance & power factor & nature of the circuit.

∵ The phase angle b/w voltage & current

$\phi = -45 - (-30)$

$\phi = -45 + 30$

$\boxed{\phi = -15}$

① Impendence

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

$\frac{80}{10} = Z$

$\boxed{Z = 8}\ \Omega$

② resistance

$R = 0.965 \times 8$

$\boxed{R = 7.727}\ \Omega$

③ power factor

$\cos\phi = \cos -15$

$\boxed{\cos\phi = 0.9659}$

④ The nature of the circuit is the current is leading so nature of circuit is RC

Q If $V = 50\sin(\omega t)$ &
$I = 5\sin(\omega t - 60)$

then calculate Z, R, X (Reactance), $\cos\phi$, P, & nature of circuit

∵ The phase angle b/w voltage & current

$\phi = 0 - (-60)$

$\boxed{\phi = 60}$

① $Z = \frac{V}{I}$

$Z = \frac{50}{5}$

$\boxed{Z = 10}$

② $R = \cos\phi \times Z$

$= 0.5 \times 10$

$\boxed{R = 5}$

③ $\cos\phi = \cos 60$

$\boxed{\cos\phi = 0.5}$

(4) $P = VI\cos\phi$

$= ~~80 \times 10 \times 0.5~~$ $= 50 \times 5 \times 0.5$

$= 250 \times 0.5$

~~P = 400~~

$\boxed{P = 125}$

(5) The voltage is leading, the nature of the circuit is RL circuit

(6) $X_L = ~~2\pi f~~ L$

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

$X_L = \sin 60 \times 10$

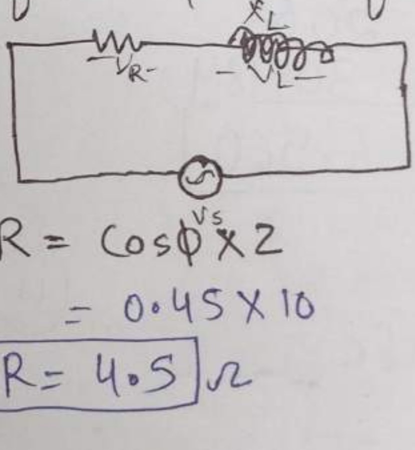
$X_L = 0.8660$

$\boxed{X_L = 8.660}$

Q If the supply voltage in a RL circuit is 100 Volt and the impedence given by 10ohm. Find the current, Resistance, Inductance and power consumed if the power factor is 0.45.

$V = 100V$

$Z = 10$



(1) $V_S = IZ$

$\frac{100}{10} = I$

$\boxed{I = 10}$ A

(2) $R = \cos\phi \times Z$

$= 0.45 \times 10$

$\boxed{R = 4.5}\ \Omega$

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

$(10)^2 = (4.5)^2 + (X_L)^2$

$100 = 20.5 + X_L^2$

$79.5 = X_L^2$

$X_L = \sqrt{79.5}$

$\boxed{X_L = 8.93}\ \Omega$

$X_L = 2\pi f L$

$\frac{8.93}{2 \times 3.14 \times 50} = L$

$\frac{8.93}{6.28 \times 50} = L$

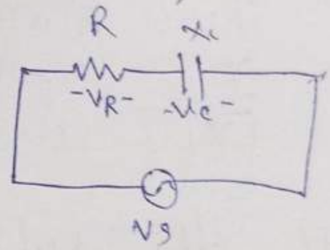
$\boxed{L = 0.028}$ Henry

$P = VI\cos\phi$

$= 100 \times 10 \times 0.45$

$\boxed{P = 450}$ Watt / 0.45 KW

Qn If the resistance and capacitance of a series circuit are 1.5 ohm and 120uF connected across a supply voltage of 700 Volt, 50 Hz then find out current, Impendence, Power factor, Power consumed & Volt Amp reactive.



$R = 15\Omega$

$C = 120\mu F$

$V = 200V$

$F = 50 Hz$

$X_c = ?$

(1) $I = \frac{V_s}{Z}$

$I = \frac{200}{30.484}$

$\boxed{I = 6.560}$

(2) $Z = \sqrt{R^2 + (X_c)^2}$

$Z = \sqrt{(15)^2 + (26.539)}$

$Z = \sqrt{225 + 704.325}$

$Z = \sqrt{929.325}$

$\boxed{Z = 30.484}$

(3) $X_c = \frac{1}{2\pi f c}$

$X_c = \frac{1}{2 \times 3.14 \times 50}$

$\boxed{X_c = 26.539}$

(4) $P = VI\cos\phi$

$P = 200 \times 6.560 \times \cos -15$

$P = 200 \times 6.560 \times 0.9659$

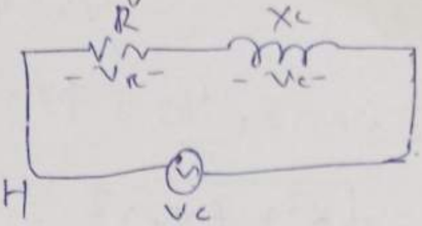
$\boxed{P = 1267.2608}$

(5) $\cos\phi = \cos -15$

$\boxed{\cos\phi = 0.9659}$

$Q = VI\sin\phi$

For a series circuit voltage is given by 200 Volt and it connected across ~~and Is~~ ~~given to be~~ resistance of 10Ω & Inductance of 5mH. Calculate the total impedence, current induced, power factor and total power of circuit



$V = 200V$
$R = 10\Omega$
$L = 5mH = 5 \times 10^{-3} H$

~~$Z = \frac{V_S}{I}$~~

~~$Z = \frac{200}{5 \times 10^{-3}}$~~

$X_L = 2\pi F L$
$X_L = 2 \times 3.14 \times 50 \times 5 \times 10^{-3}$
$X_L = 1.57$

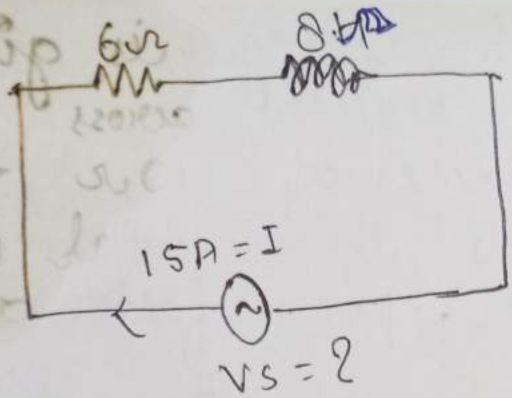
① $Z = \sqrt{(10)^2 + (X_L)^2}$
$Z = \sqrt{100 + 2.464}$
$Z = \sqrt{102.464}$
$Z = 10.122\,\Omega$

② Current induced
$I = \frac{V_S}{Z}$
$I = \frac{200}{10.122}$
$I = 19.758\,A$

③ Power factor
$\cos\phi = \frac{R}{Z}$
$\cos\phi = \frac{10}{10.122}$
~~$\cos\phi = 0.506$~~
$\cos\phi = 0.98$

④ Total power of circuit
$P = VI\cos\phi$
$P = 200 \times 19.758 \times 0.506$
~~$P = 1999.509\,W$~~
$P = 3872.568\,W$

$P = VI\sin\phi$
$P = 200 \times 19.758 \times 0.160$
$P = 632.256\,W$



Z, cos φ, Vs, power, phase angle, inductor?

$X_L = 2\pi f L$

$X_L = 2 \times 3.14 \times 50 \times 8$

$X_L = 2512$

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

$Z = \sqrt{(6)^2 + (2512)^2}$

$Z = \sqrt{36 + 6310144}$

$Z = \sqrt{6310180}$

$\boxed{Z = 2512.01}\ \Omega$

2) $\cos\phi = \frac{R}{Z}$

$\cos\phi = \frac{6}{2512.01}$

$\boxed{\cos\phi = 2.388 \times 10^{-3}}$

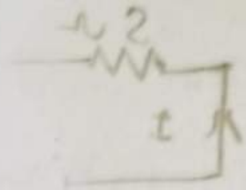
Power $= VI\cos\phi$

$= 37680.15 \times 15 \times 2.388 \times 10^{-3}$

$V_s = I \times Z$

$V_s = 15 \times 2512.01$

$\boxed{V_s = 37680.15}$



$R = 8$

(1) $Z = \sqrt{(6)^2 + (8)^2}$

$Z = \sqrt{36 + 64}$

$Z = \sqrt{100}$

$\boxed{Z = 10}$

(2) $\cos\phi = \frac{R}{Z}$

$\cos\phi = \frac{6}{10}$

$\boxed{\cos\phi = 0.6}$

(3) $P = VI\cos\phi$

$= 150 \times 15 \times 0.6$

$\boxed{P = 1350}$

(4) $V_s = I \times Z$

$V_s = 15 \times 10$

$V_s = 150$

(5) Phase angle

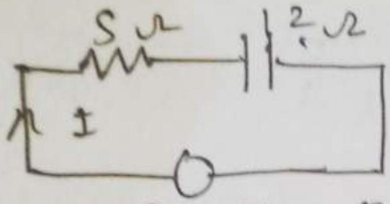
$\phi = 0.6 \cos^{-1}$

$\boxed{\phi = 53.130}$

(6) $\frac{X_L}{2\pi F} = L$

$\frac{8}{2 \times 3.14 \times 50} = 6$

$\boxed{L = 0.025}$ H



220V , 50Hz

I, Z, cos ϕ, capacitor, apparent power

① $I = \frac{V_s}{Z}$

$I = \frac{220}{13.37}$

$I = 16.454$

② $Z = \sqrt{(5)^2 + (12)^2}$

$Z = \sqrt{25 + 144}$

$Z = \sqrt{179}$

$Z = 13.37$

③ $\cos\phi = \frac{R}{Z}$

$\cos\phi = \frac{5}{13.37}$

$\cos\phi = 0.373$

④ $X_c = \frac{1}{2\pi f C}$

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

$C = 2.653 \times 10^{-4}$

⑤ $S = VI$

$S = 220 \times 16.454$

$S = 3619$

Q if $V = 150 \sin(\omega t - 60)$
$I = 15 \sin(\omega t + 30)$
the find Z, Reactance (X_L or X_C), cos ϕ, Resistance

the phase difference in Voltage and current

$\phi = -60 - (+30)$ $\phi = 30 - (-60)$
$-60 - 30$ $\boxed{\phi = 90}$
$\boxed{\phi = +90}$

$\cos\phi = \cos + 90$
$\boxed{\cos\phi = 0}$

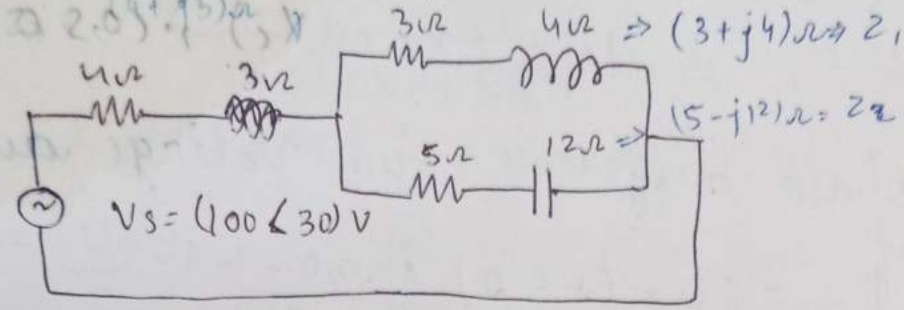
$\cos\phi = \frac{R}{Z}$
$0 \times 10 = R$
$\boxed{R = 0}$

$Z = \frac{V_s}{I}$
$Z = \frac{150}{15}$
$\boxed{Z = 10}\ \Omega$

$Z = \sqrt{R^2 + X_C^2}$
$Z^2 = R^2 + X_C^2$
$(10)^2 = (0)^2 + X_C^2$
$100 = X_C^2$
$X_C = \sqrt{100}$
$\boxed{X_C = 10}$

Since the current leads the voltage by 90° this circuit is purely capacitive

11 Series and series / Parallel circuits.



Calculate total Impedance, current and cos ϕ

$$\frac{(3+j4)(5-j12)}{(3+j4)+(5-j12)} \Rightarrow \frac{(5\angle 53.13)(13\angle -67.38)}{3+j4+5-j12}$$

$$\Rightarrow \frac{(5\angle 53.13)(13\angle -67.38)}{(8-j8)} \Rightarrow \frac{65\angle -14.25}{8-j8}$$

$$\Rightarrow \left(\frac{65\angle -14.25}{11.31\angle -45}\right) + (4+j3)$$

$$\Rightarrow (~~5.72\angle 30.75) + (4+j3~~)$$

$$Z = (4.91 + j2.92) + (4+j3)$$

$$\boxed{Z = 8.91 + j5.92}$$ In Rectangular

$$\boxed{Z = 10.697\angle 33.60}$$ In polar

Now for current

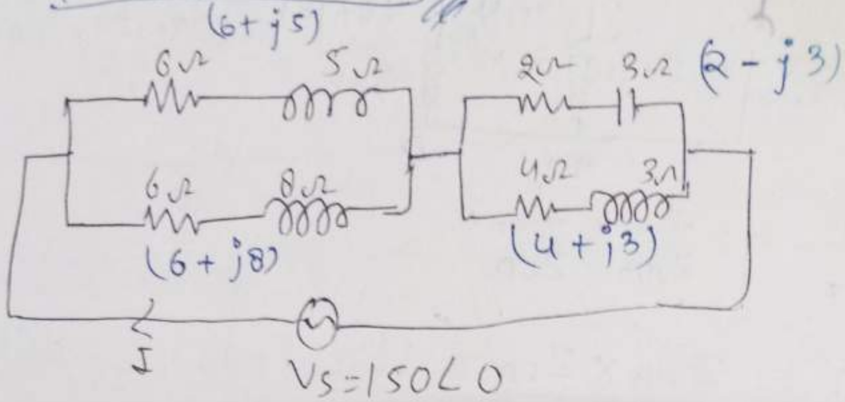
$$V_s = IZ$$

$$\frac{100\angle 30}{10.697\angle 33.60} = I$$

$$\boxed{I = 9.348\angle -3.60}$$

$\cos\phi = \cos 33.60$

$\boxed{\cos\phi \;\; 0.832}$



$Z, I, \cos\phi$

$$\frac{(6+j5)(6+j8)}{(6+j5)+(6+j8)} + \frac{(2-j3)(4+j3)}{(2-j3)+(4+j3)}$$

$$\frac{(7.81\angle 39.805)(10\angle 53.130)}{(12+j12)} + \frac{(3.60\angle -56.30)(5\angle 36.869)}{(6+j0)}$$

~~11.73 ∠ 2.049~~

$$\left(\frac{78.1\angle -13.325}{16.97\angle 45}\right) + \left(\frac{18\angle -93.169}{6\angle 0}\right)$$

$$(4.621\angle -58.325) + (3\angle -93.16)$$

$7.62\angle$

$$(2.42 - j3.932) + (-0.165 - j2.99)$$

$\boxed{Z = 2.255 - j6.92}$

$\boxed{Z = 7.27\angle 71.98}$

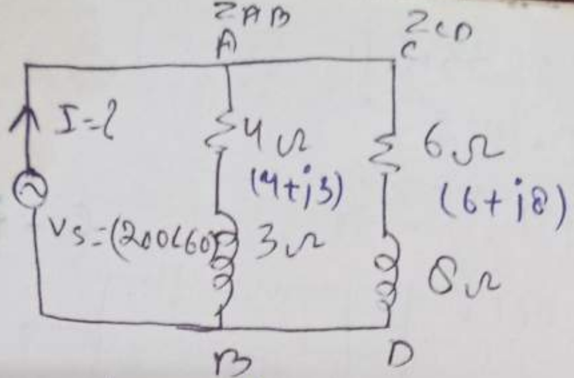
$\cos\phi = \cos 71.98$

$\boxed{\cos\phi = 0.309}$

$$I = \frac{150\angle 0}{7.27\angle 71.98}$$

$\boxed{I = 20.6\angle -71.98}$

Q



Calculate total impedance, total current, cos ϕ

$$\frac{1}{Z_T} = \frac{1}{Z_{AB}} + \frac{1}{Z_{CD}}$$

$\cos\phi = \frac{R}{Z}$

$$Z_T = \frac{Z_{AB} \times Z_{CD}}{Z_{AB} + Z_{CD}}$$

$$Z_T = \frac{(4+j3)(6+j8)}{(4+j3)+(6+j8)} = \frac{(5\angle 36.86)(10\angle 53.13)}{(10+j11)}$$

$$Z_T = \frac{50\angle +90}{(14.866\angle 47.72)}$$

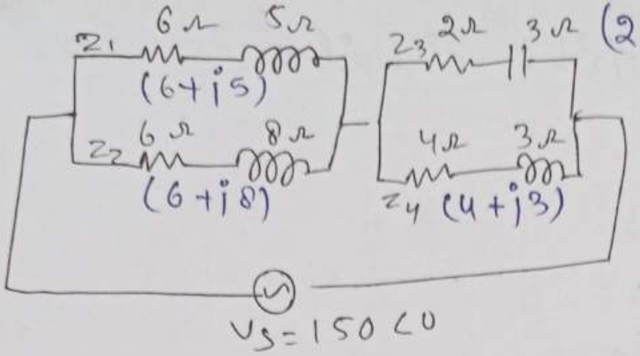
$$\boxed{Z_T = 3.36\angle +42.28} \quad \boxed{Z_T = 2.488 + j2.263}$$

$$I = \frac{V}{Z} = \frac{200\angle 60}{3.36\angle 42.28}$$

$$\boxed{I = 59.52\angle 17.72} \text{ A}$$

$$\cos\phi = \cos 42.28$$

$$\boxed{\cos\phi = 0.739}$$



Resonance in ... at resonance

Z, I, $\cos\phi$?

$$\frac{Z_1 \times Z_2}{Z_1 + Z_2} = \frac{(6+j5)(6+j8)}{(6+j5)+(6+j8)} = \frac{(7.81\angle 39.80)(10\angle 53.13)}{12+j13}$$

$$= \frac{78.1\angle 92.93}{12+j13} = \frac{78.1\angle 92.93}{17.69\angle 47.29}$$

$$\boxed{Z' = 4.41\angle 45.64}$$

$$\frac{Z_3 \times Z_4}{Z_3 + Z_4} = \frac{(2-j3)(4+j3)}{(2-j3)+(4+j3)} = \frac{(3.60\angle -56.30)(5\angle 36.86)}{6}$$

$$= \frac{18\angle -19.44}{6\angle 0} = 3\angle -19.44$$

$$\boxed{Z'' = 3\angle -19.44}$$

$$Z' + Z'' = (4.41\angle 45.64) + (3\angle -19.44)$$

$$(3.08 + j3.15) + (2.82 - j0.99)$$

$$\boxed{Z' + Z'' = 5.90 + j2.16} \quad = 6.27\angle 20.13$$

$V = I \times Z$

$$I = \frac{150\angle 0}{6.27\angle 20.13} = \frac{150\angle 0}{(6.27\angle 20.13)}$$

$$\boxed{I = 23.92\angle 20.13}$$

$$\cos\phi = \cos 20.13$$
$$= 0.938$$

Resonance in Series RLC circuit

At resonance $\boxed{V_L = V_C}$

$$I X_L = I X_C$$

$$\boxed{X_L = X_C}$$

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

$$f^2 = \frac{1}{(2\pi L)(2\pi C)}$$

$$f = \sqrt{\frac{1}{4\pi^2 LC}}$$

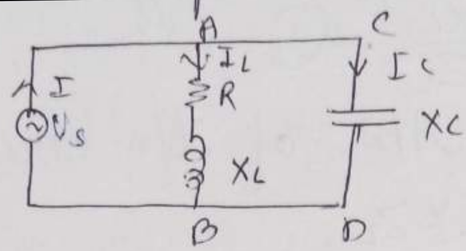
$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}}$$

Where, f_0 = resonant frequency in hertz

L = Inductor in henry

C = Capacitor in farad

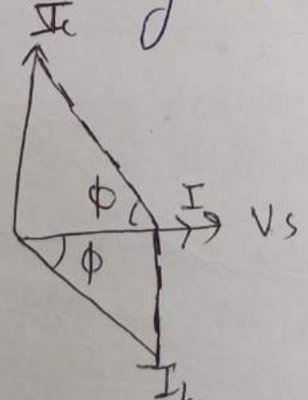
11. Resonance in parallel RLC circuit



Consider an RLC circuit in which a coil is connected in (||P) with the capacitor across the supply voltage 'V_s'. The value in the coil are 'R' & 'X_L' and capacitive reactance in the capacitor. The current across the coil is 'I_L' and the current across the capacitor is 'I_C'.

For the condition of resonance, the face angle b/w supply voltage 'V_s' must be zero degree (0°) with the current.

So drawing the phasor we get



From the above triangle

$$\sin\phi = \frac{I_C}{I_L} \quad \text{--- (1)}$$

$\frac{P}{H}$

From the impedence triangle of RL circuit

$$\sin\phi = \frac{X_L}{Z} \quad \text{--- (2)}$$

equating both the eqn, We get

$$\frac{I_C}{I_L} = \frac{X_L}{Z_L} \quad \text{— (3)}$$

From the branch AB of the circuit

$$V_S = I_L \times Z_L$$

$$\boxed{\frac{V_S}{Z_L} = I_L} \quad \text{— (a)}$$

From the Branch CD

$$V_S = I_C \times X_C$$

$$\boxed{\frac{V_S}{X_C} = I_C} \quad \text{— (b)}$$

Putting the eqn of 'a' & 'b' in the eqn (3)

$$\frac{\frac{V_S}{X_C}}{\frac{V_S}{Z_L}} = \frac{X_L}{Z_L}$$

$$\frac{V_S \times Z_L}{X_C \times V_S} = \frac{X_L}{Z_L}$$

$$\frac{Z_L}{X_C} = \frac{X_L}{Z_L}$$

$$Z_L^2 = X_L X_C$$

$$Z_L^2 = 2\pi f L \times \frac{1}{2\pi f C}$$

$$Z_L^2 = \frac{L}{C}$$

$$(R^2 + X_L^2) = \frac{L}{C}$$

$$X_L^2 = \frac{L}{C} - R^2$$

$$(2\pi f L)^2 = \frac{L}{C} - R^2$$

$$(2\pi)^2 \times f^2 \times L^2 = \frac{L}{C} - R^2$$

$$(2\pi)^2 \times f^2 = \frac{L}{L^2 C} - \frac{R^2}{L^2}$$

$$(2\pi)^2 \times f^2 = \left(\frac{1}{LC} - \frac{R^2}{L^2}\right)$$

$$f^2 = \left(\frac{1}{2\pi}\right)^2 \times \left(\frac{1}{LC} - \frac{R^2}{L^2}\right)$$

$$\boxed{f = \frac{1}{2\pi}\sqrt{\left(\frac{1}{LC} - \frac{R^2}{L^2}\right)}}$$

Since the value of resistance is very small as compared to inductor so, its square can be neglected.

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}}$$

The above eqn is the resonant frequency for parallel RLC circuit.

The resonant frequency for series and parallel RLC circuit is same or equal.

Dynamic Impedence - The total impedence of parallel RLC circuit including R, X_L and X_C is called the Dynamic Impedence.

From the above phasor diagram

$$\tan\phi = \frac{I_C}{I}$$

From the impedence triangle

$$\frac{X_L}{R} = \frac{\frac{V_S}{X_C}}{\frac{V_S}{Z_{Total}}}$$

$$\frac{X_L}{R} = \frac{Z_{Total}}{X_C}$$

$$\frac{X_L X_C}{R} = Z_{Total}$$

$$\frac{2\pi f L \times \frac{1}{2\pi f C}}{R} = Z_{Total}$$

$$\frac{\frac{L}{C}}{R} = Z_{Total}$$

$$\frac{L}{R \times C} = Z_{Total}$$

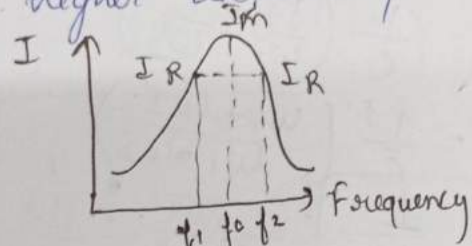
$$\boxed{Z_{tot.} = \frac{L}{CR}}$$

where L = inductor
C = Capacitor
R = Resistance

Resonance curve →

The Resonance curve is drawn b/w current & frequency of the series circuit. The current varies inversely with the variation of and So it is max. at resonance We need to have a sharp curve which is drawn with a lower value resistance.

The sharpness of the curve is deffine in terms of selectivity. A Lower value of resistance have a higher selectivity.



In the above diagram f_1 is the lower cutoff frequency & f_2 is the upper cutoff frequency & these frequency, the current riches at its RMS values the points at which F_1 & F_2 are attend are called cut off point.

At these points the power is half of the resonant value so these points are also called half power of points and frequency are called half power frequency

$$I_{Rms} = I_m(0.707)$$

$$I_{Rms} = \frac{I_m}{\sqrt{2}}$$

$$\frac{V_S}{Z} = \frac{V_S}{R(\sqrt{2})}$$

$$Z = R\sqrt{2}$$

$$R^2 + (X_L - X_C)^2 = R^2 \times 2$$

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

$$(X_L - X_C) = \pm R$$

$$\left(\omega L - \frac{1}{\omega C}\right) = \pm R$$

$$\omega_1 L - \frac{1}{\omega_1 C} = -R \quad \text{—} \ (1)$$

$$\omega_2 L - \frac{1}{\omega_2 C} = +R \quad \text{—} \ (2)$$

adding (1) & (2)

$$\left(\omega_1 L - \frac{1}{\omega_1 C}\right) + \left(\omega_2 L - \frac{1}{\omega_2 C}\right) = 0$$

$$(\omega_1 L + \omega_2 L) = \frac{1}{C}\left(\frac{1}{\omega_1} + \frac{1}{\omega_2}\right)$$

$$L(\omega_1 + \omega_2) = \frac{1}{C}\left(\frac{\omega_1 + \omega_2}{\omega_1 \omega_2}\right)$$

$$\boxed{\omega_1 \omega_2 = \frac{1}{LC}} \quad \text{—} \ (3)$$

Substracting (2) & (1)

$$\left(\omega_2 L - \frac{1}{\omega_2 C}\right) - \left(\omega_1 L - \frac{1}{\omega_1 C}\right) = 2R$$

$$L(\omega_2 - \omega_1) + \frac{1}{C}\left(\frac{1}{\omega_1} - \frac{1}{\omega_2}\right) = 2R$$

$$L(\omega_2 - \omega_1) + \frac{1}{C}\left(\frac{\omega_2 - \omega_1}{\omega_1 \omega_2}\right) = 2R$$

From equ^n (3) we get

$$(\omega_2 - \omega_1)L + \frac{1}{C}\left(\frac{(\omega_2 - \omega_1)LC}{1}\right) = 2R$$

$$(\omega_2 - \omega_1)L + (\omega_2 - \omega_1)L = 2R$$

$$2L(\omega_2 - \omega_1) = 2R$$

$$\boxed{\omega_2 - \omega_1 = \frac{R}{L}} \quad \text{—} \ (4)$$

From equ^n (3) & (4)

$$\omega_1 \omega_2 = \frac{1}{LC}$$

$$(\omega_1)\left(\frac{R}{L} + \omega_1\right) = \frac{1}{LC}$$

$$\omega_1\left(\frac{R}{L}\right) + \omega_1^2 = \frac{1}{LC}$$

$$\omega_1^2 + \frac{R}{L}\omega_1 - \frac{1}{LC} = 0$$

$$\omega_1 = \frac{-\frac{R}{L} \pm \sqrt{\left(\frac{R}{L}\right)^2 - 4 \times 1 \times \left(-\frac{1}{LC}\right)}}{2 \times 1}$$

$$\omega_1 = \frac{-R/L \pm \sqrt{R^2/L^2 + \frac{4}{LC}}}{2}$$

$$\omega_1 = -\frac{R}{2L} \pm \frac{1}{2}\sqrt{4\left(\frac{1}{LC} + \frac{R^2}{4L^2}\right)}$$

$$\boxed{\omega_1 = -\frac{R}{2L} \pm \sqrt{\frac{1}{LC} + \frac{R^2}{4L^2}}} \quad \boxed{\omega_2 = \frac{R}{2L} \pm \sqrt{\frac{1}{LC} + \frac{R^2}{4L^2}}}$$

Putting the value of resonant angular frequency

$$\omega_1 = -\frac{R}{2L} \pm \sqrt{\omega_0^2 + \frac{R^2}{4L^2}}$$

if $\frac{R}{2L}$ is taken as α $\qquad \frac{1}{LC} = \omega_0^2$

$$\omega_1 = -\alpha \pm \sqrt{\omega_0^2 + \alpha^2} \quad \text{— (5)}$$

Like wise

$$\omega_2 = -\alpha \pm \sqrt{\omega_0^2 + \alpha^2} \quad \text{— (6)}$$

From resonant angular velocity & equ^n

$$\boxed{\omega_0 = \sqrt{\omega_1 \omega_2}} \quad \text{— (7)}$$

The difference b/w lower cutoff frequency f_1 & upper cutoff frequency f_2 is called the Bandwidth

$$\boxed{f_2 - f_1 = \text{Band width}}$$

$$\boxed{f_2 - f_1 = \frac{1}{2\pi}\left(\frac{R}{L}\right)} \quad \text{--- (1)}$$

// **Quality Factor** :- The quality factor can be deffined for series and RLC circuit seperatally.

The quality factor for series RLC circuit is deffined as the ratio of voltage across the inductor or capacitor and the total supply voltage. It is also called Voltage magnification factor.

For series circuit = Voltage magnification $= \frac{V_L \text{ or } V_C}{V_S}$

$$= \frac{IX_L \text{ or } IX_C}{IR}$$

$$\frac{1}{R}\sqrt{\frac{L}{C}}$$

total impedance $= \frac{L}{CR}$

$$\Rightarrow \frac{X_L}{R} \text{ or } \frac{X_C}{R}$$

In Parallel RLC circuit the quality factor is deffined as the ratio of current across inductor or capacitor and the total current of the circuit. For Parallel circuit It is called current magnification.

For parallel circuit = Current magnification $= \frac{I_C \text{ or } I_L}{I}$

$$\frac{1}{R}\sqrt{\frac{L}{C}}$$

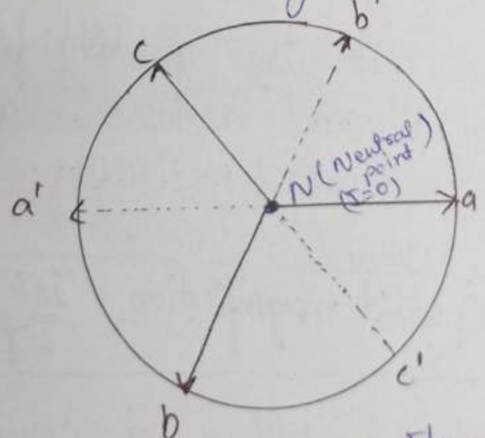
// **Three Phase system** :- When a conduct OR coil is placed in a magnetic field, a voltage is produced according to Faradays law

$$e = \frac{-d\phi}{dt}$$

That is called a single phase system when [illegible] phases are placed in the magnetic field and voltage is induced on each conductor, the system is called Three phase system.

The three phase system have many advantages over single phase system which are explained below

1. The rating of three phase system is higher than the single phase system for same output.
2. The three phase system need less conducting matterial, so it is more economical.
3. Since the conducting material is less required, its efficiency is high.
4. The power factor of three phase system is greater than single phase system
5. We can make a single phase system by three phase system but its opposite is not possible.
6. The three phase system is more capabele & reliable
7. The three phase system motors are selfstarting motor because the magnetic field is rotating in nature.



For phase 'a'

$$v_a = V_{am} \sin(\omega t) \quad (1)$$

For phase 'b'

$$V_b = V_{bm} \sin(\omega t - 120) \quad (2)$$

$$V_c = V_{cm} \sin(\omega t - 240) = V_{cm} \sin(\omega t + 120) \quad (3)$$

here for symmetrical system $V_{am} = V_{bm} = V_{cm}$
adding equ^n ①, ②, ③ -

$V_{(total)} = V_a + V_b + V_c$

$= V_m \sin\omega t + V_m \sin(\omega t - 120) + V_m \sin(\omega t + 120)$

$= V_m \sin\omega t + V_m [\sin(\omega t - 120) + \sin(\omega t + 120)]$

$= V_m \sin\omega t + V_m [\sin\omega t \cos 120 \pm (\cos\omega t \sin 120) + \{ (\sin\omega t \cos 120 - \cos\omega t \sin 120)]$

$= V_m \sin\omega t + V_m [2 \sin\omega t \cos 120]$

$= V_m \sin\omega t + 2 V_m \sin\omega t \left(-\frac{1}{2}\right)$

$= V_m \sin\omega t + (- V_m \sin\omega t)$

$\boxed{V_{total} \Rightarrow 0}$

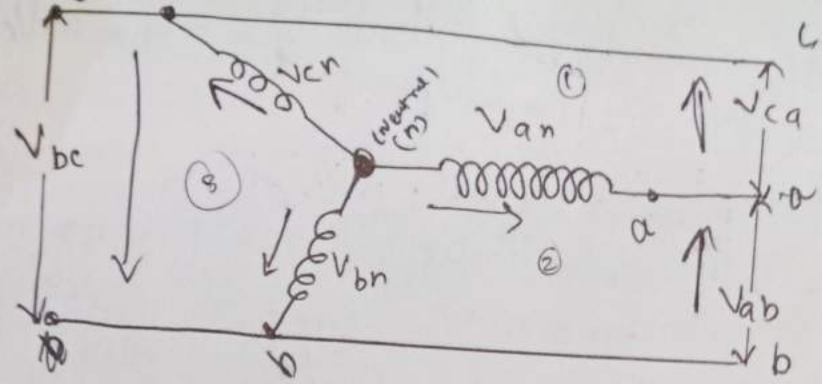
From the above equ^n of different phases, When we add all of them there total sum is Zero (0). It means that the point where all the voltages meet have zero voltage (0V) it is called neutral point.

There are two different sequence of the phases. By sequence we mean that the arrangment of phases. For example In the above diagram the phase sequence may be ab bc, ca Or it may be ac, cb, ba.

There can be two types of connections which are star connection and Delta connection

#marks ★ Imp

① **Star connection** - When the three phase are so arranged that they form a node is called the star connection.



Consider a star connection of three phase system. The phases a, b, c have there voltages V_{an}, V_{bn} & V_{cn}.

The voltage in the phase is called the phase voltage. In other words the voltage b/w a phase and neutral is called the phase voltage. The voltages V_{an}, V_{bn} & V_{cn} are the phase voltages.

$$V_a = V_{an} \angle 0$$
$$V_b = V_{bn} \angle -120$$
$$V_c = V_{bn} \angle -240$$

The voltage which exist outside the phase is called the line voltage. In other words the voltage b/w any two phases is called the line voltage. In the above diagram V_{ab}, V_{bc} & V_{ca} are the line voltages

The current determined due to phase voltage is phase current.

For example I_{an}, I_{bn} & I_{cn} are the phase current

The current determined by the line voltage is called the line current for example I_{ca}, I_{ab} & I_{bc} are line currents.

V_{ph} = Phase voltage

I_{ph} = phase current
I_L = line current

- Applying KVL in mesh ① :-

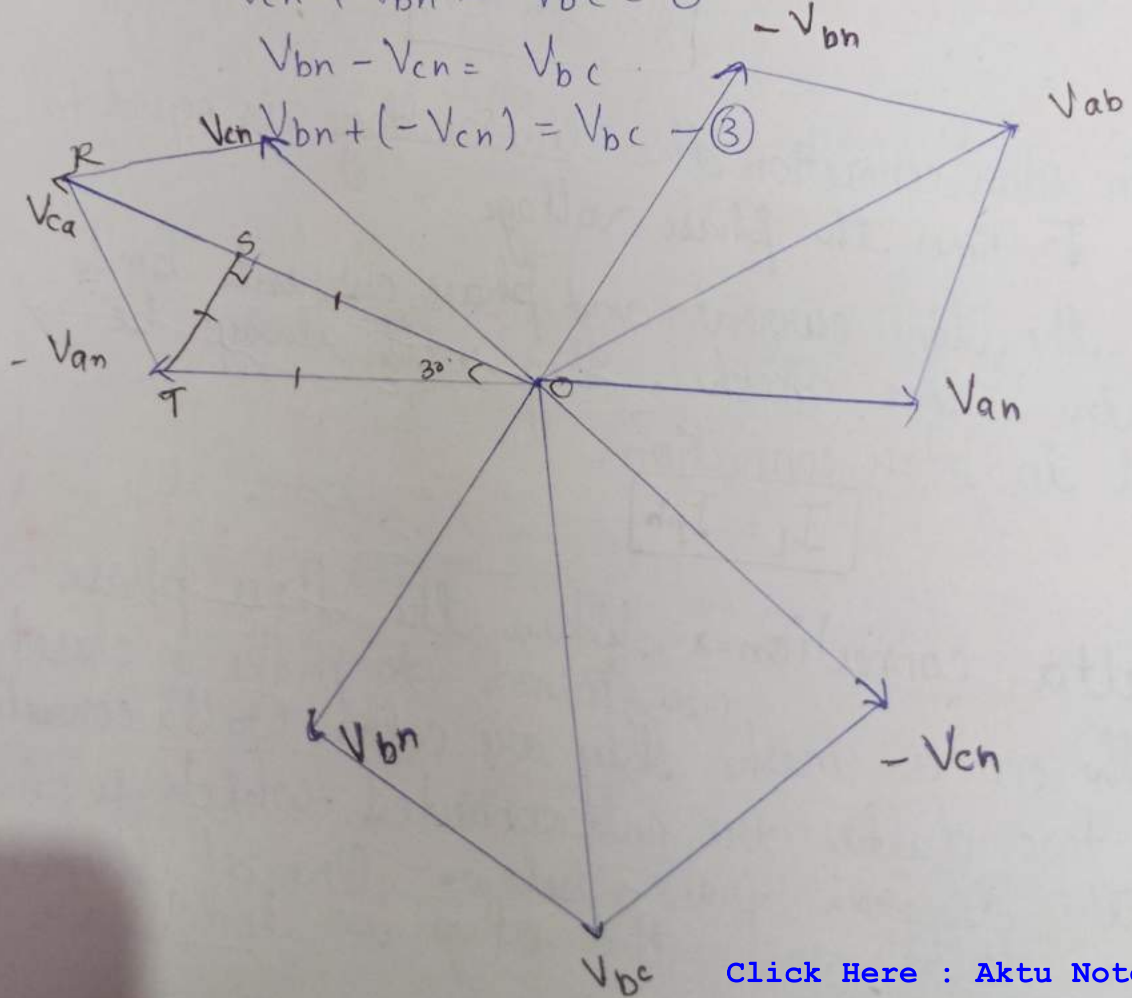
$$-V_{ca} - V_{an} + V_{cn} = 0$$
$$V_{cn} - V_{an} = V_{ca}$$
$$V_{cn} + (-V_{an}) = V_{ca} \quad -①$$

- In mesh ②

$$V_{an} - V_{ab} - V_{bn} = 0$$
$$V_{an} - V_{bn} = V_{ab}$$
$$V_{an} + (-V_{bn}) = V_{ab} \quad - ②$$

- Like case in mesh ③

$$-V_{cn} + V_{bn} - V_{bc} = 0$$
$$V_{bn} - V_{cn} = V_{bc}$$
$$V_{bn} + (-V_{cn}) = V_{bc} \quad - ③$$



(like Similar)

When we draw a perpendicular on the line OR its cuts it into two equal parts & as

$$OR \Rightarrow O.S + SR$$

$$OS = SR$$

$$OR = 2OS = 2SR$$

$$\boxed{\frac{OR}{2} = OS}$$

From the triangle ΔOST cos 30° is equal to $OS/_{OT}$

$$\cos 30^\circ = \frac{OS}{OT}$$

$$\frac{\sqrt{3}}{2} = \frac{OS}{OT} = \frac{OR}{2OT} = \frac{V_L}{2V_{pn}}$$

$$\frac{\sqrt{3}}{2} = \frac{V_L}{2V_{pn}}$$

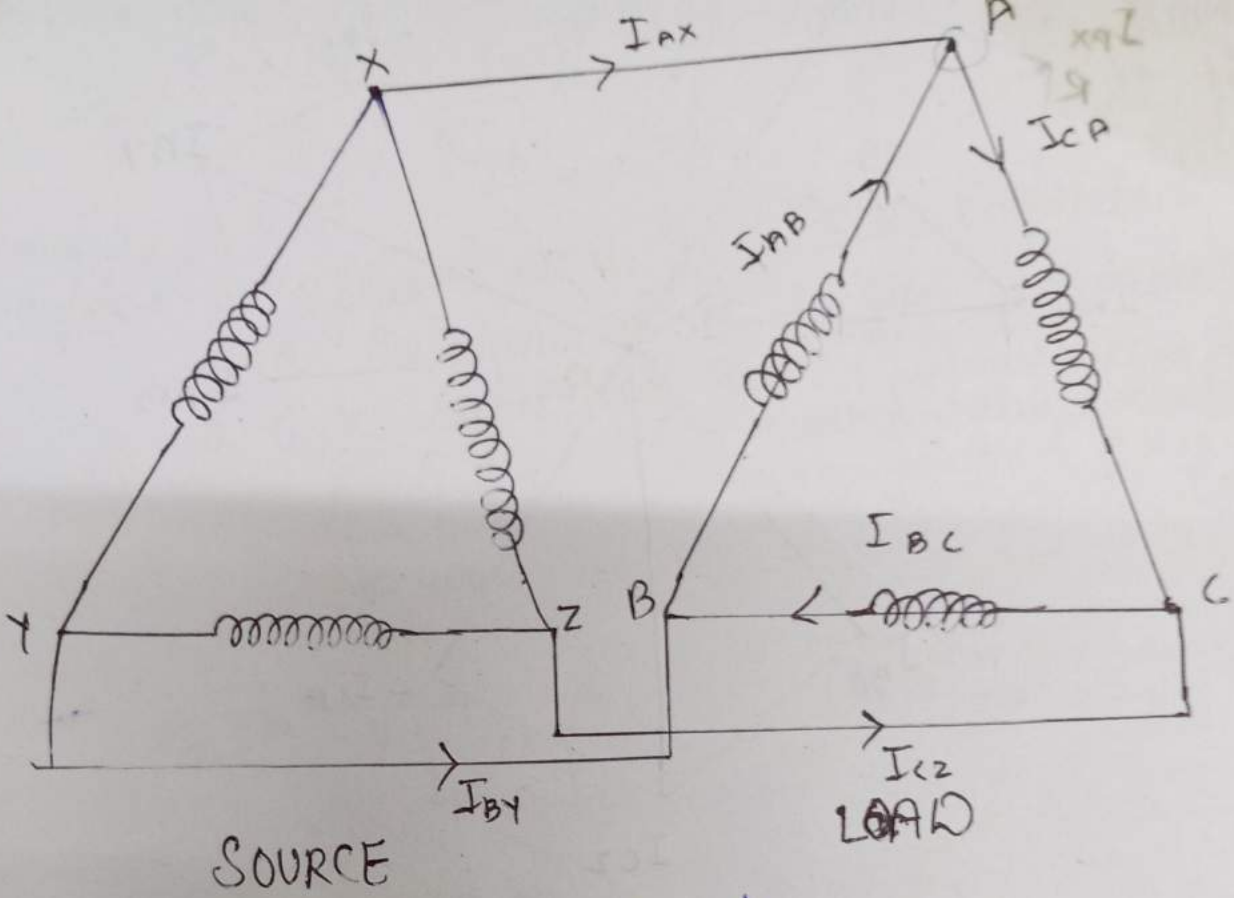
$$\boxed{\sqrt{3}\, V_{ph} = V_L}$$

In star connection the line voltage is equal to $\sqrt{3}$ times the phase voltage

Since the line current and phase current both lie in same mesh, they will always be equal in star connection.

$$\boxed{I_L = I_{ph}}$$

(2) Dalta connection → When the three phase are joined to make a closed path or a mesh they are called Dalta connectio The two daltas are enterconnected - which is show in the diagraw drawn below. One of them is a source dalta and the other is load dalta



Applying KCL at node A

$$I_{AX} + I_{AB} - I_{CA} = 0$$

$$I_{AX} = I_{CA} + (-I_{AB}) \quad - (3)$$

At nod B

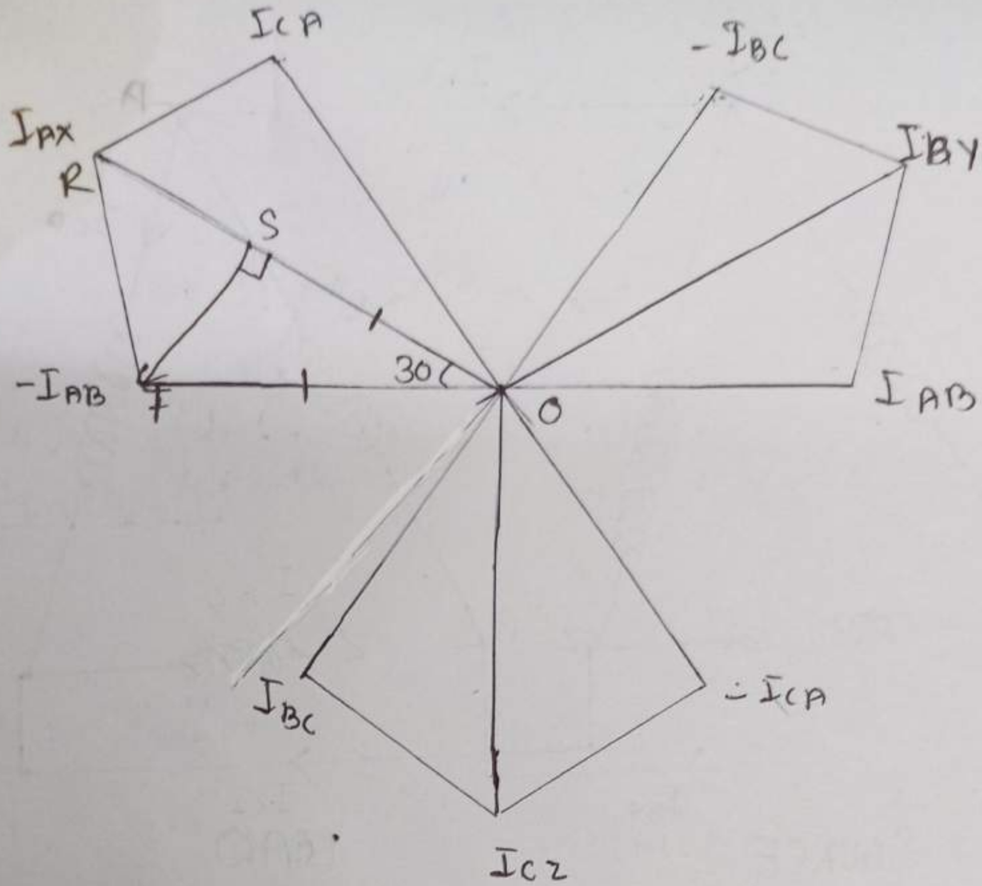
$$I_{BY} + I_{BC} - I_{AB} = 0$$

$$I_{BY} = I_{AB} + (-I_{BC}) \quad - (2)$$

At node C

$$I_{CA} + I_{CZ} - I_{BC} = 0$$

$$I_{CZ} = I_{BC} + (-I_{CA}) = 0 \quad - (3)$$



Draw a line ⊥ on OR which cuts it into two equal part as

$$OR \Rightarrow OS + SR$$

$$OS = SR$$

$$OR = 2OS = 2SR$$

$$\boxed{\frac{OR}{2} = OS}$$

From the ΔOST

$$\cos 30^\circ = \frac{OS}{OT}$$

$$\frac{\sqrt{3}}{2} = \frac{OR}{2OT}$$

$$\sqrt{3}\, I_{ph} = I_L$$

$$\boxed{I_L = \sqrt{3}\, I_{ph}}$$

Since the branches of the circuit are parallel, there voltages will be equal.

$$V_{ph} = V_L$$

(Numerical)

Example → A 3 phase, 400 V, 50 H, star connected load has a Resistance & Inductive reactance of 8Ω & 6Ω respectively. Find Z, per phase, line voltage, phase voltage, line current, phase current, power factor (cos φ) & total power?

$R = 8Ω$

$L = 6Ω$

$V_s = 400V = V_L = 400$

$freq = 50H$

$Z = \sqrt{3}\,V_{ph} = V_L$

$I_{ph} = I_L$

(1) $Z_{ph} = \sqrt{(R_{ph})^2 + (X_L)_{ph}^2}$

$Z = \sqrt{(8)^2 + (6)^2}$

$Z = \sqrt{64 + 36}$

$Z = \sqrt{100}$

$\boxed{Z = 10}$

(2) $\cos\phi = \frac{R_{ph}}{Z_{ph}}$

$\cos\phi = \frac{8}{10}$

$\boxed{\cos\phi = 0.8}$

(7) $V_{ph} = \frac{400}{\sqrt{3}}$

$\boxed{V_{ph} = 230.94}$ V

(3) $I_{ph} = \frac{V_{ph}}{Z_{ph}}$

$= \frac{230.94}{10}$

$\boxed{I_{ph} = 23.094}$ A

(4) $P_{ph} = 3 \times V_{ph} I_{ph} \cos\phi_{ph}$

$P = 230.94 \times 23.094 \times$

$\boxed{P = 3 \times 4265.923}$ ω

$\boxed{P = 12799.771 \Rightarrow 12800}$

(5) $I_L = I_{ph}$

$\boxed{I_L = 23.094}$ A

(6) $\boxed{V_L = 400}$ V

Q A Dalta connection connected two an impedance of 440V, 50Hz, supply is 12 ohm per phase, Find the V_L, V_{ph}, I_L, I_{ph}, R_{ph}, Z_{ph}, Inductance if the Power factor is 0.85.

$$\sqrt{3} I_{ph} = I_L$$
$$V_{ph} = V_L$$

(1) $\boxed{V_L = 440}$ V

(2) $\boxed{V_{ph} = 440}$ V

$\boxed{Z_{ph} = 12}$ ohm

$$V_{ph} = I_{ph} Z_{ph}$$

(3) $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{440}{12}$ (220, 110 / 6, 3)

$\boxed{I_{ph} = 36.666}$

(4) $I_L = 36.666 \times \sqrt{3}$

$\boxed{I_L = 63.508}$ A

(5) $\cos\phi = \cos 0.85$

$\boxed{\cos\phi = 0.999}$

(6) $\cos\phi = \frac{R}{Z}$

$0.999 \times 12 = R$

$R = 11.998$

$\boxed{R = 12}$ Ω

(7) $Z^2 = R^2 + X_L^2$

~~$(12)^2 = (12)^2 + X_L^2$~~

~~$\boxed{X_L = 0}$~~

$144 - 143.95 = X_L^2$

$0.047 = X_L^2$

$\boxed{X_L = 0.216}$

(8) $X_L = 2\pi f L$

$\frac{0.216}{2\pi f} = L$

$\boxed{L = 6.904 \times 10^{-4}}$

Unit 5

Electrical Installation

Battery

The device which is used as the substitute of electrical supply is called the battery. In the recent world when electrical and electronic system are increasing, the battery plays an important role. The Batteries are basically divided into different types on different basis.

On the basis of charging, the battery is divided into primary and Secondary

① **Primary Battery** → The battery which can be used only once and can not be reused are called primary battery. The chemical reaction in this battery are irreversible. ~~invisible~~ They are very much used because of their low cost & simplicity

The primary battery are used in watches, toys, and many electronic devices. They are used in basically two areas which are consumer product and electronic product. The consumer product are those where the initial cost is ~~low~~ important. The electronic product are those where recharging is not possible

② **Secondary battery** → The secondary battery are also called storage battery or accumulator

The secondary batteries are used, recharged and again reused. The chemical reaction in these battery are reversible. The process of inducing the current or energy in the battery is called the charging. The process of taking out the current or energy from the battery is called the discharging. They are called secondary battery because they can be used only when they have been charged.

The development of secondary battery have improved the performance and reduced the cost. They are used for both consumer and industrial purpose.

The secondary battery can be further divided into different types on the basis of material used which are explained below

① LEAD ACID BATTERY → The lead acid battery are used to supply power for starting, lighting and igniting of engine of vehicles. These batteries consist of 6 cells connected in series.

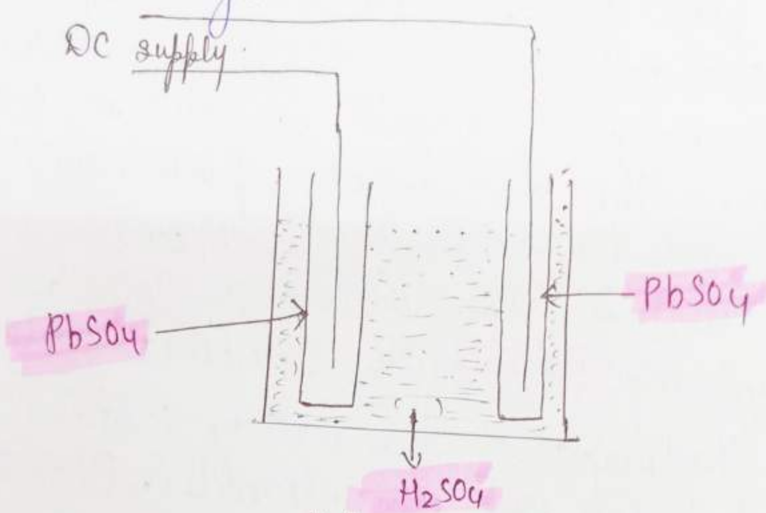
(a) Automative battery → These batteries are normally maintaince free and no need of water is required throughout their life span of 2 to 5 yrs. They with draw no gases during charging. They are used in light vehicles like motorcycles, cars and buses.

(b) Motive power battery → They are of better quality as compared to automotive battery. They provide constant output voltage, good resistance to vibrations and a long service life. They are capable of with standing prolonged deep discharge and deep recharge.

(c) Stationary battery → They are used for stationary conditions. They are used to provide alarms or emergency lighting in case of power cut.

Construction:- The construction of lead acid battery consist of three parts positive plate, negative plate and an electrolyte.

The lead peroxide (PbO_2) is used as the ~~pl~~ +ve plate, lead as the (-ve) plate & (H_2SO_4) Sulphuric acid as the electrolyte.



$$\underset{(+ve)}{PbO_2} + 2H_2SO_4 + \underset{(-ve)}{Pb} \underset{charge}{\overset{discharge}{\rightleftharpoons}} \underset{(+ve)}{PbSO_4} + 2H_2O + \underset{(-ve)}{PbSO_4} + \text{electrical energy}$$

Charging Indicator → To know if the battery is fully charged, the following indicators are used

① Gassing → When fully charged, the hydrogen ~~atom~~ gas is liberated at cathod and oxygen at anode.

② Colour → The lead sulphate anode gets converted to lead peroxide which given brown colour.

③ Voltage → At fully charged, the terminal voltage is 2.6 V.

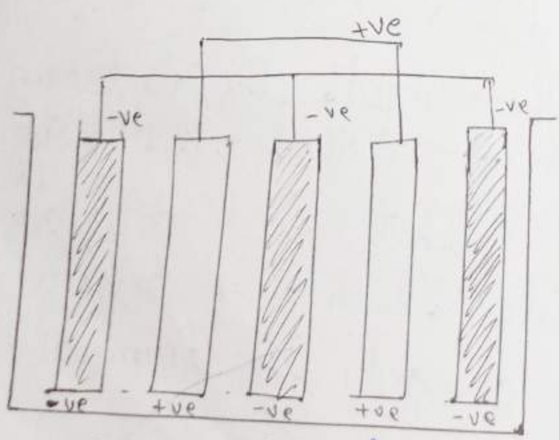
④ Specific gravity of electrolyte → At fully charged, the specific gravity of electrolyte will be 1.21.

Uses of lead acid battery :- They are used in telephone exchange railway train, mines, hospitals, emergency lighting etc.

2. Nickel iron battery → The Nickel - Iron battery have three component which are +ve plate, -ve plate and electrolyte. The positive plate consist of nickel - Hydroxide $[Ni(OH)_3]$ or Nickel Per-oxide $[NiO_2]$ Some amount of graphite is added to increase its conductivity. The ~~ne~~ negative plate consist of powdered iron and its oxides like $[FeO]$ or $[Fe(OH)_2]$. The electrolyte used in this battery is 20% of potassium hydroxide $[KOH]$ with distilled water

Construction :- The beaker of this battery contains electrolyte and the electrodes. Ebonite sticks are connected in b/w plate to avoid direct connection. The no. of -ve plates are one more than +ve plates. The extreme -ve plates are externally connected to the container o beaker.

(Ebonite sticks → No connect the +ve & -ve plate using like barrier)



The chemical reaction of Ni-Fe battery is given as -

$$\underset{+ve}{Ni(OH)_3} + 2KOH + \underset{-ve}{Fe} \underset{charge}{\overset{discharge}{\rightleftharpoons}} \underset{+ve}{2Ni(OH)_2} + 2KOH + \underset{-ve}{Fe(OH)_2} + \text{elect. energy}$$

Advantage :- ① They are lighter in weight
② They have rugged construction and are durable.
③ They have long service life
④ Lead is not used which is a costly material
⑤ They do not evolve toxic fumes
⑥ They need less maintaince.

Disadvantage :- ① Higher intial cost
② High internal resistance
③ They have low voltage per cell.
④ They have low efficiency.

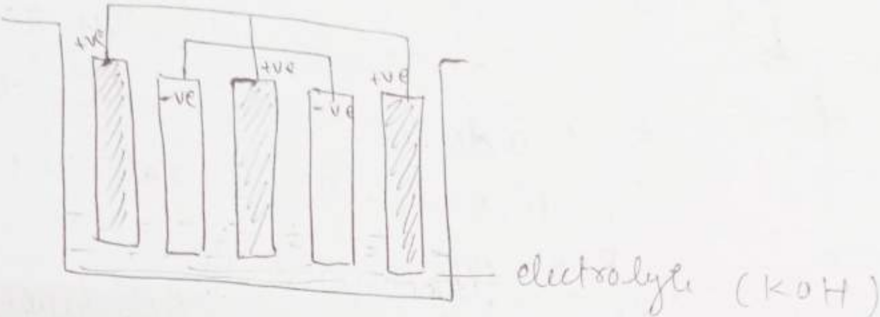
Applications or Uses :- They are used in industrial trucks, in railway car lighting & ac.

Nickel - cadmium Battery → In this type of battery the (+ve) plate is same as (Nickel - Iron) battery which is Nickel but the -ve plate is of cadmium. The basic difference b/w these two batteries is that the +ve plate are more than (-ve) plates. Another difference is that, the +ve plates are in extreme position and are electrically connected to the container.
Increase in the +ve plates decrease the interval resistance of the battery so that large current can be with drawn. The chemical reaction of the Nickel - cadmium is -

$$2Ni(OH)_3 + 2KOH + Cd \rightleftharpoons Ni(OH)_2 + 2KOH + Cd(OH)_2 + \text{electrical energy}$$

positive plates ⇒ Nickel Hydroxides $[Ni(OH)_3]$ OR Nickel peroxide $[NiO_2]$

electrolyte → potassium hydroxide [KOH]



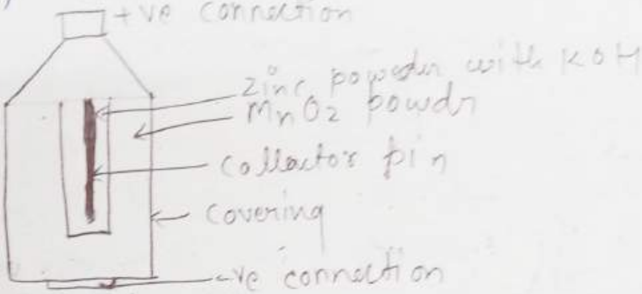
Advantages →
1. It is available in different design & size
2. It has a wide range of temp. for operatn
3. It has a low internal resistance
4. It can be kept discharged or charged for long duration.
5. Has long life
6. Has low maintance cost
7. It has a better efficiency

Disadvantage →
1. It is heavy battery.
2. It is expensive in cost

Types of Primary battery → There are many type of primary battery like daniel cell, Zinc-carbon battery etc. Some of them are explained below.

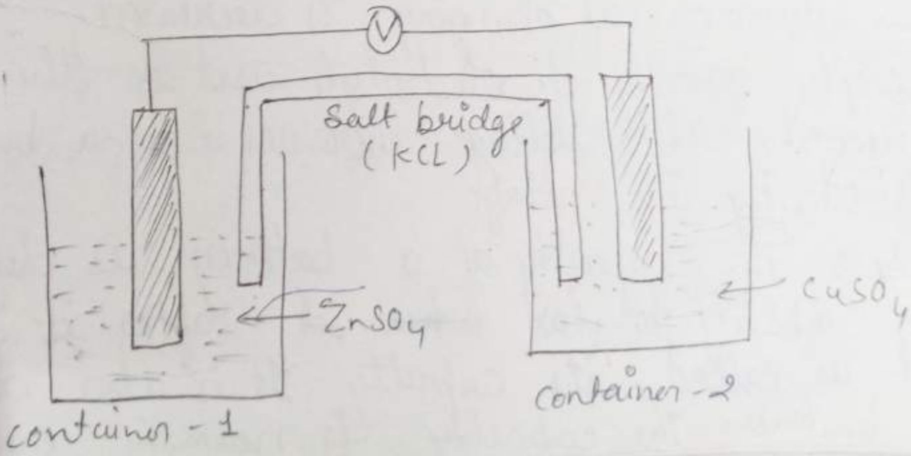
① **Zinc - Carbon cells** → They are the primary cells in which the -ve plate is made up of Zinc & the +ve plate is made of carbon. They have lower per unit cost and used for lighter loads. The electrolyte used here is ~~ammonium~~ ammonium chloride. They are used in large scale because they are cheap

③ **Alkaline Battery** → In the primary alkaline battery, the +ve plate is made of ~~mano~~ Magnesedioxide [MnO_2]. The -ve plate is of Zinc. The electrolyte used is potassium hydroxide [KOH]



They are used is CD players, digital cameras, flash light, radio & torch etc.

② **Danial cell** → The danial cell is a type of primary cell which uses two electrolytes. These electrolytes are Zinc sulphate [$ZnSO_4$] & copper sulphate [$CuSO_4$]. In these electrolytes Zinc & copper plates are dipped & a salt bridge is made to connect these electrolyte. This salt bridge is of KCL (potassium chloride) to get the required dc supply



Electrical characterstics of Battery → The electrical characterstics of battery are basically divided into three parts which are voltage, capacity & efficiency.

1. **Voltage** → The average voltage per cell of a battery is around 2V. The voltage does not remain constant but changes with different parameters. The voltage increases with increase in temp. The voltage increase if the duration of charging is decreased. Also, when the specific gravity of electrolyte used in the battery is increased, the voltage increases. So a battery can be diffined by its voltage

2. **Capacity** → The capacity of a battery is defined the ability to last ~~when at~~ after it is full charged is called its capacity. It is also called battery backup. The capacity is normally expressed

in ampere - hour (A-H) It means the capacity of a battery is the product of value of current it is discharged & the time it is discharged.

For example → If the capacity of a battery is 20AH means that 1 ampere of current is taken for 20 hours. It may be said that 2 Ampere of current is taken for 10 hours & so on.

Efficiency → The efficiency of the Battery is the ratio of discharging values to the charging values of battery they can be classified in two ways, ampere-hour efficiency & watt - hour efficiency.

① Ampere-Hour efficiency → It is defined as the ratio of discharged ampere-hour to the charging ampere- hour values of battery. It is also called quantity efficiency.

$$\text{A-H efficiency} = \frac{A_d H_d}{A_c H_c} \times 100$$

② Watt - hour efficiency → It is also called energy efficiency. It is defined as the product of Voltage, current & time in discharging to the product of voltage, current and time in charging

$$\text{W-H efficiency} \rightarrow \frac{V_d A_d H_d}{V_c A_c H_c} \times 100$$

Both the efficiencies are expressed in percentage (%).

WIRES & CABLES

Wires & Cables → Wires & cables are almost same. The basic difference b/w them is a wire is 1 electrical conductor & a cable is a seat of many conductors or a group of wires

(1) **Cables** → The cables are the group of wires inclosed together. They are divided into many types on different basis.

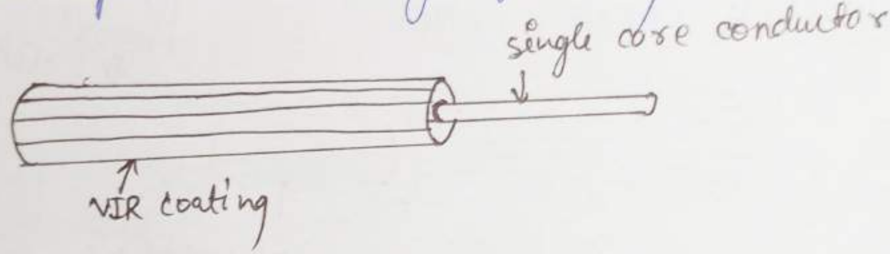
(i) On the basis of conductor used, the cables are divided into two types which are copper wire, & aluminium wire

(ii) On the basis of number of ~~course~~ cores, the cables are divided into single core, two core & three core cable.

(iii) On the basis of voltage gradiant, the cables are divided into two classes 250V/440V & 650 V/1100V

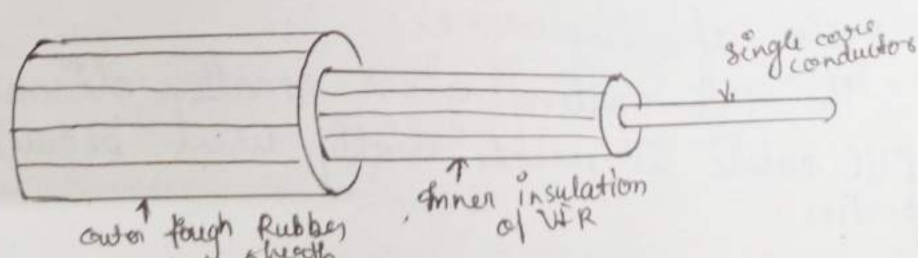
(iv) On the Bases of insulation use the cable can be divided into many types.
The insulation means the coating of the wire by some insulator so that the current flowing in the wire do not harm us while working.

① **VIR cables:**— The full form of VIR is Vulcanized Indian Rubber. These cables are available in both of grades 250V/440V & 650V/1100V. Over the rubber insulation, a taping of cotton sheath is done to provide moisture resistance. The thickness of the insulation depends upon the voltage gradieing

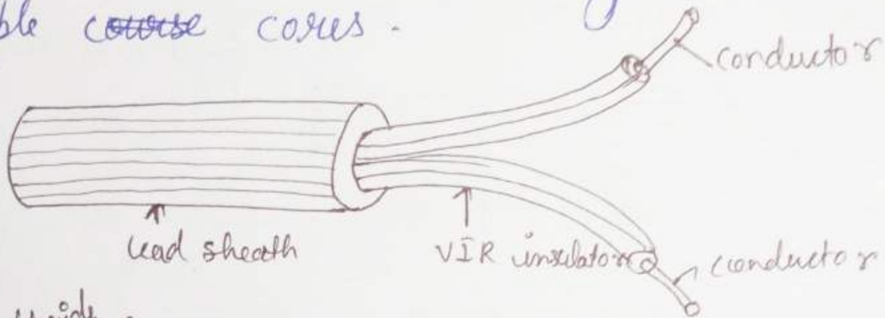


② (TRS) **Tough rubber sheath** → It is also called cab tyre sheath (CTS)

These cables are available in both gradings of 240V/440V and 650V/1100V. The TRS cable is a VIR insulated conductor with an outer protective covering of tough rubber which provide additional insulation & protection from wear & tear. These cables are water proofe. So, they are used in moisture conditions. They are available in different cores these cores are insulated from each other & covered with a common sheath. They are cheaper in cost & are lighter in weight



(i) **Lead sheath cable** – These cables are available in 240V/440V & ~~650V~~/1100V grade. The lead sheath is a ~~two~~ vulcanized rubber insulated conductor covered with a sheath of lead. The lead sheath provide very good protection against the absorbing of moisture & protection against machanical enjury so it can be used without casing it is available in multiple ~~course~~ cores.

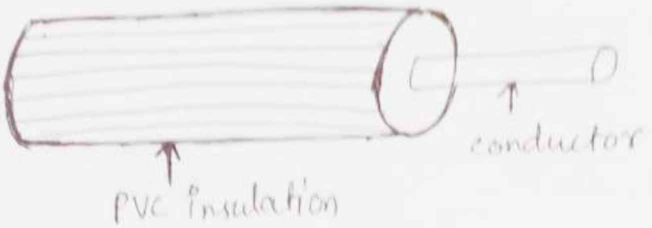


(4) **Polyvinyle chloride cable** → (PVC) These cables are better than VIR cables they are also available in both gradings & used in casing capping & conduit system. In this type of cable conductor is insulated with PVC insulation. Since PVC is harder than rubber, it does not require cotton tapping over it for machanical & moisture condition the PVC is better than VIR because of following reasons:

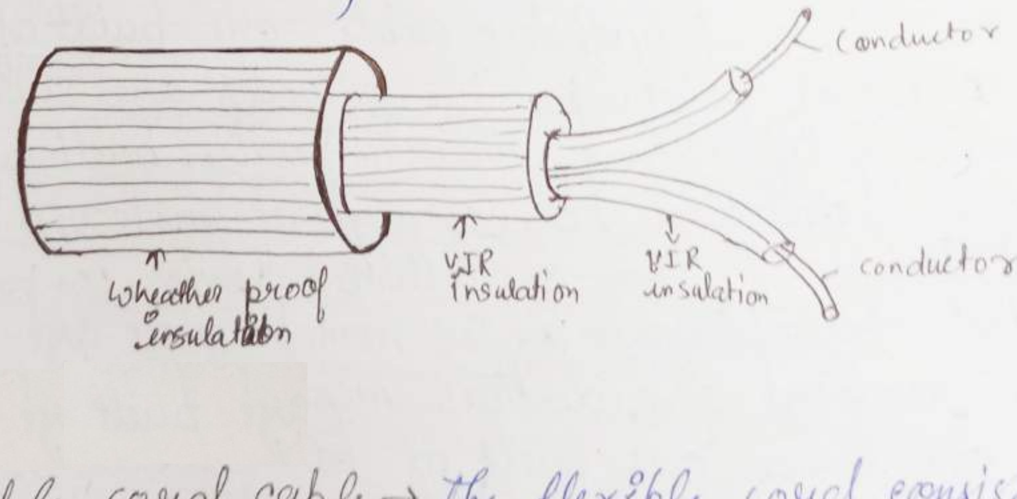
1. PVC insulation has better insulating properties
2. PVC provide better flexibility.
3. The PVC insulation has no chemical effect on metal of the wire.
4. The PVC coating gives smaller diameter of cable.

PVC cable is much widly used because of these properties

6

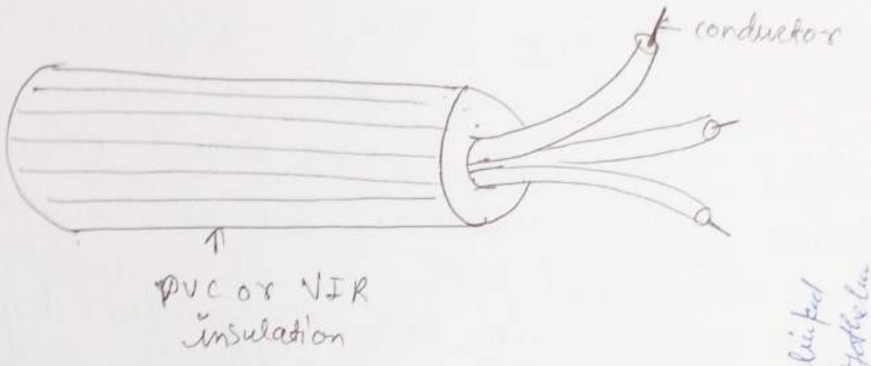


(5.) 1. **Wheather proof cable** → These cables are used for outdoor wiring & for industrial supply these cables are either PVC insulation VIR insulation. After the insulation they are compounded with wheather resisting matterial. They are available in both the grades. They are not effected by heat, sun and rain. Allthrough & TRS capals are also used for outdoor purpose but due to there high cost, wheather proof cables are normally used.



(6) **Flexible cord cable** → the flexible cord consist of wires with catton & Plastic covering. The plastic cover is very popular as it is available in different colours. The flexible cords are very tiny copper conductor

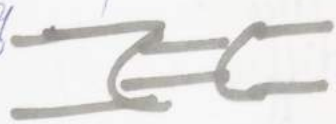
and flexibility of the strength is obtained by using conductors having large no. of strands. They are used as connecting wires for lamp holder, socket for fans, lamp & heaters etc. The flexibility of these wires prevents them from breakage.



cross linked
Polyethylene

(7) XLPE cable → The XLPE cables OR cross linked Polyethelene cable are built of insulation made of polymers. The polymers are substances consisting of long macromolecules built up of small molecules or group of molecules at repeated unit. They are divided into co-polymer and homopolymer. The homopolymers are built by reactions of Identical monomerse. The co-polymers are built of atleast two different types of monomerse. The mechanical properties of the polymerse are tensile strength, elasticity and resistance against cold. They are the best insulation because of following regions

1. It has a higher current rating.
2. High short circuit rating



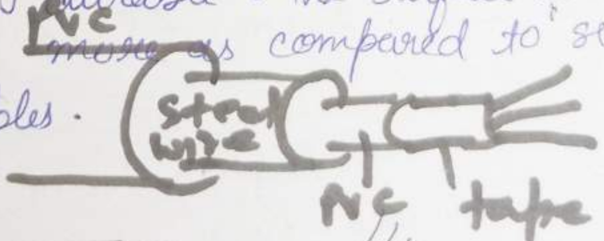
3. Long service life
4. Can withstand higher temperature upto 130° Centigrate
5. They are heaving less internal streass.
6. The thermal resistivity is low.
7. Protection against external effect.

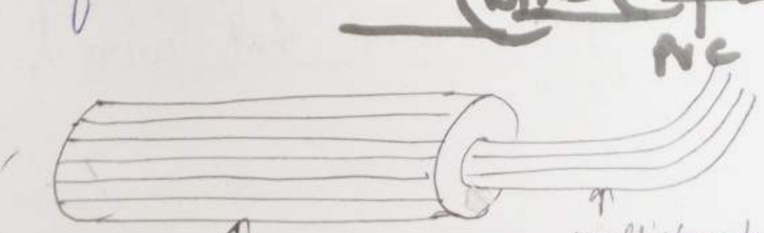
The PVC cable are the best cable after XLPE cable due to following ~~regions~~ reasones

1. They are not affected by vibrations.
2. They have tough sheath with good fire resisting quality.
3. They have complete protection against chemical ~~[illegible]~~ corrosion
4. They are almost uneffected by mositure.

8. Multistrand cables :- They are available in 3, 7, 19, 37 etc strands.

They have many properties in which they are more flexible & durable. The surface area of these cable is ~~more~~ PVC as compared to surface area of other cables.





Type of wires –

There are many type of wire that are classified on different basis Some example of these wires are coaxial wire; twisted wire; low voltage wire; NM wire; Armorded wire; Magnet wire; underground wire and phone & data wire etc.

① **Low voltge wire** → The low voltag wires are used for circuit requiring 50 V OR less.

Examples of these wire are light wire, doorbell wire, specker wire etc. There size ranges from 22 gauge to 12 gauge (differ width). They are cheap in rate & there is not chance or less chance for any electric shock.

② **Magnet wire** → They are also called binding wire because they are used in motor, generator & transformer for binding

③ **Co-axial wire** → They are made of copper cable specially built with metal sheath & other component. They have the empdence of 50 ohm, 52 ohm, 75 ohm & 93 ohm.

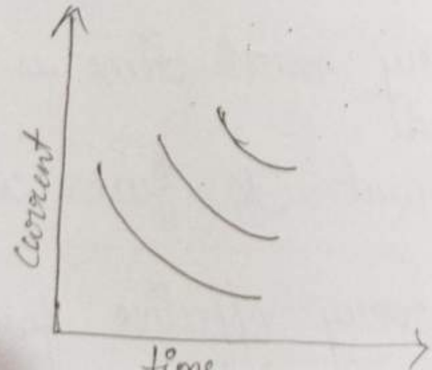
④ **N M wire** → They are used for dry locations & they containe hot wire, neutral wire & ground wire

Fuse

Fuse → A fuse is a simplest and cheapest protecting device used for preventing & electrical circuit under shot circuit conditions. The action of a fuse is based on the heating effect of the current. In normal conditions, when the current flowing through the circuit is with in the safe limites, the heat developed in the fuse element carring the current dissipated in the air and there-fore the fuse element remains at a temperature below its malting point.

When a fault (over voltage in circuit) accurs, the circuit current is increased, increasing the temperature. This heat can't be dissipated fast enough & the fussible element melts and hence its breaks the circuit. By doing so, the fuse protect the divice from damage.

The time of it blowing out of the fuse depends upon the magnitude of the current. The fuse setisfied inverse time - the current characterstics



Inverse time- current charactertics

The function of the fuse is to carry the normal working current safely with heating. The fuse breaks the circuit when the current increases from its normal value. The fuse unit basically divided into four parts, which are a metal fuse, a set of contacts, a body to support and isolate it. There are different types of fuse which are ① round type fuse unit, ② rewireable fuse unit (kitkat fuse unit), ③ cartridge type fuse unit & ④ high rupturing capacity (HRC fuse unit)

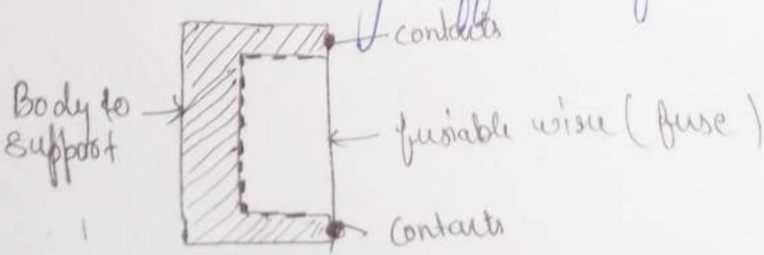
Advantages →

① It is the cheapest form of protection.
② It does not need any maintaines.
③ Its operation is free from noise, flame & any other type of gase.
④ The minimume time of operation can be made much smaller.
⑤ The inverse time current characterstic enables its use for protection.
⑥ Its operation is totally automatics

Disadvantage →

① In this method very much time is losted in replasing the fuse
② On having short circuit to fuses can not be connected in series
③ The fuse is not very effective fore higher loads.

Switch fuse Unit →



Miniature circuit breaker (MCB) - The circuit

device that protect the wiring and delicate devices. The MCB has two function for protection. The first function is protection against overload and the other is protection against shot circuit faults.

The thermal operation is done in case of overload protection. It is actived with a bybimetallic strip which is deflected when heated by any over current flowing through it. In doing so, the latch machanism is released which causses the contacts to open in the MCB.

The inverse time current characterstics are shown in the MCB which means that higher is the current, lower is the tripping ty time when a shot circuit is occured, the rising current energies the solenoid. It mians that a magnetic field is produced in it. Over this due to this the solenoid strike the plunger and hence ~~and~~ ~~hence~~ the contacts are open.

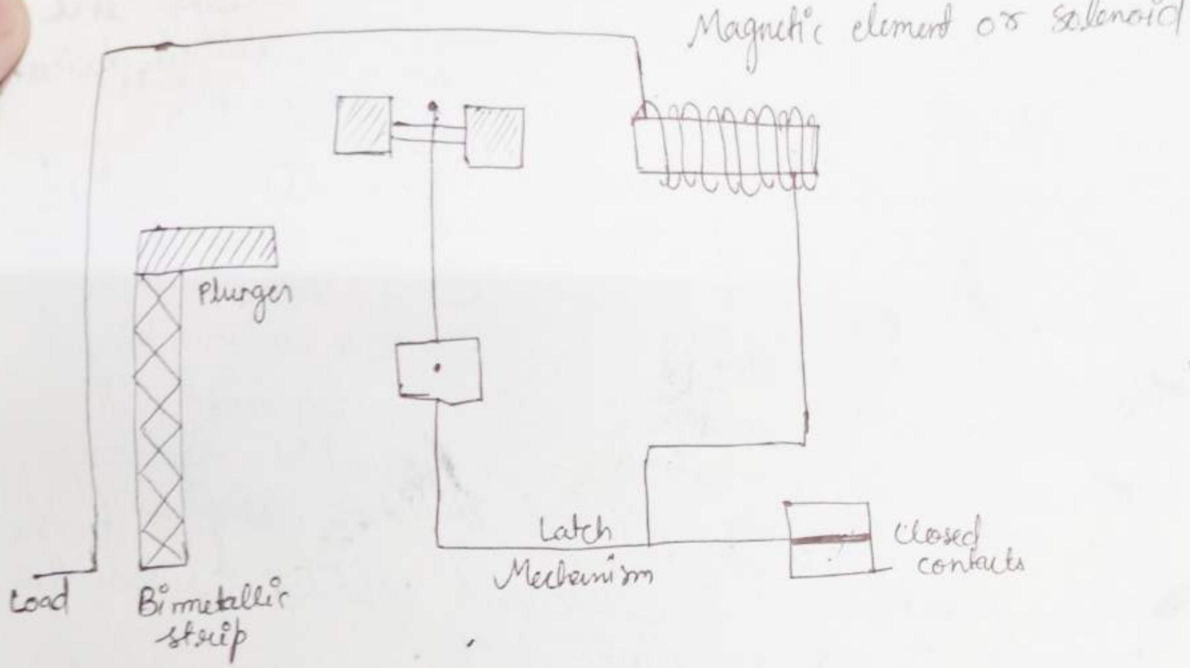
The MCB are available in different current ratting of 0.1, 2A, 5A, 10A, 40A, 100A & So one.

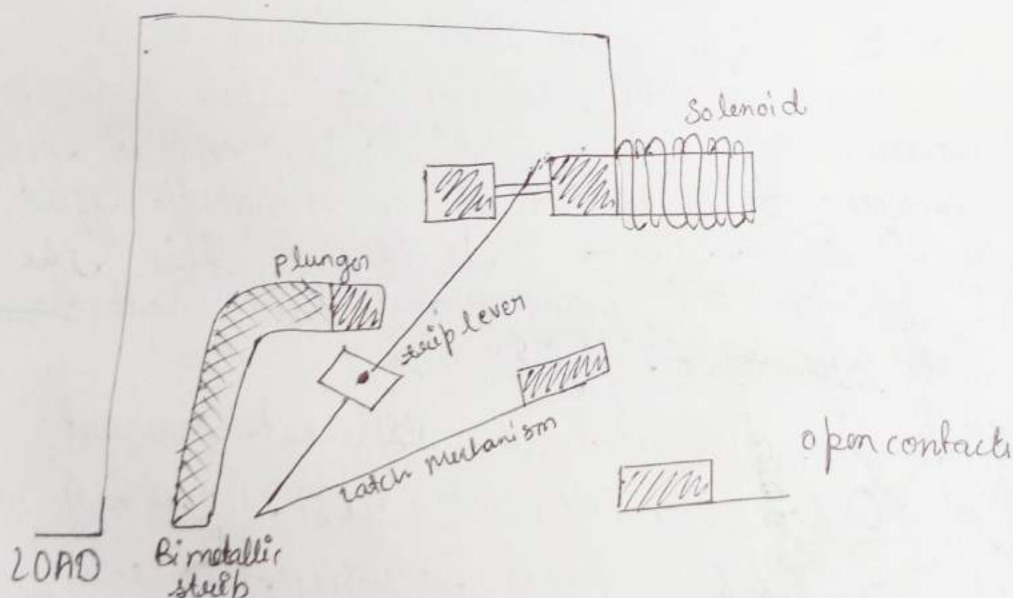
This opening time of MCB is very low which is around 5 mseconds. So they are very reliable for the protection of important and delicate devices.

Advantages →

1) They are more sensitive to current than the fuse.
2) They are very quick againsed shot circuit fault.
3) It is very simple to resume the supply after tripping.

(4) Handling of the MCB is much safer than fuse





1. **Disadvantges** :-

1. MCB is costly than Fuse.
2. They are not effective in earth faults
3. The tripping of MCB is slow
4. At high voltage, MCB can lead to fire.

The miniature circuit breaker are called so because they are the smallest circuit breaker. They are available with different current ratings of 1A, 2A, 3A, 5A, 10A, 40A, 100A and so on. The operating time of MCB is very less. They are better than fuse & are used in domestic purpose such as AC, frige & computers.

11. **Molded case circuit Breaker (MCCB)** :- The molded case circuit breaker is also an electrical protection device that can be used for a valid range of voltages and frequencys. The main difference b/w MCB & MCCB is that the MCCB are used for heavy loads or higher current rating upto 2500 Amp. The MCB is used for lighter loads of same 100 Amp. The other difference b/w them is that the tripsetting of MCCB is normally adjustable. A part from that the MCCB are much larger than MCB.

The MCCB have 3 main functions

1. Protection against overload.
2. Protection against electrical fault.
3. Switching a circuit ON & OFF

[Same diagram on MCB in this circu]

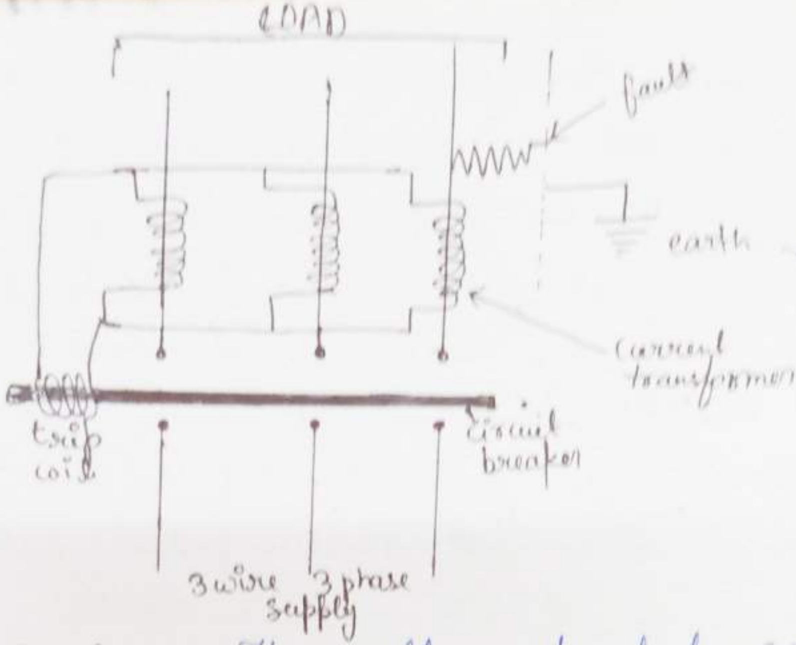
The wide range of current rating in MCCB helps us to protect in wide range of Application. The MCCB are available in currents ratings of 15 Amp. to 2500 Amp. so they are used in industrial purpose.

Over load protection is due by means of thermal heating. It has a Bimetallic strip which when heated gets diflected and hits the trip lever to on open the contacts.

When any shot circuits occur, the solenoid gets energized & hits the trip coil to open the contact

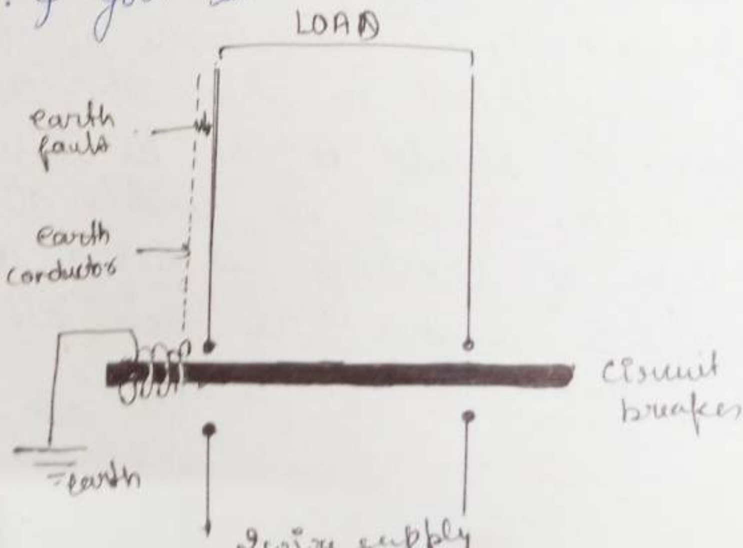
II. Earth leakage circuit Breaker (ELCB) → The ELCB is a device that provide protection against earth leakge. There are two types of ELCB which are current operated & voltage operated.

① **Current operated** → It is use when the product of operating current and earth impidence is less than 40. When such circuit breaker is used the consumer earth terminal is connected to a suitable earth electrode. A current operated ELCB has no earth leakage in normal condition & so, the algebric sum of the current in three coils of the current transformer is zero. & no current flows through the trip coil. In case of any earth leakage, the currents are unbalanced & the trip coil is energizsed & so the circuit breaker is tripped.



Voltage operated → The voltage operated earth leakage circuit breaker is suitable for use when the earth impedance exceedes the values applicable to current operated circuit breaker. When the voltage b/w the earth conductor and earth electrode rises to a sufficient value, the trip coil will carry the required current to trip the circuit breaker. With a such a circuit breaker the earthing lead b/w the trip coil & the earth electrode must be insulated.

For both the above type the tripping operation may be tested by a test button which passes a current from the line wire through a high resistance to trip the coil & goes into the earth.



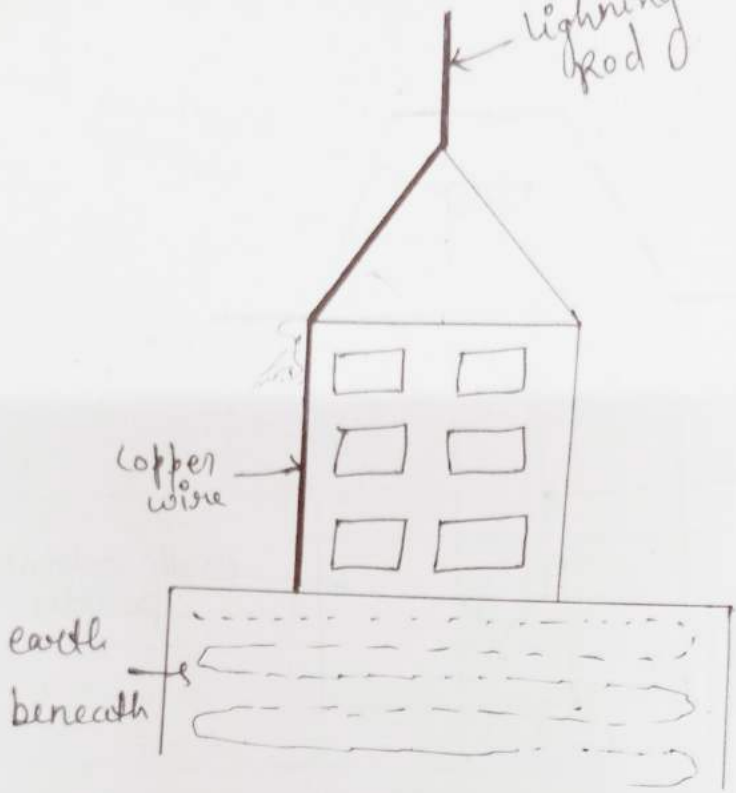
Earthing → The earthing means the connection of neutral point of a supply system or the non-current carrying part of electrical device to the general mass of earth in such a manner that at all ~~tymes~~ times & immediate discharge of electrical energy takes place with out danger.

The earthing is provided.

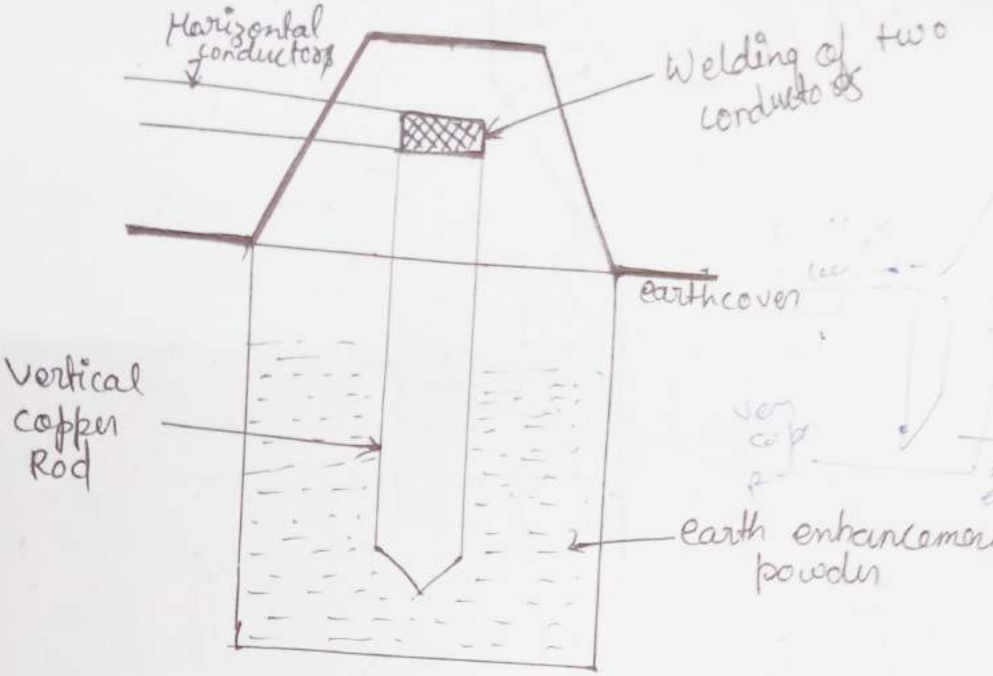
1. To avoid electric shock to the human being.
2. To avoid risk of fire due to earth leakage current.
3. To ensure that no current carrying conductor rises to a potential with respect to general mass of earth than its designed insulation

There are four types of earthing which are wire earthing, pipe earthings, rood earthing & plate earthing.

(i) **Wire earthing →** In this system of earthing the wire electrodes of 25 mm into 1.6 mm area of copper and iron are bared horizontally ~~pos~~ at minimum depth of 0.5 m. If round conductors are used, there area should be at least $3mm^2$. The length of the conductor shall be sufficient to give the required earth resistance. It should ~~be~~ not be less than 15 meter. The electrodes should be widely distributed. This type of earthing is used at the places having rocky soil because at such places excavation not possible

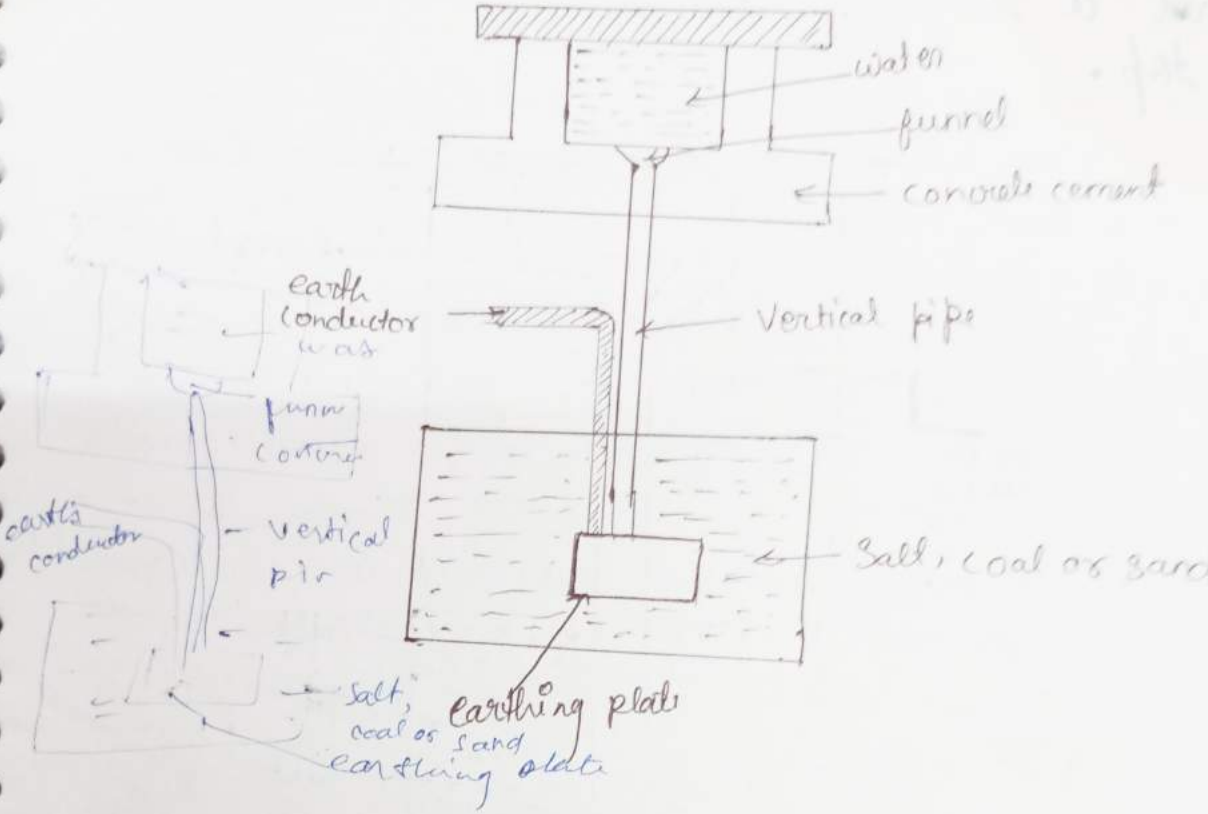


(ii) Rod earthing :- In this system of earthing 12.5 mm diameter solid rod of copper and iron of the length at-least 2.5 m are driven vertically into the earth either by hammer or manually. In order to increase the length of electrode under the ground, more than one rod is used. This system of earthing is suitable for areas which are sandy in nature. This system is very cheap because no excavation is done.

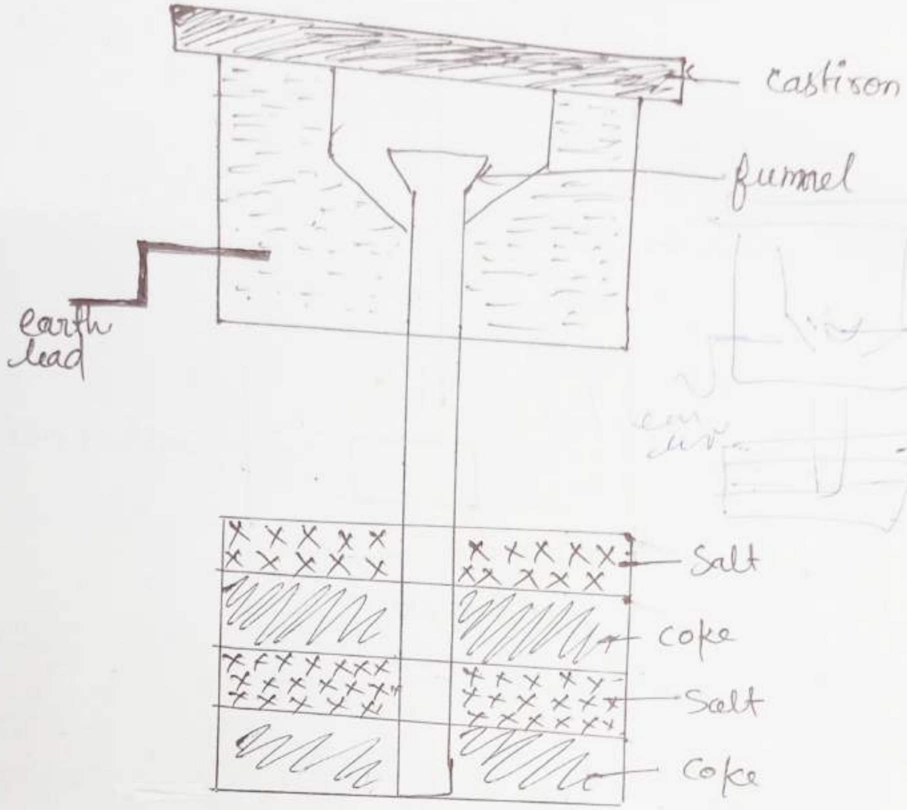


(iii) <u>Plate earthing</u> :- This is another common system of earthing. In plate earthing, an earthing plate of copper or iron of dimensions 60cm into 3mm. is burred into the ground with its face vertical at a depth of atleast 3m. The earth plate is covered in alternate layers of coke & salt for a minimum thickness of 15cm. The earth wire is bolted to the earth plate with the help of nut, bolt & washer made of material same as of plate.

A small concrete (cemented) of brick wall with cast iron cover on ~~touch~~ top is provided for its identification of the copper plate & copper wire are usually not used because of there high cost.



(iv) <u>Pipe earthing</u> :- This is the most common & best system of earthing as compared to others. In this method a steel pipe of a given length and diameter is placed upright in a wet soil. The size of the pipe dependence of the pipe to be carryed & type of soil the dimension of the pipe should be 40 mm of diameter, 2.5 m of length & the depth should be at least 3.75 m. The pipe is provide with tapered ~~costly~~ costing at the lower end. The pipe is surrounded by broken pieces of coke & salt. The coke is used to increase the effective area of the earth and the salt is used to decrease earth resistance. Another pipe of 19mm diameter and a length of 1.25m is connected at the top.



Lighting

The lighting is a huge spark which is due to electrical discharge taking place b/w to clouds, within the cloud and b/w cloud and earth. In this process large no. of discharges takes place b/w earth & cloud which are enough to make serious hazards.

Many theories have been given for this discharging in which one is most common. When a thunder cloud becomes electrically charged due to some atmospheric process, the charges are accumulated in the clouds.

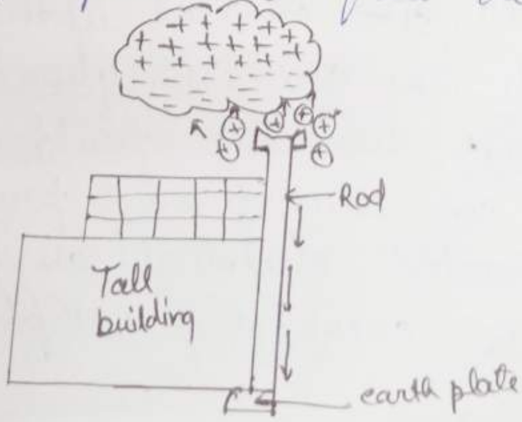
Protection against lighting

When the lightning occur, lacks of voltage and current is transferred to the earth which may cause serious damage. To prevent lightning, protection system is use. The lightning protection system is designed to protect a structure from damage due to lightning strike by detecting them and safely passing them to the ground.

It consist of a network of air terminal, bonding conductors and grounding electrodes which are designed for providing low resistance path.

Since a very high amount of current & voltage are released in lightning, no protection system is 100% relibale. Secondly the side flashing of light can also be dangerous.

The lighting system consist of a lightning rod which is mounted on the top of the building. It is electrically connected to the earth using bonding conductors. If the light stricks a building it will first strik rod & will be grounded through the wires into the earth. The lightning rods may have different shapes which are hollow, solid, rounded, pointed & flate rods.



Bus Bar

The bus bar is a metalic strip or conductor for the connection of different conductor for the in ~~high~~ high current distribution. They are also used in the connection of high valtage device in battery banks. They are normally uninsulated and have a sufficient toughness to be supported in the air by the insulated pole. Their feature allow them for proper connection of conductor & ability of tapping at various point without creating a new joint.
The bus bars are arranged in different configuratio to achive proper aperating flexibility, reliablity and have a minimum cost. There are three type of Bus bar system. which are –

① Single Bus bar system
② Two Bus bar system
③ There Bus bar system

① 88980
② 19457
③ 38880

Air circuit Breaker (ACB)

The air circuit Breaker is an electrical device use for the protection of Short circuit ~~fat~~ fault & over ~~cur~~ current upto 15 Kilovolt. In this method the arc is quenched with the help of air when a fault is occured. It operates at an atmospheric pressure to protect the connected electrical device.
This method is complotly replaced by

oil circuit breaker because there is no chance of fire in this method.

The working principle of air circuit breaker is very different. [During an intruption of Arc it creates an Arc voltage insted of supply voltage. The arc voltage is diffiened as the minimum voltage requilled to stablish the Arc It increase the Arc voltage by 3 ways

(1) The Arc voltage is increased by coolling the Arc.

(2) By splitting the arc into number of series

(3) The arc voltage can be increased by increasing the length of Arc.

It is operated within voltage level of 1 KV. It contains to pair of contacts. The main pair consist of current & is made up of copper. Another pair is made of [carbon]. When the breaker is opened the main contact also opens. During the opening of contact, The Arc contact remains in touch with each other. The Arcing gets started when the Arc contact gets seperated. There are four types of Air circuit breaker which are.

(1) Plain break circuit breaker.

(2) Magnetic blow out

(3) Air slap circuit breaker.

(4) Air blast circuit breaker

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Application -

1. It is used for the protection of electrical machine
2. It is used for the protection of tranformer & capacitor.
3. It is also used in the low voltage & high voltage and current.

ACB → Use in company
Motors - 3 ϕ

1. Shortcut protection
2. Overload "
3. Earth fault "

Electrical & Electronic Device

Both Manually / Automatic   800 Amp to 10,000 Amp

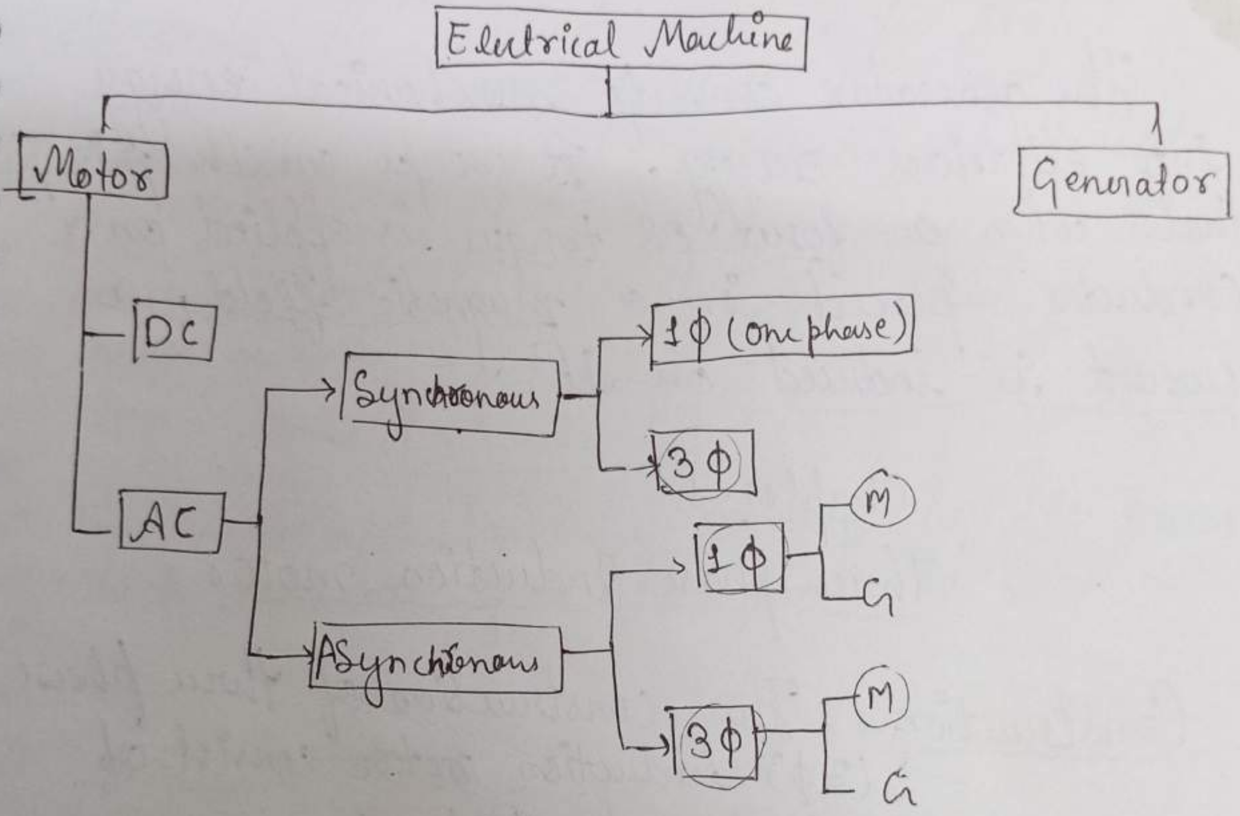
→ Electrical arc
→ In ACB Air produced by the Arc
Becau at the high voltage produce Arc

LISG → Ground fault Tripping → Acc. %

- Long time ↓ Acco %
- Instaneous tripping ↓ Starting current of motor is higer → Time wise
- Shortcut tripping ↓ Time wise 1000 Amps 3 times 1000 × 3 3000 Amp break

Unit - 4

Electrical Machines



The electrical machine is a device which converts electrical energy into machanical energy and ~~into~~ machanical energy into electrical energy it works on the principle of electro-mechanical energy conservation. Depending of upon its working, the machine can be motor and generator.

(i) Motor

The motor converts electrical energy into machanical energy. It works on the principle that when a current carrying conductor is placed in a magnetic field, a force or torque. Torque is applied on it

II. Generator

The generator converts mechanical energy into electrical energy. It works on the principle that when a force OR torque is applied on a conductor placed in a magnetic field, a current is induced on it

Chapter. 1

Three phase Induction motor

Construction → The construction of three phase (3ϕ) induction motor consist of two parts, Stator & Rotor

(i) **Stator** → The stator is the stationary part of the motor. When the three phase supply is given to the stator, a rotating magnetic field (RMF) is produced in the air gap of stator & rotor. The magnetic field rotates at sychronous speed (N_s). The synchronous speed is the constant speed of magnetic field which depend on the no: of poles & supply frequency. It is given by.

$$f_s = \frac{PN_s}{120}$$

where, f_s = Supply frequency in Hertz
P = No. of poles of Rotor
N_s = Synchronous speed in Rpm (Revolution per min)

The star OR dalta binding is done in the stator. The inner portion of stator in which winding is done is made of laminated silicon steel. It is slotted for the winding.

Normally the winding done in the stator is of dalta connection which helps the motor to reduce the costing of conducting material. It is so because in dalta connection the phase current is normally less than the line current because

$$\boxed{\sqrt{3}\, I_{ph} = I_L}$$

$P\uparrow = N_s\downarrow$

The core of the stator is covered by its frame which is made of cast Iron.

cast Iron

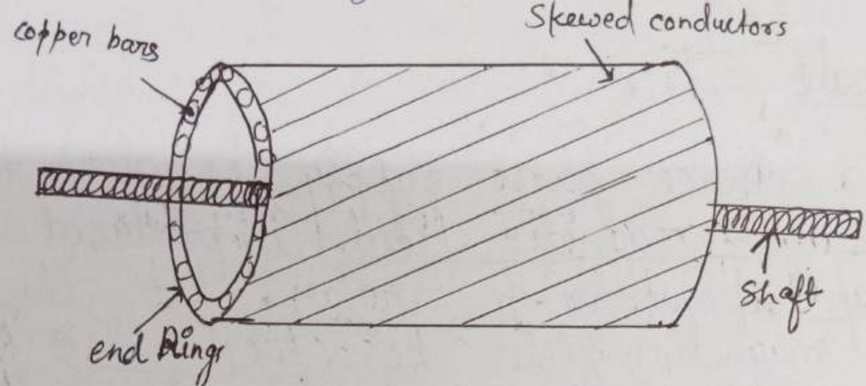
laminated silicon steel.

(ii) **Rotor** → The rotor is the rotating path of the motor. The speed at which the rotor rotates is called the rotor speed (N_R). The rotor speed is actually the speed of the motor. The rotor of three phase induction of motor are of two type which are Cage or squirel cage Rotor and Slip Ring or wound Rotor.

(i) **Cage rotor** → The cage rotor is the most common rotor of three phase induction motor. The rotor has copper conductors which are inserted into copper bars. These copper conductors are the copper rods & they are inserted in skewed form. It is so to increase the starting torque of motor. They have a low starting torque because their speed is regulated by the ~~sppuly~~ so supply voltage only.
Inspite of that there is no method for adding the external resistances to increase the torque.

Advantages → ① It has the robust construction & is cheap.
② Absence of slip rings & brushes reduces the risk of sparking.
③ Cooling is better because it has a sufficient space.
④ There efficiency is high & copper loses are low

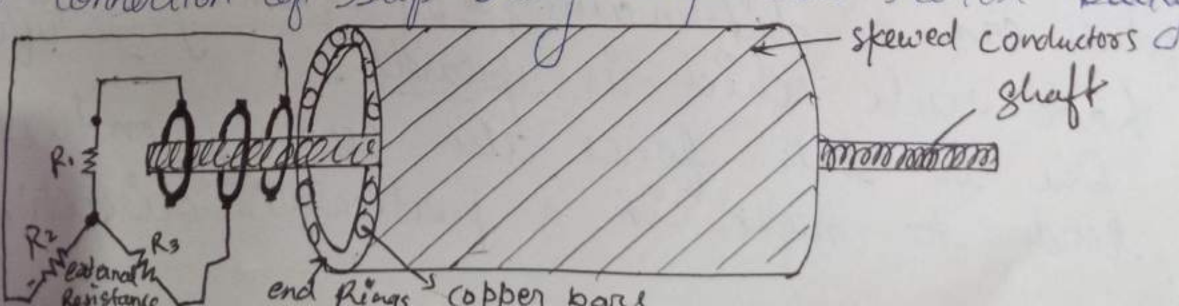
Disadvantage → ① They has a low starting torque
② They have a low power factor.
③ There is no arrangement for speed regulation



Slip Rings Rotor → The slip ring rotor is also called wound rotor. In this rotor the external resistances are connected with it with the help of slip rings & brushes. The connection of this rotor is done in star because the external resistances has to be connected in series with it. By doing show, the starting torque of the motor is increased. Hence, these rotors are used where high load devices are required. Due to the pressence of slip rings, this rotor is less efficient.

Advantage → ① They have a high starting torque.
② Speed control can be done by this rotor

Disadvantage → ① This rotor has lower efficiency
② The copper loses in this rotor are high.
③ Connection of slip ring makes the rotor bulky.



The cage Rotor is normally prefered in all the application where other methods are not fessible. The slip ring rotor is used when we need a high starting torque.

Most Imp

Principale

When a three phase supply is given to stator, a rotating magnetic field is produced in the air gap of stator & rotar. Let the direction of magnetic field be clock wise & speed is synchronous speed. It produces the same effect as if the magnetic field is stationary & the conductor is rotating in oposite direction which is anticlock wise according to faraday's law of electromagnetic induction $e = -\frac{d\phi}{dt}$, a voltage is induced in the rotor conductor. Since the circuit is closed by end Rings OR short circuit, current is induced in each rotor conductor. The direction of current can be determined by fleming's Right hand rule which is outwards. We know that when a current carrying conductor is placed in a magnetic field, A force is experienced by the conductor. So each rotar conductor experinces the force. The direction of this force can be diterniained by fleming's ~~right~~ left hand rule which is upwards.

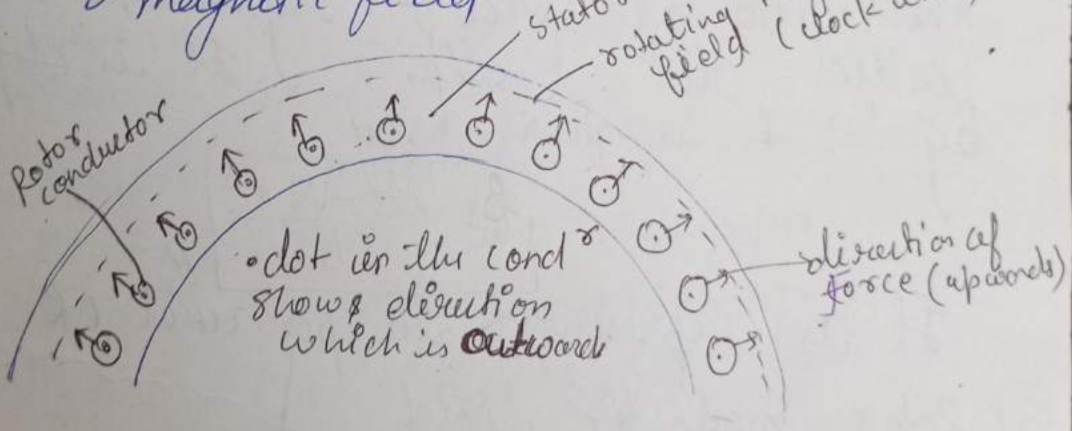
Due to this force the rotor conductors tends to move in a particular direction.

according to Lenz law. These rotor conductor start rotating in the direction of magnetic field which is clock wise. This is so because the rotor will try to appose its cause of production.

The three face induction motor start rotating by just giving supply to the stator winding so the three face phase Induction motor are called self starting motor's

Since a voltage is produced during its working of rotation of conductors So this three face motor is called the induction motor.

So, we conclude that rotors of three face induction motors. always runs less than the speed of rotating magnetic field



Synchronous speed → The speed at which the magnetic field of induction motor rotates is called the synchronous speed. It is denoted by N_s. It's depends upon supply frequency & no. of poles

$$\frac{P \cdot N_s}{120} = f_s \quad \text{--- (1)}$$

② Rotor speed

The speed at which the rotor conductors rotates is called the Rotor speed. It is the Actual speed of Motor. It is denoted by N_r.

③ Slip speed →

The difference b/w synchronous speed & Rotor speed is called the slip speed

$$\text{slip speed} = N_s - N_r$$

④ Slip.

The ratio of slip speed & synchronous speed is called the slip. It is denoted by 's' & is given by

$$s = \frac{N_s - N_r}{N_s}$$

It is represented in per unit OR Percentage

⑤ Rotor magnetic field

The Magnetic field produced around the rotor conductors is called the rotor magnetic field. It's speed is also synchronous speed.

⑥ Rotor frequency

The frequency of the rotor conductor is called the Rotor frequency it is denoted by f_r. It is given by

$$\frac{P(N_s - N_r)}{120} = f_r \quad \text{— (2)}$$

from equ^n ① & ②

$$\frac{\frac{PN_s}{120}}{\frac{P(N_s-N_r)}{120}} = \frac{f_s}{f_r}$$

$$\frac{N_s}{(N_s-N_r)} = \frac{f_s}{f_r}$$

$$\frac{1}{s} = \frac{f_s}{f_r}$$

* $\boxed{f_r = s f_s}$ — ③

Numerical

Q Determine the no. of pole of an induction motor running at 970 RPM & its stator frequency is 50Hz.

By hit & trial method We see that at P = 2, N_s will be 3000 rpm,
P = 4, N_s will be 1500 rpm,
P = 6, N_s will be 1000 rpm,
P = 8, N_s will be 750 rpm, & so on

The rotor speed is always less than & near to the synchronous speed so the no. of poles will be 6 & synchronous speed will be 1000 rpm.

... 8 pole 750 rpm alternator supplys an induction motor of 4 pole its speed is 1450 rpm calculate the supply frequency, synchronous speed & slip of the induction motor.

$$f_s = \frac{8 \times 750}{120} = \frac{6000}{12} = 50$$

$$\boxed{f_s = 50}$$

Since the alternator is given supply to induction motor, their frequencys will be equal, so, for alternator
→ (Solve the above)

Now, for induction motor

$$50 = \frac{4 \times N_s}{120}$$

$$N_s = \frac{50 \times 120}{4}$$

$$N_s = \frac{6000}{4} = 1500$$

$$\boxed{N_s = 1500}$$

→ slip of the induction motor

$$s = \frac{N_s - N_r}{N_s}$$

$$s = \frac{1500 - 1450}{1500}$$

$$\therefore s = \frac{50}{1500} = \frac{1}{30}$$

$$s = 0.033 \times 100$$

$$\boxed{s = 3.33\%}$$

Q Calculate the synchronous speed and slip of a three phase, 50 Hz, 4 pole induction motor running at

(a) 1440 rpm, b) 1480 rpm c) 1450 rpm.

$$\frac{P \cdot N_s}{120} = f_s$$

$$N_s = \frac{50 \times 120}{4}$$

$$N_s = \frac{6000}{4} \; 1500$$

$$N_s = 1500$$

a) $s = \frac{N_s - N_r}{N_s} = \frac{1500 - 1440}{1500} = \frac{60}{1500}$

$s = 0.04 \times 100 = 4\%$

b) $s = \frac{1500 - 1480}{1500} = \frac{20}{1500} = 0.013 \times 100$

$s = 1.3\%$

c) $s = \frac{1500 - 1450}{1500} = \frac{50}{1500} \; 30 = 0.033 \times 100$

$s = 3.3\%$

Torque / slip characterstics

The Torque slip characterstics can be determined by the following equ^n.

$$T_d = \frac{kSE^2R}{R^2+(SX)^2} \quad -(1)$$

where T_d = developed torque,
S = slip.
E = Voltage
R = Rotor resistance.
X = Rotor reactance,
k = Constant

The Torque and slip releastion ship can be explained in 3 different modes, which are generating mode, motoring mode and Breaking mode

s = (-ve)

① Generating mode → In the generating mode when the motor is rotated by an external prime mover, the speed of rotor conductors becomes more than the synchronous speed and hence according to equ^n of

$$\boxed{S = \frac{N_s - N_r}{N_s}}$$

, S are slip becomes negative.

$$\boxed{S < 0}$$

(S = 0 to 1)

② Motoring Mode → In the motoring mode when the rotor speed is Zero and hence slip will be One (1)

$$\boxed{S = \frac{N_s - N_r}{N_s}}$$

$$S = \frac{N_s - 0}{N_s}$$

$$, S = \frac{N_s}{N_s},$$

$$\boxed{S = 1}$$

When the rotor speed is equal to synchronous speed, the slip will be zero

$$S = \frac{N_s - N_r}{N_s}$$

$$N_s = N_r$$

$$T_d = \frac{K S E^2 R}{R^2 + (SX)^2}$$

$$S = \frac{N_s - N_r}{N_s}$$

$$S = \frac{0}{N_s}$$

$$\boxed{S = 0}$$

It means in the motoring mode, the slip ranges from zero to one (0 to 1). The motoring mode can be explained in three main regions

(i) Low slip region (stable) → ① When the speed of the motor is equal to synchronous speed, slip is zero there will be no torque. It means that the torque slip curve start from origin. with no load.

② When the load is given to the motor, the speed starts decreasing and hence, the slip and the torque of the motor start increasing.

③ As the slip increases by increasing the load the speed drops but the developed torque increases upto it maximum value.

④ Mathematically at low slip region the value of slip is so small that it's square can be neglected so equⁿ ① becomes $\boxed{T_d \propto S}$

(ii) **Medium slip region** (stable) : The medium slip region is the region where the maximum torque is obtained. This maximum torque is also called pull out OR breakdown torque. The slip at which the pull out torque is obtained is called pull out slip OR breakdown slip.

For obtaining maximum torque, equ^n ① is differentiated with respect to slip and putting it equal to Zero

$$T_d = \frac{kSE^2R}{R^2+(SX)^2}$$

differ. w.r.t (S) we get

$$\frac{dT_d}{ds} = \frac{\{[R^2+(SX)^2][kE^2R]\} - \{[kSE^2R][2SX^2]\}}{[R^2+(SX)^2]^2}$$

putting $\frac{dT_d}{ds}$ equal to 0 :-

$$[R^2+(SX)^2][kE^2R] = [kSE^2R][2SX^2]$$

$$[R^2+(SX)^2] = [S][2SX^2]$$

$$R^2+(SX)^2 = 2(SX)^2$$

$$R^2+S^2X^2 = 2S^2X^2$$

$$R^2 = 2S^2X^2 - S^2X^2$$

$$R^2 = S^2X^2$$

$$\boxed{R = \pm SX}$$ //

$$\frac{d}{dx}\frac{f_1}{f_2} = \frac{f_2\frac{d}{dx}f_1 - f_1\frac{d}{dx}f_2}{f_2^2}$$

The equⁿ ② is the condition for getting maximum torque.

From equⁿ ① & ② we get

$$T_{dmax} = \frac{kSE^2R}{R^2+(R)^2}$$

$$T_{dmax} = \frac{kSE^2R}{2R^2}$$

$$\boxed{T_{dmax} = \frac{kSE^2}{2R}} \quad (3)$$

equⁿ ③ is maximum ~~topic~~ torque

(Unstable)
(iii) High slip region → In the high slip region the torque starts decreasing when the slip is increased beyond pullout value if the load is continously given to the motor, the speed decreases & hence the slip further increases but the torque start decreasing after it max. value this region is also called unstable region because in this region the motor speed continously decreases and eventually stops. The motor should not be runing in this region. Mathamatically from equⁿ ① the value of slip is a modrate value and its square can not be neglected so equⁿ ① becomes

$$\boxed{T_d \propto \frac{1}{S}}$$

(3) Breaking Mod (S>1) ([struck out])

In this mod when we have to stope the rotor, the terminals of the supply are reversed due to this magnetic field of the motor reverses and the slip increases from One (1) we have
$$S = \frac{N_s - N_r}{N_s}$$

if N_s is reversed then the equ^n becomes

$$S = \frac{N_s - (-N_r)}{N_s} = \frac{N_s + N_r}{N_s}$$

so, 'S' is greater than 1 (One).

Application

The cage rotor is suitable for constant speed of small power factor. They are used in printing machine, flour mils & other drives where low starting torque is required.
When the requirement of high starting torque is needed, slip ring rotor are used in these applications the efficiency is not an issue. They are used in crans, lift, elivators etc.

Single phase induction motor

The most common type of electric motor is single phase induction motor. It is widly use in domestic & inductrial purpose. They are small in size. They are used in fans, washing machine, vacumcleaner & hair dryer in domestic applications in industries they are used in heavy machines, AC, fans and farming equipments

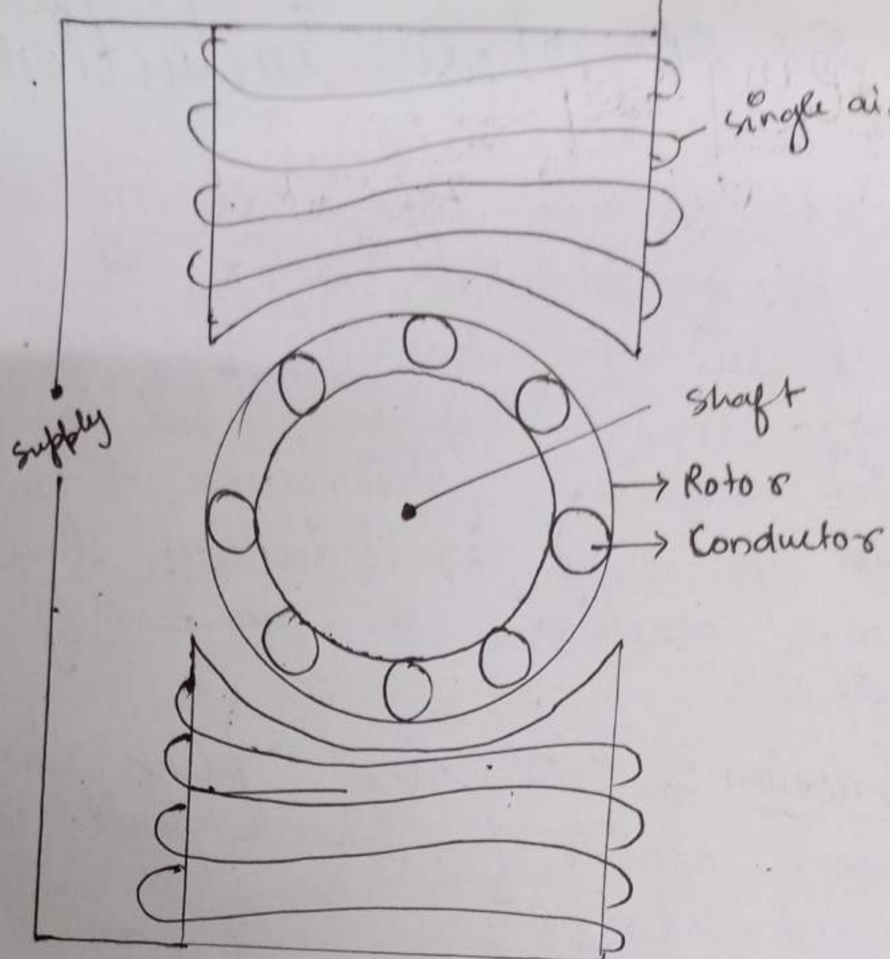
Construction → The single phase induction motor consite of two parts which are rotor & stator.

Stator → The stator is stationary part of the motor. It consits of winding called the main winding in which supply is given. By giving supply, the motor does not rotate. So we can say that a single phase induction motor is a non-self starting motor. There are two bindings is the stator which are starting winding and main windings. The equ^n for these windings are given by

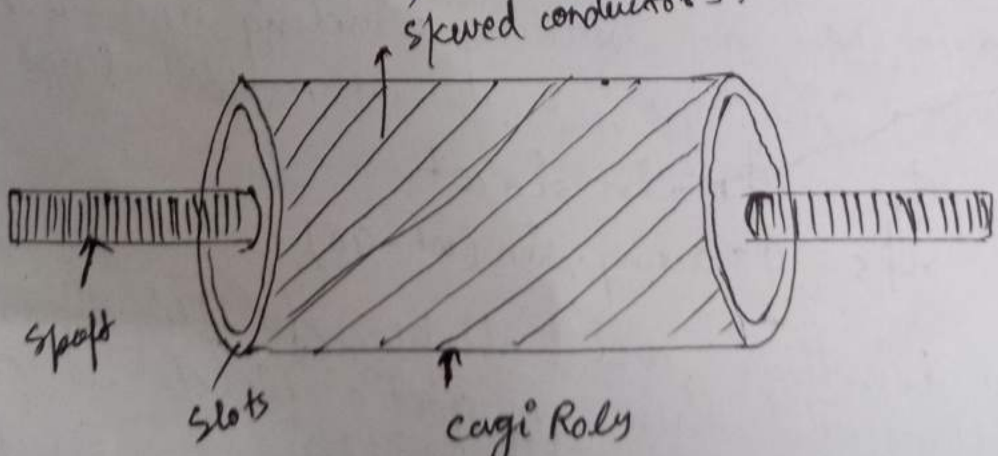
$$\phi_m = \phi_{main} \sin \omega t$$

$$\phi_s = \phi_{starting} \sin(\omega t - 90)$$

These windings are displaced 90° apart. The resultant of these magnetic field is a rotating magnetic field must be uniform in nature, because a uniform magnetic field runs the rotor without noise & they also produce a high starting torque.



Rotor → The rotor is the rotating of the motor. They can be of cage rotor & wound rotor. Normally cage rotors are used in the single phase induction motor. The cage rotor has copper conductors inserted into the slots of the rotor. They are the copper conductors made up of the copper & the starting torque



Principle →

When the single phase AC supply is given to the stator winding, an alternating magnetic field is produced. The alternating or pulsating magnetic field means that it builts up in one direction falls to 0 & again built up in opposite direction. Under these condⁿ, the rotor does not rotate due to inertia. So we can say that a single phase indⁿ motor is not a self starting motor.

To explain its performance, two theories have been suggested which are cross field theory & double revolving field theory

Double Revolving field theory–

According to this theory which states that the stationary pulsating magnetic field can be resolved into two equal parts, each of equal magnitude but rotating in opposite direction. The induction motor respond to each magnetic field separately & the net torque in the motor is equal to the sum of the torque due to each magnetic field

The equⁿ for magnetic field produced and whose ~~access~~ access is field in space is given by

$$\beta = \beta_{max} \sin \omega t \cos \alpha$$

$$\beta = \beta \frac{max}{2} \sin(\omega t - \alpha) + \beta \frac{max}{2} \sin(\omega t + \alpha)$$

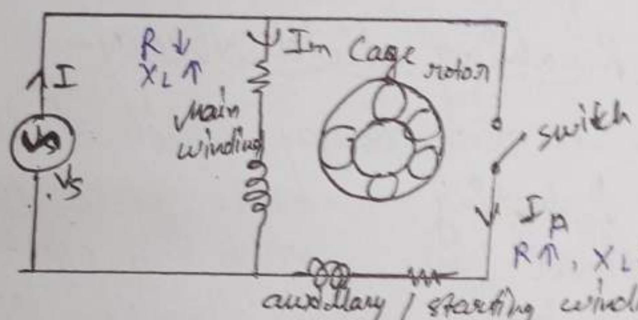
↑ Forward direction ↑ Backward direction mag field.

∵ $\sin A \cos B = \frac{1}{2} \sin(A-B) + \frac{1}{2} \sin(A+B)$
where $A = \omega t$, $B = \alpha$

where α is the space displacement angle. The first eqn of right hand side is the eqn which represents the magnetic field rotating in forward direction. The second eqn in the right hand side represents the eqn of magnetic field rotating in backward direction. Both the magnetic field have equal magnitude of $\frac{B_{max}}{2}$ rotating in same frequency & angular velocity in both the directions

Starting methods of single phase induction motor

① Split Phase Method :-



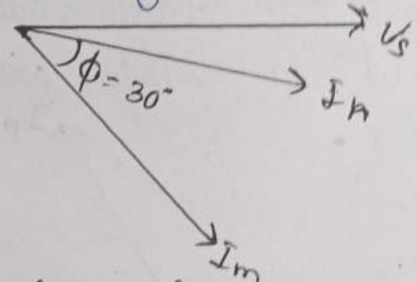
The split phase motor is also called resistance start motor. It has a cage rotor & its stator has two winding Main winding & auxillary winding. They are displaced 90° in space. The auxillary winding has high resistance & low inductive reactance. On the other hand the main winding has low resistance & high reactive inductance. Due to this the current I_m of main winding lags the supply voltage by around 90° the current I_A lags the voltage by around 0° (zero degree). Due to this there is a phase difference of around 30° to 40° b/w I_A & I_m which is ~~suphicient~~ sufficient to rotate the rotor conductors this is because of the production of rotating magnetic field

Since, the magnetic field produced is a non uniform, the motor runs with noise.

When the motor reaches its speed of 80% of synchronous speed the switch is opened and the auxillary winding is disconnected from the supply.

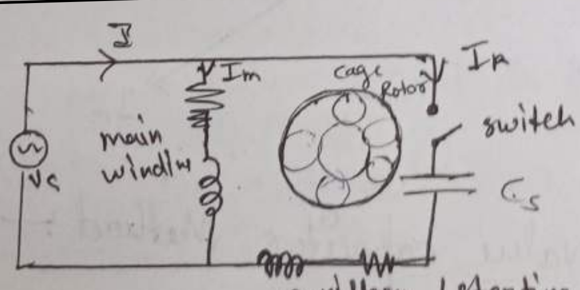
These motors are used in AC, Fans, blowers, washing machine etc. because they are very cheap.

The motor direction of rotation can be reversed by reversing the connection of main winding OR auxillary winding.



Phasor diagram

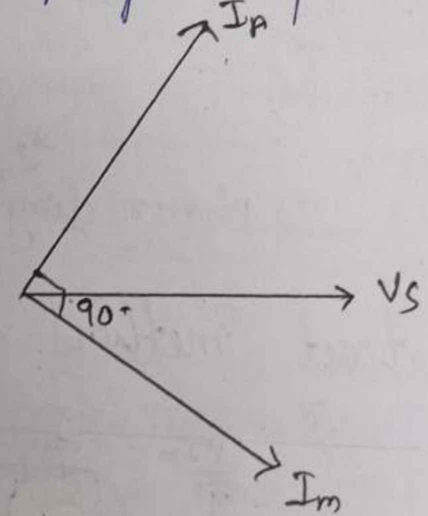
② Capacitor start method



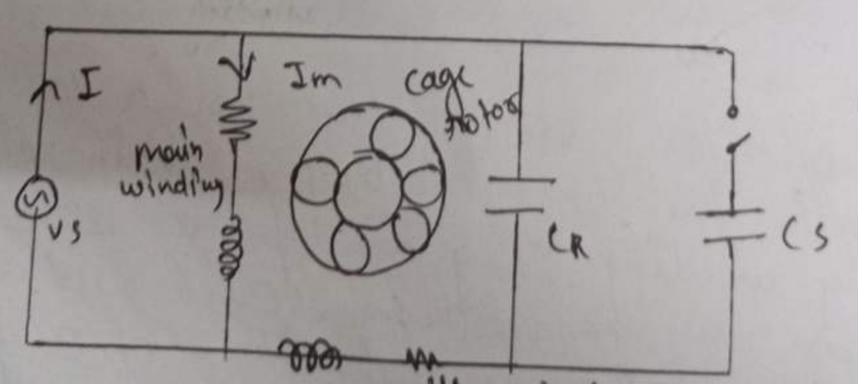
The capacitor start motor has a cage rotor & its stator has two windings, Main winding & auxillary winding. They are placed 90° apart. A capacitor is connected in series with the auxillary winding by selecting a capacitor of a proper rating the current I_m in the main winding is made to large the current I_A of auxillary winding by 90°. Those a single phase supply current is splited into 2 phase there fore the motor produces a magnetic field which is a uniform. When the motor reaches 80% of synchronous speed, the auxillary winding and the capacitor are disconnected from the supply. The motor is so named it uses only one capacitor for the purpose of starting of the motor.

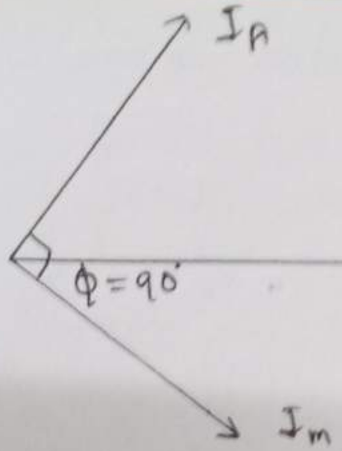
Its direction can be reversed by reversing the connection of One of the winding.

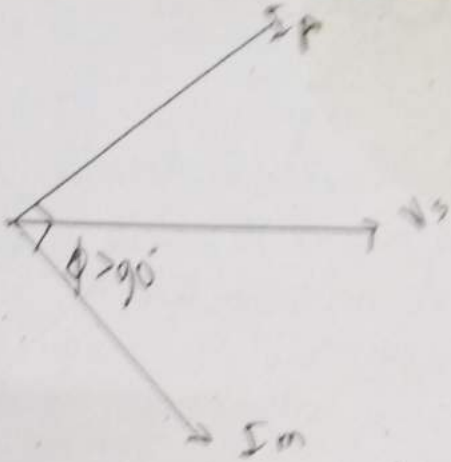
They are used in high loads of high inertia. They are used in pump, compressore for AC & Refrigerator.



(3) Two value capacitor Method :-

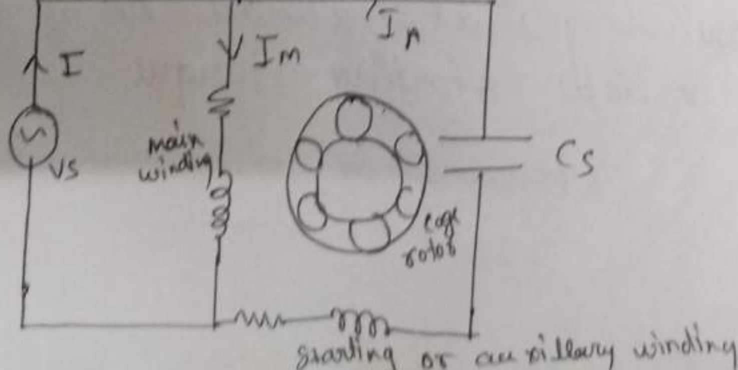


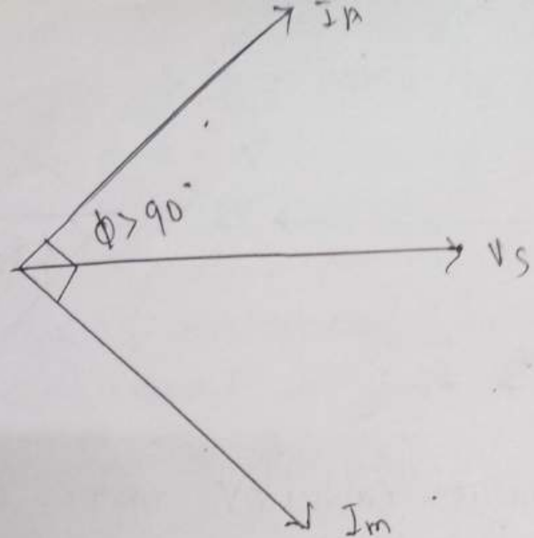




The two value capacitor motor is also called capacitor start capacitor run motor. It has a cage rotor and has two windings, main & auxillary winding. They are displaced 90° in space. The motor uses two capacitor which are starting & running capacitors. They are connected to parralled each other. To obtain a high starting torque, the capacitive reactance in the starting winding should be low. Hence, a large value of starting capacitor is required. During normal condition, a modrate torque is needed and for that running capacitor should be less. As the motor reaches 80% of its synchronous speed. The starting capacitor is disconnected by supply. The direction of rotation of the rotor can be reversed by reversing the terminals of either main winding or starting winding.

(4) Permanent capacitor method :-





The permanent capacitor motor is the most common method of starting. It's consist of a cage rotor and its stator has two windings, main & auxillary winding. Since the capacitor is permanantly connected in the circuit, it does not need any switch this motor is very efficient & cheap so it is commonally used in house hold purpose

Advantage →

1. This method has a higher efficiency.
2. It produces a uniform magnetic field.
3. It does not need any switch.
4. This method is cheap and robust.

Disadvantage →

1. Since a higher amount of current is delivered from starting winding, it should be of good quality.
2. It has a low starting torque

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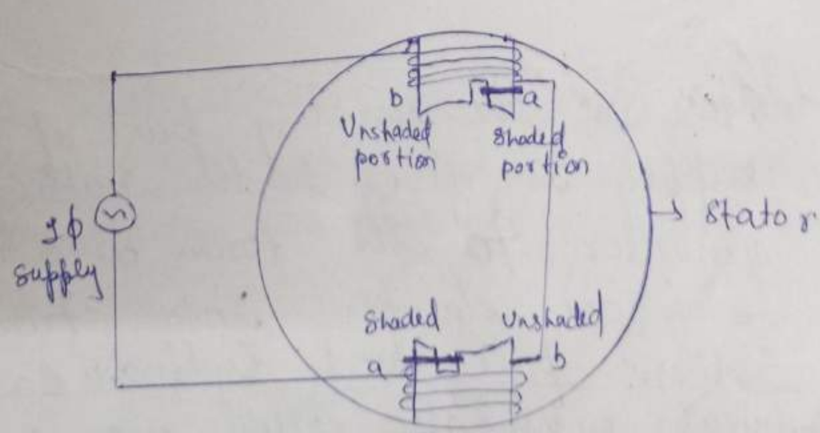
(5) Shaded pole method : V → M.f main → V shad → flux induced

The shaded pole method it is a simple type of self starting motor. In this method some part of the pole is slotted and a copper ring OR Winding is fitted into it. This portion is called shaded portion of the pole. The unslotted portion of the pole is called unshaded portion Like the other method, the motor uses cage rotor.

When an alternating voltage is given to the motor, an alternating flux is produced. Some portion of this flux links with the shaded portion and according to faradays law an alternating voltage is induced in the shaded porssion of the pole. This induced voltage further produces an induced flux this induced flux opposes the main flux of the motor. Hence, when there is the displacement of 90° b/w the main flux & induced flux, a rotating magnetic field is produced this rotating magnetic field start rotating the rotor conductor. This magnetic field is uniform in nature & the direction of rotor is constant which can not be reversed.



1. Three phase synchronous machine

The 3ϕ synchronous machines are those in which the rotor is rotated at synchronous speed. They are of two types which are synchronous motor & synchronous generator. The synchronous generator are also called the alternator.

The synchronous speed of rotating magnetic field depends upon the number of poles (P) & supply frequency (f_s). It can be written as

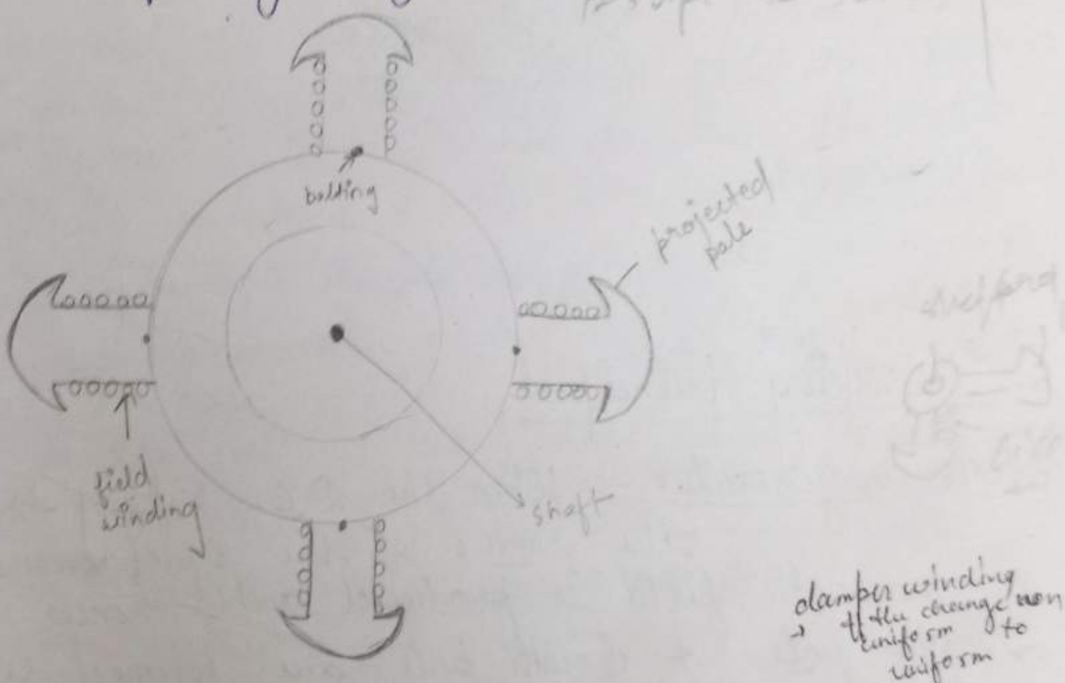
$$\frac{P \cdot N_s}{120} = f_s$$

II. construction -

Like the other machine the alternator can be divided into stator & rotor. Unlike the other machine the stator has armature winding & rotor as field winding. Due to this we can say that the three phase synchronous generator has a rotating magnetic field but a stationary armature winding. It is done because it is easy to resive the induced current in a stationary armature winding.

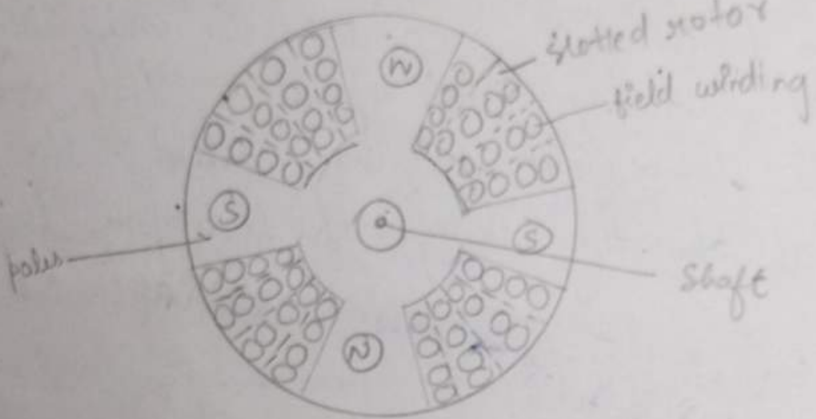
The rotor is the rotating part of the machine. The D.C supply is given to the rotor in both motor and generator to the form of a magnetic field. The rotor are classified into two types which are Salient pole and Cylindrical type Rotor. The cylindrical rotor are also called non salient pole rotor

Salient pole → The salient pole rotors are also called projected pole rotor because they are projected out of the surface of the machine. The air gap is non-uniform and so a non-uniform magnetic field is produced. They have a higher diameter so they are operated for low speed machines. Since they produce a non-uniform magnetic field, they use damper winding to operate. They are built of thick steel laminations and are bolted to the rotor. They have an operating range of 125 r/pm to 500 r/pm.



② Cylindrical type rotor → They are also called non-salient OR non-projected pole rotor. The rotor consist of smooth solid steel cylinder having number of sloats. These sloats consist of field winding. The sloated portion of the rotor act as pole. Hence the poles are not projected out of the surface. In this case the rotor surface is smooth & the air gap is uniform. So a uniform magnetic field to produced

They are mechanically very strong & there speed is high which ranges from 1500rpm to 3000rpm.
Due to there high speed they are called terbogenerator OR terboalternaters.



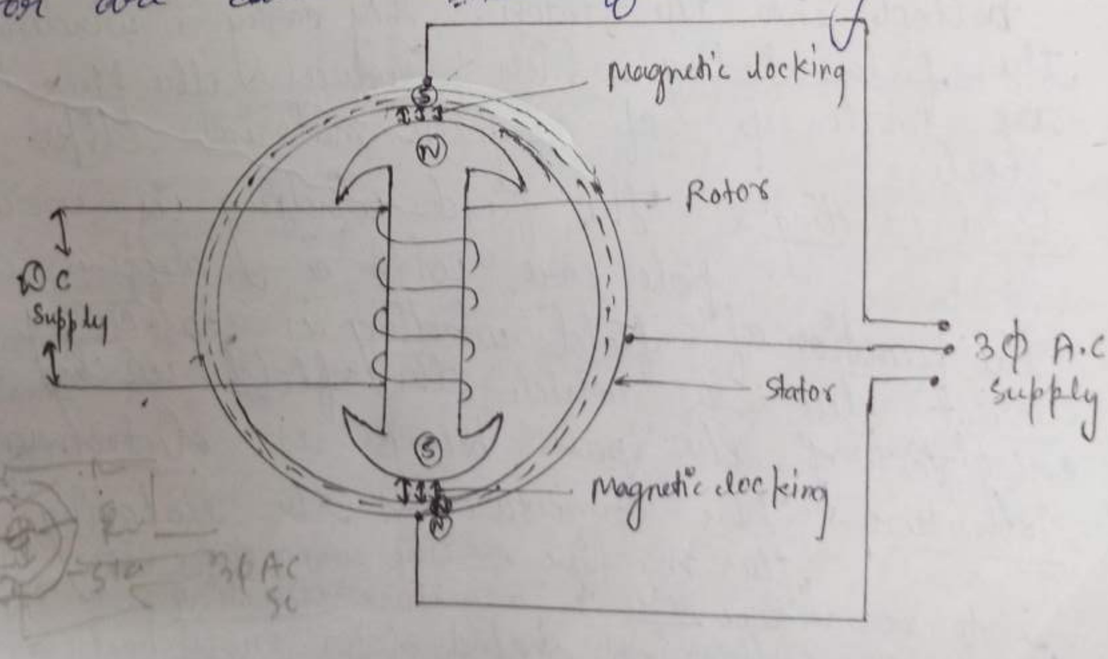
Working principal

① **As a generator** → When the D.C. supply is given to the rotor of the synchronous generator, a magnetic field is produced and hence North pole & South pole are formed when the rotor is rotated by any method, cutting off flux is occured. According to faradays law electromagnetic induction $e = -\frac{d\phi}{dt}$, and emf is indused on the armature conductor placed in the stator of the generator. The voltage is resived from the armature winding.

ii. **As a motor** → The principale of three phase synchronous motor work on magnetic locking.

When a three phase A.C. voltage is given to stator winding, a rotating magnetic field is produced in the air gap of stator & rotor. The stator field rotates at synchronous speed. Due to the supply given to rotor which is D.C and other magnetic field is produced in the rotor. Therefore, there are two magnetic field in the motor. The rotor will try to align with the stator field. Since, the stator magnetic field is rotating, the rotor and the rotating magnetic field is rotated with the stator magnetic field this process is called magnetic locking. Due to this the rotor of the motor start rotating with the synchronous speed.

Since, the two supply are given to the motor So a 3ϕ synchronous motor is called Doubly excited motor. Since, the D.C supply is given to the rotor, the three phase synchronous motor are called Non-self starting motor



D.C. Machine

The D.C machine is mainly divided into two types which are D.C motor & D.C generator. The construction of D.C machine in both the cases is same but the working principal is different.

1. Construction →

The construction of a D.C machine consist of following parts which are explained below -

① Frame → The frame is also called the stator OR the yoke. It is the outer portion of the machine. It is made up of cast iron because it is very cheap and provide low reluctance path. The frame gives a protecting covering to the machine from external means. It also provide the machanical support to the pole & forms the part of magnetic field.

② Poles → Each pole is divided into two parts which are pole core & pole shoe. The poles are bolted into the stator. They carry a winding called the field winding which produces the flux. They are made up of magnetic material like iron & steel

③ Field winding → The field winding is wound on the pole core with a different direction.

The function of field winding is to carry the current due to which the field winding is energized & the pole behaves as electromagnets

④ Armature → The armature is the rotating part of the machine. The armature is sub divided into armature core & armature winding. The armature core is the cylindrical shaped drum mounted on the shaft. Its function is to provide house for armature winding. It also provide the path of low reluctance. The armature winding are made up of two types. which are Lap winding & Wave winding. In the lap winding the number of parallel paths (A) are equal to number of poles (P) Hence,

$$A = P$$

In the wave winding the no. of parallel path (A) are always 2 (two)

$$A = 2$$

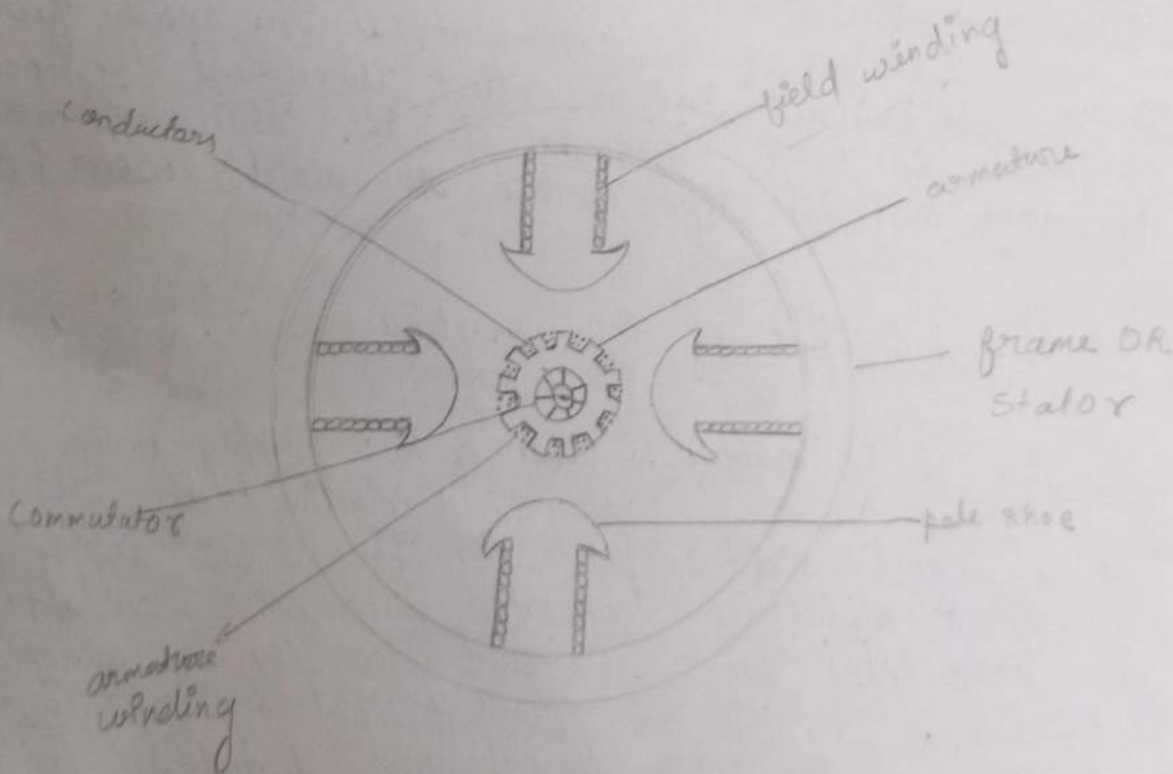
(5) Commutator → The commutator is a device which performs the rectification in case of D.C. generator. (A.C to D.C) & inversion in case of D.C motor (D.C to A.C).

(6) Brushes → The brushes are stationary & resting on the surface of the commutator. The main function the brushes is to collect the current from commutator & provide it to the external circuit. They are made up of soft material like carbon to avoid wear & tear.

II. Working Principal of DC machine

(I) Machine as a motor → When a D.C supply is given to the field winding of the motor a magnetic field is produced. The D.C supply produces a current which is converted into A.C current by the commutator and is send to the armature through the brushes. According to the principal of motor when a current carrying conductor is placed in a magnetic field, torque is produced on that conductor. So due to this the torque is produced on the armature conductors & they start rotating. Hence, the torque is achieved on the output giving supply at input.

2) **Machine as a DC generator →** In D.C generator the D.C supply is given to the field winding to produce a magnetic field in the core. When the armature conductor is given torque through the saft, an A.C voltage is produced in the armature conductors. This is because of faradays low of electromagnetic induction which states that the current is produced on the conductor placed in magnetic field when a torque is given to it. The induced emf OR current is converted into D.C supply by the commutator & is send to output through the bruseh. Hence, by giving the machanical energy OR the torque in the input we get D.C supply at the output.



Emf equation of D.C Machine → Let us consider one conductor placed in the D.C machine & rotating at 'N' rpm. This conductor when cuts the flux produces a voltage according to faraday's law of electromagnetic induction. Hence, this eqn becomes:-

$$E = \frac{d\phi}{dt} \quad \text{--- (1)}$$

Let us assume that the flux produced by one pole of the machine be ϕ & hence, if the total number of poles are 'P' then the total flux induced in the machine will be $P\phi$

$$P\phi \text{ --- (a)}$$

The time taken by the conductors to complete one revolution will be

$$\frac{60}{N} \quad \text{--- (b)}$$

because the speed of the rotor is N_{rpm} putting the values of a & b in eqn (1)

$$E = \frac{P\phi}{\frac{60}{N}}$$

$$E = \frac{NP\phi}{60}$$

the above eqn represents the emf induced in one conductor.

If the total no. of conductors 'Z' are placed in 'A' parallel path then the total emf induced of machine will be

$$E = \frac{NP\phi Z}{60A}$$

where, E = emf induced (in volt)
N = speed of motor (in RPM)
P = No. of poles
ϕ = flux per pole (in weber)
Z = no. of conductors
A = No. of parallel path

For as disussed erliar there are two types of armature windings

(i) For lap winding when

$A = P$

The emf equ^n

$$E = \frac{N\phi z}{60}$$

(ii) for wave winding when

$A = 2$

The equ^n becomes

$$E = \frac{NP\phi z}{120}$$

Types of D.C Machine

The D.C machine can be divided into two type on the basis of supply given.

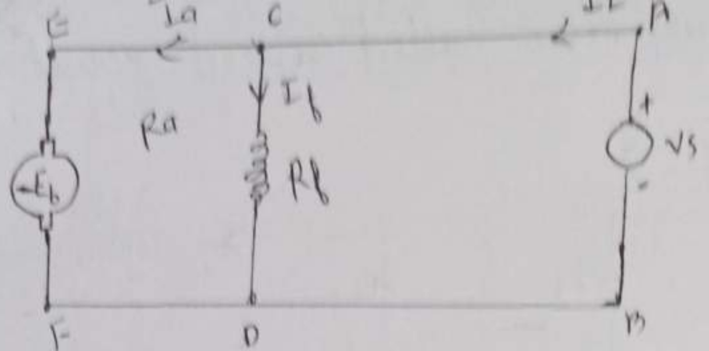
They are separatly excited D.C machine and self excited D.C machine

The machine in which the supply is given to the machine from other source is called the seperately excited machine.

The machine in which supply is given with in the machine is called the self excited machine.

The word excitation mean to give supply to the machine. The self excited machine can be classified into three types which are DC shunt machine, D.C. series machine & D.C compound machine.

(1) DC Shunt. Machine

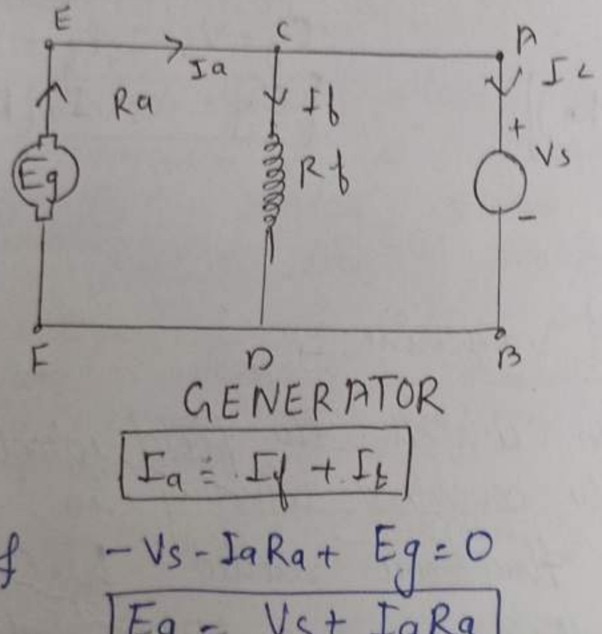


MOTOR

$$\boxed{I_L = I_f + I_a}$$

& $V_s - I_a R_a - E_b = 0$

$$\boxed{E_b = V_s - I_a R_a}$$



GENERATOR

$$\boxed{I_a = I_f + I_L}$$

& $-V_s - I_a R_a + E_g = 0$

$$\boxed{E_g = V_s + I_a R_a}$$

Where
E_b = back emf of motor
E_g = generated emf of generator
V_s = supply voltage
I_f = field current
R_f = field resistance
I_a = armature current
R_a = armature resistance

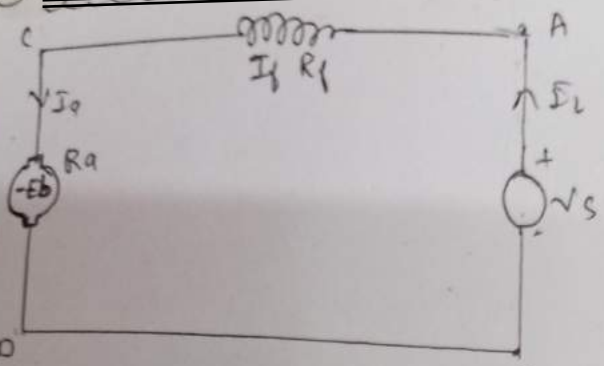
I_L produce $B\uparrow \to \phi\uparrow$

$\hat{I}_L$ = line current / Load current

branch CD is the branch for field winding.
EF is the branch for armature winding

The voltage equ^n are also called speed equation.

(2) D.C Series machine →

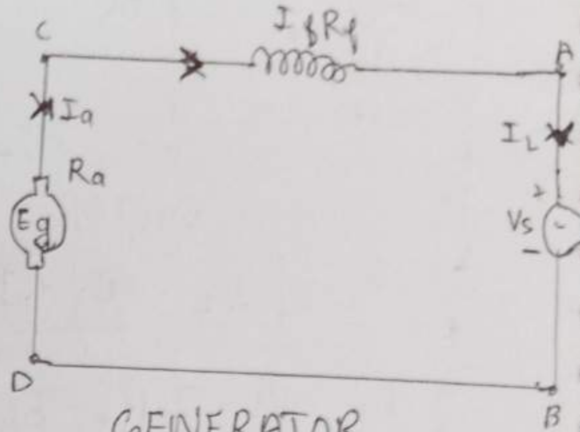


MOTOR

$$\boxed{I_L = I_a = I_f}$$

$$E_b = V_s - I_f R_f - I_a I_f$$

$$\boxed{E_b = V_s - I_a (R_f + R_a)}$$



GENERATOR

$$\boxed{I_a = I_f = I_L}$$

$$E_g = V_s + I_f R_f + I_a R_a$$

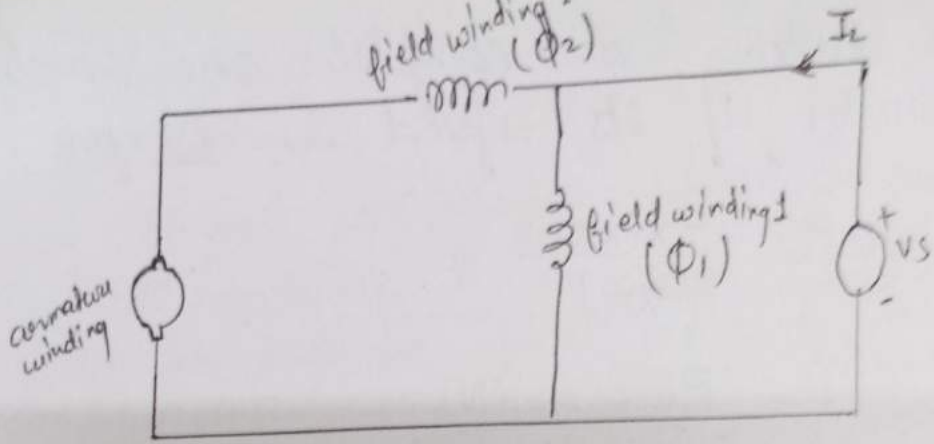
$$\boxed{E_g = V_s + I_a (R_f + R_a)}$$

(3) D.C compound machine →

The machine in which the field winding is connected with the armature winding in both series & parallel, they are called D.C compound machine. Since, there are two field winding in the machine so there will be two fluxes.

If these two fluxes oppose each other, the total flux of the machine is decreased. This is called Differential compound D.C machine

If these fluxes addup, the total flux will be increased. This is called Cumulative compound D.C. machine.



when $\phi_1 - \phi_2 \Rightarrow$ differential

$\phi_1 + \phi_2$ = cumulative

Torque equation of D.C. motor

The turning force along axis is called the torque. It is denoted by 'T'. In the D.C. motor gross torque developed by the armature is called the armature torque OR Developed torque. The power developed in armature winding is actully the work done by the conductor per unit time so it can written as.

$$Power = \frac{work\ done}{time} \quad -(1)$$

The work done by the conductor is the force applied on it into distance travelled by it so

$$work\ done = force \times distance\ travelled \quad (2)$$

Along the circumference distance travelled will be $2\pi r$ so from equation (1) & (2) we get

$$Power = \frac{force \times distance}{time}$$

$$P = \frac{f \times d}{t}$$

$$P = \frac{f \times 2\pi r}{t}$$

The time taken to complete one revolution the D.C motor if its speed is N rpm

$$P = \frac{F \times (2\pi r)}{\left(\frac{60}{N}\right)}$$

$$P = \frac{F \times (2\pi r)(N)}{60}$$

The power developed in the armature winding is the product of Back emf & the armature current so

$$E_b \times I_a = F \frac{\times (2\pi r) \times N}{60}$$

$$\frac{NP\phi Z}{60A} \times I_a = \frac{F \times (2\pi r) \times N}{60}$$

$$\frac{P\phi Z I_a}{A} = (F \times r) \times (2\pi)$$

$$\frac{P\phi Z}{(2\pi) A} \times I_a = T_d$$

$$T_d = \left(\frac{PZ}{2\pi A}\right) \times \phi \times I_a$$

$$\boxed{T_d = \left(0.159 \frac{PZ}{A}\right) \times \phi \times I_a}$$

keeping $0.159 \frac{PZ}{A}$ constant

$$\boxed{T_d \propto \phi I_a}$$

The developed torque of D.C motor is directly proportional to the flux & Armature current

Q A 4 pole 1000 rpm D.C. generator as 240 conductor. & is lap wound. If the flux per pole is 0.04 weber. Calculat the emf induced in the machine What will be the generated emf if the winding is wave connected

$$E = \frac{NP\phi Z}{60A}$$

lap = A = P
wave A = 2

N = 1000 rpm
P = 4
Z = 240
ϕ = 0.04

For lap winding (A = P)

$$E = \frac{1000 \times 4 \times 0.04 \times 240}{60 \times 4 \times 100}$$

E = 10 × 16

E = 160 Volt

For wave winding A = 2

$$E = \frac{1000 \times 4 \times 0.04 \times 240}{12000}$$

E = 320 V

Q. The armature of 4 pole D.C motor has speed of 600 rpm & produces 220 V with 100 conductor. Calculate the flux per pole

$E = 220$
$N = 600$ rpm
$P = 4$
$Z = 100$
$\phi = ?$

For lap winding $(A = P)$

$$\frac{220 \times 60 \times 4}{600 \times 4 \times 100} = \phi$$

$\boxed{\phi = 0.22}$ weber 0.22 wb

For wave winding $(A = 2)$

$$\frac{220 \times 60 \times 2}{600 \times 4 \times 100} = \phi$$

$\boxed{\phi = 0.11}$ weber

Characterstics of D.C motor

① D.C shunt motor

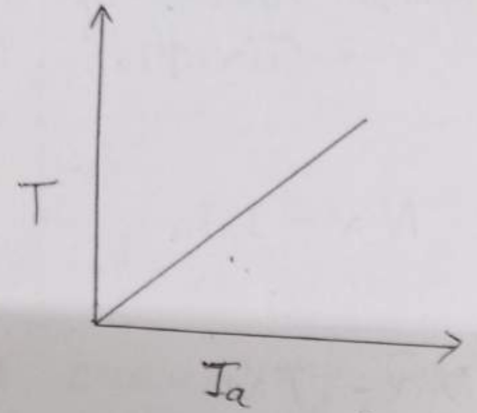
The characterstics in the D.C motor is analysed by three quantities which are torque, speed & armature current.

(a) Torque / armature current → From the torque equ^n of D.C motor, we get $\boxed{T \propto \phi \times I_a}$

keeping ϕ constant we get

$\boxed{T \propto I_a}$

From this equ^n we conclude that the torque



(b) Speed/armature current :- from the speed equⁿ of D.C. motor

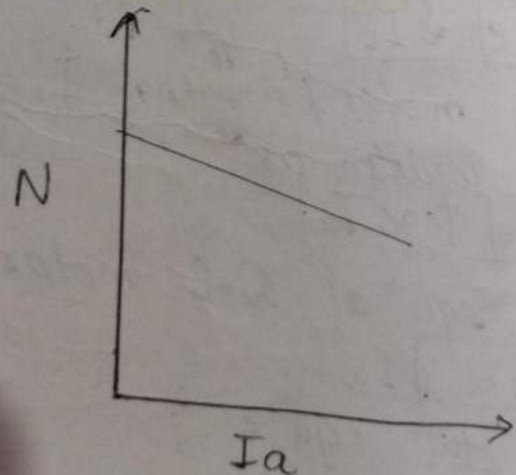
$$\boxed{E_b = V_s - I_a R_a}$$

$$\frac{NP\phi Z}{60A} = V_s - I_a R_a$$

neglecting all the constant we get

$$\boxed{N \propto -I_a R_a}$$

From the above equⁿ it can be seen that the speed of the D.C motor is decreased with an increase in armature current.



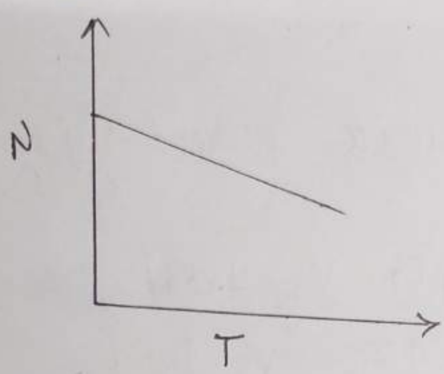
Speed / Torque → From the equation of $T_d \propto \phi I_a$,

and,

$$N \propto - I_a R_a$$

we get

$$N \propto - T R_a$$



② D.C. series motor

(a) Torque / armature current → The magnetic flux is produced due to the line current OR load current of the supply so we can write as

$$\phi \propto I_L$$

Since, in series motor (circuit), $I_L = I_a$
so it can be written as

$$\phi \propto I_a$$

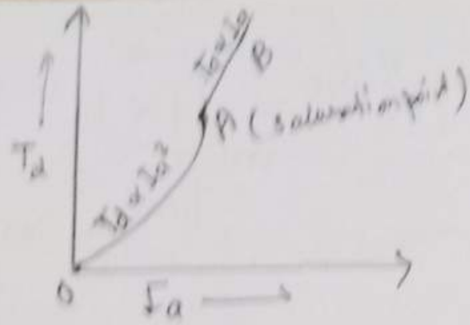
From the torque equ^n of D.C. motor

$$T_d \propto \phi I_a$$

From the above two equ^n,

$$T_d \propto I_a^2$$ ///

This equ^n represent for parabola in increasing order so the curve will drawn as.



It is so because up to point 'A' the value of flux was increasing with increase in load current after saturation value of flux will be constant and the torque equ^n become

$$T_d \propto I_a$$

It is represented by the straight line in the graph

(b) Speed armature current → From the speed equ^n of D.C series motor

$$E_b = V_s - I_a R_a - I_a R_f$$

$$\frac{NP\phi Z}{60A} = V_s - I_a(R_a + R_f)$$

Neglecting all constants

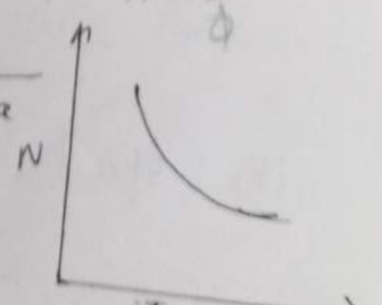
$$N \propto \frac{V_s - I_a(R_a + R_f)}{\phi}$$

If $(R_a + R_f)$ are so small then their value can be neglected

$$N \propto V_s$$

$$N \propto \frac{V_s}{\phi}$$

$$N \propto \frac{1}{\phi} \Rightarrow N \propto \frac{1}{I_a}$$



Since,

$$\phi \propto I_a$$

$$N \propto \frac{1}{I_a}$$

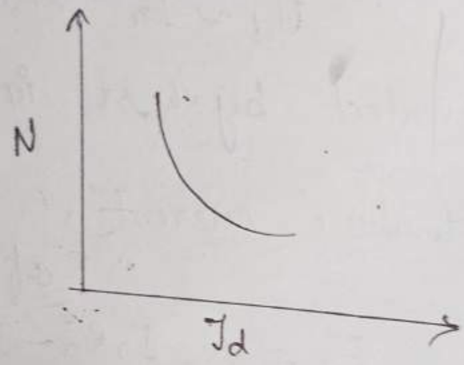
this equ^n shows that the speed decreases with increase in armature current.

(c) Speed / Torque → Since $T_d \propto I_a^2$
and
$N \propto \frac{1}{I_a}$

From these two equⁿ we get

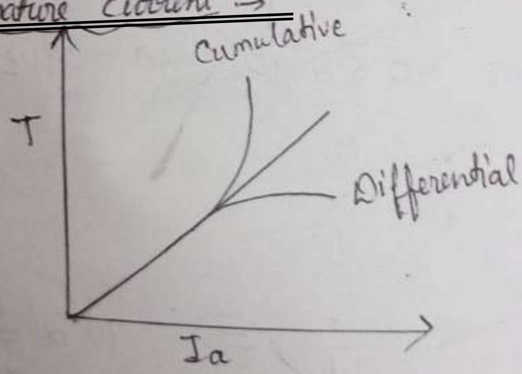
$$N \propto \frac{1}{\sqrt{T_d}}$$

& hence from this equation we conclude that the speed decreases with increase in developed torque

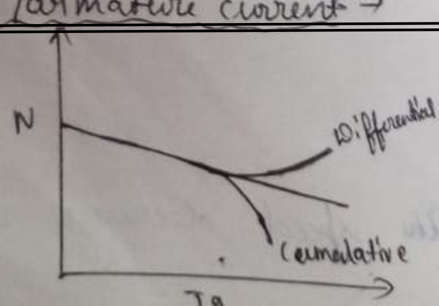


(3) D.C compound motor

(a) Torque / Armature current →



(b) Speed / armature current →



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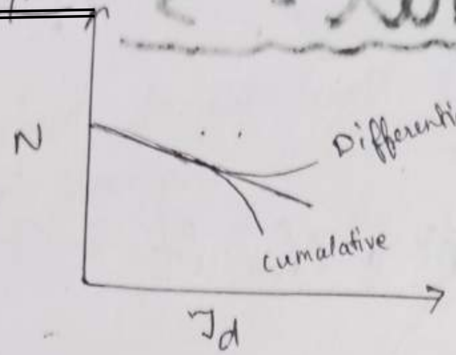
(c) Speed / Torque



The cumulative and differential. D.C compound motor should be defined with its explaination.

11. Applications of D.C motor

1. The D.C shunt motor has a moderate torque and its speed is almost constant. They are used in machine tools, lathe machine (convert the steel and in different design), blowers and fans.
2. The D.C series motor has a high starting torque and it can be avoided for no load conditions. It has a varaible speed and are use in crans & elevators.
3. The cumulative D.C motor has a high starting torque and no load condition is alowed in this motor. They are used in alivator, rolling meals.
4. The differential compound D.C motor are not used in any type of applications.

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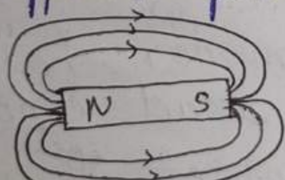
Unit - 5

Magnetic circuit

The closed path having magnetic lines of forces is called magnetic circuit. In the magnetic circuit the direction of magnetic lines are always from North to South pole.
The magnetic surface are explained in detail by the following terms.

① **Magnetic field** → The region around a magnet with which the enfluence of magnet can be expirenced is called Magnet field.

② **Magnetic lines** → The magnetic field is represented by imiginary line around it which is called the magnetic lines. They always move in closed path and never intersect each other. They always prefer a least opposition path



③ **Magnetic flux** → The total numbers of line in a magnetic field is called the magnetic flux. Its unit is 'Weber' and is denoted by 'ϕ'. Mathematically

$$10^8 \text{ magnetic lines} = 1 \text{ weber}$$

④ **Magnetic flux density** → It is diffened is the total flux per unit area in a magnetic field. It is denoted by 'B' & its unit is 'Tesla' OR Weber/m^2

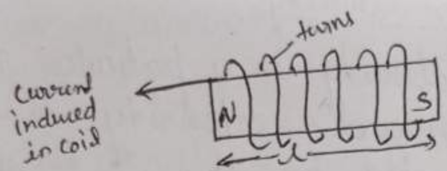
$$B = \frac{\phi}{A}$$

where $B \Rightarrow$ Magnetic flux density
$\phi \Rightarrow$ flux
$A \Rightarrow$ Area of cross section

(5) Magnetic field intensity → It is diffined as the ratio of number of turns multiplayed by the current induced to the length of the magnetic material. It denote the strongness of the magnetic material it is denoted by 'H' & is given by

$$H = \frac{NI}{l}$$

where - H ⇒ field intensity
N ⇒ No. of turns
I ⇒ current induced
l ⇒ length of the magnetic material.



(6) Magnetomotive force (mmf) → The driving force for the establishment of flux in a magnetic material is called the mmf. It is diffined as the product of the no. of turns and the current induced in it

$$mmf = N \times I$$

Its unit is Amp. / turn

(7) Reluctance → The opposition offered by the magnetic material to the stablishment of flux is called the Reluctance. It is directly proportional length of the magnetic material and inversly proportional area of cross section. It is denoted by 'S'. and is given by

$$S \propto l \quad -①$$

$$S \propto \frac{1}{A} \quad -②$$

So,

$$S \propto \frac{l}{A}$$

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(8) **Permeance** → It is defined as the property of magnetic circuit due to which it allow the flow of magnetic flux.

$$P = \frac{1}{Reluctance}$$

(9) **Permeability** → The ability of a magnetic material to stablish the flux is called the Permeability.

There are two types permeabilities which are absolute and relative permeability.

(a) **Absolute permeability**

The ratio of magnetic flux density in a perticular medium (other than vacume) to the magnetic intensity is called the absolute permeability. It is denoted by 'μ'. It is given by

$$\mu = \frac{B}{H}$$

at vacume this permeability is given by

$$\mu_0 = \frac{B_0}{H}$$

where → B → Magnetic flux density
H → Mag. field intensity
B_0 → Mag. flux density in Vacuum

(b) **Relative Permeability**

It is defined as the ratio of magnetic flux density (other than vaccum) to the magnetic flux density in vaccam is called the Relative Permeability. It is given by

$$\mu_r = \frac{B}{B_0}$$

Analogy b/w electric circuit and Magnetic circuit

Electric circuit	Magnetic circuit
1) The path traced by ~~magn~~ current is called electric circuit	(1) The path traced by magnetic flux is called Magnetic ckt.
2) EMF is the driving force for current	(2) MMF is the driving for flux

③ Resistance is the opposition of current

④ $R \propto l$

⑤ $R \propto \frac{1}{A}$

⑥ Current is given by $I = \frac{emf}{R}$

⑦ Current density is $\delta = \frac{I}{A}$

⑧ Kirchoff's current & Emf (Voltage) laws are applicable

⑨ Conductance = $\frac{1}{Resistance}$

⑩ The current actually flow

⑪ The current does have insulator.

⑫ Energy is required to establish and to maintain it

⑬ Current can not flow through air.

⑭ The direction of current is either ways

③ Reluction is the opposition of flux

④ $S \propto l$

⑤ $S \propto \frac{1}{A}$

⑥ Flux is given by $\phi = \frac{mmf}{S}$

⑦ flux density is $B = \frac{\phi}{A}$

⑧ Kirchoff's flux and mmf laws are applicable

⑨ Permeance = $\frac{1}{Reluctance}$

⑩ The flux does not flow, it establishes.

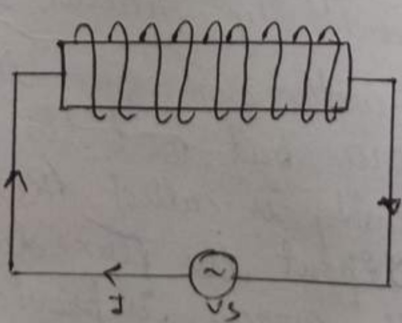
⑪ The flux does not have any insulator.

⑫ Energy is require to establish but not to maintain it

⑬ Flux can flow through air

⑭ The direction of magnetic lines is from North to south pole

B-H curve



The B-H curve is also called Hysterisis curve
From the equⁿ

$$H = \frac{NI}{l}$$

If the number of turn of the coil (N) & the length of the magnetic material (l) are kept constant the equⁿ becomes

$$H \propto I \quad -(1)$$

This equⁿ shown that by the increasing the current, field intensity is increased. From the equⁿ

$$\mu = \frac{B}{H}$$

$$B = \mu H$$

$$B \propto H \quad -(2)$$

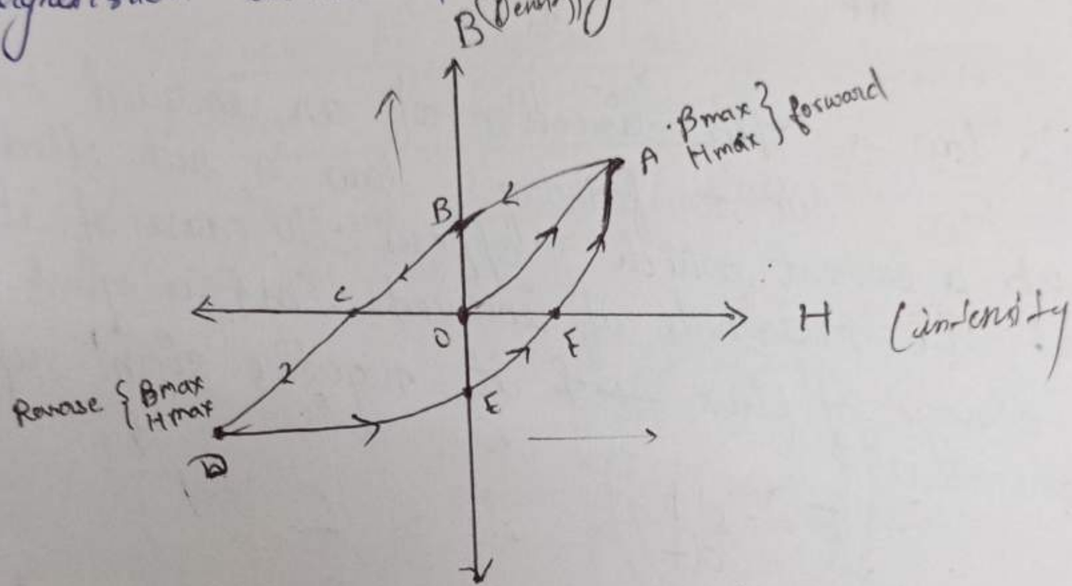
We conclude that the flux density also increases with the increase in field intensity.

Let us consider a solenoid drawn above in which number of terns are N. This solenoid is fully demagnetised now. When an amount of current is provided in forward direction in the solenoid, the intensity and hence the density start increasing. It means that the solenoid is gradually magnetising. At the sacuration point, Solenoid is fully magnetised. At this point the flux density & intensity reaches their max. values

When the current withdrawn from the solenoid, the intensity becomes zero but not the flux density. This remaining flux density is called Residual flux density. The force required to wipeout the flux density is called Coresive force. When the current is provided to solenoid in reverse direction, the density becomes zero but the intensity gets Negative. If the current is further density and field intensity are obtained. maximum value of flux

When the solenoid is fully magnetised, it can not be fully demagnetised. This property of a magnetic material is called the hysterisis loss. ~~The curve~~

The curve representing all the points of flux density and field intensity during magnetistion and dimagnetistion is called hysterisis curve.



at O → I = 0, B = 0 & H = 0
(fully demagnetised)

at A ⇒ Bmax & Hmax
(fully magnetised)

at B ⇒ residual flux density (H = 0, B = +ve)

at C ⇒ Coresive force (H -ve, B = 0)

at D ⇒ Bmax & Hmas in reverse direction.

at E ⇒ H = 0, B = -ve

at F ⇒ H = +ve, B = 0

Faraday's law of electromagnetic induction

It state that when ever the no. of magnetic line connect with the coil OR the circuit changes, an EMF is induced in the coil. It is given by

$$E = -\frac{d\phi}{dt}$$

where, E = Emf induced &

$\frac{d\phi}{dt}$ = Rate of change of flux per unit time

① **Lenze's law** :- The direction of an induced EMF due to faraday's law is such that it set up a current which opposes the cause of its production. The magnitude of induced EMF is equal to the Rate of change of flux ~~per~~ & its negative sign represent Lenzi's law

$$E = -\frac{d\phi}{dt}$$

① **Magnetic leakage law** :- In some devices having Magnetic circuit with an air gap & flux in air gap represent the effect of leakage flux the flux does not follow a diffined path and completes the loop with the surrounding air as medium is called the Magnetic leakage flux.

When a apply current a winding wounded on a core, a flux is produced with is called the Total flux.

$\boxed{\phi_{total}}$

Some part of the flux connect with the air and use it as a medium to travel an hence does not follow the path of the **core**. This flux is called leakage flux.

$\phi_{leakage}$

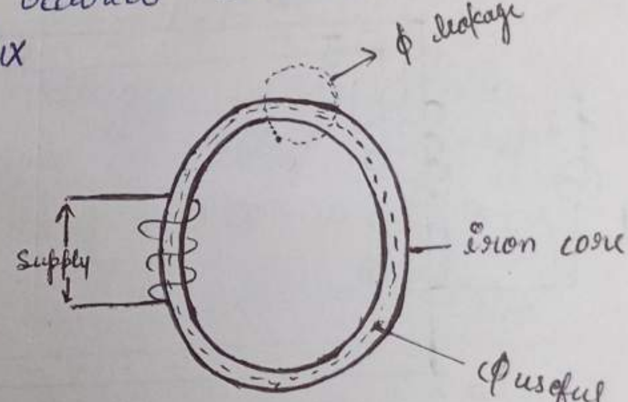
The part of the total flux which follow the emitted path is called the usfull flux

ϕ_{useful}

Hence, It can be written as

$$\phi_{total} = \phi_{leakage} + \phi_{useful}$$

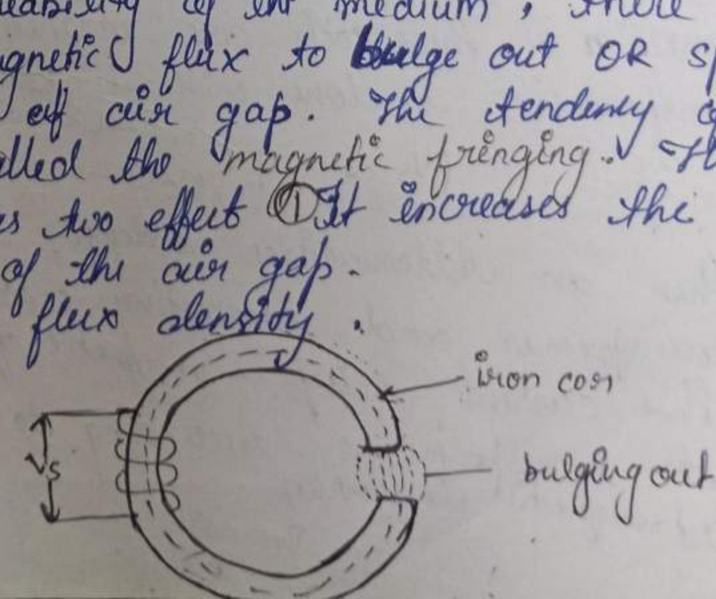
The leakage flux is occured because there is no perfect insulation of the flux



When the flux enters into the air gap of it passes through in terms of parallel flux line. Hence due to change in permeability of the medium, there is a tendency of the magnetic flux to bulge out OR spread out at the Edge of air gap. The tendency of bulging out is called the magnetic fringing. The Magnetic fringing has two effect ① It increases the effective cross section air of the air gap.

② It reduces the flux density.

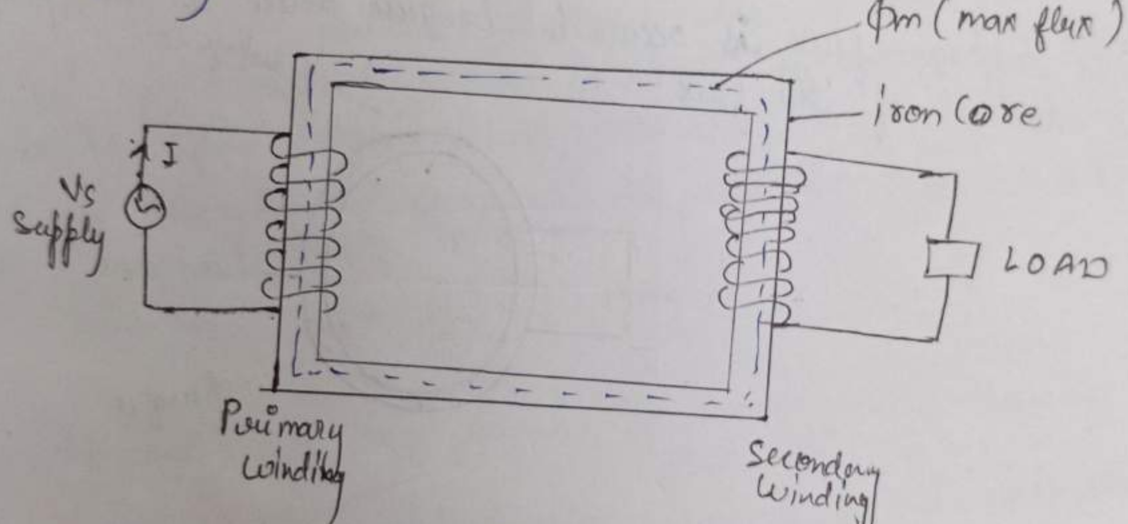
increas the effective cross section air of



TRANSFORMER

A transformer is a static divice which consist of two windings connected with an iron core. The winding which is directly connected with the supply voltage is called the Primary winding. The no. of turns and the voltage indued in the primary winding is N_1 & E_1 respectively. The winding which is directly connection with the load of transformer is called the Secondary winding.

The voltage indued & number of terns are E_2 & N_2 respectively



The transformer transfer the electrical energy from one coil to the other coil without any electrical connection. These coils are magnetically connected. The transformation is done without the change in frequency

Principal $\left(V_s \to I \to \phi \begin{cases} \to E_1 \text{ (Self induction)} \\ \to E_2 \text{ (Mutual induction)} \end{cases}\right)$

When an Alternating voltage is applied to the transformer and alternating current is induced. This current setup a magnetic flux in the iron core of the transformer. According to Faradays low of electromagnetic induction

$$E = -\frac{d\phi}{dt}$$

and emf is induced in Primary winding the induction of voltage is primary winding is called the self Induction.

Since, the secondary winding is also connected in the magnetic field so emf is induced in secondary winding too.

This type of induction in the secondary winding is called the mutual Induction.

So, by the self and Mutual induction, a voltage is transfered.

(no change of freq in transformer)

Types of transformer →

(change no. of turns in transformer & flux ...)

If the primary voltage is greater than the Secondary voltage the transformer is called Step-down transformer

If the primary voltage is less than the Secondary voltage, the transformer is called Step-up transformer

Example of Step-down transf. → 3300V / 330V

Example of Step-up transf. → 330V / 3300V

Emf equ^n of transformer

The instantaneous equ^n of flux is given by

$$\phi = \phi_m \sin\omega t \quad -(1)$$

from the faradays law

$$E = -\frac{d\phi}{dt} \quad -(2)$$

from equ^n (1) & (2), we get

$$E = -\frac{d(\phi_m \sin\omega t)}{dt}$$

$$E = -\phi_m \frac{d \sin\omega t}{dt}$$

$$E = -\phi_m \omega \cos\omega t$$

$$E = -\phi_m \omega \sin(90 - \omega t)$$

$$\boxed{E = \phi_m \omega \sin(\omega t - 90)} \quad -(3)$$

Comparing equ^n ① & ③ we conclude that the emf induced lags the flux 'ϕ' by 90°.
Comparing equ^n ⑧ with the Instantaneous equ^n of emf we get

$$E_m = \phi_m \omega$$

$$E_m = \phi_m \omega$$

$$\frac{E_{RMS}}{0.707} = \phi_m \omega$$

$\because E_{RMS} = 0.707\, E_m$

$E_m = \frac{E_{RMS}}{0.707}$

$$E_{RMS} = 0.707 \times \phi_m \times 2\pi f$$

$$\boxed{E_{RMS} = 4.44\, \phi_m f}$$

This is the emf equ^n induced for One turn. If there are N turns in the transformer

$$\boxed{E_{RMS} = 4.44\, \phi_m f N} \quad -④$$

This equ^n is the emf equ^n of Transformer,

where, E = EMF induced (V)

f = frequency (Hz)

ϕ_m = Maximum flux (Weber)

N = No. of turns in winding

In transformer Deviation of Primary winding (1) is down-minutes

for primary winding

$$E_1 = 4.44\, \phi_m f N_1 \quad -(a)$$

For secondary winding

$$E_2 = 4.44\, \phi_m f N_2 \quad -(b)$$

Dividing equ^n ⓐ & ⓑ we get

$$\frac{E_1}{E_2} = \frac{4.44\, \phi_m f N_1}{4.44\, \phi_m f N_2}$$

$$\boxed{\frac{E_1}{E_n} = \frac{N_1}{N_2} = K = a}$$

This ratio is called transformation ratio.

In a transformer the power in both the winding is equal so

$$P_1 = P_2$$

$$E_1 I_1 = E_2 I_2$$

$$\boxed{\frac{E_1}{E_2} = \frac{I_2}{I_1}}$$

So the complete ratio will be

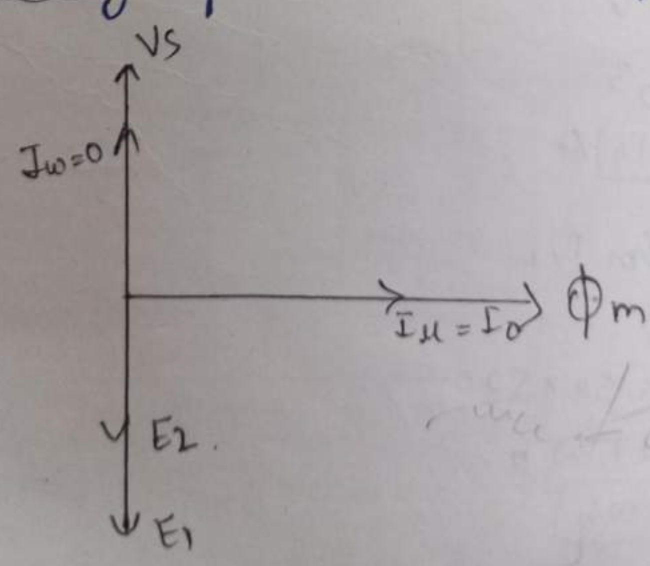
$$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}}$$

1 in suffix is for primary values.
2 in suffix is for Secondary values.

Ideal Transformer

An Ideal transformer is an imaginary transformer which consist of the following features.

1. The Primary and secondary resistances are Zero
2. The losses are Zero So the efficiency is 100%.
3. The leakage flux are Zero.
4. The permeability of the core is Infinite



Q, Numerical.

Q A 25 KVA tranformer has 500 turns on the primary and 40 turns on the secondary winding. The primary is connected to 3000 Volt, 50Hz means. Determine the Secondary voltage, Primary & Secondary current, Max. flux

$P = 25\,KVA = 25000\,VA$

$N_1 = 500$, $E_2 = ?$

$N_2 = 40$, $I_1 = ?$

$E_1 = 3000$, $I_2 = ?$

$F = 50$, $\phi_m = ?$

$E_1 I_1 = 25 \times 10^3$

$I_1 = \frac{25 \times 10^3}{3000}$

$\boxed{I_1 = 8.333}$ A

X^{mn} Ratio

$\frac{E_1}{E_2} = \frac{N_1}{N_2}$

$\frac{3000}{E_2} = \frac{500}{40}$

$\boxed{E_2 = 240}$ V

$E_2 I_2 = 25 \times 10^3$

$\boxed{I_2 = 104.16}$ A

$E_1 = 4.44 f \phi_m N_1$

$\phi_m = \frac{3000}{4.44 \times 50 \times 500}$

$\phi_m = 0.027\ wb$

$\boxed{\phi_m = 27\ m\,wb}$

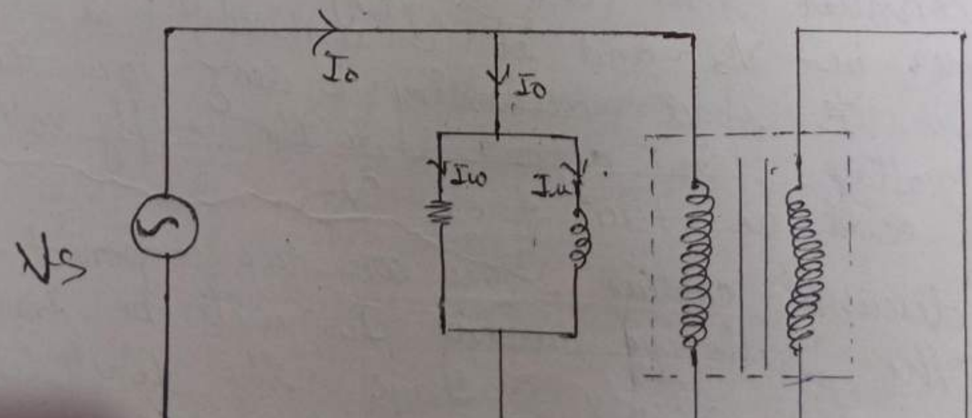
Transfor on No-load

The condition in which when the secondary is short circuited or when there is no load connected to the output of the transformer is called the transformer on No Load. Generally the induced current consist of two components which are wattful & Wattless component of current.

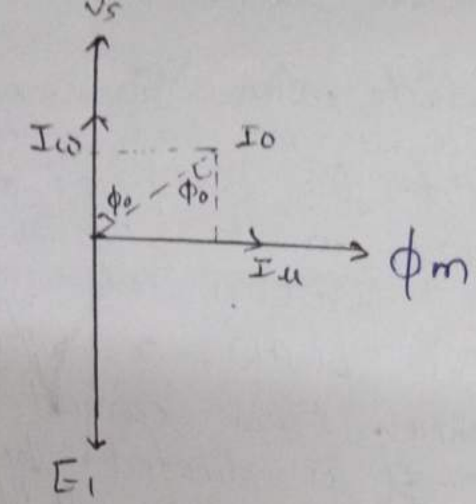
At the condition of NO LOAD, a small current is circulated in the transformer. This current is called the NO LOAD CURRENT. It is denoted by (I_o). The first component of current is called the Wattful current. It produces the losses in the core in the form of heat. The Wattful Current defines the Resistive part of the winding. (I_w)

The other component is called the Wattless current. It produces the magnetic flux in core so it is also called Magnetising current. It is denoted by (I_μ).

$$I_0 = I_\omega + I_\mu$$



The phasour diagram is No-load transformer is explained below.



From Right angle trangle

$$\sin\phi_a = \frac{I_\mu}{I_0}$$

$$I_\mu = I_0 \sin\phi_a$$

$$\cos\phi_a = \frac{I_\omega}{I_0}$$

$$I_\omega = I_0 \cos\phi_a$$

$$\boxed{I_0^2 \Rightarrow I_\omega^2 + I_\mu^2}$$

Let us consider that the supply voltage of the transformer be V_s and it is assumed to be drawn in V_s space according to lenz law the primary voltage is apposite to the supply voltage so it will be 180° from $\underline{V_s}$.

As we have discussed earlier there are two component of current. The resistive current I_ω will be in phase with the supply voltage the Wattless I_μ will be in 90%. lagging to supply voltage since the current I_μ stablishes the flux so ϕ_m will be in phase with the I_μ (Wattless current).

So, the No load current I_0 will lie b/w I_w & I_μ. The phase angle b/w the supply voltage and the No-load current will be ϕ_0 & this is called Phase angle at No-load.

Losses In Transformer

Basically there are two types of losses in the transformer they are iron loss OR core loss and copper loss OR I^2R loss.

(1) Iron loss → The iron loss is the constant loss of the transformer. It is also called CORE LOSE because exists in the core of the transformer. It is produced due to production of magnetic flux so, it is a constant loss. There are two types of losses which are hysterisis loss and eddy current loss

(i) Hysterisis loss → The property of a magnetic matterial that it can not be fully demagnetise Once ~~demo~~ fully demagnetise is called the hysterisis loss.

The hysterisis loss given by

$$P_h = K_h f B_m^x \quad \text{—— (1)}$$

$P_h = K_h f B_m^x$

where P_h = Hysterisis loss
f = frequency
B_m = Max of flux density
x = Constant whose value depend upon magnetic material
K_h = Hysterisis constant

From the emf equ^n of transformer.

$$E_1 = 4.44 f \phi_m N_1$$

$$E_1 = 4.44 f B_m A N_1$$

so

$$\boxed{\frac{E_1}{4.44 f A \cdot N_1} = B_m} \quad \text{— (2)}$$

from equ^n (1) & (2)

$$P_h = k_h f \left(\frac{E_1}{4.44 f A \cdot N_1}\right)^x$$

$$P_h = k_h \times E_1^x \left(\frac{1}{4.44 A N_1}\right)^x \times f^{1-x}$$

Since,

k_h and $\left(\frac{1}{4.44 A N_1}\right)^x$ are constant, they can be multiplied

$$\boxed{P_h = k_h E_1^x \times f^{1-x}} \quad \text{— (a)}$$

From the equ^n 'a' the hysteresis loss depends upon the supply voltage & the supply frequency

(ii) <u>Eddy current loss</u> →

$$\boxed{P_e = k_e f^2 B_m^2} \quad \text{— (3)}$$

From equ^n (2) & (3)

$$P_e = k_e f^2 \left(\frac{E_1}{4.44 f A \cdot N_1}\right)^2$$

$$P_e = k_e \times f^2 \times E_1^2 \times \left(\frac{1}{4.44 A \cdot N_1}\right) \times \frac{1}{f^2}$$

$$\boxed{P_e = k_e E_1^2} \quad \text{— (b)}$$

From the equ^n 'b', the eddy current loss is independent of supply frequency and is directly proportional to the square of the supply voltage.
So, the total Iron loss will be

$$P_i = K_h E_1^x f^{1-x} + K_e E_1^2$$

(2) Copper loss → The copper loss is a variable loss whose value depends upon supply current and is given by I^2R.
So, this loss is also called I^2R loss.
Since, there two winding in the transformer the total copper loss will be sum of copper loss of Primary and Secondary winding. So it can be written as –

$$P_c = I_1^2 R_1 + I_2^2 R_2$$

From the transformation Ratio.

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = a$$

it can be written as

$$\frac{I_2}{I_1} = a \quad \text{OR} \quad I_2 = I_1 a$$

Putting this value in the above equ^n we get

$$P_c = I_1^2 R + (I_1 a)^2 \times R_2$$

$$P_c = I_1^2 R_1 + I_1^2 a^2 R_2$$

$$P_c = I_1^2 [R_1 + a^2 R_2]$$

$$P_c = I_1^2 R_{e_1}$$

where $R_{e_1} = R_1 + a^2 R_2$
This is the value of resistance referred to primary.

The transformation ratio

$$\frac{I_2}{I_1} = a$$

can also be written as

$$I_1 = \frac{I_2}{a}$$

So putting the value of I_1 in the above equ^n we get

$$P_c = \frac{I_2^2}{a^2} R_1 + I_2^2 R_2$$

$$P_c = I_2^2 \left[\frac{R_1}{a^2} + R_2\right]$$

$$\boxed{P_c = I_2^2 R_{e2}}$$

where $R_{e2} = \frac{R_1}{a^2} + R_2$

This is the value of resistance referred to secondary

$$\boxed{P_c = I_1^2 R_{e1} = I_2^2 R_{e2}}$$

The above equ^n is the overall copper lose of the transformer

Efficiency of transformer

Efficeancy of transformer is given by the ratio of output and input.

$$\eta = \frac{\text{Output}}{\text{Input}}$$

$$\eta = \frac{\text{Output}}{\text{output} + \text{losses}}$$

$$\eta = \frac{VI\cos\phi}{VI\cos\phi + I^2R + P_i}$$

This is the efficency of the tranformer which is independent of the load. If we consider the load, a factor is included which is called The load factor. It is denoted by 'm' & the value depend upon the transformer

$$m = \frac{\text{given load of transformer}}{\text{total load of transformer}}$$

So the complete efficiency of the transformer will be -

$$\eta = \frac{mVI\cos\phi}{[mVI\cos\phi + (m^2I^2R) + Pi]}$$

Where, VI = (KVA) of X^{mer}
$\cos\phi$ = power factor
I^2R = Cu losses
Pi = Iron losses

For getting the maximum efficency equ^n ① will be differentiated w.r.t I (current) and the putting this value to zero.

$$\frac{d\eta}{dI} = \frac{[mVI\cos\phi + (m^2I^2R) + Pi][mV\cos\phi] - [mVI\cos\phi][mV\cos\phi + 2m^2IR]}{[mVI\cos\phi + (m^2I^2R) + Pi]^2}$$

when $\frac{d\eta}{dI} = 0$

$$(mVI\cos\phi + m^2I^2R + Pi)(mV\cos\phi) = (mVI\cos\phi)(mV\cos\phi + 2m^2IR)$$

$$mVI\cos\phi + m^2I^2R + Pi = I(mV\cos\phi + 2m^2IR)$$

$$mVI\cos\phi + m^2I^2R + Pi = mVI\cos\phi + 2m^2I^2R)$$

$$m^2IR + Pi = 2m^2I^2R$$

$$P_i = 2m^2 I^2 R - m^2 I^2 R$$

$$P_i = m^2 I^2 R$$

$$\boxed{P_i = m^2 I^2 R}$$ //

From equ^n ② we get the condition of maximum efficiency that variable copper loses are equal to the constant Iron losses

From equ^n ① & ② we get

$$\eta_{max} = \frac{(VI)_{max} \cos\phi}{[((VI)_{max} \cos\phi) + (2P_i)]}$$

KVA at maximum efficiency.

The condition for maximum

$$P_i = m^2 I^2 R$$

So, at this condition the current will be maximum

$$P_i = m^2 I_m^2 R$$

multiplying I_{fl}^2 (full load current square both sides)

$$\frac{I_{fl}^2 \times P_i}{I_{fl}^2 R} = m^2 I_m^2$$

at $m = 1$ $\qquad\qquad$ I_{fl} = full load current

$$I_m^2 = \frac{I_{fl}^2 \times P_i}{I_{fl}^2 R}$$

The function in the denomenator is the copper loss of the transformer at full load.

$$I_m^2 = \frac{I_{fl}^2 \times P_i}{P_{cfl}}$$

P_{cfl} - full load current of copper loss

$$I_m = I_{fl}\sqrt{\frac{P_i}{P_{cfl}}} \quad \text{— (4)}$$

Multiplying both side the voltage we get

$$V I_m = V I_{fl}\sqrt{\frac{P_i}{P_{cfl}}}$$

$$(KVA)_{max} = (KVA)_{fl}\sqrt{\frac{P_i}{P_{cfl}}} \quad \text{— (5)}$$

where. $(KVA)_{max}$ = load at max. efficiency

$(KVA)_{fl}$ = load at full load

P_i = iron loss

P_{cfl} = full load copper loss

$P_i = m^2 I^2 R$

$P_i = m^2 I_m^2 R$

$$\frac{I_{fl}^2 \times P_i}{I_{fl}^2 \times R} = I_m^2$$

$$\frac{I_{fl}^2 \times P_i}{I_{cfl}} = I_m^2$$

$$I_m = I_{fl}\sqrt{\frac{P_i}{I_{cfl}}}$$

voltage

$V I_m = V I_{fl} \sqrt{\ }$

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Q A single phase 100 kVA, transformer has full load copper loss of 1200 watt & Iron loss of 960 watt. Calculate

1. The efficiency at full load, unity power factor
2. η (efficiency) at half load, 0.8 p.f
3. η of 75% of full load, 0.7 p.f
4. load kVA at max. efficiency → This is any time missing but this solve for (e) question
5. Max. η at 0.85 p.f.

(1) Given

$VI = 100 \text{ kVA}$

$P_{cu} = 1200 \text{ watt}$

$P_i = 960$

(1) $m = 1$ because of condition of full load

$\cos\phi = 1$ in unity

$$\eta = \frac{mVI\cos\phi}{mVI\cos\phi + P_i + m^2 I^2 R}$$

$$\eta = \frac{1 \times 100 \times 10^3 \times 1}{1 \times 100 \times 10^3 \times 1 + 960 + 1^2 \times 1200}$$

$$\boxed{\eta = 0.97888 \times 100}$$

$$\boxed{\eta = 97.885\ \%}$$

(2) $m = \frac{1}{2}$; $\cos\phi = 0.8$ (11)

$$\eta = \frac{mVI\cos\phi}{mVI\cos\phi + P_i + m^2 I^2 R}$$

$$\eta = \frac{0.5 \times 100 \times 10^3 \times 0.8}{0.5 \times 100 \times 10^3 \times 0.8 + 960 + (0.5)^2 \times (1200)}$$

$$= \frac{40000}{40000 + 960 + 300}$$

$$\eta = 0.9694 \times 100$$

$$\boxed{\eta = 96.946} \%$$

(3) $m = \frac{3}{4}$, $0.7 \cos\phi$

$$\eta = \frac{mVI\cos\phi}{mVI\cos\phi + P_i + m^2 I^2 R}$$

$$\eta = \frac{0.75 \times 100 \times 10^3 \times 0.7}{0.75 \times 100 \times 10^3 + 960 + (0.75)^2 \times (1200)}$$

$$\eta = \frac{52500}{52500 + 960 + 675}$$

$$\eta = 0.9697 \times 100$$

$$\boxed{\eta = 96.979} \%$$

(4) $(KVA)_{max} = (KVA)_{full\ load} \sqrt{\frac{P_i}{P_{cfL}}}$

$(KVA)_{max} = 100 \times 10^3 \sqrt{\frac{960}{1200}}$

$(KVA)_{max} = 100 \times 10^3 \times 0.8944$

$(KVA)_{max} = 89442.7$

$(KVA)_{max} = 89.442\ VA$

(5) $\eta_{max} = \frac{VI_{max} \times \cos\phi}{VI_{max}\cos\phi + 2P_i}$

$= \frac{~~89.442 \times 0.85~~}{}$

$= \frac{89442.7 \times 0.85}{89442.7 \times 0.85 + (2 \times 960)}$

$= ~~8.208 \times 10^{?}~~$

$\frac{76026.295}{77946.295}$

$= 0.97536 \times 100$

$\eta_{max} = 97.536\ \%$

Q) A transformer is rated at 500 KVA. The copper loss at full load is 1800 watt. and the Iron loss is 1200 watt. Calculate

1. The efficiency at full load, 0.8 p.f
2. Efficiency at half load, unit p.f.
3. Efficiency at 60% of full load 0.6 p.f
4. Max efficiency at 0.7 p.f.

A) Given KVA = VI = 50 watt

$P_{CFL} = 1800$ watt

$P_i = 1200$ watt

(1) $m = 1, \cos\phi = 0.8$

$$\eta = \frac{mVI\cos\phi}{mVI\cos\phi + P_i + m^2 I^2 R}$$

$$\eta = \frac{1 \times 50 \times 10^3 \times 0.8}{1 \times 50 \times 10^3 \times 0.8 + 1200 + 1^2(1800)}$$

$$= \frac{40000}{43000}$$

$= 0.9302 \times 100$

$= 93.02\%$

(2) $m = \frac{1}{2}, \cos\phi = 1$

$$\eta = \frac{0.5 \times 50 \times 10^3 \times 1}{0.5 \times 50 \times 10^3 + 1200 + (0.5)^2(1800)}$$

$$= \frac{25000}{25000 + 1200 + 450}$$

$\eta = 0.938008 \times 100$

~~$= 0.977008 \times 100$~~

$\eta =$ ~~97.7008~~ %

$\eta = 93.8008$

(3) $m = 0.6 \quad \cos\phi = 0.6$

$$\eta = \frac{mVI\cos\phi}{mVI\cos\phi + P_i + m^2I^2R}$$

$$\eta = \frac{0.6 \times 50\times10^3 \times 0.6}{0.6\times50\times10^3\times0.6 + 1200 + (0.6)^2(1800)}$$

$$\eta = \frac{18000}{18000+1200+648}$$

$$\eta = 0.9068 \times 100$$

$$\boxed{\eta = 90.68}$$

$$(KVA)_{max} = (KVA)_{fl}\sqrt{\frac{P_i}{P_{cfl}}}$$

$$= 50\times10^3\sqrt{\frac{1200}{1800}}$$

$$= 50\times10^3 \times 0.8164$$

$$(KVA)_{max} = 40820 \text{ VA}$$

(4)

$$\eta_{max} = \frac{VI_{max}\cos\phi}{VI_{max}\cos\phi + 2P_i}$$

$$= \frac{40820\times0.7}{40820\times0.7 + 2\times1200}$$

$$= 0.92251$$

$$\boxed{\eta_{max} = 92.251}\ \%$$

Q The efficiency of a 40 kVA single phase transformer has iron loss of 800 W and copper loss of full 1140 W when supplying full load at unit power factor calculate the efficiency of transformer at (a) full load unity power factor

(b) Half load unity p.f

$P_i = 800$ $\quad I^2R = 1140$

$P_{cu} = 1140$ $\quad VI = 40$

$m = 1$

(a) $\eta = \dfrac{mVI\cos\phi}{mVI\cos\phi + P_i + m^2 I^2 R}$

$\eta = \dfrac{1 \times 40 \times 10^3 \times 1}{1 \times 40 \times 10^3 \times 1 + 800 + (1)^2 (1140)}$

$\eta = \dfrac{40000}{40000 + 800 + ~~129600~~ \; 1140}$

$\eta = \dfrac{40000}{1340400} = \dfrac{40000}{}$

$\eta = 0.9537 \times 100$

$\eta = 95.37\%$

(b) $\eta = \dfrac{\frac{1}{2} \times 40 \times 10^3 \times 1}{\frac{1}{2} \times 40 \times 10^3 + 800 + \frac{1140}{4}}$

$= \dfrac{20 \times 10^3}{20 \times 10^3 + 800 + 285}$

$\eta = 0.9485 \times 100$

$\eta = ~~43.589~~ \; 94.85\%$

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Q. The full load iron & copper losses of a 150 kVA transformer are 320 W & 200 W. Calculate of the efficiency of transformer subject

(a) at full load.

(b) at half load

(c) at 75% of full load

the power factor in each case will be 0.8.

(a)

$$\eta = \frac{m V I \cos\phi}{m V I \cos\phi + P_i + m^2 I^2 R}$$

Given,

$VI = 150 \times 10^3$ VA

$\cos\phi = 0.8$

$P_i = 200$

$I^2 R = 320$

$$\eta = \frac{(1) \times 150 \times 10^3 \times 0.8}{1 \times 150 \times 10^3 \times 0.8 + 200 + (1)^2 (320)}$$

~~$\eta = \frac{40 \times 10^3}{40 \times 10^3 + 200 + 320}$~~

$$\eta = \frac{12000}{12000 + 200 + 320}$$

$\eta = 0.9584 \times 100$

$\eta = 95.84\%$

(b) $m = \frac{1}{2}$

$$\eta = \frac{0.5 \times 15 \times 10^3 \times 0.8}{0.5 \times 15 \times 10^3 \times 0.8 + 200 + \frac{320}{4}}$$

$\eta = 0.9554 \times 100$

$\eta = 95.54\%$

80

(c) $m = 0.75$

$$\eta = \frac{0.75 \times 15 \times 10^3 \times 0.8}{0.75 \times 15 \times 10^3 \times 0.8 + 200 + (0.5625 \times 320)}$$

$$\eta = \frac{9000}{9000 + 200 + 180}$$ 180

$$\eta = 0.9594 \times 100$$

$$\eta = 95.94\ \%$$ //

Q 100 kVA, single phase transformer has an efficiency of 98.5 %. when supplying full load at 0.8 p.f the efficiency of this transformer becomes 99 %. when supplying half load unity power factor Calculate the Iron & copper losses at full load.

$I^2R = ?$ 5607.3 980.7

$P_i = ?$

$$\eta = \frac{mVI\cos\phi}{mVI\cos\phi + P_i + m^2 I^2 R}$$

$$0.985 = \frac{1 \times 100 \times 10^3 \times 0.8}{1 \times 100 \times 10^3 \times 0.8 + P_i + (1)^2 I^2 R}$$

$$78800 + 0.985 P_i + 0.985 I^2 R = 80000$$

$$0.985 P_i + 0.985 I^2 R = 1200 \quad -(1)$$

$$\eta = \frac{mVI\cos\phi}{mVI\cos\phi + P_i + m^2 I^2 R}$$

$$0.99 = \frac{0.5 \times 100 \times 10^3 \times 1}{0.5 \times 100 \times 10^3 \times 1 + P_i + 0.25 I^2 R}$$

$$49500 + 0.99 P_i + 0.2475 I^2 R = 50 \times 10^3$$

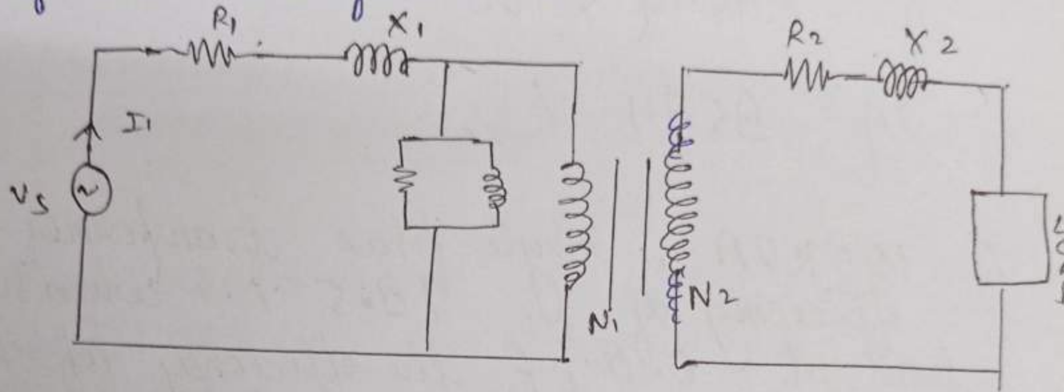
$$0.99 P_i + 0.245 I^2 R = 500 \quad -(2)$$

$P_i = x = 267.30$ //

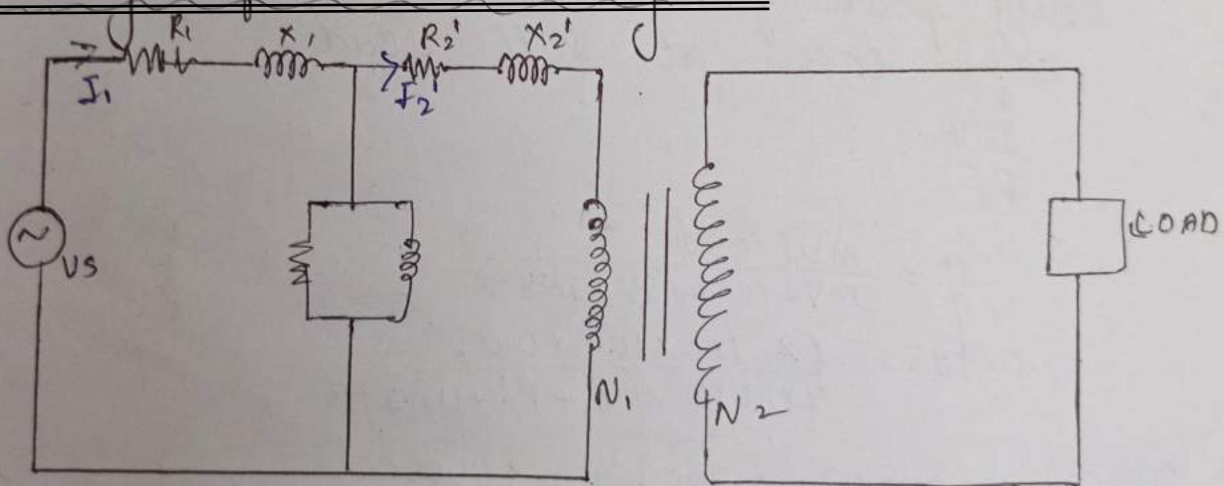
$I^2R = y = 950.96$ //

Referred values

The shifting of primary values to the secondary and secondary values to be primary is called the Refered values. The generalised equivalent circuit of the transformer is



(a) Secondary referred to Primary :



Since the copper losses in secondary before and after shifting will be equal.

So,

$$I_2^2 R_2 = I_2'^2 R_2'$$

$$\left(\frac{I_2}{I_2'}\right)^2 R_2 = R_2' \quad \text{— (a)}$$

Like wise the MMF before and after the shifting will also be equal

$$N_2 I_2 = N_1 I_2'$$

$$\left(\frac{N_2}{N_1}\right) I_2 = I_2' \quad \text{— (b)}$$

From equ^n (a) & (b)

$$\left(\frac{I_2}{\left(\frac{N_2}{N_1}\right) I_2}\right)^2 R_2 = R_2'$$

$$\left(\frac{N_1}{N_2}\right)^2 R_2 = R_2'$$

From the transformation ratio

R_2' eq^n ① R_2 refer

$$\frac{N_1}{N_2} = \frac{E_1}{E_2} = \frac{I_2}{I_1} = a = k$$

$$\boxed{(a)^2 R_2 = R_2'} \quad \text{— (1)}$$

where a = Transformation ratio
R_2 = Secondary resistance
R_2' = Secondary resistance refered to primary

In the same manner reactance will be

$$\boxed{(a)^2 X_2 = X_2'} \quad \text{— (2)}$$

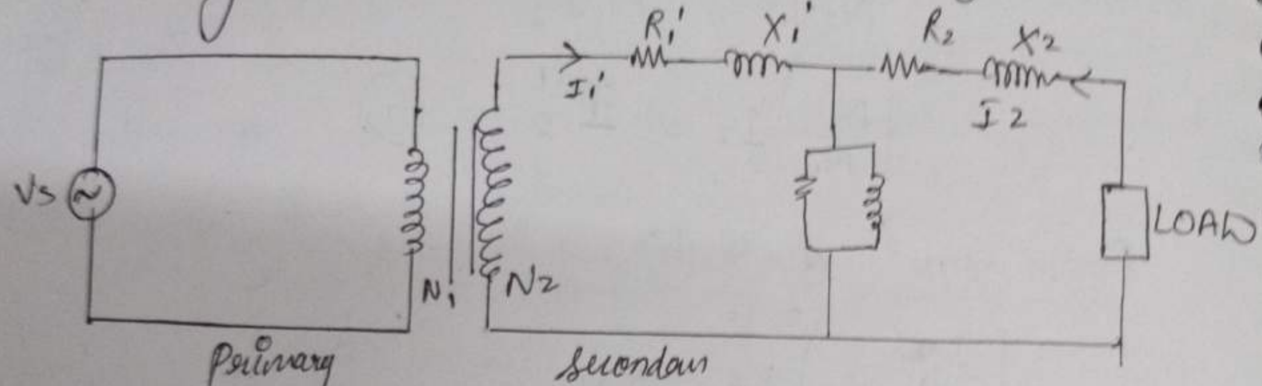
where X_2 = Secondary ~~res~~ reactance
X_2' = Secondary reactance refered to primary.

So, the overall resistance at primary side will be will be $R_{total} = R_1 + a^2 R_2$ } Primary side

In the same manner the over all reactance will be $X_{total} = X_1 + a^2 X_2$ } primary side

4

(b) Primary ~~reffere~~ referred to Secondary



The copper losses before and after referring will be same so the eqⁿ will be

$$I_1^2 R_1 = I_1'^2 R_1'$$

$$\left(\frac{I_1}{I_1'}\right)^2 R_1 = R_1' \quad \text{— (c)}$$

Like the copper losses the MMF will also be equal before and after referring

$$N_1 I_1 = N_2 I_1'$$

$$\left(\frac{N_1}{N_2}\right) I_1 = I_1' \quad \text{— (d)}$$

from (c) & (d)

$$\left(\frac{I_1}{\left(\frac{N_1}{N_2}\right) I_1}\right)^2 R_1 = R_1'$$

$$\left(\frac{N_2}{N_1}\right)^2 R_1 = R_1'$$

$$\frac{R_1}{a^2} = R_1'$$

where, R_1 = primary resistance
R_1' = primary resistance referred to sec.

It will be same for reactance :-

$$X_1' = \frac{X_1}{a^2}$$

where,
X_1' = Reactance primary referred to sec.
X_1 = primary Reactance

So, the overall resistance on secondary side will be

$$R_{total} = R_2 + \frac{R_1}{a^2}$$

&

$$X_{total} = X_2 + \frac{X_1}{a^2}$$

} Secondary side

Where,

$$a = \frac{N_1}{N_2} \text{ (transformation ratio)}$$

Considering overall resistance and reactance, the total impedence for Both the sides will be

$$Z_{total} = \sqrt{R_{total}^2 + X_{total}^2}$$

Q An 1100/220V, 60Hz, single phase transformer rating is 100KVA. It has the following resistance and leakage reactance. $R_1 = 0.1\,\Omega$, $R_2 = 0.004\,\Omega$, $X_1 = 0.3\,\Omega$, $X_2 = 0.012\,\Omega$

(a) The equivalent resistance referred to primary side
(b) " " reactance " " " "
(c) " " resistance " " secondary side
(d) " " ~~Reactance~~ " " " "
(e) " " impedance " " primary side
(f) " " " " " secondary

Given · $V = 1100/220$ (V_1, V_2)

$$\frac{E_1}{E_2} = \frac{1100}{220} = \frac{N_1}{N_2} = 5 = a$$

$a = 5$

(a) $R_{total} \Rightarrow R_1 + a^2 R_2$

$= 0.1 + (5)^2 \times 0.004$

$= 0.2\,\Omega$

(b) $X_{total} \Rightarrow X_1 + a^2 X_2$

$X_{total} \Rightarrow 0.3 + 25 \times 0.012$

$X_{total} \Rightarrow 0.6\,\Omega$

(c) $R_{total} \Rightarrow R_2 + \frac{R_1}{a^2}$

$\Rightarrow 0.004 + \frac{0.1}{25}$

$\Rightarrow 8 \times 10^{-3}$

$\Rightarrow 0.0008\,\Omega$

(d) $X_{total} \Rightarrow X_2 + \frac{X_1}{a^2}$

$\Rightarrow 0.012 + \frac{0.3}{25}$

$\Rightarrow 0.024\,\Omega$

(e) $Z_{total} = \sqrt{R_{tot}^2 + X_{tot}^2}$

$Z_{total} = \sqrt{(0.2)^2 + (0.6)^2}$

$Z_{total} = 0.6324$

(f) $Z_{total} = \sqrt{R_{total}^2 + X_{tot}^2}$

$Z_{total} = \sqrt{(0.008)^2 + (0.024)^2}$

$Z_{total}\ 0.0253$

Short questions

1. Ohm's law.
2. Explain KVL & KCL.
3. What do you mean by Ideal & Practical Source.
4. Independent OR dependent source.
5. On what factor does resistance of material depend

$R \propto l$

$R \propto \frac{1}{A}$

6. Name a ~~self~~ single excited motor? → Single phase Ind motor, 3φ motor
7. Name a double excited motor? → Synchronous Motor, 3φ Induction Motor
8. What is excitation?
9. Name a self excited Motor OR Self start motor
10. Name a non-self excited motor? OR Non-self start motor? → 1φ Induction motor

Excitation → give supply to motor

11. Name the different type of rotor in Induc^n motor? → cage & wound rotor
12. Name the different " of rotor in synchronous motor → Salint & Non-Salint
13. Write the application of D.C shunt motor & D.C. series motor? — Shunt / cage: Use (S.Torq ↓) low starting torque; Series / wound: Use high starting torque (S.Torq ↑)
14. Write the application of Cage rotor & wound rotor?
15. What is synchronous speed? → speed of stator Magnetic speed fn (Ns) A.C (Induction motor)
16. Write the Difference b/w synchronous motor & Ind^n motor. — synchronous: ① synchronous speed ② Doubly excited; Ind^n: ① less than synchro speed ② singly excited
17. What is rotor speed, Nr
18. What is slip & slip speed → the differen synchr speed & rotor speed — $s = \frac{N_S - N_r}{N_S}$
19. Who is the supply frequency f_S related to sync. speed? N_S — $\frac{P \cdot N_S}{120} = f_S$

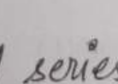
(20) diffine reluctance & flux density & field intensity?
opposition of D.C machine on magnetic field
ϕ ~~total of flux~~ Total no. of flux per unit area
$H = \frac{NI}{l}$

(21) Form factor & Peak factor?
(22) What are factor effecting the battery performance?
Nominal Voltage, capacitance, efficiency

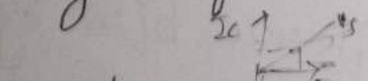
(23) Why is commutator need in DC machine?
AC → DC. Use → Inversion & rectification in D.C machine
DC → A.C

(24) Classifie the losses in transformer
→ Copper loss
→ Iron loss

(25) What are active element & Passive elements
(26) What are Unilateral & Bilateral.
(27) Differentiate b/w linear & Non-linear Circuit
(28) Diffine the different power in A.C circuit
Active, Reactive, apparant.
(29) Mention the cond^n Max. ~~effect~~ efficiency of transformer.
(30) Prove that average power in a purely Inductive circuit is zero.
(31) Draw the phasor diagram of series RLC circuit



(32) What the Difference b/w a cell & a Battery



1 Define the types of Battery
1° & 2°

(34) Why is DC never connected to transformer
The DC anable to stablish magnetic flux so the process of self & Mutual induction will not exsist.

(35) Why do we represent the Alternating current by synesoidal wave form.

0 — 0
90 — max
180 — 0
270 — -max
360 — 0

(36) Write the generated equ^n for voltag in D.C generator & D.C generator for shunt

D.C generator → $Eg = Vs + IaRa$

Motor → $Eg = Vs - IaRa$

(37) Write any two advantage of three phase system.

→ 3 φ system have higher efficiency.
→ They have higher power factor.
→ There motors are self starting.
→ They requires less conducting matterial

(38) What is series resonance.
$X_L = X_C$

(39) $V_A = 150 \sin(\omega t + 45°)$ lead or lage
$V_B = 75 \sin(\omega t - 15°)$

$= 45 - (-15)$
$= 60°$ leading.

(40) What is the phase & line current

(41) What is the RMS value for valtage in
$V = 416 \sin \omega t$

$V_{RM} = 416 \times 0.707$
94.1

(42) What do you mean by back EMF even odd 2,4,6 3,1,5

E_b →

(43) What is quality factor of AC series circuit 1,3,5 2,4,6

(44) What is the significance of Peak factor?

(45) What is the funⁿ of transformer

(46) Why are Induction motor are called a synchronous motor.

slitly differ of speed so calle syn. motor.

(47) How we can change the direction of rotation of D.C motor.

By changing the terminal of supply voltage.

(48) What is necessity of earthing

For short circuit

(49) Explain the losses in mag. circuit

→ Hysteresis loss

→ Eddy current loss

(50) Explain the phase sequence of 3ϕ circuit RYB

(51) What do you mean by Magnetic hysteresis

(52) What is condition for maximum torque in 3ϕ system

$R \Rightarrow sX$

(53) Give the condition for Maximum efficiency $R = sX$

$$\eta_{max} = \frac{(VI)_{max} \cos\phi}{(VI)_{max} \cos\phi + 2P_i}$$