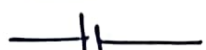
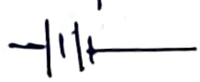
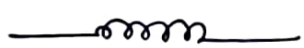
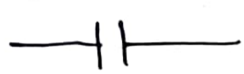
Asst. Prof. Ballay Kumar Sahu

BEE NOTE

BEC, BBSR

D.C. Network

Sl no.	elements	Symbols	unit
1	Resistance (R)		ohm (Ω)
2.	Inductance (L)		Henry (H)
3.	Capacitance (C)		farad (f)
4.	Voltage (V)	for DC  battery.  For AC 	volt (V)
5.	Current (I)		Ampere (A)
6.	Impendence (Z)	combination of (L, C, R) (R, L), (R, C), (L, C)	Ω
7.	Reactance (X)	—	Ω
8.	Inductive reactance ($X_L = 2\pi f L$)		Ω
9.	Capacitive reactance ($X_C = \frac{1}{2\pi f C}$)		Ω
10.	Conductance (G)	—	Mho (℧) Siemen (S)

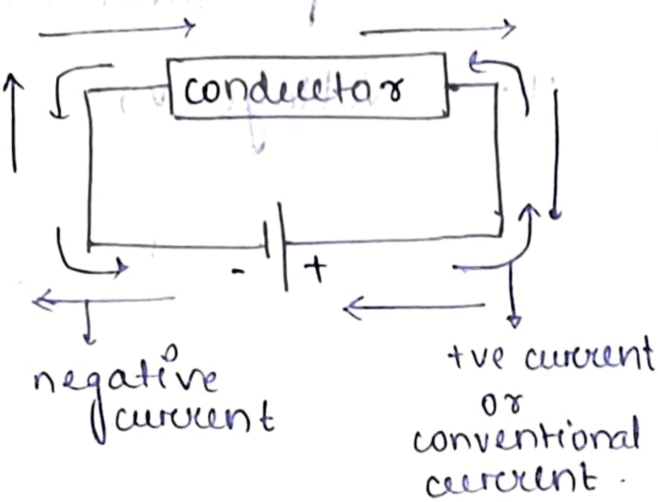
⇒ Current (I) :-

→ Current is the flow of e^- or charge.

→ It is the rate of flow of charge.

i.e. $$i = \frac{dq}{dt}$$

- dq → charge in columb.
- dt → time in second.



→ Current always flow in a closed circuit.

→ the unit of current is Ampere (A)

→ current measuring instrument :- Ammeter

→ the direction of +ve current is always opposite that of the direction of flow of electron.

⇒ Resistance (R) :-

→ It is the property of a material which opposes the flow of e^- or current.

$$R \propto l$$
$$\propto \frac{1}{A}$$

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

- l → length
- A → area of cross-section
- ρ → Resistivity or specific resistance.

$$\Rightarrow \boxed{\rho = \frac{RA}{l}} = \frac{\Omega m^2}{m}$$

unit = $\boxed{\rho = \Omega m}$

unit = "Ω"

Resistance measuring instrument : ohm meter,
- we can also measure it by multimeter.

⇒ **Conductance (G) :-**

It is the reciprocal of resistance which allows the flow of current or e⁻.

$$G = \frac{1}{R} = \frac{1}{\rho \frac{l}{A}} = \frac{1}{\rho} \cdot \frac{A}{l} = \boxed{\sigma \cdot \frac{A}{l} = G}$$

σ → Conductivity or specific conductance

$\therefore G \propto A$

$G \propto \frac{1}{l}$

unit of Conductance = Mho (℧), siemen (S)

$$G = \frac{\sigma A}{l}$$

$$\sigma = \frac{G l}{A} = \frac{℧ \cdot m}{m^2} = \boxed{℧/m = \sigma}$$

↖ unit.

⇒ **Capacitance :-**

- It is a charge storing element.
- It is also used to improve the power factor
- It is also sometimes used to maintain the voltage constant.
- It units is farad.

$$\boxed{C = \frac{q}{V}}$$

q → charge
V → voltage.

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

d → Separation betⁿ two plates of capacitors

ε_0 → Permitivity.

$$\boxed{\varepsilon_p = \varepsilon_0 \times \varepsilon_r}$$

- The energy stored in a capacitor,

$$U = \frac{1}{2} C V^2$$

$$V_C = I X_C$$

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

$$V_C = \frac{1}{C} \int i_C \cdot dt$$

V_C → voltage across the capacitor

i_C → current through the capacitor.

$$i_C = C \frac{dV_C}{dt}$$

if many capacitors like C_1, C_2, C_3 are connected in series the its C_{eq} :-

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

if C_1, C_2, C_3 are connected in parallel,

$$C_{eq} = C_1 + C_2 + C_3 + \dots$$

→ Inductance (L) :-

$$X_L = 2\pi f L$$

- It is also used to store the charge.
- Sometimes it is used to limit the current.
- Its unit is henry (H).
- The amount of charge stored in a inductor $= \frac{1}{2} L i^2$

$$V_L = i X_L = i \times 2\pi f L$$

$$V_L = L \frac{di}{dt}$$

$$i = \frac{1}{L} \int V_L \, dt$$

$$L = \frac{N \phi}{i}$$

N → no. of turns of coil.

ϕ → magnetic flux in weber,

- if many Inductances like $L_1, L_2, L_3 \dots$ are connected in series then its equivalent inductance will be.

$$L_{eq} = L_1 + L_2 + L_3 + \dots$$

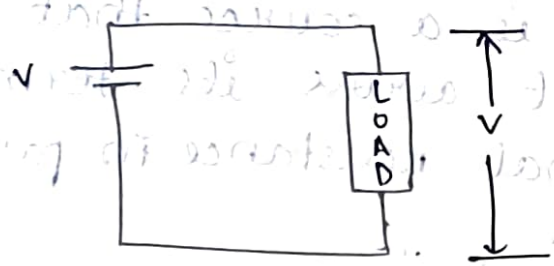
- If many induction like $L_1, L_2, L_3 \dots$ are connected in parallel.

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \dots$$

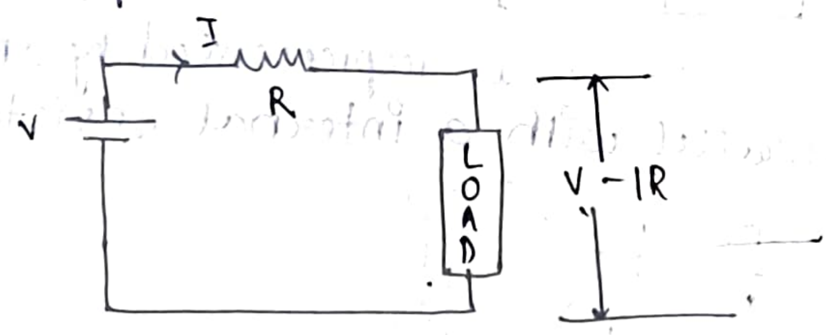
→ Voltage :-

- The potential difference across the two end of the conductor is known as voltage.
- voltage sources are of 2 types.
  i) Ideal.
  ii) Real or practical.

(i) Ideal :- It is a source that maintain the same voltage across its terminal and it has no Internal resistance.



(ii) Real or practical :- It is represented by an ideal v.s with a series resistance

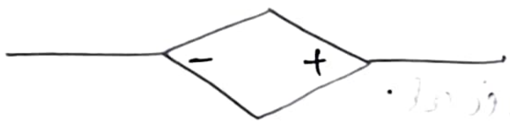


⇒ Independent and dependent voltage sources :

(i) Independent :- If the voltage across an ideal voltage source which doesnot depen upon the other variable in that circuit.

(ii) dependent :-

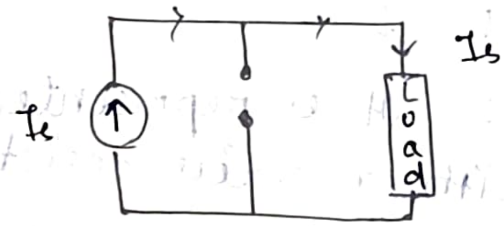
If the voltage across an ideal voltage sour is determine or dependent by some other voltage or current in a circuit then it is called a dependent voltage source.



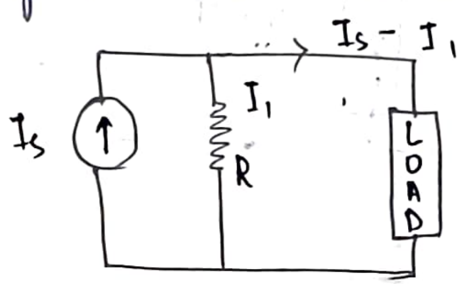
⇒ Current Source :-

It is of two types, (i) Ideal c.s
(ii) Real or practical c.s

(i) Ideal c.s :- It is a source that maintai the same current across its terminal an it has ∞ internal resistance in parallel.

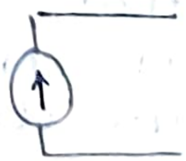


(ii) Practical c.s :- It is represented by an ideal c.s in parallel with a internal resistance

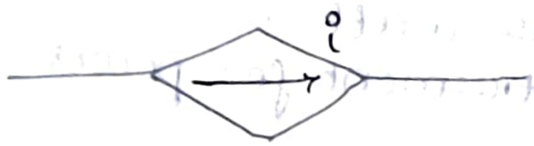


→ Independent and dependent current source :-

i) Independent C.S :- If the current through an ideal current source which doesnot depend upon any other variable in a circuit then it is called an independent current source.



ii) dependent or controlled :- If the current through an ideal current source is dependent on some other voltage or current in that circuit or determined by some other voltage or current in that circuit then it is called a dependent or controlled current source.



different types of loads :-

An electrical load is an application of consuming electrical power and that are resistance, inductance, capacitance or the combination of these 3 elements

1. Resistance load (R-load)
2. Inductive load (L-load)
3. capacitive load (C-load)
4. Resistive - Inductive (R-L load)
5. Resistive. capacitive (R-C load)

6. Inductive - capacitive (L - C load)

7. L - C - R load.

ohm's law :-

It state that the potential difference across the two end of the conductor is ∝ with the current flowing through that conductor with taking all physical conditions constant :- temperature, pressure etc.

$V \propto I$

$V = R I$

R → Resistance of the conductor.

Power :- Rate of workdone is known as power

$P = \frac{W}{t}$ W → workdone / energy, t → time.

unit of power is watt.

the measuring instrument for power - watt meter

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

$P = \frac{VIt}{t} = VI = IR \cdot I = I^2R$

$P = VI = V \cdot \frac{V}{R} = \frac{V^2}{R}$

$$\boxed{P = VI = I^2R = \frac{V^2}{R}}$$

Energy (P/W) :- It is the product of power and time.

$W = P \times t$

$W = VIt$

$W = I^2Rt$

$W = V^2/R\,t$

unit of energy - Joule

| 1 unit = 1 kWh |

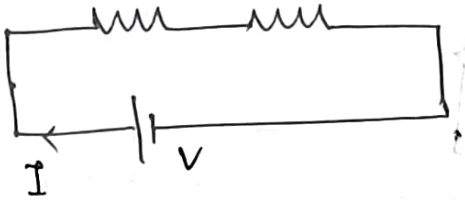
| 1 hp = 746 watt |

measuring instrument = energy meter.

- Power factor meter :- It is a power factor measuring device.
- tacometer :- It is a speed measuring device and it measures the speed in revolution/min
- Ammeter :- It is a current measuring instrument and it is always connected in series because of its low resistance.
  - ↳ easy to calculate.
- Voltmeter :- It is a voltage measuring instrument and it is always connected in parallel because it has a resistance.
  - ↳ It can measure the actual voltage.

- Resistance in Series :-

Resistance or conductance are said to be connected in series if they are connected in end to end that means one after another. one end of the first conductor will be starting point of the next conductor.



$V_1 = IR_1$

$V_2 = IR_2$

$V = IR_{eq}$

$V = V_1 + V_2$

$IR_{eq} = IR_1 + IR_2$

$$R_{eq} = R_1 + R_2$$

- Current flows through each resistance will be same.
- Voltage across each resistance will be different

Power = $\frac{1}{P_T} = \frac{1}{P_1} + \frac{1}{P_2}$

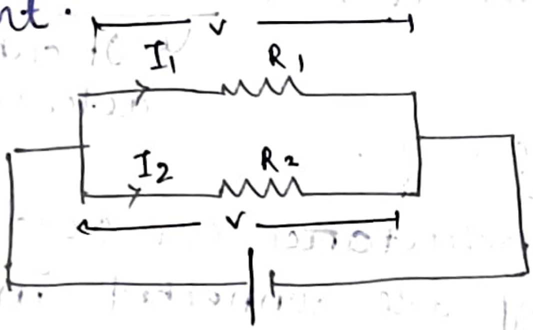
- if an equal resistances having resistance 'R', R connected in series, then its equivalence resistance will be

$$\boxed{R_{eq} = n \cdot R}$$

⇒ **Resistance in Parallel :-**

If the starting point or ending point of all the resistances are same, then we can say these resistances are connected in parallel.

- Voltage across each resistance will be same
- Current through each resistance will be different.



$I = I_1 + I_2$

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

$$\boxed{R_{eq} = \frac{R_2 + R_1}{R_1 R_2}} \Rightarrow$$

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

→ $\frac{1}{\text{Resistance}}$ = Conductance (G)

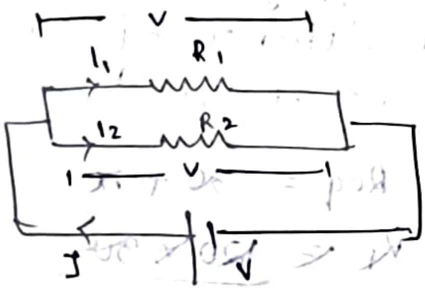
$$G_{eq} = G_1 + G_2 + \cdots G_n$$

$$P_{eq} = P_1 + P_2 + \cdots P_n.$$

⇒ If n number of equal resistances having resistance R each are connected in parallel then its equivalent resistance will be -

$$R_{eq} = \frac{R}{n}$$

→ Current division Rule :-

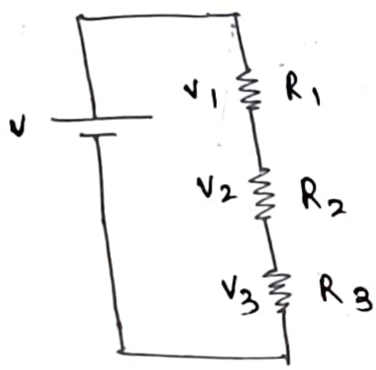


$$I_1 = \frac{I \times R_2}{R_1 + R_2}$$

$$I_2 = \frac{I \times R_1}{R_1 + R}$$

↳ = $\dfrac{\text{Total current entering to the current division point} \times \text{equivalent resistance of the opposite path}}{\text{Total equivalent resistance in both the path.}}$

→ Voltage division Rule :-



$$R_{eq} = R_T = R_1 + R_2 + R_3$$

$$V_1 = \frac{V \cdot R_1}{R_1 + R_2 + R_3}$$

$$V_2 = \frac{V \cdot R_2}{R_1 + R_2 + R_3}$$

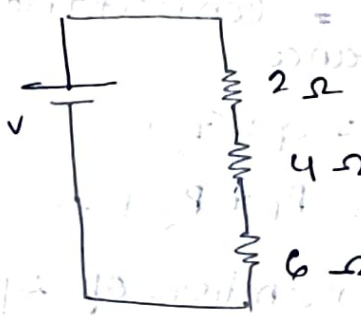
$$V_3 = \frac{V \cdot R_3}{R_1 + R_2 + R_3}$$

$R_{eq} = 2 + 4 + 6 = 12\,\Omega$

$V_1 = \frac{24 \times 2}{12} = 4\,V$

$V_2 = \frac{24 \times 4}{12} = 8\,V$

$V_3 = \frac{24 \times 6}{12} = 12\,V$



Q. 3 lamps are connected in series across a 120 V supply and take a current of 1.5 A. If the resistance of two of the lamp is 30 Ω each then what is resistance of third lamp?

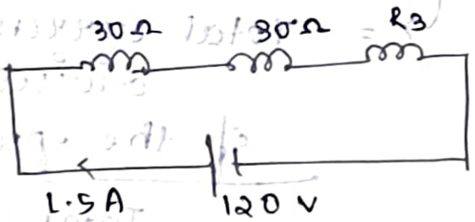
→ $\frac{V}{I} = \frac{120}{\frac{15}{10}} = \frac{120 \times 10}{15} = 80$

$R_{eq} = 80\,\Omega$

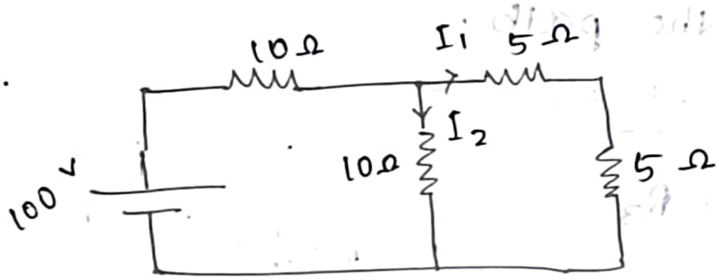
$R_{eq} = 30 + 30 + x\,\Omega$

$80 = 60 + x\,\Omega$

$x = 20\,\Omega$



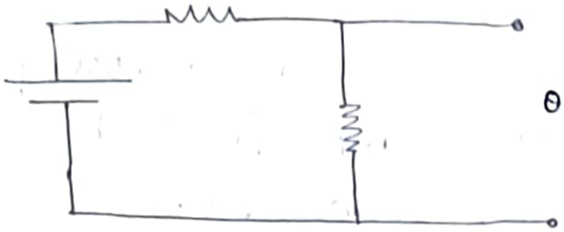
Q.



11.09.24

⇒ Open Circuit :-

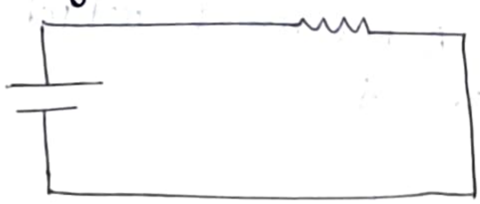
- Two points are said to be open circuited when there is no direct connection between them.
- It has practically ∞ resistance
- There is no flow of current between these two points
- There will be voltage present across these two points.



open ckt.

⇒ Short-Circuit :-

- when two points of a circuit are connected together by a thick mettallic wire they are said to be short-circuited.
- It has praticically zero resistance.
- The current through it is very high (approx. ∞)
- No voltage can exist across it.



short circuit.

⇒ Different terms and definations :-

(i) Circuit :- A closed conducting path through which an electric current flows.

(ii) Parameter - The various elements like resistance, inductance, capacitance of an electric circuit are called its parameter.

(3) linear Circuit :- A linear circuit is one whose parameter are constant that means they don't change with voltage or current.

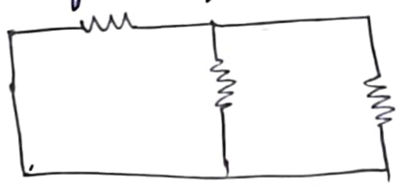
(4) Non linear circuit :- It is a circuit in which their parameters changes with voltage or current.

(5) Bilateral circuit :- It is one whose property or characterstics are same in either dirn
ex - transmission line, triac etc.

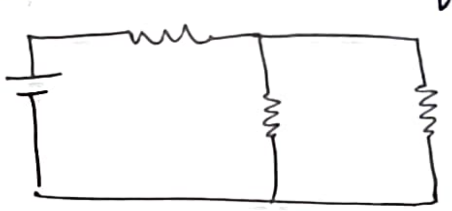
(6) Uni-lateral circuit :- It is one whose properties or characterstics changes with the dirn of its operation.
ex - diode

(7) Electric Network :- A combination of various electric element connected in any manner is called an electric network

(8) Passive network :- A network which has no source of emf in it

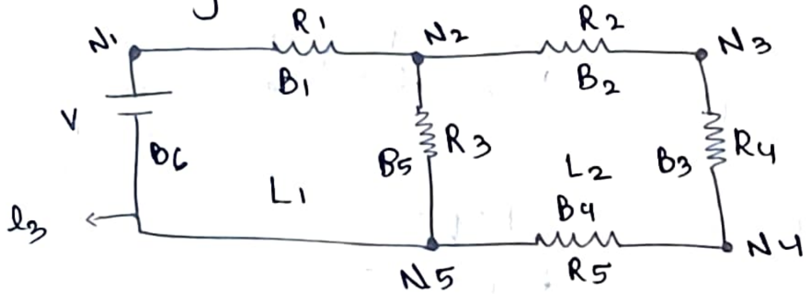


(9) Active network :- A network which contains one or more source of emf in it.



10) **Node** :- It is a junction in a circuit where two or more circuit elements are connected

11) **Branch** :- The part of a network is lies betn two junctions.



Node = 5
Branch = 6
loop = 3.

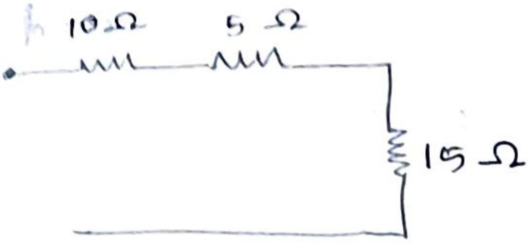
12) **Loop** :- It is a closed path in a circuit in which no element or node is encounters more than one.

13) **Mesh** :- It is a loop that has no other loop within it. or we can say it is a individual loop.

ex - L_1 and L_2

Numericals

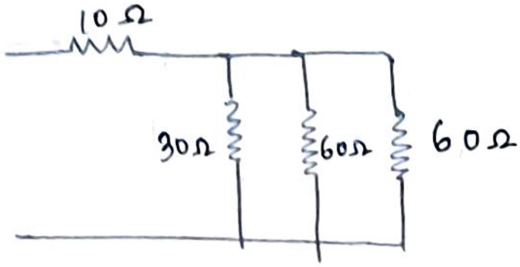
1)



$R_{eq} = 10\Omega + 5\Omega + 15\Omega$

$= 30\Omega$

2)



$\frac{1}{R_{eq}} = \frac{1}{60} + \frac{1}{60} + \frac{1}{30}$

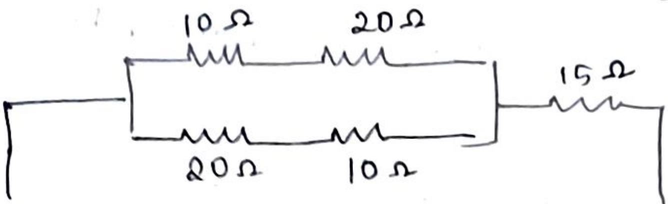
$= \frac{1+1+2}{60} = \frac{4}{60} = \frac{1}{15}$

$R_{eq} = 15$

$R_{eq} = 15 + 10\Omega$

$= 25\Omega.$

3)



$R_{eq} = 10 + 20 = 30\Omega.$

$R_{eq} = 20 + 10 = 30\Omega$

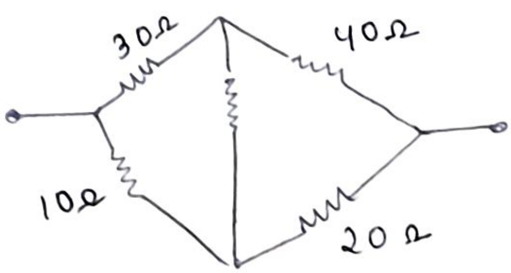
$\frac{1}{R_{eq}} = \frac{1}{30} + \frac{1}{30}$

$= \frac{2}{30} = \frac{1}{15}$

$R_{eq} = 15$

$R_{eq} = 15 + 15 = 30\Omega.$

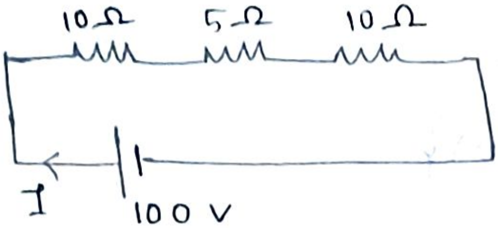
4)



$R_{eq} =$ ~~30+40~~

$30 \times 20 = 40$

5)



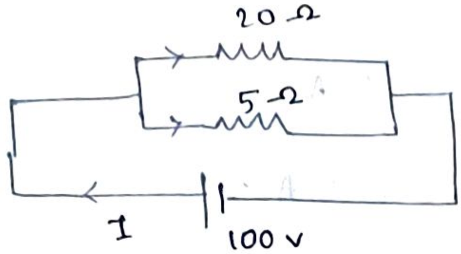
$R_{eq} = 10 + 5 + 10$

$= 25\ \Omega$.

$I = \frac{V}{R} = \frac{100}{25}$

$= 4A$.

6)



$\frac{1}{R_{eq}} = \frac{1}{20} + \frac{1}{5}$

$= \frac{1+4}{20} = \frac{5}{20} = \frac{1}{4}$

$R_{eq} = 4$

$I = \frac{V}{R} = \frac{100}{4} = 25\ A$.

$I_2 = \frac{V_1}{R_2} = \frac{100}{5} = 20\ A$.

$I_1 = \frac{V_1}{R_1} = \frac{100}{20} = 5\ A$.

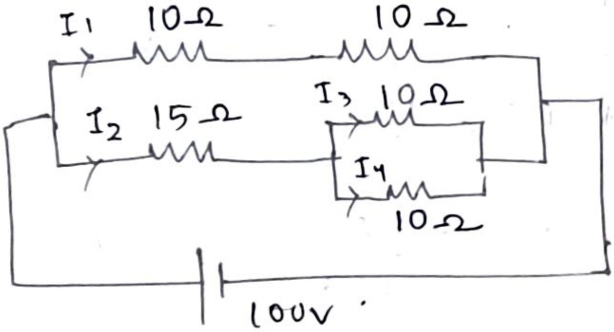
OR $I_1 = \frac{I \times 5}{20+5}$ (opposite eq. resistance)

$= \frac{25 \times 5}{25} = 5A$.

$I_2 = \frac{I \times 20}{20+5} = \frac{20 \times 25}{25} = 20A$

} current division rule.

7)



$\frac{1}{20} + \frac{1}{20} = \frac{2}{20} = \frac{1}{10}$

$R_{eq} = 10$ ~~A~~.

→ $R_{eq} = 10 + 10 = 20\ \Omega$.

→ $\frac{1}{R_{eq}} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10}\ \frac{1}{5}$

$R_{eq} = 5$

↳ $R_{eq} = 5 + 15 = 20\ \Omega$

$I_1 = \frac{100}{20} = 5A$.

$I_2 = \frac{100}{20} = 5A$.

$I_2 = I_3 + I_4$

$5A = 2(I_3)$

$I_3 = I_4 = \frac{5}{2} = 2.5\ A$.

OR

$$I_1 = \frac{I \times \{15 + (10 \| 10)\}}{(10+10) + \{15 + (10\|10)\}}$$

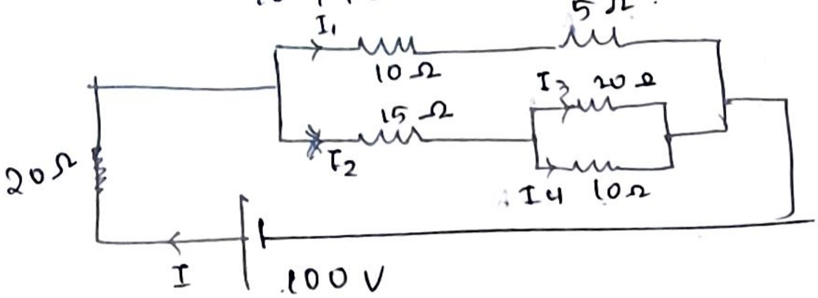
$$= \frac{10 \times 20}{20 + 20} = \frac{200}{40} = 5\,A.$$

$$I_2 = \frac{I \times 20}{20 + 20} = \frac{20 \times 10}{40} = 5\,A.$$

$$I_3 = \frac{I_2 \times 10}{10 + 10} = \frac{5 \times 10}{20} = 2.5\,A.$$

$$I_4 = \frac{I_2 \times 10}{10 + 10} = 2.5\,A.$$

7)



$\Rightarrow R_{eq} = 10 + 5 = 15\,\Omega.$

$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{20} + \frac{1}{10} = \frac{3}{20}$

$R_{eq} = \frac{20}{3}.$

In series, $15 + \frac{20}{3} = \frac{65}{3}$

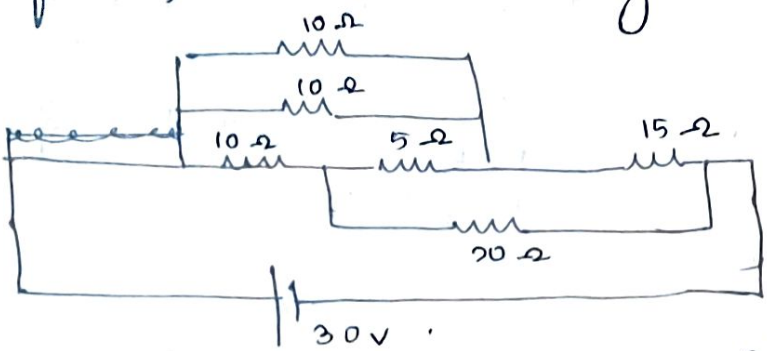
In total parallel, $\frac{1}{15} + \frac{3}{65} = \frac{13 + 9}{195}$

$\frac{1}{R_q} = \frac{22}{195}$, $R_{eq} = \frac{195}{22}.$

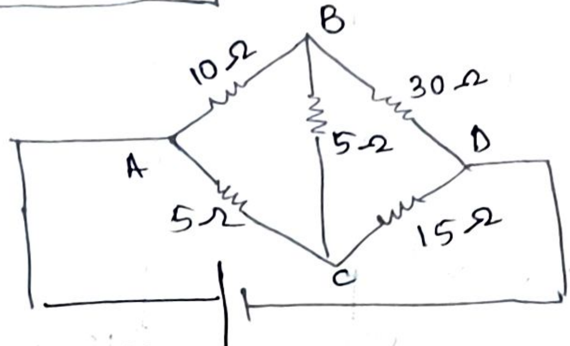
$$I = \frac{V}{R} = \frac{100}{\frac{195}{22}} = \frac{100 \times 22}{195} = 11.2\,A.$$

$$I_1 = \frac{V}{R_1} = \frac{100}{20} = 5\,A.$$

Q. find the current through 5Ω resistor.

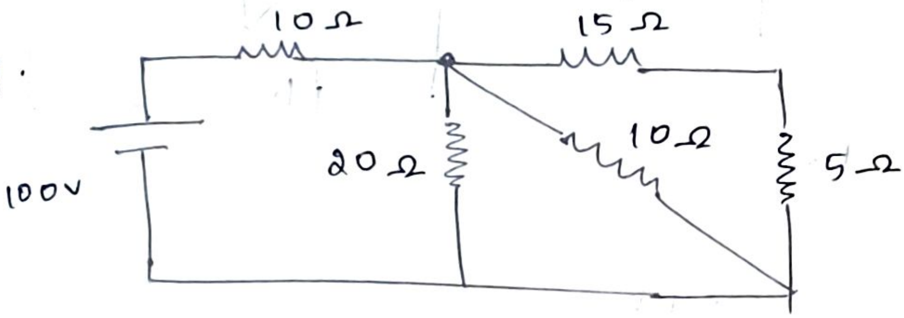


This can be converted into



According to wheatstone bridge principle, $10 \times 15 = 30 \times 5$. So, current through BC of 5Ω resistance is equal to zero.

Q.



$R_{eq} = 15 + 5\,\Omega = 20\,\Omega$.

In parallel, $\frac{1}{20} + \frac{1}{10} = \frac{1+2}{20} = \frac{3}{20}$

$R_{eq} = \frac{20}{3}$

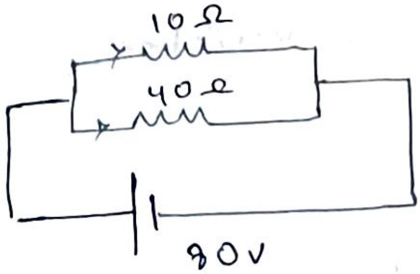
$\frac{1}{R_{eq}} = \frac{1}{20} + \frac{3}{20} = \frac{4}{20} = \frac{1}{5} = 5$.

$R_{eq} = 5\,\Omega$.

In series, $10 + 5 = 15\,\Omega$.

$I = \frac{V}{R} = \frac{100}{15} = \frac{20}{3} = 6.66A$.

Q.



In parallel, $\frac{1}{10} + \frac{1}{40}$

$$\frac{1}{R_{eq}} = \frac{4+1}{40} = \frac{5}{40} \; \frac{1}{8}$$

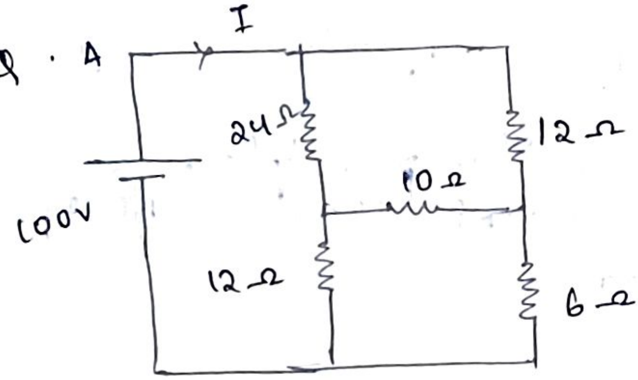
$$R_{eq} = 8$$

$$I = \frac{V}{R} = \frac{80}{8} = 10 \text{ A}$$

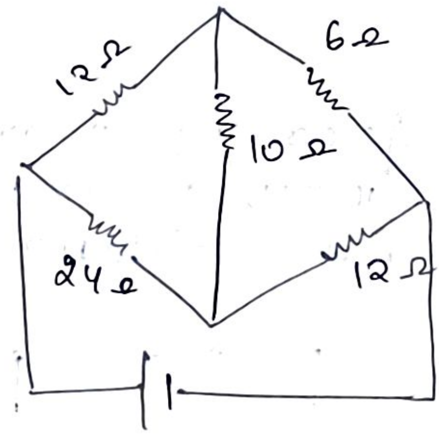
$$I_1 = \frac{80}{10} = 8 \text{ A}.$$

$$I_2 = \frac{80}{40} = 2 \text{ A}.$$

Q. A



⇒



$$12 + 6\ \Omega = 18\ \Omega.$$

$$24 + 12\ \Omega = 36\ \Omega.$$

$$\frac{1}{18} + \frac{1}{36} = \frac{2+1}{36} = \frac{3}{36} = \frac{36}{3} \; 12$$

$$R_{eq} = 12\ \Omega$$

$$I = \frac{V}{R} = \frac{100}{12} = 8.3 \text{ A}.$$

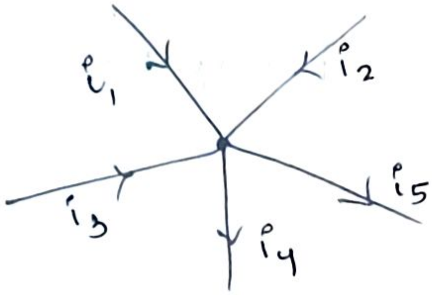
According to wheatstone bridge principle there will be no current in 10 Ω resistance

$(24 \times 6) = (12 \times 12)$.

So we can eliminate 10 Ω resistance in this circuit.

⇒ Kirchoff's current law (KCL) :-

- It states that in an electric network the algebric sum of all the current meeting at a point is equal to zero.
- we can say, the sum of entering current is equal to sum of leaving current



acc (i) $i_1 + i_2 + i_3 + (-i_4) + (-i_5) = 0$

acc (ii) $i_1 + i_2 + i_3 = i_4 + i_5$

$$\Rightarrow \frac{dq_1}{dt} + \frac{dq_2}{dt} + \frac{dq_3}{dt} = \frac{dq_4}{dt} + \frac{dq_4}{dt}$$

⇒ Integrating both sides,

$$q_1 + q_2 + q_3 = q_4 + q_5$$

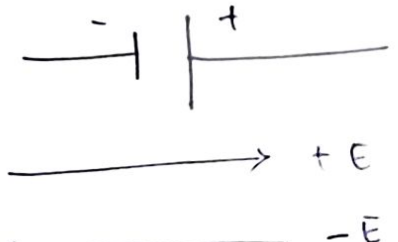
→ KCL is the result of conservation of charge.

⇒ Kirchoff's Voltage law (KVL) / Mess law :-

- It states that the algebric sum of the product of current and resistance in each of the conductor in any closed path or mess in a network plus the algebric sum of the emf in that path is zero.

* $\Sigma IR + \Sigma E = 0$ (E = emf)

⇒ Sign of battery 'emf' :-



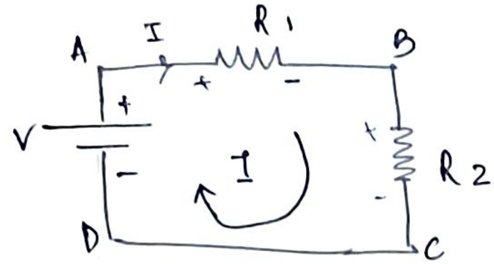
→ +E (rise in voltage)

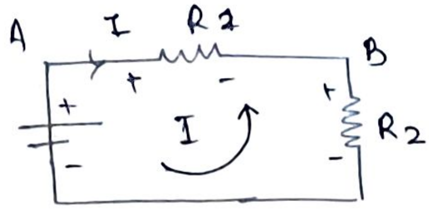
← -E (fall in voltage)

⟶ $-IR$ (fall in voltage)

⟵ $+IR$ (rise in voltage)

Q.





Applying KVL in loop ABCDA, [clockwise]

$$+V - IR_1 - IR_2 = 0$$

$$V = IR_1 + IR_2$$

multiplying 'It' on both sides,

Energy: $VIt = I^2R_1t + I^2R_2t$ — (1)

$$E = E_1 + E_2 \longrightarrow \Sigma \text{ energy}.$$

∴ KVL is the result of conservation of energy.

E/W = Energy / workdone.

[Anticlockwise]

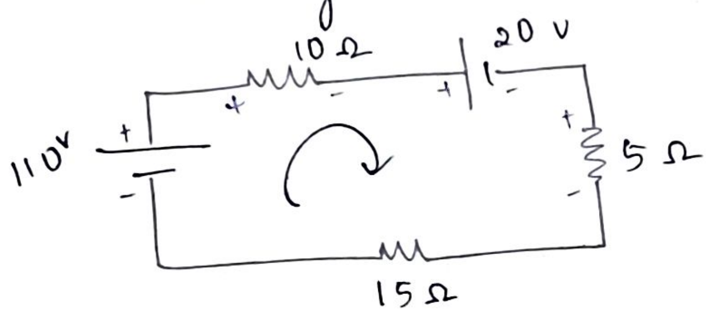
↳ Applying KVL,

$$-V + IR_2 + IR_1 = 0$$

$$V = IR_1 + IR_2$$

$$VIt = I^2R_1t + I^2R_2t \quad (2).$$

Q. Calculate the current flowing at the P.D after the three resistances by applying KVL, to the given circuit.



Applying KVL in ABCDA,

$110V - 10I - 20 - 5I - 15I = 0$

~~$130 - 15I = 0$~~   ~~$130 - 30I$~~

~~$15I = 130$~~ $90V - 30I = 0$

~~$I = \frac{130}{15}$~~ $30I = 90$

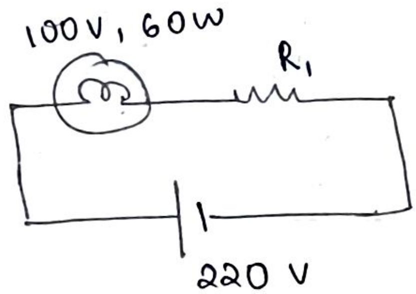
$I = \frac{90}{30} = 3A$.

$V_1 = IR_1 = 3 \times 10 = 30V$.

$V_2 = IR_2 = 3 \times 5 = 15V$.

$V_3 = IR_3 = 15 \times 3 = 45V$.

Q. A 100 V, 60 W bulb is to be operated from a 220 V supply. What is the resistance to be connected in series with the bulb to glow normally.



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

$= \frac{60}{100} = \frac{3}{5} A$.

$R = \frac{V}{I} = \frac{220}{\frac{3}{5}} = \frac{220 \times 5}{3}$

$= \frac{1100}{3} = 366.6 \Omega$

We know, $I^2R = P \Rightarrow P = I^2R$

$\Rightarrow 60 = \left(\frac{3}{5}\right)^2 \times R$

$\Rightarrow 60 = \frac{9}{25} \times R$

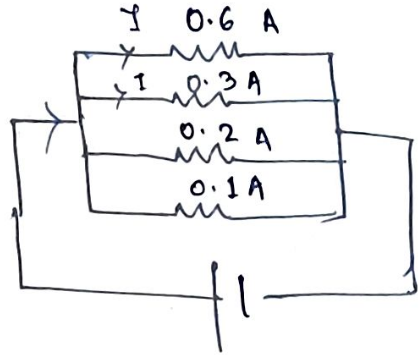
$\Rightarrow R = \frac{60 \times 25}{9} = \frac{500}{3} = 166.6 \Omega$

$R_{eq} = R + R_1$

$R_1 = R_{eq} - R = 366.6 \Omega - 166.6 \Omega$

$= 200 \Omega$

Q. The equivalent resistance of 4 resistor joint in parallel is 20 Ω. The current flowing through them are 0.6 A, 0.3 A, 0.2 A and 0.1 A find the value of resistors ?



$$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{20}$$

$$\frac{I_1}{V} + \frac{I_2}{V} + \frac{I_3}{V} + \frac{I_4}{V} = \frac{1}{20}$$

$$\frac{0.6 + 0.3 + 0.2 + 0.1}{V} = \frac{1}{20}$$

$$\frac{1.2}{V} = \frac{1}{20}$$

$$V = 20 \times 1.2 = 24\,V$$

$$R_1 = \frac{V}{I_1} = \frac{24}{0.6} = \frac{24 \times 10}{6} = 40\,\Omega$$

$$R_2 = \frac{V}{I_2} = \frac{24 \times 10}{3} = 80\,\Omega$$

$$R_3 = \frac{V}{I_3} = \frac{24 \times 10}{2} = 120\,\Omega$$

$$R_4 = \frac{V}{I_4} = \frac{24 \times 10}{1} = 240\,\Omega$$

Assignment Ques :-

Q. 3 load A, B, C are connected in parallel across a 240 V source. load A takes 9.6 kW, load B takes 60 A and load C has a resistance of 4.8 Ω i) Calculate R_A , R_B

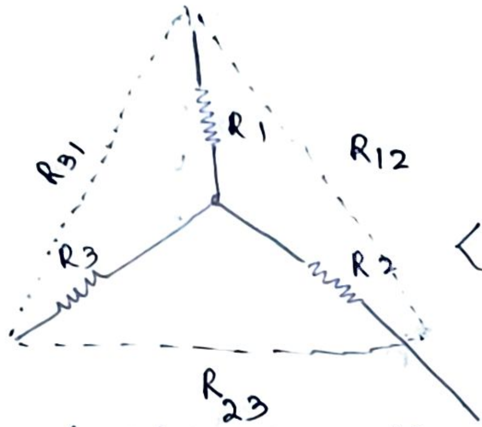
ii) Equivalent resistance.

iii) Total current.

iv) Total power.

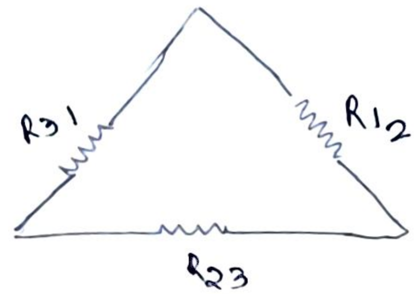
Dt-14/09/24

→ Star to delta conversion :- (Y-Δ)



∴ star connection.

⟺



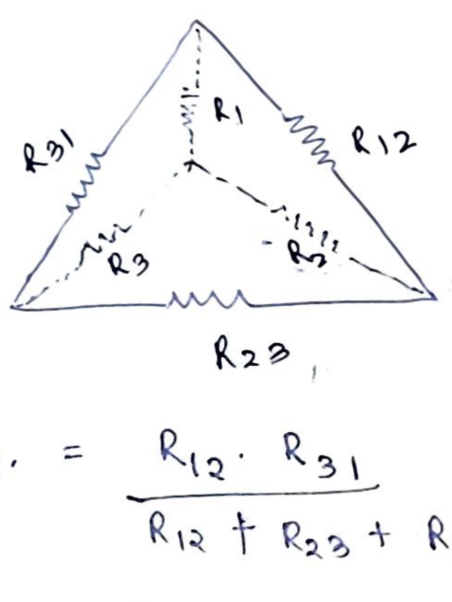
∴ delta connection.

$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

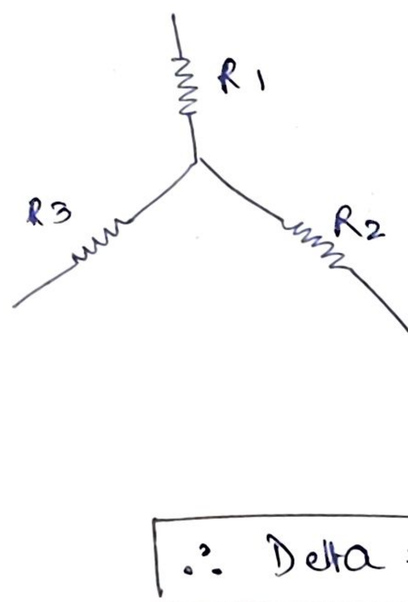
$$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

$$R_{31} = R_1 + R_3 + \frac{R_1 R_3}{R_2}$$

→ Delta to star conversion :- (Δ - Y)



⇒



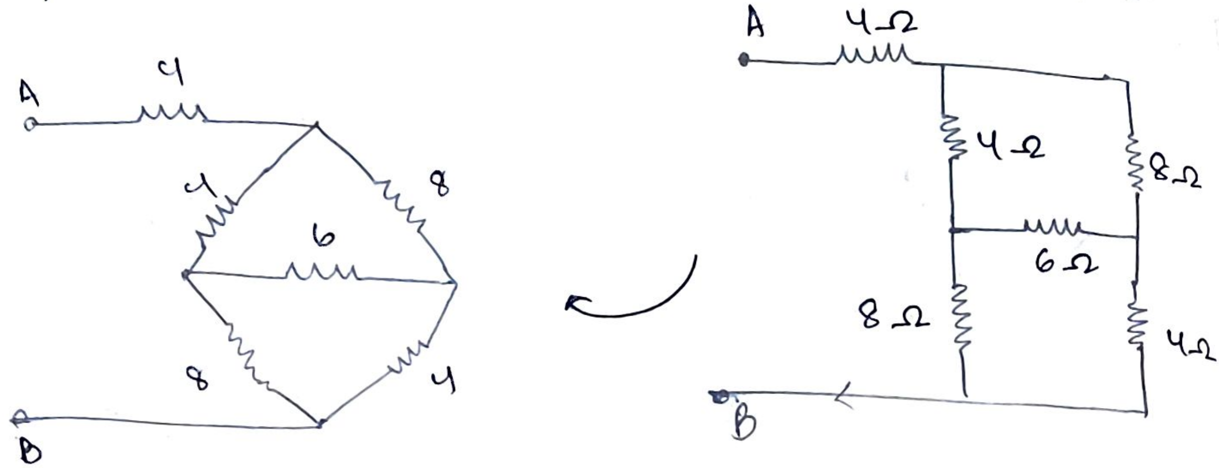
$$R_1 = \frac{R_{12} \cdot R_{31}}{R_{12} + R_{23} + R_{31}}$$

$$R_2 = \frac{R_{23} \cdot R_{12}}{R_{12} + R_{23} + R_{31}}$$

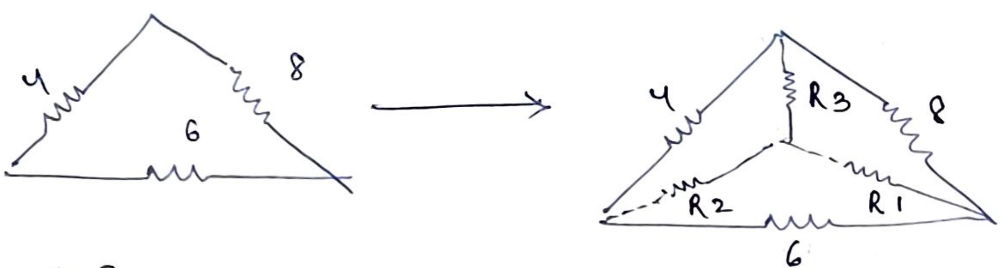
$$R_3 = \frac{R_{31} \cdot R_{23}}{R_{12} + R_{23} + R_{31}}$$

∴ Delta = 3 × star

Q. find the equivalent resistance A & B.



let the upper triangle to convert it into star.

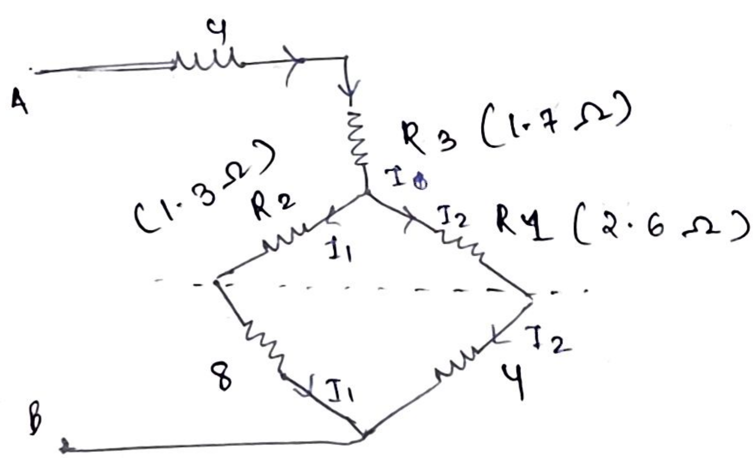


$R_1 = \frac{6 \times 8}{6+8+4} = \frac{48}{18} = 2.6\ \Omega.$

$R_2 = \frac{4 \times 6}{18} = \frac{24}{18} =$ ~~2.6 Ω~~ $1.3\ \Omega.$

$R_3 = \frac{4 \times 8}{18} = 1.7\ \Omega$

equivalent :-



$\Rightarrow R_2 (1.3) + 8 = 9.3\ \Omega$

$\Rightarrow R_1 (2.6) + 4 = 6.6\ \Omega$

$\frac{1}{Req} = \frac{1}{9.3} + \frac{1}{6.6} = 0.10 + 0.15$

$= 0.25\ \Omega$

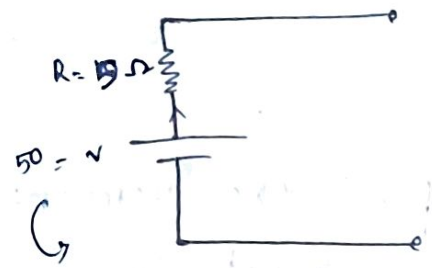
$$R_{eq} = \frac{1}{0.25} = \frac{1}{\frac{25}{100}} = \frac{100}{25} = 4\Omega$$

Total = $4 + 1.7 + 4$
$= 8 + 1.7 = 9.7\ \Omega$

Dt - 13/9/24

⇒ **Voltage to Current source conversion.**

- A voltage source with a series resistance can be converted into a current source with a parallel resistance.



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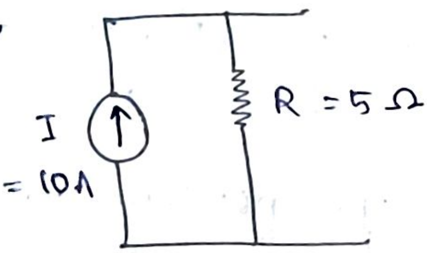
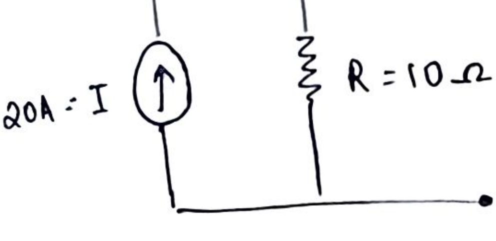


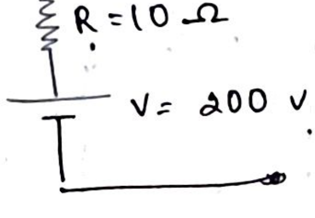
ex. let $V = 50\,V$
$R = 5\Omega$
$I = \frac{50}{5} = 10\,A$

⇒ **Current to Voltage Source conversion :-**

- A current source with a parallel resistance can be converted into a voltage source in series with the same resistance.



⇒



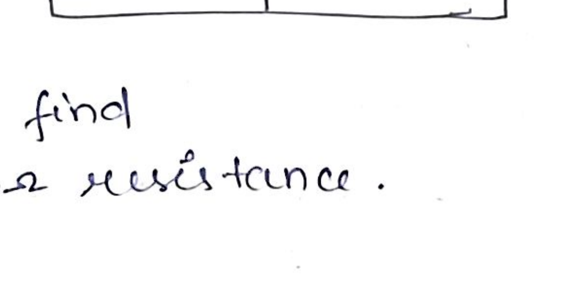
ex. $I = 20\,A$, $R = 10\,\Omega$
$V = IR$
$= 200\,V$.

Superposition theorem :-

It states that, a network containing more than one source of emf or current source, the current which flows at any point; is the sum of all the currents which would close at that point where (i) each emf source considers separately and other emf sources are replaced by their internal resistances and current sources should be open circuited.

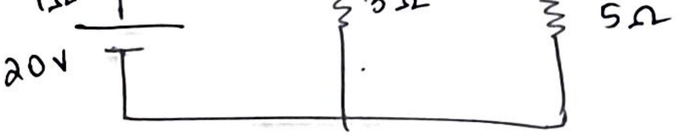
(ii) each current source consider separately and other emf sources are replaced by their internal resistances and remaining current sources should be open circuited.

Q. Using superposition theorem, find the current through 3Ω resistor and also find the voltage across 3Ω resistor.



Step 1 - Active the 20V voltage source and short-circuit the 30V voltage source and replaced by their internal resistance 5Ω. then find the current through 3Ω resistance.

dia.1



$$R_{eq} = \frac{1}{4} + \frac{1}{5} = \frac{5+4}{20} = \frac{9}{20} = \frac{20}{9}$$

$R_{eq} = 4+5 = 9\ \Omega$

$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{9} = \frac{3+1}{9} = \frac{4}{9}$

$R_{eq} = \frac{9}{4}$

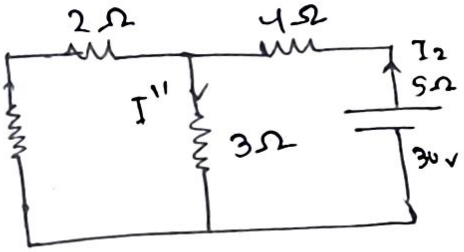
then $R_{eq} = \frac{9}{4} + \textcircled{3} = \frac{9+12}{4} = \frac{21}{4} = 5.25\ \Omega$ (3 = 2+1)

$I_1 = \frac{20}{5.25} = 3.8\ A$

$I' = \frac{I_1 \times (4+5)}{3+(4+5)} = \frac{I_1 \times 9}{3+9} = \frac{3 I_1}{4}$ (KCL) — Resistance of diff path.

$I' = \frac{3 \times 3.8}{4} = 2.84\ A$

Step.2 - Now active the 30 v voltage source and short circuit the 20 v voltage source by replacing their internal resistance 1Ω.



$R_{eq_2} = 5+4+[3 \parallel (1+2)]$

$= 9 + (3 \parallel 3)$

$= 10.5\ \Omega$

$I_2 = \frac{30}{10.5} = 2.8\ A$

$I'' = \frac{I_2 \times (1+2)}{3+(1+2)} = \frac{2.8 \times 3}{6} = 1.4\ A$

Step-3 - In both the cases, the current I' and I'' are going in same dirn in 3Ω resistance, so total current through 3Ω resistance $= I' + I''$

$= 2.85 + 1.4$

$I = 4.25\ A$

voltage across 3 Ω resistor :

$V = IR$

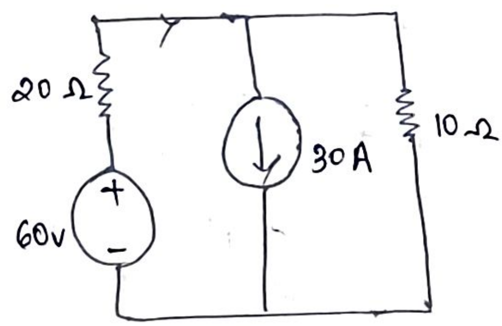
$V = 4.25 \times 3$

$= 12.75$ V.

(signature) 18.09.24

Dt - 19/09/24.

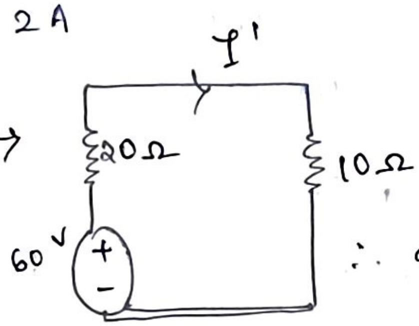
→ Using Superposition theorem find the current through 10 Ω resistance.



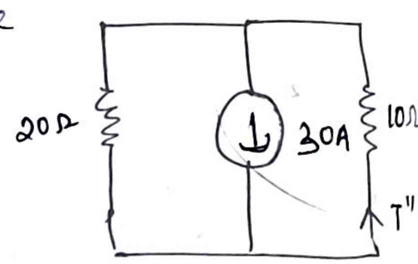
Step-1 - activate the voltage ~~the~~ source and open the current.

$R_{eq} = 20 + 10 = 30\,\Omega$.

$I' = \dfrac{60}{30\ (20+10)} = 2$ A



∴ dig - 1



dia - 2.

step - 2 - activate the current source and short circuited the voltage source.

$I'' = \dfrac{30 \times 20}{20 + 10} = \dfrac{600}{30} = 20$

$= 20$ A.

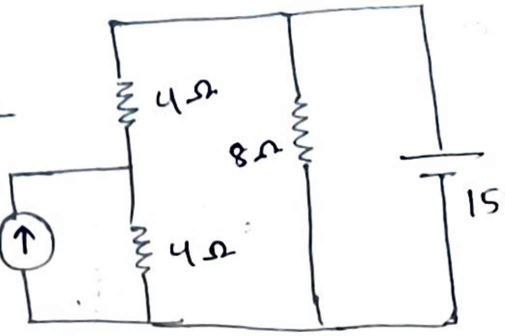
Step-3 - total current through 10 Ω resistance

$= I'' - I'$ as the I' and I'' are flowing is opp. dirn.

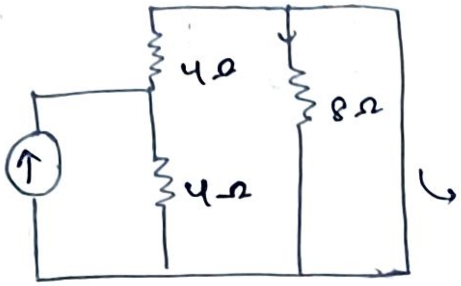
$= 20 - 2$

$= 18$ A.

Q. Using superposition theorem, find the current through 8Ω resistance.

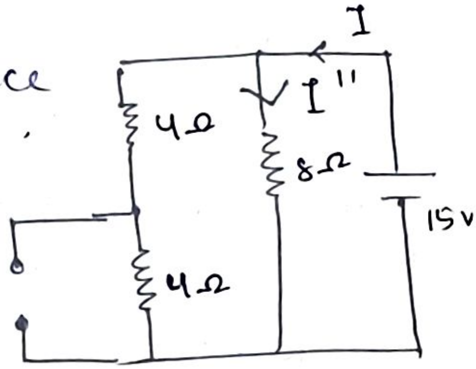


Step-1 - activate the current source and short-circuit the voltage source.



∴ Here the current through 8Ω resistance will be zero or no current flows through 8Ω resistance because current always follows the short-circuit path

Step 2. activate the voltage source and open the current source.



$R_{eq} = 8 \parallel (4+4)$

$= 4\,\Omega$

$I = \frac{15}{4} = 3.75\text{ A}$

$I'' = \frac{I \times (4+4)}{(4+4)+8} = \frac{3.75 \times 8}{16} = 1.37\text{ A}$

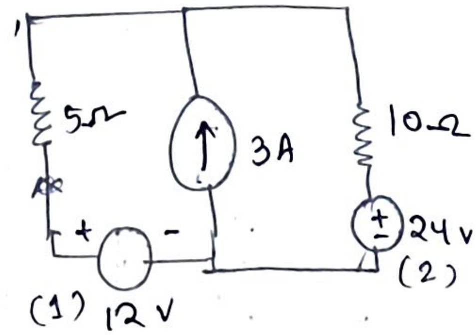
Step-3. total current through 8Ω resistor,

$= I'' - I$

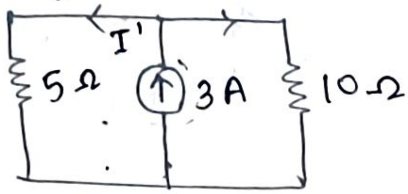
$= 1.87 - 0$

$= 1.87\text{ A}$

Q. Using super position theorem, find the current through 5 Ω resistance.

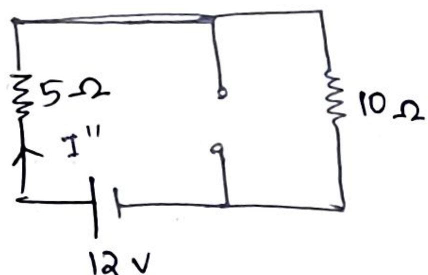


Step-1 - Active the current source and shot-circuit the voltage source.



$$I_1 = \frac{3 \times 10}{5+10} = \frac{30}{15} = 2A.$$

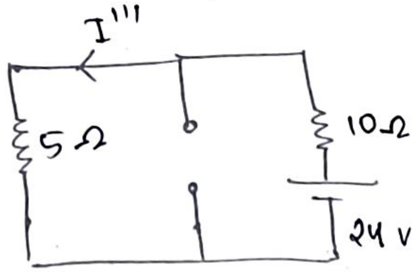
Step-2 - Active the voltage source (1) and open the current source



$$Req = 5 + 10 = 15\ Ω.$$

$$I = \frac{12}{15} = 0.8\ A$$

Step-3 Active the voltage source (2) and open the current source.



$$Req = \frac{V}{I} = \frac{24}{15} = 1.6\ A.$$

Step-4 - total current through 5 Ω resistance.

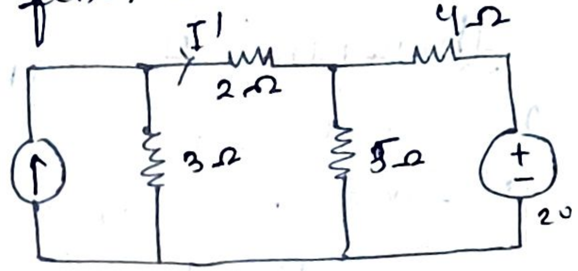
$$I' + I''' - I''$$

$$2A + 1.6 - 0.8$$

$$3.6 - 0.8 = 2.8\ A.$$

33

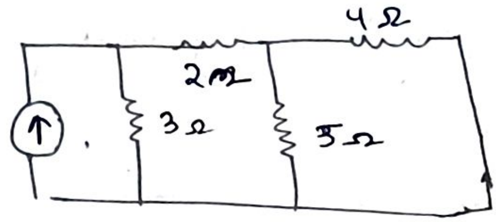
Q. Using super position theorem find current I.



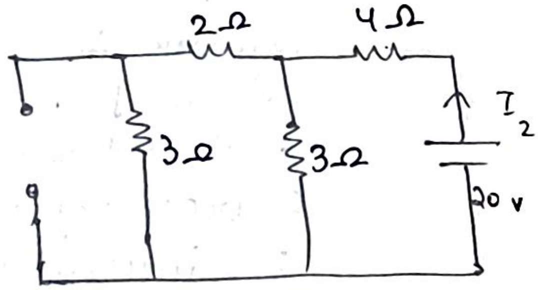
Step-1. Active the current Source and shot the Voltage source.

$$I' = \frac{10 \times 3}{3 + \{2 + (4 \| 5)\}}$$

$$I' = \frac{30}{3 + 4.2} = \frac{30}{7.2} = 4.16\,A$$



Step-2 - Active the Voltage source and open the current source.



$$Req = 4 + \{5 \| (2+3)\}.$$

$$= 4 + 2.5 = 6.5\,\Omega$$

$$I = \frac{20}{6.5} = 3.07\,A.$$

$$I'' = \frac{3.07 \times 5}{5 + (2+3)} = 1.53\,A.$$

Step-3. Total Current $= I' - I''$

$$= 4.16 - 1.53$$

$$= 2.63\,A.$$

Dt - 21/09/24

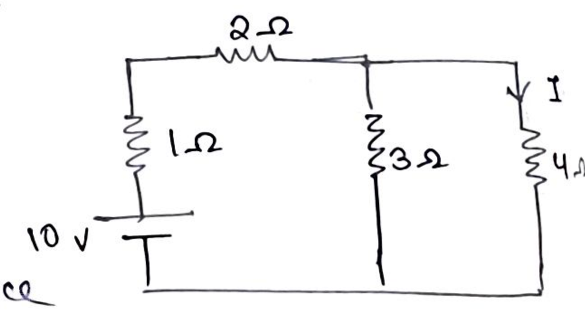
Thevenin's theoram :-

It states that the current I flowing through a load resistance (R_L) connected across any two terminal of a network containing one or more source of current or voltage is given by :-

$$I = \frac{V_{th}}{R_{th} + R_L}$$

- V_{th} → Thevenin eq. voltage / open circuit voltage betn that two point where R_L disconnected. $V_{th} = V_{oc}$
- R_{th} → equivalent Resistance of the network from open circuit terminal with all voltage sources replaced by internal res. and current sources replaced by open circuit.
- R_L → load resistance through which current is to be found out.

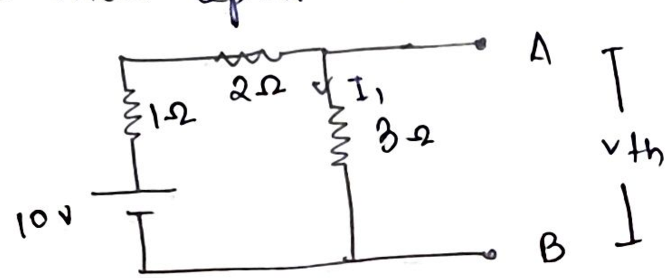
Q. Using Thevenin's theoram, find the current through 4Ω resistor.



Here, R_L = 4Ω

Step-1: To find V_{th} or V_{oc} first open circuit or dis-connect the 4Ω resistance and find out the voltage across that open circuit terminal.

(Ihn se current ja rha h usko open krna h)



$R_{eq} = 1\Omega + 2\Omega + 3\Omega = 6\Omega$.

$I_{eq} = \frac{V}{R} = \frac{10}{6} = \frac{5}{3} = 1.66\ A$.

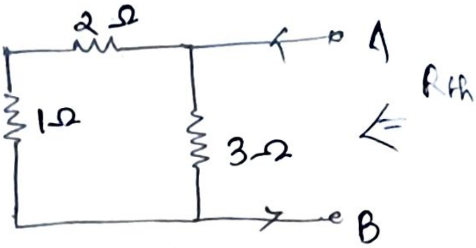
$V_{th} / V_{oc} = 1.66 \times 3 = 5\ V$.
(IR)

step-2.

$R_{th} = (1+2) \| 3$

$= 3 \| 3$

$= \frac{3}{2} = 1.5\ \Omega$.



step. 3

$I = \frac{V_{th}}{R_{th} + R_L}$

- Now draw the thevenin's equivalent circuit dig. then find the current through 4Ω resistance.

equ. diagram

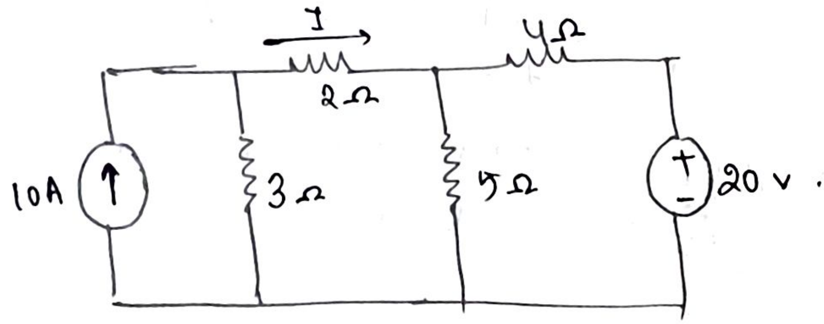
$I = \frac{5}{1.5 + 4} = 0.9\ A$.

Q. If on the above circuit, it was given to find out the voltage across 4Ω resistance then it will be,

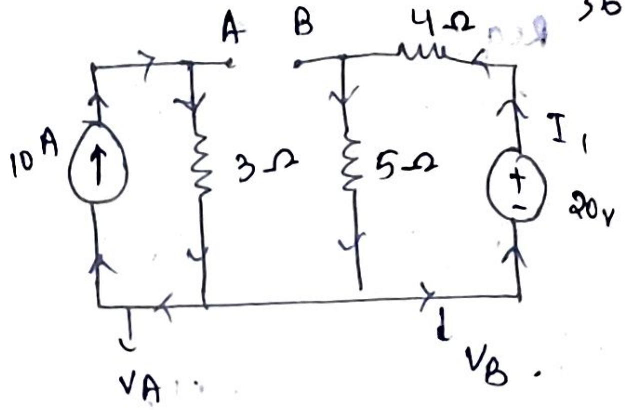
$V = IR$.

$V = 0.9 \times 4 = 3.6\ V$.

Q. Using the Thevenin's theoram, find the current I.



Step-1.



→ $R_L = 2\Omega$.

(i) $V_A = 10 \times 3 = 30\ V$ — (1)

(i) $R_{eq} = 5 + 4 = 9\Omega$.

$I_1 = \frac{V}{R} = \frac{20}{9}$

$= 2.2\ A$.

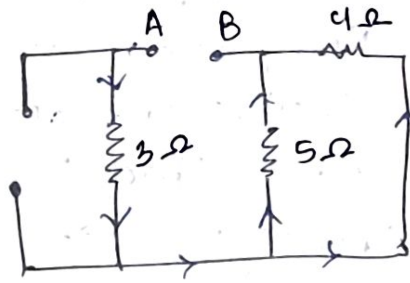
$V_B = 2.2 \times 5 = 11.0\ V$ — (2)

$V_A - V_B = V_{AB}$.

$30\ V - 11\ V = 19\ V = V_{AB} / V_{th} / V_{oc}$.

Step-2.

R_{th} → To shot the voltage source and open the current source.



$R_{th} = 3 + (4 \| 5)$

$= 3 + \frac{4 \times 5}{4 + 5}$

$= 3 + \frac{20}{9}$

$= 5.2\ \Omega$.

Step-3.

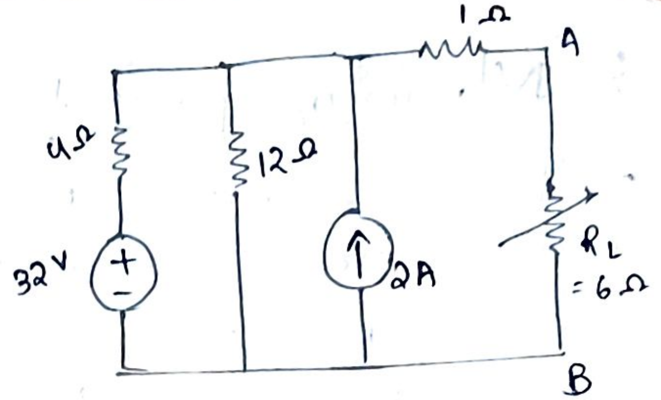
equi. dig..

$I = \frac{V_{th}}{R_{th} + R_L}$

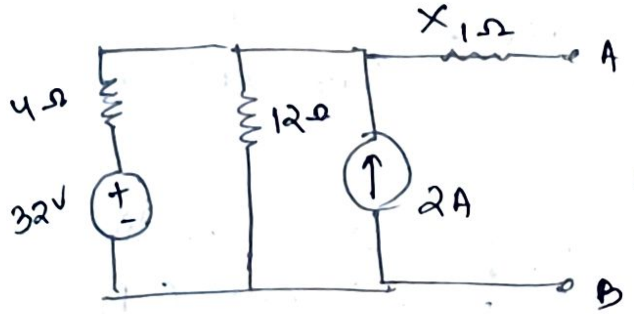
$= \frac{19}{5.2 + 2}$

$= \frac{19}{7.2} = 2.63\ A$.

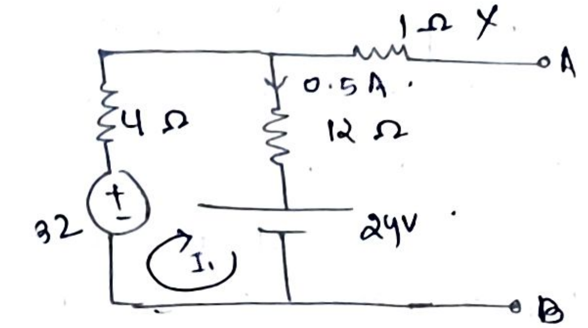
Q. Using thevenin's theorem find the current through R_L where $R_L = 6\ \Omega$.



step-1



=>



$V = IR$

$= 12 \times 2 = 24V.$

Applying KVL,

$32 - 4I_1 - 12I_1 - 24 = 0.$

$8 - 16I_1 = 0.$

$16I_1 = 8$

$2I_1 = 1. \Rightarrow I_1 = 0.5A.$

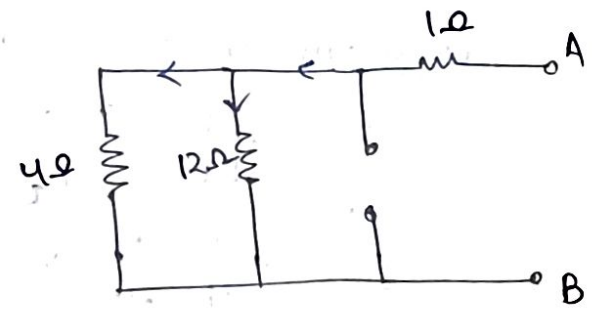
$\Rightarrow V_{th} = IR = \frac{1}{2} \times 12 = 6V.$

Total = $24 + 6V = 30V.$ → (V_{th}.)

Step-2.

$R_{eq} = \frac{4 \times 12}{4+12} = \frac{48}{16} = 3$

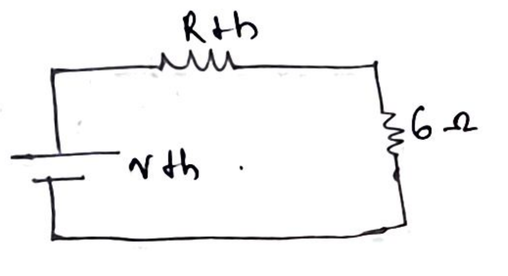
$\Rightarrow 3 + 1 = 4\Omega.$



step-3

$I = \frac{V_{th}}{R_{th} + R_L}$

$= \frac{30}{4+6} = 3A.$



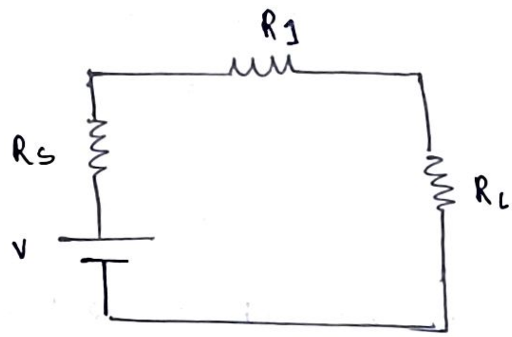
⇒ Maximum power transfer theorem :-

- It states that a resistive load will abstract maximum power from a network when the load resistance is equal to the internal resistance of the network as view from the output terminal with all emf sources short-circuited and leaving their internal resistance.

OR

- It states that maximum power is delivered by a source to the load resistance (R_L), where the R_L = internal resistance of the circuit i.e $R_L = R_i$

$$R_S + R_1 = R_i$$



$$I = \frac{V}{R_S + R_1 + R_L}$$

$$= \frac{V}{R_i + R_L}$$

$$\text{Power } (P) = I^2 R_L$$

$$= \left(\frac{V}{R_i + R_L}\right)^2 R_L$$

for maximum power transfer, $\frac{dP}{dR_L} = 0$.

$$\Rightarrow \frac{d}{dR_L}\left(\frac{V}{R_i + R_L}\right)^2 \cdot R_L = 0.$$

$$\Rightarrow \frac{d}{dR_L}\left\{\frac{V^2}{(R_i + R_L)^2}\right\} \cdot R_L = 0.$$

$$\Rightarrow V^2 \frac{d}{dR_L}\left\{\frac{R_L}{(R_i + R_L)^2}\right\} = 0.$$

$$\Rightarrow V^2 \left[\frac{(R_i + R_L)^2 \frac{d}{dR_L}(R_L) - (R_L) \cdot \frac{d}{dR_L}(R_i + R_L)^2}{\{(R_i + R_L)^2\}^2} \right] = 0$$

$$\rightarrow (R_i + R_L)^2 \cdot 1 - R_L \; 2(R_i + R_L) \cdot (0 + 1) = 0$$

$$\Rightarrow R_i^2 + R_L^2 + 2 R_i R_L - R_L \cdot 2(R_i + R_L) = 0$$

$$\Rightarrow R_i^2 + R_L^2 + 2 R_i R_L - 2 R_i R_L - 2 R_L^2 = 0$$

$$= R_i^2 - R_L^2 = 0$$

$$\Rightarrow R_i^2 = R_L^2$$

$$\Rightarrow \boxed{R_i = R_L}$$

$$P = \left(\frac{V}{R_i + R_L} \right)^2 \cdot R_L$$

$$\Rightarrow P_{max} = P_{L\,max} = \left(\frac{V}{R_L + R_L} \right)^2 \cdot R_L$$

$$= \frac{V^2}{4R_L^2} \cdot R_L$$

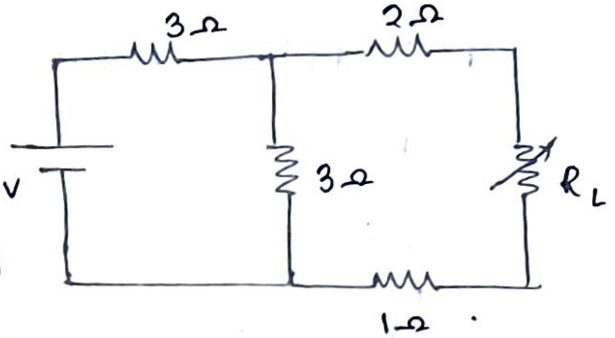
$$\rightarrow \boxed{P_{L\,max} = \frac{V^2}{4R_L}} \qquad \Rightarrow \boxed{R_L = R_{th} = R_i}$$

$$\Rightarrow \boxed{P_{L\,max} = \frac{V_{th}^2}{4R_L}}$$

- The overall efficiency of a network supplying maximum power to any branch is 50 %.
- For this reason, the application of this theorem to power transmission and distribution is limited.

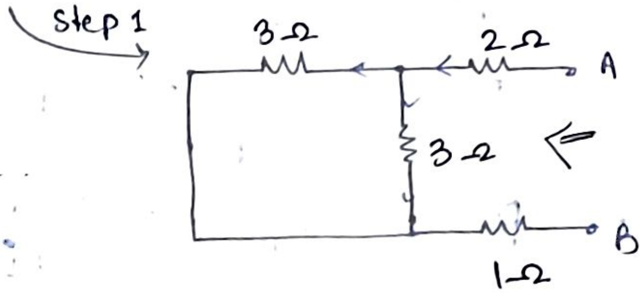
→ It is basically used in electronic and comm. network.

Q. find the value of R_L such that max. possible power will be transformed to R_L. find also the value of max. power and the power supplied by source under these conditions.



→ Step. 1

R_{th} → To short the voltage source and open the current source.



$R_{th} = R_L = R_i$

$= 2 + (3 \| 3) + 1$

$= 2 + 1.5 + 1$

$= 4.5\ \Omega$.

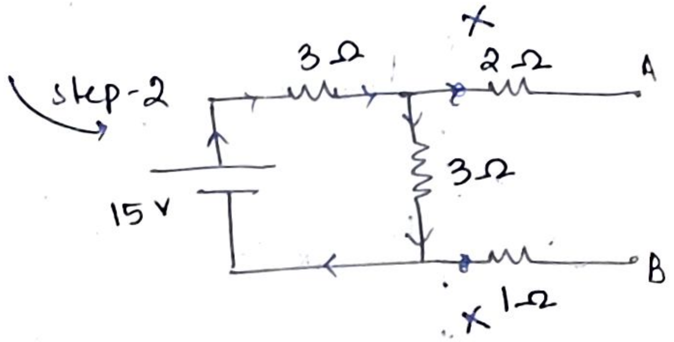
→ Step-2

$R_{eq} = 3 + 3\ \Omega$

$= 6\ \Omega$

$I = \frac{V}{R} = \frac{15}{6} = \frac{5}{2}$

$= 2.5$ A.



$V_{th} / V_{oc} / V_{AB} = 2.5 \times 3 = 7.5$ V

→ $P_{L\,max} = \frac{V_{th}^2}{4R_{th}} = \frac{(7.5)^2}{4 \times 4.5} = \frac{56.25}{18}$

max. power $= 3.125$ watt (W).

*
→ supply power $= 2 \times$ max. power

$= 2 \times 3.125 = 6.25$ W.

Dt- 25/09/24

⇒ Norton's theorem :-

It states that the current in any passive circuit element (R_L) in a network is the same as would flow in it if it were connected in parallel with (R_N) and the parallel pair were supplied with a constant current (I_{sc}).

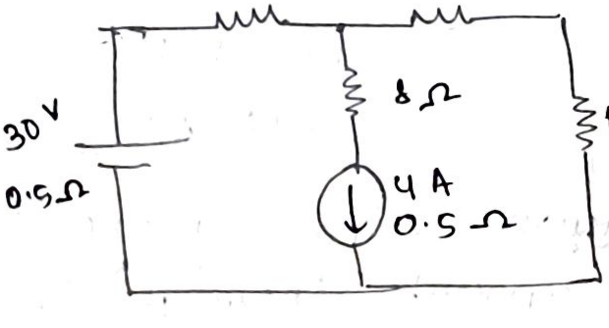
where,
$$I = \frac{I_{sc} \times R_N}{R_N + R_L}$$

where $R_N = R_{th}$ = equivalent resistance (= norton's equivalent resistance) of the network from open circuit terminal with all voltage sources replaced by internal resistance and current sources replaced by open circuit.

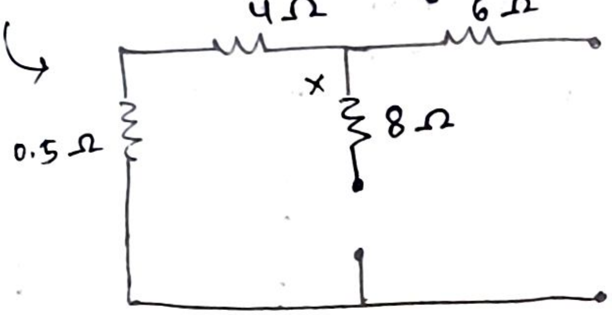
R_L = load resistance through which current is to be found out.

I_{sc} - It is the current which will flow in a short placed at the terminals of R_L in the original circuit (short-circuit current)

Q. Using norton's theorem find the current through 15 Ω resistance



step1 - To find R_{th} by opening R_L and current source and short the voltage.

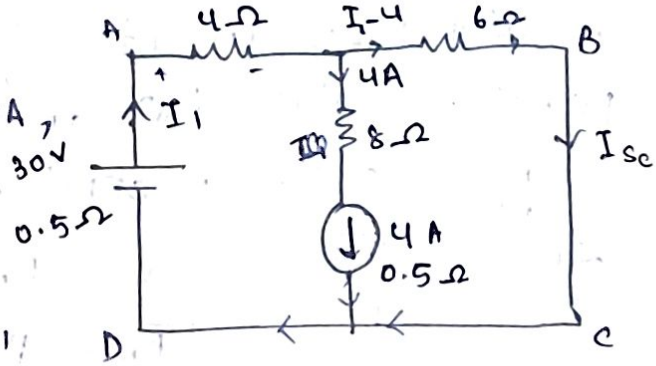
↳


$R_N = R_{th} = 0.5 + 4 + 6$

$= 10.5\ \Omega$.

Step-2 To find I_{sc} -

From original



$I_1 - 4 = I_{sc}$

Applying KVL in loop ABCDA,

$= 30 - 4I_1 - 6(I_1 - 4) - 0.5 I_1$

$= 30 - 4I_1 - 6I_1 + 24 - 0.5 I_1$

$\Rightarrow 30 - 10.5 I_1 + 24 = 0$

$\Rightarrow 54 = 10.5 I_1$

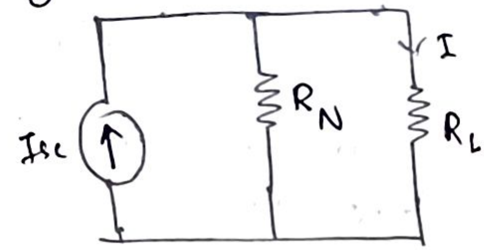
$\Rightarrow I_1 = \frac{54}{10.5} = 5.14\ A$.

$I_{sc} = I_1 - 4$.

$= 5.14 - 4$.

$= 1.14\ A$.

Step-3. draw the norton's equivalent circuit and find the I. through R_L



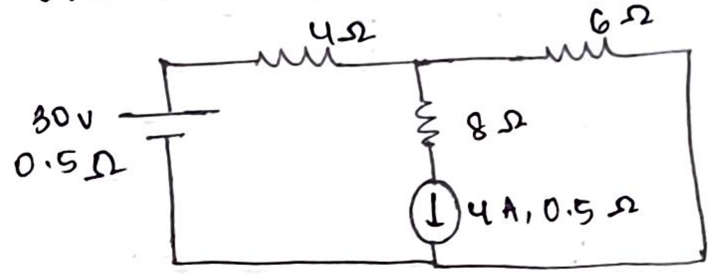
$I = \frac{I_{sc} \times R_N}{R_N + R_L}$

$= \frac{1.14 \times 10.5}{10.5 + 15}$

$= 0.46\ A$.

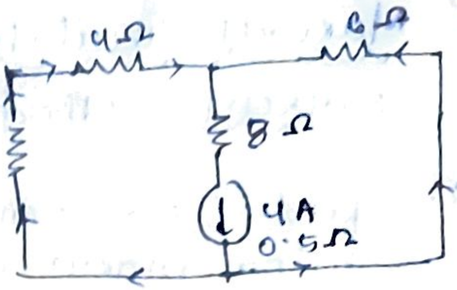
A.2

Step-4 Using superposition theorem, find the current through $6\ \Omega$ resistance.



43

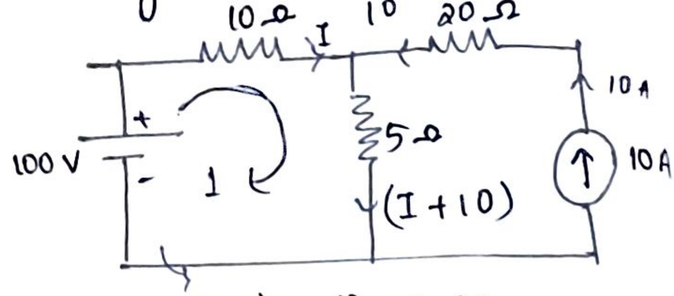
ans step.1. active the current source and shot circuit the voltage source.



Dt - 26/09/24

* Maxwell Circulating Current theorem or loop current method or mess analysis

Q. find the current through all the resistances using maxwell circulating current theorem.



taking I as an individual current.

Applying KVL in loop 1.

$100 - 10I - 5(I+10) = 0$

$100 - 10I - 5I - 50 = 0$

$50 - 15I = 0$

$15I = 50$

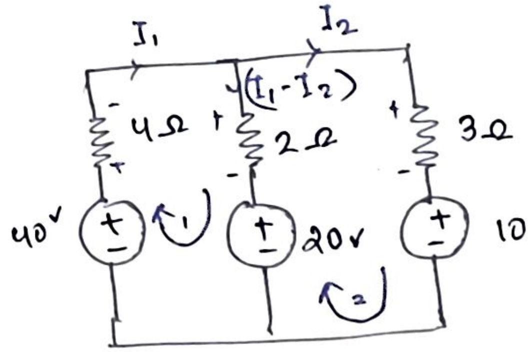
$I = \frac{50}{15} = \frac{10}{3} = 3.33\ A$

- Current through 10 Ω resistance = 3.33 A
- Current through 20 Ω resistance = 10 A
- current through 5 Ω resistance = I + 10

$= 3.33 + 10$

$= 13.33\ A$

Q. find the current through 2 Ω resistance using loop current method.



Applying KVL, in loop 1.

$\Rightarrow 40 - 4I_1 - 2(I_1 - I_2) - 20 = 0$

$\Rightarrow 20 - 4I_1 - 2I_1 + 2I_2 = 0$

$\Rightarrow 20 - 6I_1 + 2I_2 = 0$

$\Rightarrow 10 - 3I_1 + I_2 = 0$

$\Rightarrow 3I_1 - I_2 = 10$ ——— (1)

Applying KVL, in loop 2.

$\Rightarrow 20 + 2(I_1 - I_2) - 3I_2 - 10 = 0$

$= 10 + 2I_1 - 2I_2 - 3I_2 = 0$

45

$\Rightarrow \quad 2I_1 - 5I_2 = -10$ —— (2)

$$\begin{cases} (3I_1 - I_2 = 10) \times 5 \\ 2I_1 - 5I_2 = -10 \end{cases} \Rightarrow \begin{array}{l} 15I_1 - 5I_2 = 50 \\ 2I_1 - 5I_2 = -10 \\ (-) \quad (+) \quad (+) \\ \hline 13I_1 = 60 \end{array}$$

$$I_1 = \frac{60}{13}$$

$$= 4.61$$

$\Rightarrow \quad 2 \times \frac{60}{13} - 5I_2 = -10$

$$\frac{120}{13} - 5I_2 = -10$$

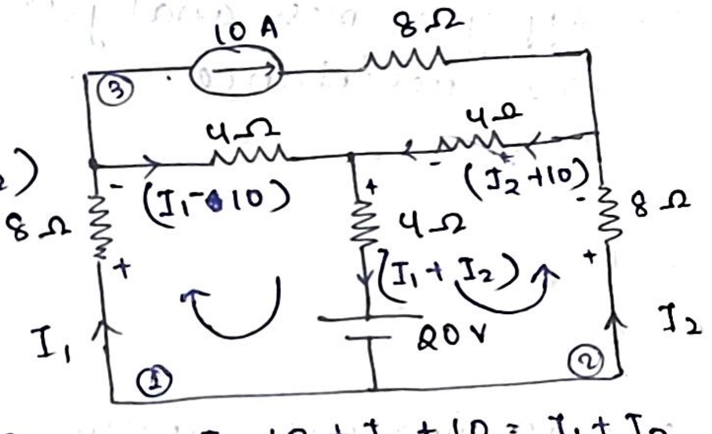
$$5I_2 = \frac{120}{13} + 10 = \frac{120 + 130}{13}$$

$$\frac{50}{13} = \frac{250}{13} \times \frac{1}{5} = 3.84$$

current through 2Ω resistance =

$$I_1 - I_2 = 4.61 - 3.84 = 0.77\ A$$

Q. Using mesh analysis, calculate I_1 and I_2.



$I_1 - 10 + I_2 + 10 = I_1 + I_2$

Applying KVL in loop 1,

$\Rightarrow -8I_1 - 4(I_1 - 10) - 4(I_1 + I_2) - 20 = 0$

$\Rightarrow -8I_1 - 4I_1 + 40 - 4I_1 - 4I_2 - 20 = 0$

$\Rightarrow -12I_1 - 4I_1 - 4I_2 + 20 = 0$

$\Rightarrow -16I_1 - 4I_2 = -20$

$\Rightarrow 4I_1 + I_2 = 5$ —— (1)

Applying KVL in loop 2,

$\Rightarrow -8I_2 - 4(I_2 + 10) - 4(I_1 + I_2) - 20 = 0$

$\Rightarrow -8I_2 - 4I_2 - 40 - 4I_1 - 4I_2 - 20 = 0$

$\Rightarrow -16I_2 - 4I_1 - 60 = 0$

$\Rightarrow -4I_1 - 16I_2 = 60$ ——— (2)

$4I_1 + I_2 = 5$

(+) $-4I_1 - 16I_2 = 60$

$-15I_2 = 65$

$I_2 = \frac{-65}{15} = \frac{-13}{3} = -4.33\ A.$

$4I_1 - \frac{13}{3} = 5$

$4I_1 = 5 + \frac{13}{3} = \frac{15+13}{3} = \frac{28}{3}$

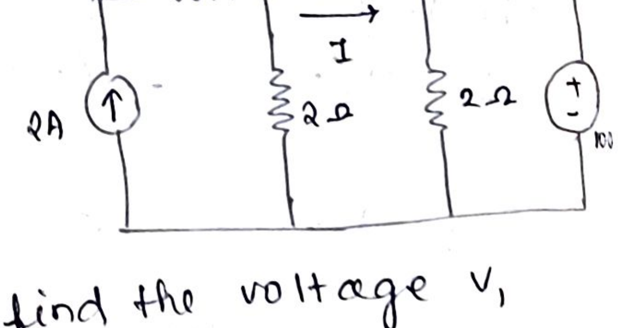
$I_1 = \frac{28}{3} \times \frac{1}{4} = \frac{7}{3} = 2.33\ A.$

$I_1 = 2.33\ A.$

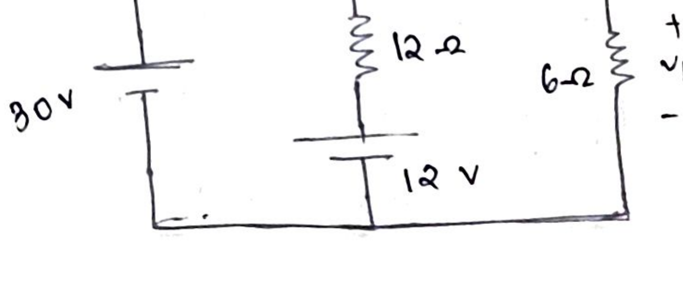
$I_2 = -4.33\ A.$

A-3

Q. Applying mesh analysis, find the current through 5 Ω resistance.



Q. Applying mesh analysis, find the voltage V_1 across 6 Ω resistance



Dt. 28/09/24

⇒ Nodal Analysis or Node voltage method.

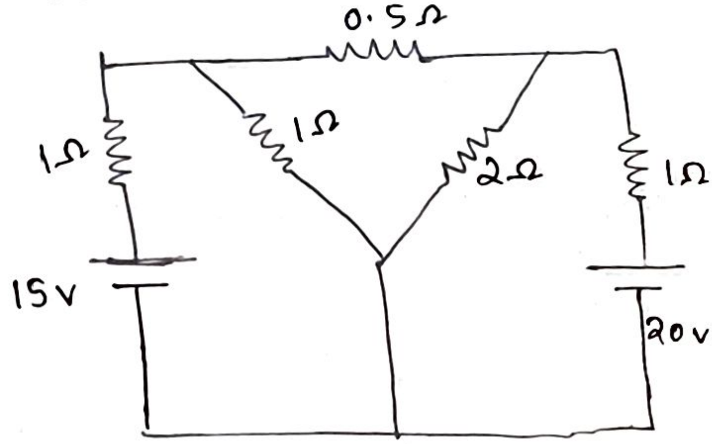
- It states that a minimum number of eqⁿ need to be written to find the unknown quantity than loop current method.
- It is particularly suitable for network having many parallel circuit with common ground.
- for the application of this method every junⁿ in the network where three or more branches regarded as a node.
- Out of these regarded nodes one node is taken as reference or 0 potential or datum node.
- Hence the number of simultaneous equation will be :- $n - 1$

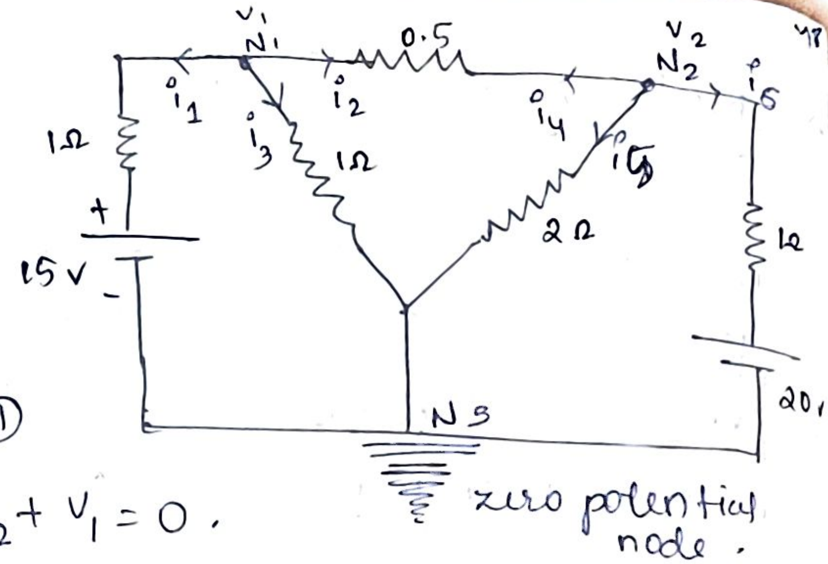
∴ where n = Total no. of node.

Q. Using Nodal analysis or node analysis, find the current through 2Ω & 0.5Ω resistor find the total power consume by the passive element of the given network

Note ⇒ power loss or power dissipated or power consumed

$= I^2 R = \frac{V^2}{R}$





KCL . 1

$i_1 + i_2 + i_3$

$\Rightarrow \frac{V_1 - 15}{1} + \frac{V_1 - V_2}{0.5} + \frac{V}{1} = 0$

$\Rightarrow 4V_1 - 2V_2 = 15$ — ①

$\Rightarrow V_1 - 15 + 2V_1 - 2V_2 + V_1 = 0.$

KCL - 2

$i_1 + i_2 + i_3$

$\rightarrow \frac{V_2 - V_1}{0.5} + \frac{V_2}{2} + \frac{V_2 - 20}{1} = 0.$

$\Rightarrow 2V_2 - V_1 + 0.5V_2 + V_2 - 20 = 0$

$\Rightarrow -2V_1 + 3.5V_2 = 20$ — ②.

$$+\begin{array}{l} 4V_1 - 2V_2 = 15 \\ -4V_1 + 7V_2 = 40 \end{array}$$

$+5V_2 = 55$

$V_2 = -55/5 = 11$ V

$4V_1 - 22 = 15$

$4V_1 = 37$

$V_1 = \frac{37}{4} = 9.25$ V

∘) $i_1 = \frac{V_1 - 15}{1} = 9.25 - 15 = -5.76$ A.

∘) $i_2 = \frac{V_1 - V_2}{0.5} = \frac{9.25 - 11}{0.5} = -3.5$ A

∘) $i_3 = \frac{V_1}{1} = \frac{9.25}{1} = 9.25$ A

- $i_4 = \frac{V_2 - V_1}{0.5} = \frac{11 - 9.25}{0.5} = 3.5\ A$.
- $i_5 = \frac{V_2}{2} = \frac{11}{2} = 5.5\ A$
- $i_6 = \frac{V_2 - 20}{1} = \frac{11 - 20}{1} = -9\ A$

∴ Current through 2Ω resistance = $i_5 = 5.5\ A$.
∴ Current through 0.5 Ω = $I_2 = I_4 = 3.5\ A$.

→ Power consumed through all resistances,

$\Rightarrow (i_1^2 \times 1) + (i_2^2 \times 0.5) + (i_3^2 \times 1) + (i_5^2 \times 2) + (i_6^2 \times 1)$.

$= (-5.75)^2 \times 1 + \{(-3.5)^2 \times 0.5\} + \{(9.25)^2 \times 1\} + ((5.5)^2 \times 2) + ((-9)^2 \times 1)$

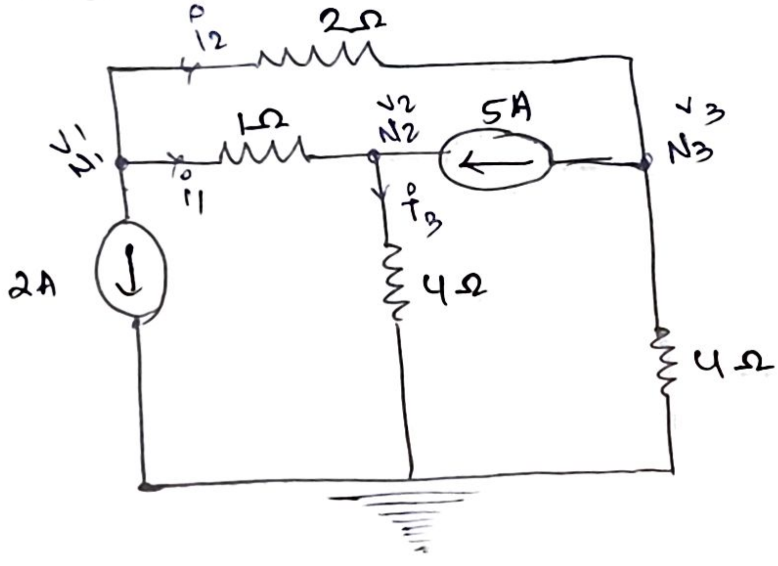
$= 33.06 + (12.25 \times 0.5) + 85.56 + (30.25 \times 2) + (81)$

$= 33.06 + 6.125 + 85.56 + 60.5 + 81$

$= 266.245$.

AQ

→ Using nodal analysis find the current through all the resistances.



KCL - 1

$2 + i_1 + i_2 = 0$

$\Rightarrow 2 + \frac{V_1 - V_2}{1} + \frac{V_1 - V_3}{2} = 0$ —— (1)

KCL - 2

$i_1 + 5 - i_3 = 0$

$\Rightarrow \frac{V_1 - V_2}{1} + 5 - \frac{V_2}{4} = 0$ —— (2)

KCL - 3

$\frac{V_1 - V_3}{2} - 5 - \frac{V_3}{4} = 0$ (3)

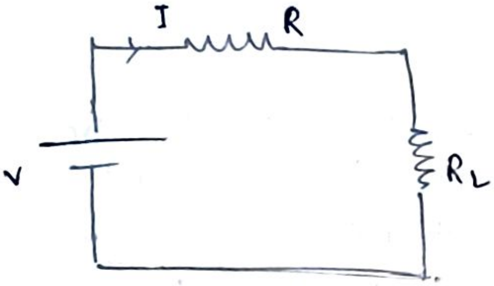
Module - 2

Dt - 30/09/24

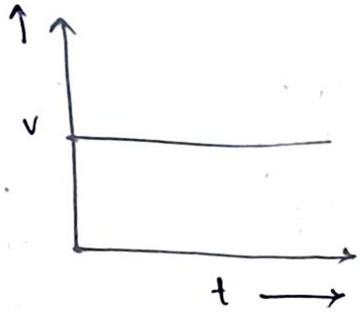
1-ϕ AC Circuit

⇒ Alternating current theory :-

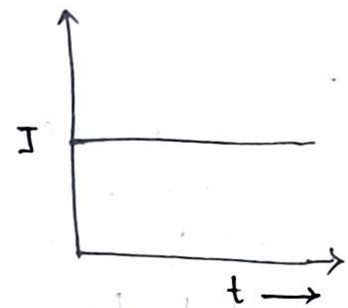
DC Current :- The direct current or DC is always flows in one direction and its magnitude remain constant.



∴ ~~Voltage waveform~~



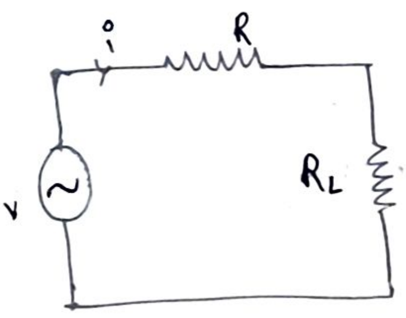
∴ voltage waveform

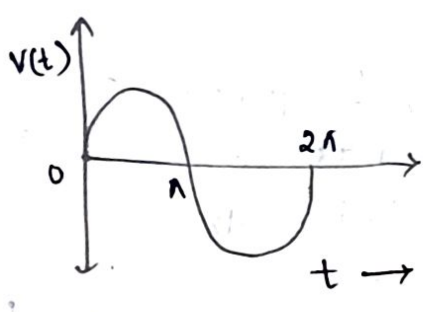


∴ current waveform.

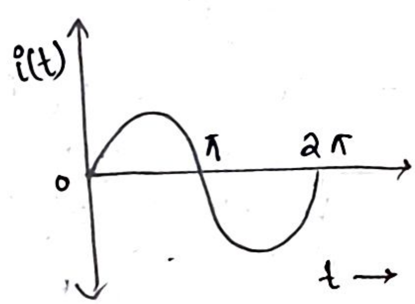
- In the above fig. the DC voltage and the DC current are always constant for anytime.

AC current :- An AC is one which changes both direction and magnitude.





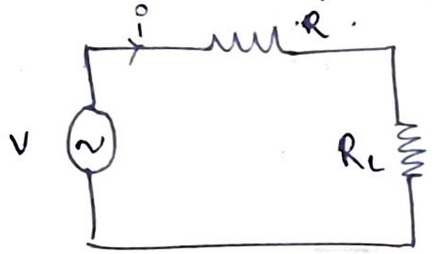
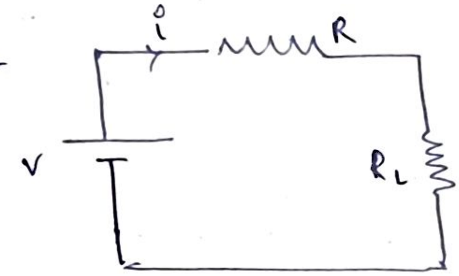
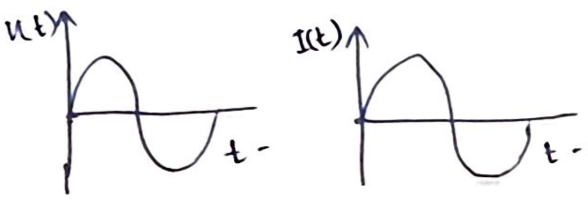
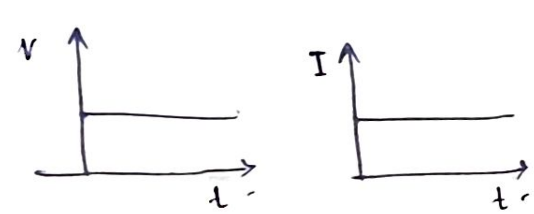
∴ voltage waveform



∴ current waveform.

- AC waveform is also known as sine or sinusoidal waveform.

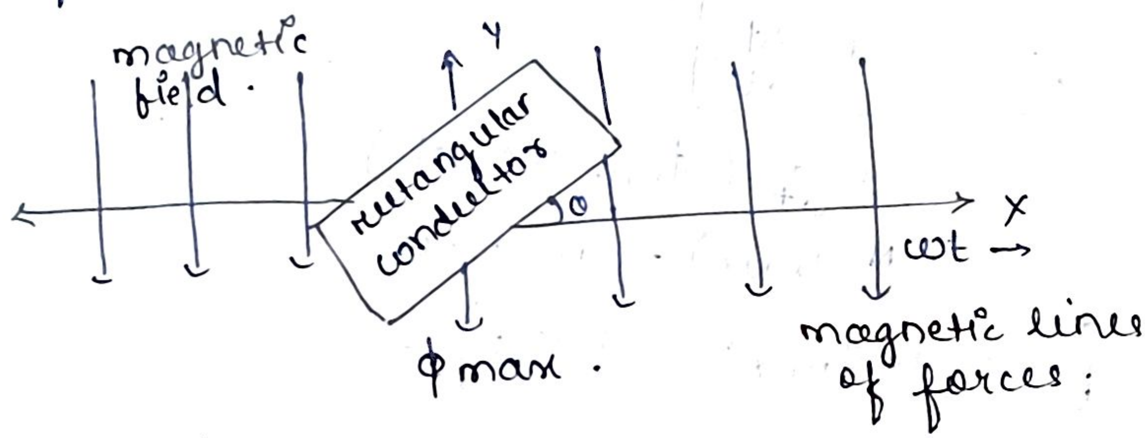
Comparision betⁿ AC and DC :-

AC	DC
The magnitude and dirⁿ both changes.	The magnitude and dirⁿ are remain constant.
By using transformer, AC voltage can be increased or decreased.	No such provisions can be made here.
AC circuit current can be decreased by using choke or capacitor without any powerloss.	for decrease in DC circuit current, a resistance has to be use but due to this some power loss (I^2R) is taking place.
AC can be converted in DC by using rectifier circuit.	DC can be converted into AC by using inverter circuit.
AC can't be use directly for eletroploting and electrotyping.	DC can be use directly for such operation.
In case of AC, frequency is 50 Hz. General frequency of India is 50 Hz	In case of DC, frequency is zero.
	
	

53

Generation of Alternating Voltage and Current.

- Alternating voltage may be generated by rotating a conductor inside a magnetic field or rotating a magnetic field by taking constant the conductor.
- The value of generated voltage in both the cases depends on the number of turns (N), strength of the field and the speed at which the conductor or magnetic field rotates.
- Alternating voltage may be generated in either of the above two cases but rotating field method is mostly used.



$\theta = \omega t$

- consider a rectangular conductor having N turn and rotating in uniform magnetic field with an angular velocity ω rad/sec and time be measure from x-axis,
- Maximum flux (ϕ_{max}) is linked with the coil when it placed coincides with x-axis
- In time t sec, this coil rotates with an angle $\theta = \omega t$.

- The component of flux or lines of force which is perpendicular to the plane of coil is

$$\phi = \phi_{max} \cos \omega t$$

$$\phi = \phi_{max} \cos \theta$$

- flux linkages of the coil for 'N' number of turn i.e

$$N\phi = N\phi_{max} \cos \omega t$$

- According to faraday's law, electromagnetic induction, the Emf induced in a coil is given by rate of change of flux linkage to the coil i.e.

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

$$= -N \frac{d}{dt} (\phi_{max} \cos \omega t)$$

$$= (-N \phi_{max}) - \sin \omega t \cdot \omega$$

$$e = N \phi_{max} \omega \sin \omega t \quad \text{——(1)}$$

when $\omega t = 90°$, $\sin \omega t = 1$.

$$E_{max} = N \phi_{max} \omega \quad \text{——(2)}$$

Now put the value of eqⁿ(2) in eqⁿ(1)

$$e = E_{max} \sin \omega t$$ → Alternating voltage eqⁿ.

$$i = I_{max} \sin \omega t$$ → current eqⁿ.

$$v = V_{max} \sin \omega t$$ → voltage eqⁿ.

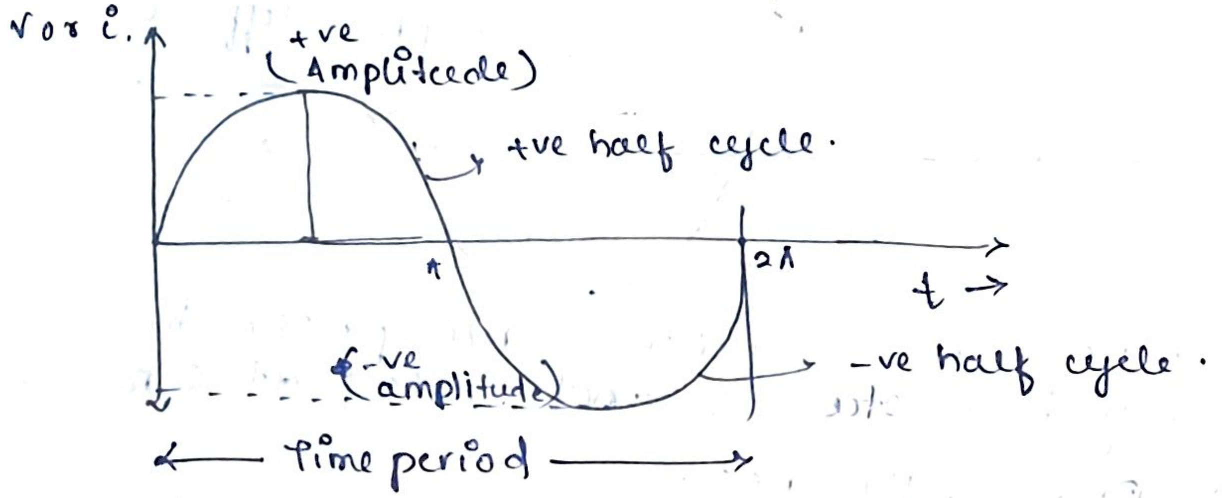
$\omega = 2\pi f$

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

$\omega = \frac{2\pi}{T}$

flux density (B) = $\frac{\phi}{A}$ = $\frac{\text{flux}}{\text{Area}}$.

→ Different terms of Alternating waveforms :-



(1) Cycle :- One complete set of +ve and -ve ~~half cycle~~ values of an alternating quantity is called as cycle.

- One completed cycle is completed at 360° or 2π rad.

(2) Time period (T) :- The time taken by an alternating quantity to complete one cycle is called time period. unit - sec.

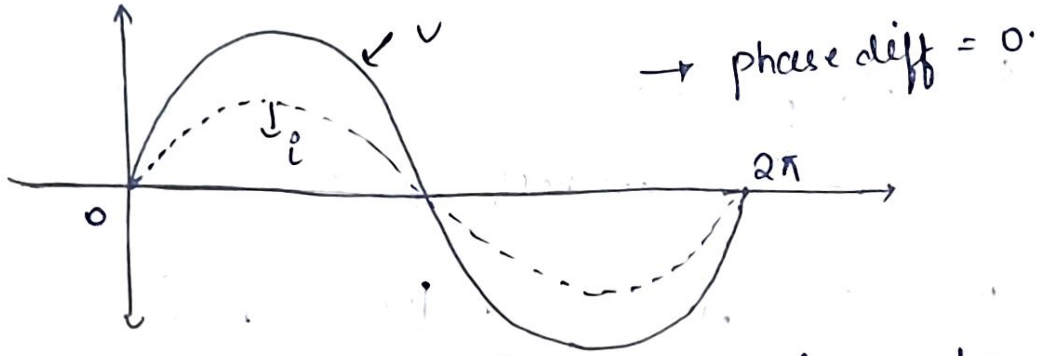
(3) frequency (f) :- The number of cycles per second is known as frequency.

- Its unit is 'Hz'.

* Relation betⁿ 'f' and 'T' - $f = \frac{1}{T}$

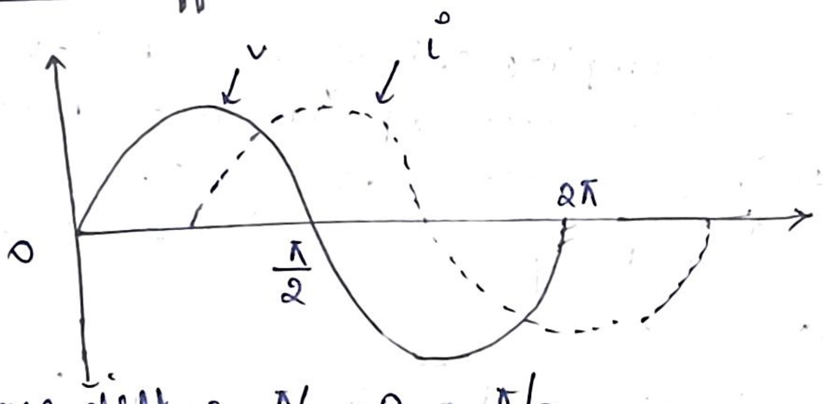
(4) Amplitude (A) :- The maximum value of +ve or -ve of an alternating quantity is known as its amplitude.

(5) Phase - The angle turned by an alternating quantity from a given instant is known as phase.



- Here v and i are in same phase because they have started and ended at same point.

(6) Phase difference -



phase diff = $\pi/2 - 0 = \pi/2$.

def^n - Phase diff. bet^n two alternating quantity is the fractional part of a period through which time of one alternating quantity has advanced over another alternating quantity.

⇒ leading alternating quantity :-

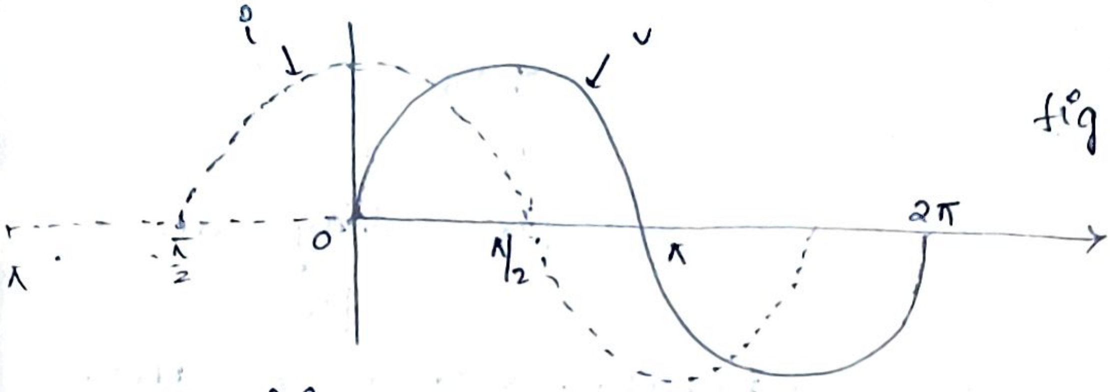
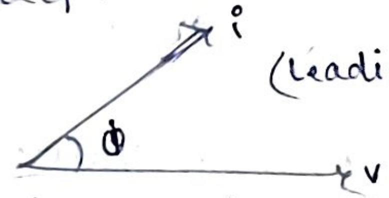


fig. (1).

- A leading alternating quantity is one which reaches max or zero value earlier as compared to the other quantity.
- A positive sign in connection with phase difference denotes by lead.



phasor diagram.

v = reference vector

$v = v\angle 0$ or $|v|\angle 0$ ←

$i = i\angle\phi$ or $|i|\angle\phi$.

ϕ = angle betⁿ i and v.

ϕ = phase diff.

⇒ lagging alternating quantity.

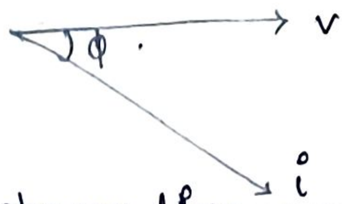
- It is one which reaches its max. or zero value later than the other quantity
- A -ve sign in connection with phase diff. denotes by lag.
- In this above ~~fig~~ waveform (fig. 1), current i is the leading quantity and voltage v is the lagging quantity. otherwise we can say - i lead v or v laggs i.

lagging.

let v = reference vector

let $v = |v| \angle 0$

$i = |i| \angle -\phi$.



∴ phasor diagram.

Dt - 3/10/24.

- Different values of Alternating voltage & current.

(1) Instataneous Value :-

Value of an alternating quantity at any instant is known as instataneous value.

inst. value: $e = E_m \sin\omega t$, $v = V_m \sin\omega t$. $i = I_m \sin\omega t$.

$E_m, V_m, I_m \rightarrow$ max. value

(2) Avarage Value :-

defⁿ - The avg. value of an alternating current is that value of steady current (DC) which when going through a circuit transfer same amount of charge as it is done by AC through the same circuit in same time.

$$i_{avg} = \frac{1}{T} \int_0^T i(t) \cdot dt$$

$$i_{avg} = \frac{1}{2\pi} \int_0^{2\pi} i \cdot d\theta$$

* Relation betⁿ avg value and max. value :-

$$i_{avg} = 0.637\, I_m$$

$$\frac{i_{avg}}{I_m} = 0.637$$

$$V_{avg} = 0.637\, V_m$$

3) RMS (Root mean square) value :-

- It is also known as effective value.
- The RMS value of AC is that steady current (DC) which when flowing through a given resistance for a given time, produces the same amount of heat as produced by the AC when flowing through the same resistance for the same time.

$$i_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 \cdots + i_n^2}{n}}$$

$$i_{rms} = \sqrt{\frac{1}{T}\int_0^T \{i(t)\}^2 \cdot dt}$$

$$i_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (i)^2 \cdot d\theta}$$

* Relation betn rms current and max. current.

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

$$V_{rms} = \frac{V_m}{\sqrt{2}} = 0.707\ V_m$$

(4) Peak value / max value / crest value / Amplitude :-

- The max. value attained by an AC during a cycle is known as amplitude
- for a sinusoidal waveform, an alternating value attain its peak value at 90° or $\pi/2$ rad.

⇒ **form factor (K_f)**

- It is defined as the ratio of Rms value to avg value.

$$K_f = \frac{I_{rms}}{I_{avg}} = \frac{0.707\ I_m}{0.637\ I_m} = 1.11$$

⇒ **Crest / peak / amplitude factor (K_P)**

- It is defined as the ratio of max value to Rms value.

$$K_p = \frac{I_{max}}{I_{rms}} = \frac{I_m}{I_m/\sqrt{2}} = \sqrt{2} = 1.414.$$

Q. An Ac waveform is given by,
$v = 141.4 \sin 628t$. find :-

(i) Max value.
(ii) Rms value
(iii) Avg. value.
(iv) peak factor.
(v) form factor.
(vi) frequency.
(vii) time period.

(iii) $V_{avg} = 0.637 \times 141.4 = 90.07$

(i) $V_{max} = 141.4\ v$.

(vi) $\omega = 628$ rad/sec.

$2\pi f = 628$

$f = \frac{628}{6.28} = 100$ Hz.

(vii) $T = \frac{1}{f} = \frac{1}{100} = 0.01$ sec.

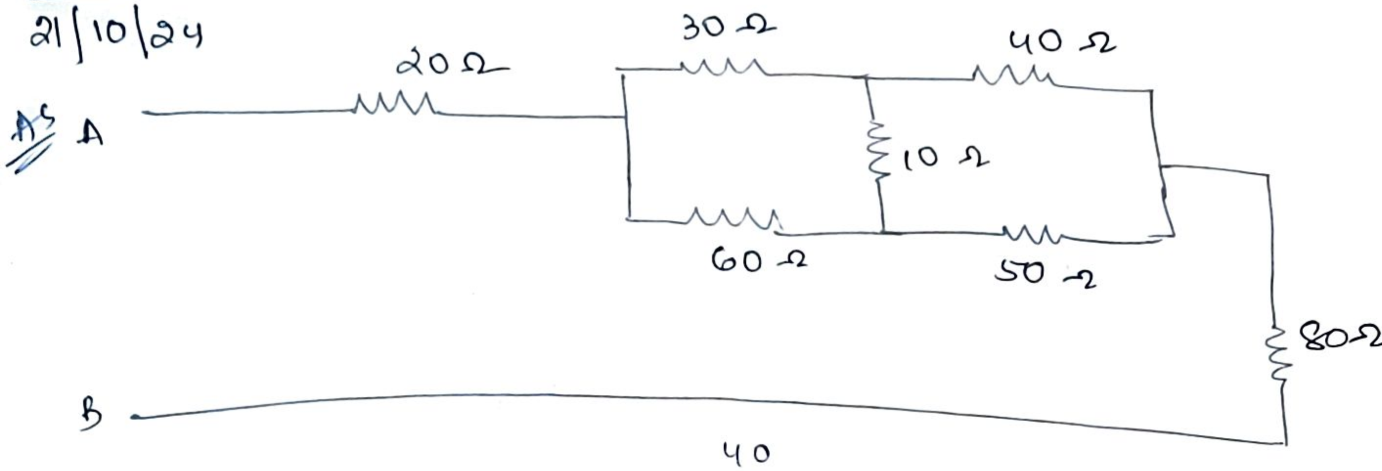
(ii) $V_{rms} = \frac{141.4}{\sqrt{2}} = 99.96 \simeq 100.$

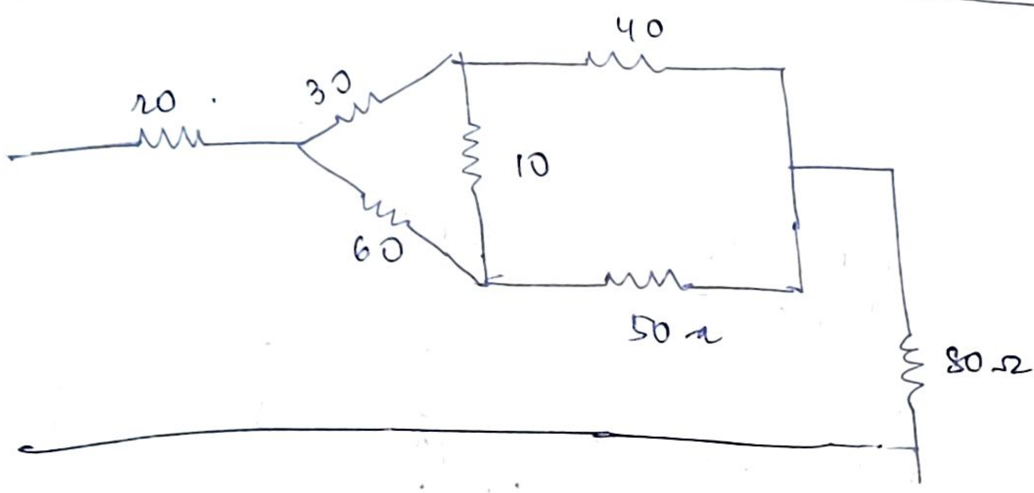
(iii) $K_f = \frac{V_{rms}}{V_{avg}} = \frac{99.96}{90.07} = 1.1$

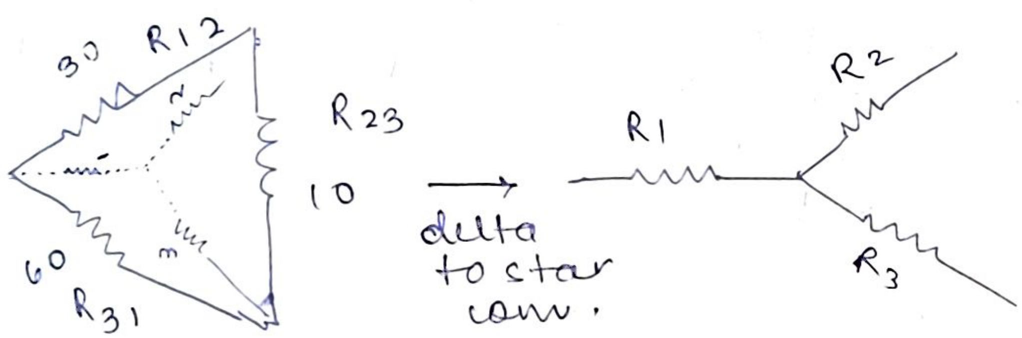
(iv) $K_p = \frac{V_m}{V_{rms}} = \frac{141.4}{99.96} = 1.41$

CW
21/10/24

AS



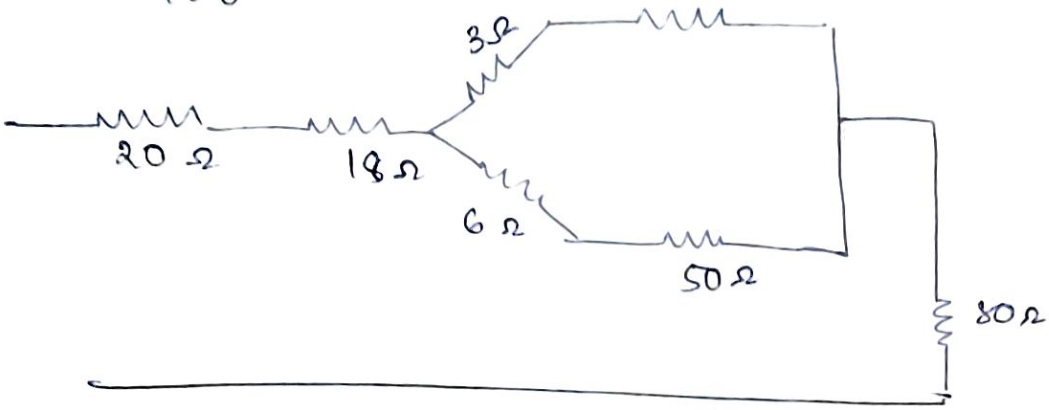


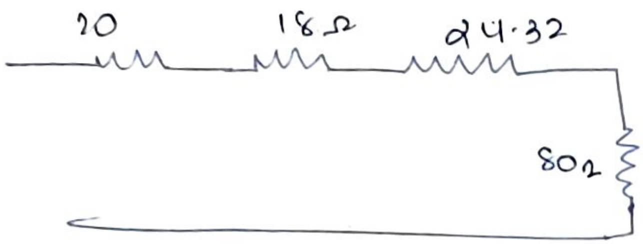


$R_1 = \frac{R_{12} \cdot R_{31}}{R_{12} + R_{23} + R_{31}} = \frac{30 \times 60}{100} = \frac{1800}{100} = 18$

$R_2 = \frac{R_{23} \cdot R_{12}}{R_{12} + R_{23} + R_{31}} = \frac{10 \times 30}{100} = 3.$

$R_3 = \frac{60 \times 10}{100} = 6$





$\frac{1}{Req} = \frac{1}{43} + \frac{1}{56}$

$\frac{1}{Req} = \frac{99}{2408}$

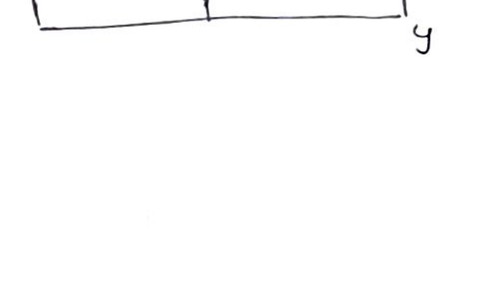
$Req = \frac{2408}{99}$

$= 24.32$.

$Req = 20 + 18 + 24.32 + 80$

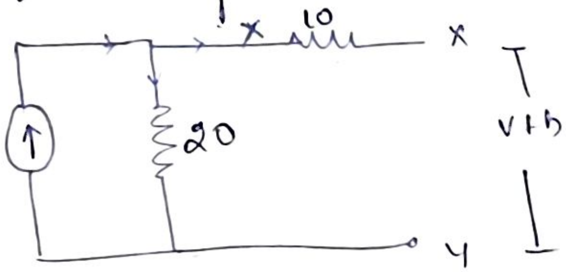
$= 142.32$.

; Using Thevenin's theorm, find current through 5Ω resistance.



Here $R_L = 5\Omega$

Step.1 - To find V_{th} disconnect the 5Ω and find out the voltage across that open terminal.

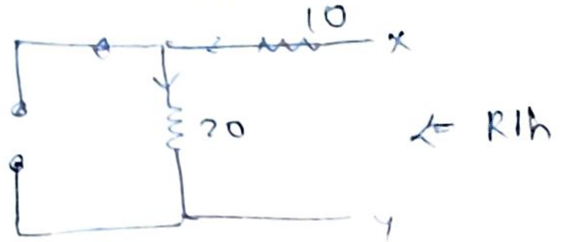


$Req = 20\Omega$.

$Ieq = \frac{V}{R}$ 4Ω

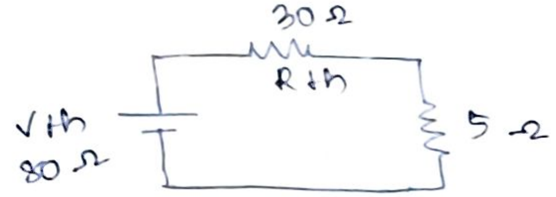
$V = IR = 20 \times 4 = 80V$.

Step 2 Rth → open the current source.



Rth = 10 + 20 = 30 Ω

Step 3.



$I = \frac{V_{th}}{R_{th} + R_L}$

$= \frac{80}{30+5} = \frac{80}{35}$ (16/7)

= 2.28 A.

Dt - 6/11/24.

Q. $z = x + jy$ → rectangular form.

$|z| = \sqrt{x^2+y^2}$ → [shift +] (5, 6) = 7.81.

$\angle z = \tan^{-1} y/x$ → Alpha tan (5, 6) = 50.19.

$z = |z| \angle z$ → polar form.

→ shift −(7.81, 50.19)

Q. $z = 3.6 \angle -40.2$

→ shift − (3.6, −40.2) = 4.27 − j 3.61

polar to rectangular

→ alphatan = −3.6.

Q. $z_1 = 5 + j6$, add & $z_1 + z_2$ or sub

$z_2 = 4 - j4$

* We can only add & two alternative quantity if they are in rectangular form.

by

$Z_1 + Z_2 = 5 + j6 + 4 - j4$

$= 9 + j2$.

$Z_1 - Z_2 = 5 + j6 - (4 - j4)$

$= 5 + j6 - 4 + j4$

$= 1 + j10$.

(Note) → In case of multiplication and division of two alternative quantity then they should be in polar form

•) $Z_1 \times Z_2 = (5 + j6) \times (4 - j4)$

$= [7.81 \angle 50.19] \times [5.65 \angle -45]$

= multiplication addition.

$= (7.81 \times 5.65) \angle 50.19 + \angle -45$

$= 44.126 \angle 5.19$

•) $\frac{Z_1}{Z_2} = \frac{5 + j6}{5 - j4} = \frac{7.81 \angle 50.19}{5.65 \angle -45}$ → 50.19 subt

division

$= \frac{7.81}{5.65} \angle 50.19 - \angle -45$

$= 1.382 \angle 95.19$.

⇒ different types of power in AC circuit:

(1) Active / true / real power. (P)

$P = VI \cos\phi$.

where ϕ = phase angle betn voltage & current.

unit of Active power = watt, KW, Megawatt b)

powerfactor = $\cos\phi = \frac{R}{Z}$ → Resistance, Z → impedence.

(2) <u>Reactive or imaginary Power (Q)</u>

$Q = VI \sin\phi$.

its unit is - VAR, KVAR, MVAR.
VAR → volt ampere reactive.

$\sin\phi = \frac{X}{Z}$ X → Reactance, Z → impedence.

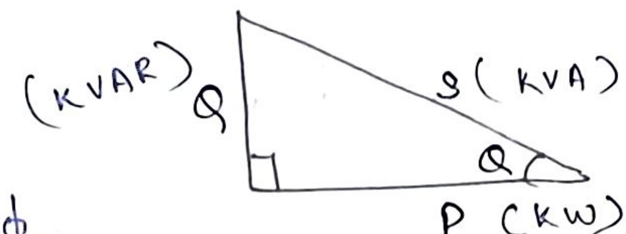
(3) <u>Apparant Power</u> :- (S)

$S = VI$

its unit is - VA, KVA, MVA.
VA → volt ampere.

$S = P + jQ$.

$|S| = \sqrt{P^2 + Q^2}$



$\cos\phi = \frac{P}{S} \Rightarrow P = S\cos\phi$.

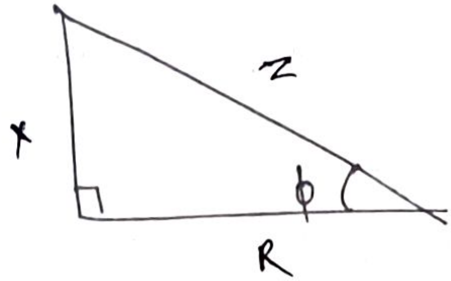
$\sin\phi = \frac{Q}{S} \Rightarrow Q = S\sin\phi$.

∴ power triangle.

$Z = R + jx$.

$|Z| = \sqrt{R^2 + x^2}$

$\phi = \theta = \tan^{-1}\frac{X}{R}$



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

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

∴ Impedence Δ.

⇒ Powerfactor ($\cos\phi$)

It is defined as the ratio of active power to apparent power

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

$$\text{Powerfactor } (\cos\phi) = \frac{\text{Active power}}{\text{Apparent power}} = \frac{VI\cos\phi}{VI}$$

$$= \cos\phi.$$

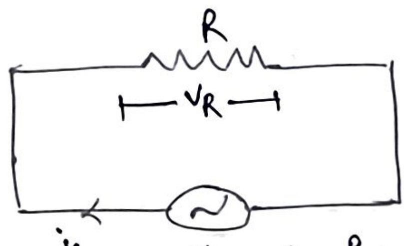
⇒ Ac through pure resistive circuit :- (Non- Inductive circuit).

- A pure resistive non- inductive circuit in which no inductance is there and its reactance is negligible as compared with resistance.

$$V_R = i \cdot R = V_{max}\sin\omega t \quad \text{--- (1)}$$

$$\Rightarrow i = \frac{V_m \sin\omega t}{R}$$

instantaneous value of current.



$V = V_M \sin\omega t$

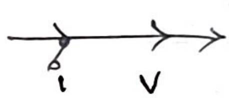
V_R = voltage across Resistance.

when $\omega t = 90°$, $\sin\omega t = 1$

So, $I_{max} = \frac{V_{max}}{R}$.

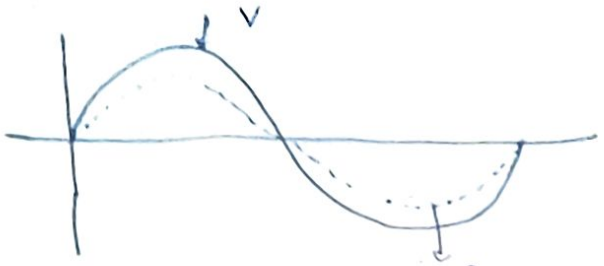
Now $i = i_M \sin\omega t$ --- (2)

Here no phase difference betn voltage & current.



(phasor diagram).

b)



(waveform diagram)

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

$\Rightarrow \cos\phi = 1$.

$\Rightarrow \phi = \cos^{-1}(1) = 0$.

$\Rightarrow$ $\boxed{\phi = 0}$

Power through pure resistive circuit :-

(P) = $v \cdot i$ ← Instantaneous power / avg power.

$= V_m \sin\omega t \cdot I_{max} \sin\omega t$.

$= (V_m \cdot I_{ma}) \sin^2\omega t$.

$= (V_m \cdot I_m) \left(\frac{1 - \cos 2\omega t}{2}\right)$

$= \frac{V_m I_m}{2} - \left(\frac{V_m I_m \cos 2\omega t}{2}\right)$

↳ over a complete cycle it is 0.

* $2\sin^2\theta = 1 - \cos 2\theta$.

$P = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}$

$P = V_{RMS} \cdot I_{RMS} = VI = I^2R = \frac{V^2}{R}$.

*. where V and I are the RMS value of voltage and current respectively.

Q. A 250V, 50Hz voltage is applied across a circuit consisting of a pure not inductive resistance of 50 Ω. Determine:

(i) the current flowing through the circuit.
(ii) Power absorbed.
(iii) Expression of voltage & current.

given, $V = 250\ V$ (RMS).
$f = 50\ Hz$
$R = 50\ \Omega$

(i) $I_{RMS} = \frac{V}{R} = \frac{250}{50} = 5A$.

(ii) $P = VI = 250 \times 5$
$= 1250\ VA$.

iii) $V = V_m \sin\omega t$, $I = I_m \sin\omega t$.

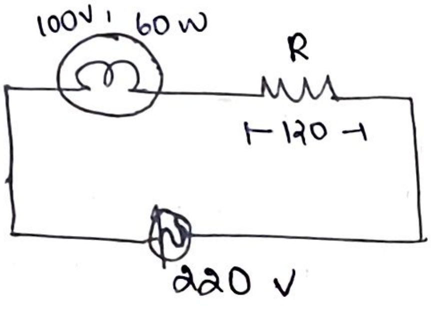
$V_m = \sqrt{2} \times V_{RMS}$.
$= \sqrt{2} \times 250 = 353.5$

$I_m = \sqrt{2} \times I_{RMS}$
$= \sqrt{2} \times 5 = 7.07\ A$

$\omega = 2\pi f$
$= 2 \times 3.14 \times 50$
$= 314$ rad/sec.

so, $V = 353.5 \sin 314t$.
$I = 7.07 \sin 314t$.

Q A 100 V and 60 W bulb is to be operated from 220V supply. what resistance must be connected in series with the bulb to glow normally.



$P = VI$

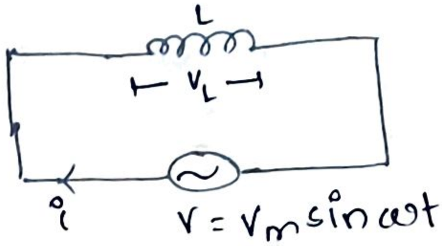
$I = P/V = \frac{60}{100} = 0.6\ A$.

voltage across resistance.
$220 - 100 = 120$.

so, $R = \frac{V}{I} = \frac{120}{0.6} = 120 \times \frac{10}{6} = 200\ \Omega$.

⇒ AC through Pure inductive circuit :-

- A pure inductive circuit is a coil which have negligible resistance



- When an alternating voltage is applied to a pure inductive coil an emf is induced in that coil, which is known as self induced emf and which opposes the supply voltage.
- Self induced emf in the coil is

$$V_L = -L\frac{di}{dt}$$

$$\Rightarrow V = V_m \sin \omega t = V_L = -\left(-L\frac{di}{dt}\right)$$

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

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

$$\Rightarrow i = \int \frac{V_m}{L}\sin \omega t$$

$$\Rightarrow i = \frac{V_m}{L}\cdot -\frac{\cos \omega t}{\omega} + c$$

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

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

* $\sin\left(\frac{\pi}{2} - \theta\right) = \cos\theta$

$\sin\left(\theta - \frac{\pi}{2}\right) = -\cos\theta$

- current will be max where $\sin(\omega t - \pi/2)$ is 1

$I_m = V_m/\omega L$

putting in eqⁿ(2),

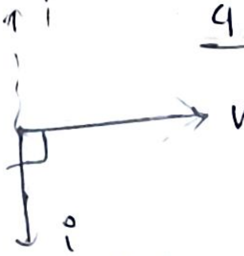
$$\boxed{I = I_m \sin\left(\omega t - \frac{\pi}{2}\right)}$$

9/11/24.

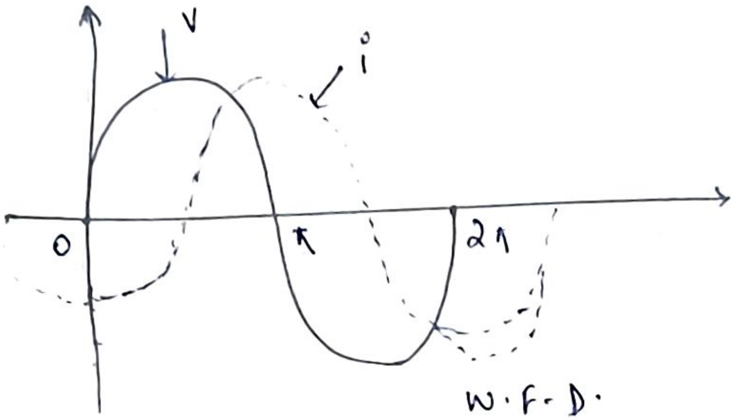
$v = V_m \sin \omega t$

$i = I_m \sin(\omega t - \pi/2)$

$\phi = -\frac{\pi}{2} \rightarrow$ (lags)



(phasor diagram).



W.F.D.

→ **power in pure inductive circuit:-**

$P = vi$

$= V_m \sin \omega t \; I_m (\sin \omega t - \pi/2)$

$= V_m I_m \sin \omega t \cdot -\cos \omega t \qquad 2\sin\theta\cos\theta = \sin 2\omega t$

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

- The power measured by the wattmeter is the average value of p which is zero. Since avg of a sinusoidal quantity of double frequency over a complete cycle is zero. Hence in a pure inductive circuit power absorbed is zero.

Q. The voltage & current through a circuit element are $100 \sin(314t + 45°)$ V and current $i = 10 \sin(314 + 315°)$ A.

i) Identify the circuit element

ii) find the value of inductance

71

(iii) obtained the exp^n for power.

→ $v = 100 \sin(314t + 45°)$ V

$i = 10 \sin(314t + 315°)$ A

$v = 100 \sin(314t + 315 - 360)$

$i = 10 \sin(314t - 45°)$

i) from the above 2 eq^n, we can concled that the current I lags the supply voltage v by 90° or $\pi/2$ rad i.e the circuit element is inductor.

ii) $Z = X_L = \omega L = 2\pi f L$.

$Z = \frac{V}{I} = \frac{V_{RMS}}{I_{RS}}$.

$V_{RMS} = \frac{V_{max}}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.7$ V

$I_{RMS} = \frac{I_{max}}{\sqrt{2}} = \frac{10}{\sqrt{2}} = 7.07$ A.

$Z = \frac{70.7}{7.07} = 10\ \Omega$

$Z = \omega L$.

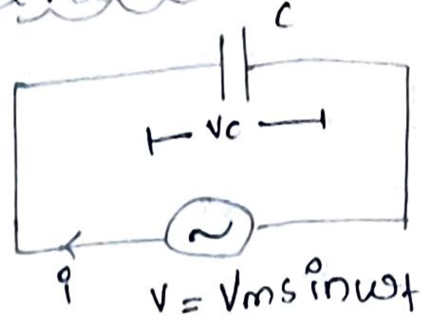
$10 = 314\, l \Rightarrow l = \frac{10}{314} = 0.031$ H.

(iii) $P = -\frac{V_M I_M}{2} \sin 2\omega t$

$= -\frac{100 \times 10}{2} \sin(2 \times 314t)$

$= -500 \sin 628t$.

⇒ AC through pure capacitive circuit



$V = V_m \sin \omega t$

$V_C = i X_C = V_m \sin \omega t$

$i = \frac{dq}{dt}$

$q = CV = C \cdot V_m \sin \omega t$

$\Rightarrow i = \frac{d}{dt}(C V_m \sin \omega t) = C V_m \cos \omega t \cdot \omega$

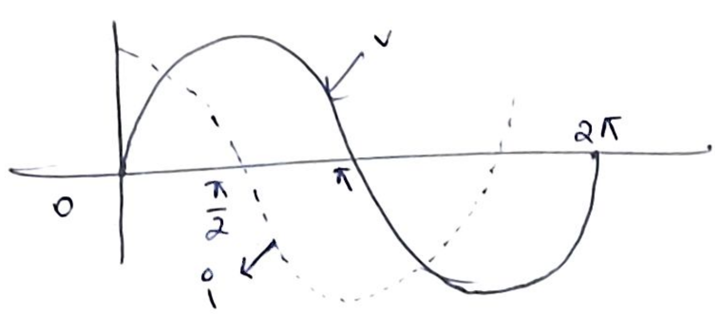
$\Rightarrow i = \frac{V_m}{\frac{1}{\omega C}} \sin(\omega t + 90)$

when $\omega t = 0$, this current i will be maximum.

$I_m = \frac{V_m}{\frac{1}{\omega C}}$

$\Rightarrow I = I_m \sin(\omega t + 90)$

$= I_m \sin(\omega t + \frac{\pi}{2})$



$P = Vi$

$= V_m \sin \omega t \cdot I_m \sin(\omega t + \pi/2)$

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

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

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

- avg power over a complete cycle is zero, so power absorbed in a pure capacitive circuit is zero

CW
11/11/24

Q. A capacitor of 100 μf is connected across a 200 V, 50 Hz single phase supply. Calculate
i) the reactance of the capacitor
ii) RMS value of current.
iii) Max value of current.

$C = 100\,\mu f = 100 \times 10^{-6}\, f.$

$V = 200\ V.$

$f = 50\ Hz.$

(i) $X_C = \frac{1}{2\pi f C} = \frac{1}{31{,}400 \times 10^{-6}} = \frac{10^6}{31400}\ \Omega.$

$= 31.83\ \Omega = Z$

(ii) $I_{RMS} = \frac{V_{rms}}{Z} = \frac{200}{31.83} = 6.28\ A.$

(iii) $I_{Max} = I_{RMS}\sqrt{2}$

$= 6.28 \times \sqrt{2} = 8.87\ A.$

→ **Ac through RL series circuit:-**

$V = V_m \sin\omega t$

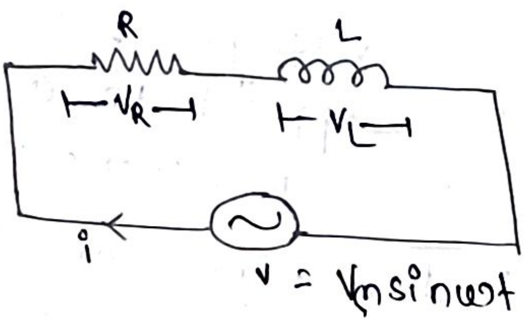
$Z = R + jX_L$

$X_L = 2\pi f L$

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

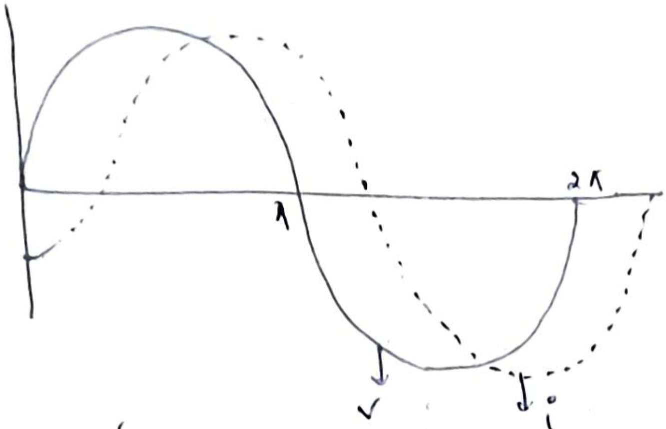
$i = I_m \sin(\omega t - \phi)$

$(0 < \phi < 90°)$

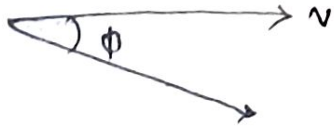


$V = V_R + jV_2$

$|V| = \sqrt{V_2^2 + V_L^2}$

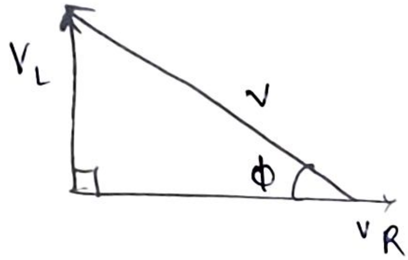


(waveform)



(phasor diagram)

* $V_R = I.R$
  $V = I.Z$
  $V_L = I.X_L$
  $\tan\phi = \frac{X_L}{R}$
  $\phi = \tan^{-1}\frac{X_L}{R}$



⇒ **Power in RL series circuit:**

$P = vi$

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

$= VI\cos\phi = V_{rms} I_{rms} \cos\phi$. unit: watt.

$Q = VI\sin\phi$

$= V_{rms} I_{rms} \sin\phi = I^2 X_L$ VAR.

$S = VI$

$= V_{rms} I_{rms} = I^2 Z$ VA.

Q. A voltage $e(t) = 150 \sin 2\pi f t$, 50Hz is applied to a series circuit of consisting 10 Ω resistance and 0.0318 H inductance.

(i) find expression for current.
(ii) phase angle betn v and I.
(iii) powerfactor.
(iv) active power consume.

(v) Max. value of pulsating energy.

$I_{max} = V_{max} = 150$ V
$f = 50$ Hz
$R = 10\,\Omega$
$L = 0.0318$ H

(i) $i(t) = I_m \sin(\omega t - \phi)$

for, $Z = \sqrt{R^2 + X_L^2}$
$= \sqrt{10^2 + (9.98)^2}$
$= \sqrt{100 + 99.6}$
$= 14.14\,\Omega$

$X_L = 2\pi f L$
$2 \times 3.14 \times 50 \times 0.0318$
$= 9.98\,\Omega$

- $I_m = \frac{V_m}{Z} = \frac{150}{14.14} = 10.6$ A

- $\omega = 2\pi f = 2 \times 3.141 \times 50 = 314$ rad/s.
- $\phi = \tan^{-1}\frac{X_L}{R} = \tan^{-1}\frac{9.98}{10} = 44.96 \approx 45^\circ$

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

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

$i_t = 10.6 \sin(314t - 45)$ — ans.

(ii) $\phi = 44.96 \approx 45^\circ$.

(iii) $\cos\phi = \frac{R}{Z}$: $\cos 45 = \frac{1}{\sqrt{2}} = 0.707$

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

$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{150}{\sqrt{2}} = 106.08$ A.

$I_{rms} = \frac{I_{max}}{\sqrt{2}} = \frac{10.6}{\sqrt{2}} = 7.49$ A.

$P = 106.08 \times 7.49 \times \cos 45$
$= 562$ W

(v) Max. value of pulsating energy = $\frac{1}{2} V_{mx} I_{mx}$.

$= \frac{1}{2} \times 150 \times 10.6 = 795$ VA.

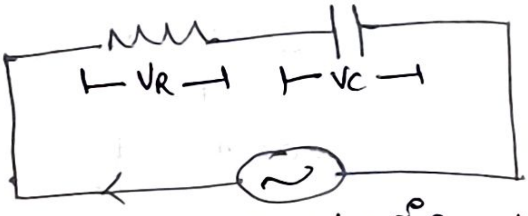
(A.Q) 7.

Q. A coil of resistance 10 Ω and inductance 0.02 H is connected in series with another coil of resistance 6 Ω and inductance 15 mH across a 230 V, 50 Hz supply. Calculate i) Impedence of circuit.

ii) Voltage drop across each coil.

(iii) the total power consume by the circuit.

→ AC through RC series circuit :-



$V = V_R - j V_C$.

$|V| = \sqrt{V_R^2 + V_C^2}$

$V_C = I X_C$

$X_C = \frac{1}{2\pi f C}$.

$V_R = I \cdot R$

$V = IZ$

$|Z| = R - j x_c$

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

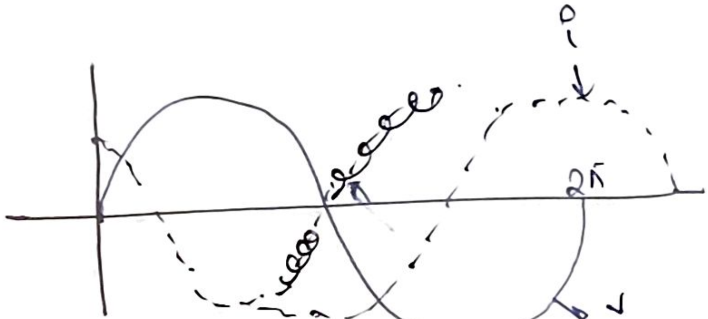
$i = I_m \sin(\omega t + \phi)$

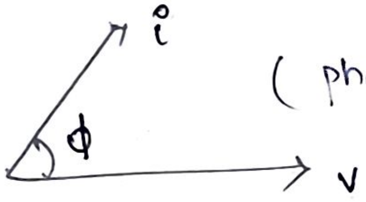
$0° < \phi < 90°$

$\cos\phi = R/Z$

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

$\sin\phi = \frac{X_C}{Z}$.





(phasor diagram)

77

power in RC circuit

p = vi

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

P = $VI\cos\phi$ → watt

Q = $VI\sin\phi$ → VAR

S = VI → VA

Dt- 13/11/24

Q. A voltage $v = 100\sin 314t$ is applied to a circuit consisting of 25 Ω resistor and 80 µF capacitor in series. determine i) peak value of current
(ii) Powerfactor
(iii) total power consumed by the circuit

$V = 100\sin 314t$

$R = 25\,\Omega$

$C = 80\,\mu f = 80 \times 10^{-6}\,f$

$V_{max} = 100\,V$

(i) $I_{max} = \frac{V_{max}}{Z} = \frac{100}{\sqrt{R^2 + X_C^2}} = \frac{100}{R^2 + \frac{1}{\omega C}^2}$

$= \frac{100}{(25)^2 + \frac{1}{314 \times 80 \times 10^{-6}}}$

$\frac{10^6}{314 \times 80} = 39.80$

so, $I_{max} = \frac{100}{\sqrt{(25)^2 + (39.80)^2}} = \frac{100}{\sqrt{625 + 1583.2}}$

$= \frac{100}{\sqrt{2208.2}} = 46.9\,\Omega$

$I_{max} = \frac{V_{max}}{Z} = \frac{100}{46.9} = 2.13\,A$

(ii) $\cos\phi = \frac{R}{Z} = \frac{25}{46.9} = 0.53.$

(iii) $V_{RMS} = \frac{V_{max}}{\sqrt{2}} = \frac{100}{1.414} = 70.72$

$I_{RMS} = \frac{I_{max}}{\sqrt{2}} = \frac{2.13}{1.414} = 1.50.$

So, $P = I_{RMS} V_{RMS} \cos\phi.$

$= 70.72 \times 1.50 \times 0.53$

$= 56.42\ W.$

A.Q (8) - A supply of 400 V, 50 Hz is applied to a series RC circuit. find the value of capacitance if the power absorbed by the resistor will be 500 W at 150 V. what is the energy stored in the capacitor

$U = \frac{1}{2}CV^2$

A.Q (9) the voltage applied to a circuit is $V = 100\sin(\omega t + 30°)$ and current flowing $I = 20\sin(\omega t + 60°)$. Determine impedence, reactance, resistance, power and Powerfactor

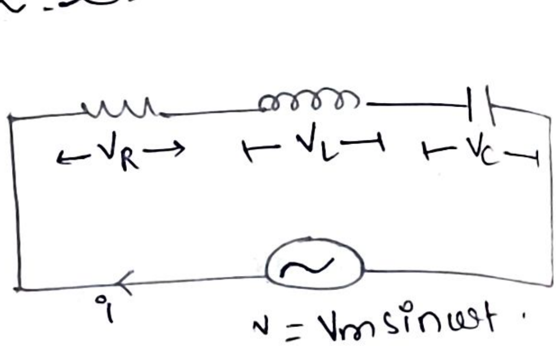
⇒ AC through RLC series circuit :-

$V = V_R + j(V_L - V_C)$

$|V| = \sqrt{V_R^2 + (V_L - V_C)^2}$

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

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



$\cos\phi = \frac{R}{Z}$ $\sin\phi = \frac{X_L - X_C}{Z}$ $\tan\phi = \frac{X_L - X_C}{R}$

$V_R = IR$

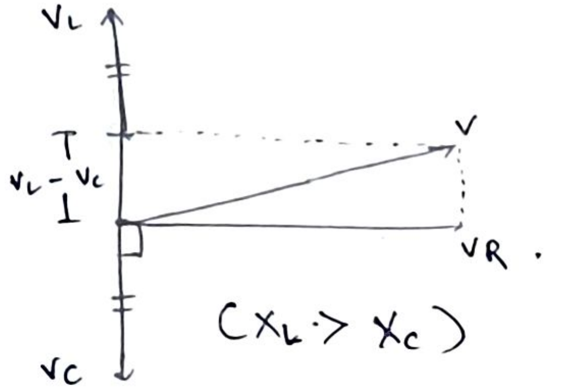
$V_L = IX_L$

$V_C = IX_C$

$V = V_m \sin \omega t$

$i = I_m \sin(\omega t \pm \phi)$

- Positive sign is used when current (I) leads the voltage (V) or $X_C > X_L$
- Negative sign is used when current lags the voltage or $X_C < X_L$



Powers

$P = VI \cos \phi$
$= I^2 R$

$Q = VI \sin \phi$
$= I^2 (X_L - X_C)$

$S = VI = I^2 Z$

Q. A voltage $e(t) = 150 \sin 1000t$ is applied across a series RLC circuit where $R = 40\,\Omega$, $L = 0.13\,H$, $C = 10\,\mu F$. Calculate

(i) the RMS value of the steady state current. (→ RMS)

(ii) find the RMS voltage across the inductor and capacitor

(iii) Draw the complete phasor diagram showing all the voltage component.

(iv) Determine the reactive power supplied by the source.

ans. given, $E_{max} = 150\,V$

$\omega = 1000$ rad/sec.

$R = 40\,\Omega$

$L = 0.13\,H$

$C = 10 \times 10^{-6}\,F$.

8

(i) $I_{max} = \frac{V_{max}}{Z}$

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

$X_L = \omega L$
$= 1000 \times 0.13$
$= 130\ \Omega$

$X_C = \frac{1}{\omega C}$
$= \frac{1}{1000 \times 10 \times 10^{-6}}$
$= \frac{1000000}{1000 \times 10}$
$= 100\ \Omega$

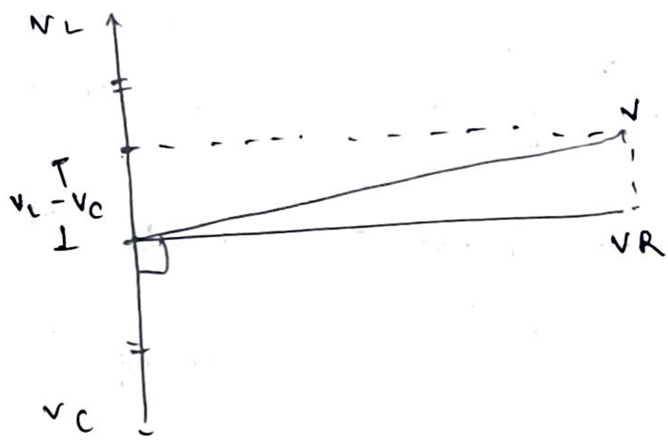
$Z = \sqrt{(40)^2 + (130-100)^2}$
$= \sqrt{1600 + (30)^2}$
$= \sqrt{1600 + 900}$
$= \sqrt{2500}$
$= 50\ \Omega$.

$I_{max} = \frac{V_{max}}{50}$
$= \frac{150}{50} = 3\ A$.

$I_{RMS} = \frac{I_{max}}{\sqrt{2}} = \frac{3}{1.141} = 2.12\ A$.

(ii) Through inductor,
$V_L = IX_L = 2.12 \times 130 = 275.6\ V$.
Through conductor.
$X_C = IX_C = 2.12 \times 100 = 212\ V$

(iii)



(iv) $Q = VI \sin\phi$ * Q = reactive power.

$\sin\phi = \frac{X_L - X_C}{Z} = \frac{130-100}{50} = \frac{30}{50} = 0.6$

$Q = 106.08 \times 2.12 \times 0.6$
$= 134.9\ VAR$.

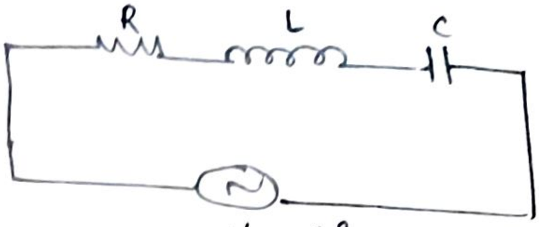
$V_{RMS} = \frac{V_{max}}{\sqrt{2}}$
$= \frac{150}{\sqrt{2}}$
$= 106.08\ V$

16/11/24

→ Resonance in LCR series circuit

- A circuit is at resonance if the imaginary component of the impedance or admitance is equal to zero.
- It can also be defined as the state of a network when the frequency = natural frequency of the network.

$$z = R + jX_L - jX_C$$
$$= R + j\omega L - j\frac{1}{\omega C}$$
$$= R + j\left(\omega L - \frac{1}{\omega C}\right)$$



at resonance,

$$\Rightarrow \omega L - \frac{1}{\omega C} = 0 \Rightarrow X_L - X_C = 0$$

$$\Rightarrow X_L = X_C \Rightarrow IX_L = IX_C$$

$$\Rightarrow V_L = V_C$$

$$\Rightarrow \omega L - \frac{1}{\omega C} = 0$$

$$2\pi f L - \frac{1}{2\pi f C} = 0$$

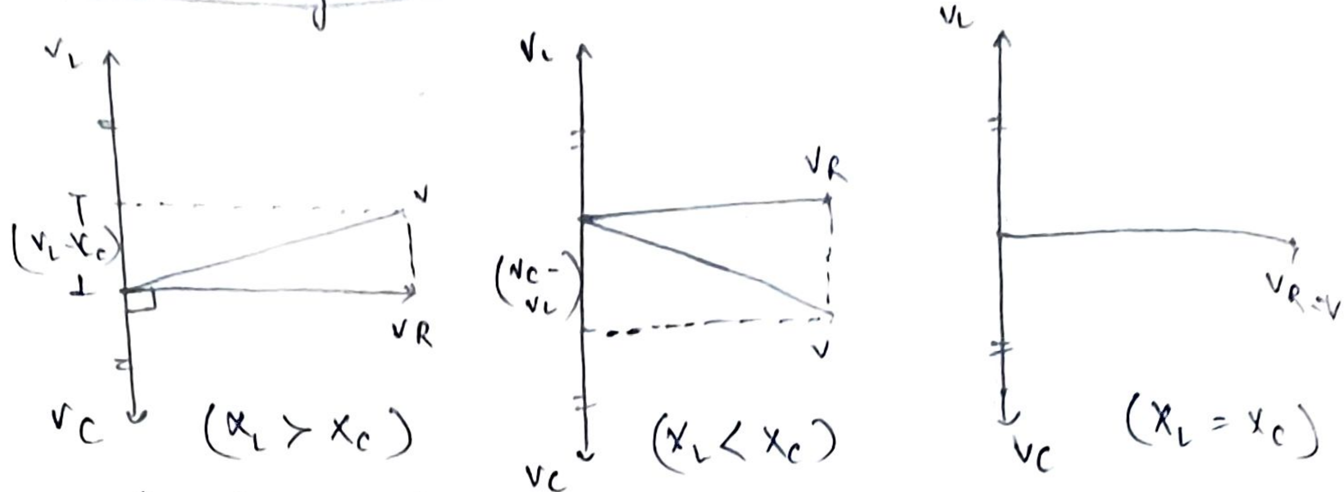
$$2\pi f L = \frac{1}{2\pi f C}$$

$$f^2 = \frac{1}{4\pi^2 LC} \Rightarrow f = \frac{1}{2\pi\sqrt{LC}} = f_0$$ ↗ Resonant frequency.

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

$$\Rightarrow \boxed{\omega_0 = \frac{1}{\sqrt{LC}}}$$ ← Resonant frequency in rad/sec.

phasor diagram



$V = V_R + j(V_L - V_C)$

- The series resonance circuit is also called acceptor circuit :
- The fun^n of a series resonance circuit is to accept only one signal from 100 signal.

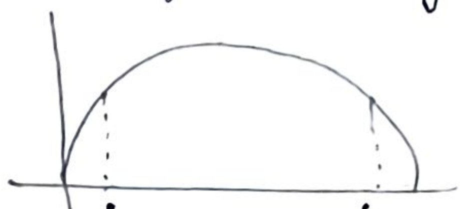
⇒ At resonance :-

(i) Net reactance = 0 ($X_L = X_C \Rightarrow X_L - X_C = 0$)
(ii) Impedence of the circuit $Z = R$
(iii) Impedence will be minimum.
(iv) Current will be maximum.
(v) $V = V_R$
(vi) $V_L = V_C$ or $X_L = X_C$
(vii) At resonance, the voltage and current are always in same phase, so $\phi = 0$
So, power factor ($\cos\phi$) = 1.
(viii) $P = VI$ watt
(ix) when all these conditions exist. then the circuit is said to be in resonance and the frequency at which it occurs is called resonance frequency.

(x) Voltage across inductance and voltage across capacitance will be equal and opposite, so the total voltage across L and C will be = 0.

Band width :-

- It is the difference betn power frequency.
- Bandwidth = $f_2 - f_1$
  or, $\omega_2 - \omega_1$ = B.W.



Selectivity :-

- It is the ratio of resonance frequency to band width.
- $\text{Selectivity} = \frac{f_0}{f_2 - f_1} = \frac{\omega_0 L}{R} = \frac{2\pi f_0 L}{R}$.

Quality factor :- (Q)

- It is defined as the ratio of maximum energy stored in the inductor to energy dissipated per cycle.

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

Q. A coil of resistance 40 Ω and L = 0.75 H forms a part of a series circuit for which resonance frequency is 55 Hz. If the supply is 250 V, 50 Hz find

(i) line current.

~~f_0 = 55 Hz~~

(ii) Power consumed.

(iii) ~~Voltage across the coil~~. Capacitance.

(iv) Power factor.

$R = 40\,\Omega$

$L = 0.75\,H$

$f_0 = 55\,Hz$

$V = 250\,V$

$f = 50\,Hz$

iii) $\phi = $

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

$= (40)^2 +$

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

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

$(2\pi f_0)^2 = \frac{1}{LC}$

$C = \frac{1}{L \times (2\pi f_0)^2} = \frac{1}{0.75 \times 4 \times (3.14)^2 \times (55)^2}$

$= 11.16\,\mu f$.

(i) $X_L = 2\pi f L$

$= 2 \times 3.14 \times 50 \times 0.75$

$= 235.5\,\Omega$

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

$= \frac{10^6}{2 \times 3.14 \times 50 \times 11.16} = \frac{1000000}{3504.24}$

$= 285.36\,\Omega$

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

$= \sqrt{(40)^2 + (49.8)^2}$

$= 63.63\,\Omega$

$I = \frac{V}{Z} = \frac{250}{63.63} = 3.92\,A$.

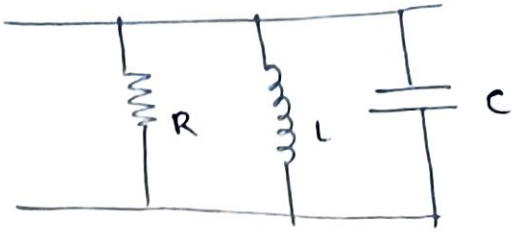
(ii) $\cos\phi = \frac{R}{Z} = \frac{40}{63.63} = 0.62$

(iii) $P = I^2 R = (3.9)^2 \times 40 = 608.4$ watt.

DT - 18/11/24

Resonance in parallel LCR circuit :-

- Admitance : (Y)
  - Reciprocal of impedence
    $Y = \frac{1}{Z}$.



$\frac{1}{Z} = Y = \frac{1}{R} + \frac{1}{jX_L} - \frac{1}{jX_C}$

$Z = R + jX_L - jX_C$ (R-L-C series circuit)

$* \frac{1}{j} = -j$

$Y = \frac{1}{R} - \frac{j}{\omega L} + \frac{j}{\frac{1}{\omega C}} = \frac{1}{R} - \frac{j}{\omega L} + j\omega C$

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

At resonance,

$\Rightarrow \omega C - \frac{1}{\omega L} = 0 \Rightarrow \omega C = \frac{1}{\omega L}$

$\Rightarrow \omega^2 = \frac{1}{LC} \Rightarrow \boxed{\omega = \frac{1}{\sqrt{LC}} = \omega_0}$

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

- Net reactance = 0
- admitance of the circuit (Y) $= \frac{1}{R}$
- admitance will be minimum.
- Current will be minimum so it is called a rejector circuit.
- Here voltage and current will be in same phase
- The power factor will be unity (1).

{Note} ↳ for series resonance, quality factor

$$= \frac{\omega_0 L}{R} \text{ or } \frac{1}{\omega_0 C R}.$$

↳ for parallel resonance, quality factor.

$$= \frac{R}{\omega_0 L} \text{ or } \omega_0 C R.$$

↳ Band width in series R·C = $\frac{R}{L}$ (← resonance circuit)

↳ Band width in parallel R·C = $\frac{1}{RC}$

- An inductive coil of inductance L connected in parallel with a capacitance 'c' is called a "Tan circuit".

↳

Dt - 21/11/24

3 phase AC-circuit :-

- In 3 phase system there are 3 phases, the voltage across 2 phases is known as line voltage and the voltage across one phase and neutral is known as phase voltage.
- Current flowing through two phases is known as line current and current flowing through ~~and~~ one phase and neutral is known as phase current.

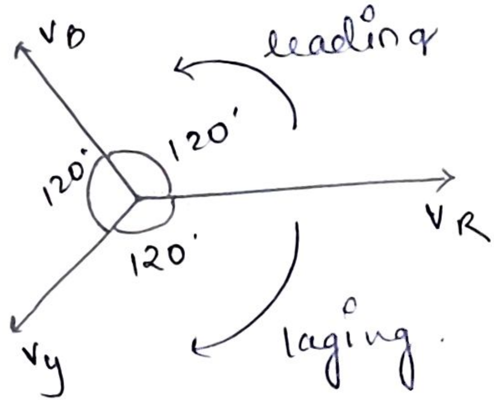
$V_R = V_m \sin\omega t$

V_y = lag - $V_m \sin(\omega t - 120°)$

lead = $V_m \sin(\omega t + 240°)$

V_B = lag - $V_m \sin(\omega t - 240)$

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

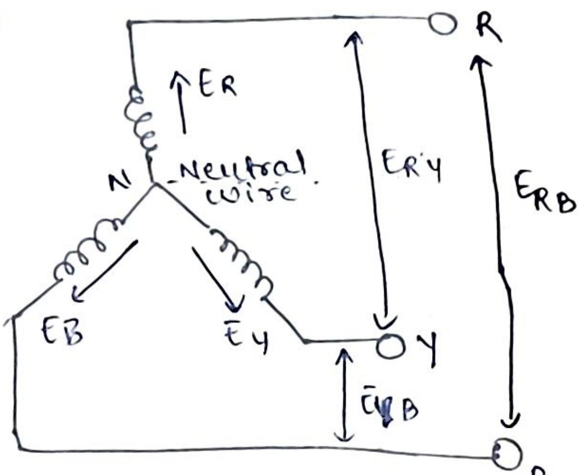


- There are 2 types of 3 phase AC system
(i) star connection (Y)
(ii) delta connection (Δ)

(i) <u>star connection</u> (Y)

- This system is obtained by joining the similar ends either the start or the finish and the other ends are joined to the line wire

- The common point (N) is called the neutral or star point



- Ordinarily in star connection, there are 3 phases and 3 wires but sometimes there will be a 4th wire known as neutral wire is carried from the neutral point to the external load circuit by giving 3 phase, 4 wire star connected system.
- The neutral point is usually earth connected.

E_{RY}, E_{YB}, E_{BR} → line voltage

E_R, E_Y, E_B → phase voltage

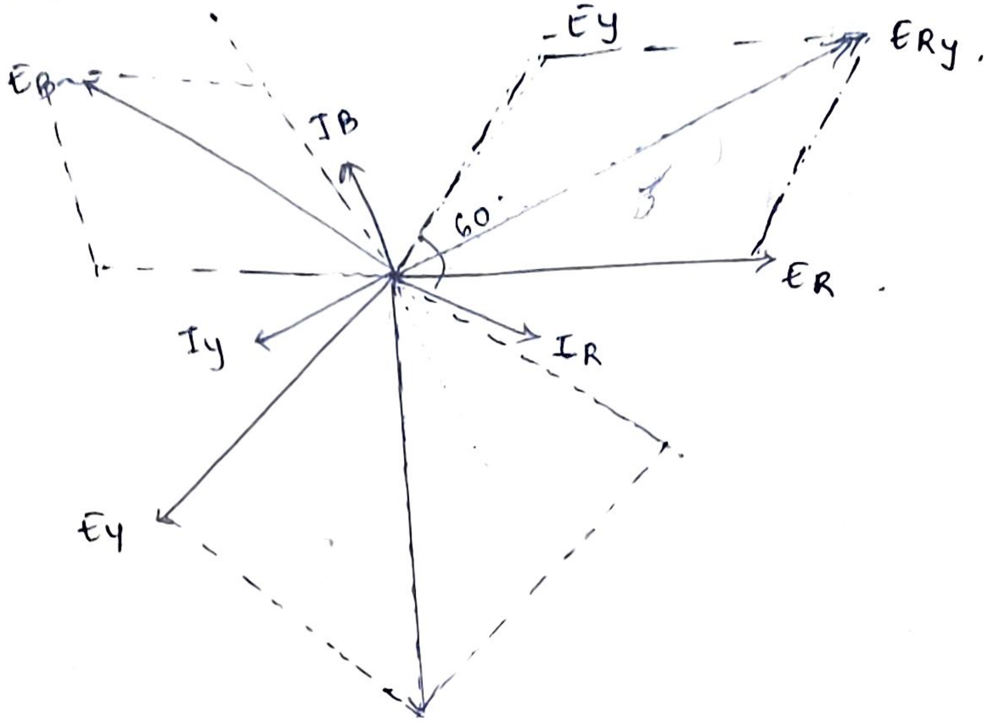
$E_{RY} = E_R - E_Y$

$E_{YB} = E_Y - E_R$

$E_{BR} = E_B - E_R$

I_R, I_Y, I_B → phase currents

phasor diagram -



$$E_{Ry} = \sqrt{E_R^2 + E_y^2 + 2E_R \cdot E_y \cos 60^\circ}$$

$E_R = E_y = E_B = E_P$ (phase voltage).

$E_{RY} = E_{YB} = E_{BR} = E_L$ (line voltage)

$$E_{RY} = \sqrt{E_P^2 + E_P^2 + 2E_P \cdot E_P \cdot \frac{1}{2}}$$

$$E_{Ry} = \sqrt{3E_P^2} = \sqrt{3}\,E_P$$

$$\boxed{E_L = \sqrt{3}\,E_P}$$

line voltage = √3 × phase voltage

=> Since in star connected system each line conductor is connected to separate phase so, current flowing through the line and phase are same. i.e line current (I_L) = phase current (I_P) $\boxed{I_L = I_P}$

23/11/24.

→ **Power Calculation :- (P)**

active power in a single phase circuit

$= VI\cos\phi = V_p I_p \cos\phi = E_p I_p \cos\phi$

active power in 3 phase circuit =

$= 3VI\cos\phi = 3V_p I_p \cos\phi = 3E_p I_p \cos\phi$.

when ϕ is the phase angle betn current & voltage so,

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

- Active power for 3 phase line to line voltage

$= 3V_p I_p \cos\phi$.

$= 3\frac{V_L}{\sqrt{3}} \cdot I_L \cos\phi$ $\quad\quad \therefore \sqrt{3}V_p = V_L$, $V_p = \frac{V_L}{\sqrt{3}}$

$= \sqrt{3}V_L \cdot I_L \cos\phi$ $\quad\quad \therefore I_p = I_L$.

- Apparent power (S) $= 3V_p I_L = \sqrt{3}V_L I_L$
- Reactive power (Q) $= 3V_p I_p \sin\phi = \sqrt{3}V_L I_L \sin\phi$.

- In a balance system the potential of neutral or star point is zero because potential of neutral or star point,

$E_{RN} + E_{YN} + E_{BN} = 0$

or $E_R + E_Y + E_B = 0$.

Q. A balanced 3 phase star load has load impedence of $(5 - j10)\Omega$ per phase and supplied from a balanced 3 phase 400 V, 50 Hz AC supply. Calculate the values for

i) line voltage

ii) phase voltage.

iii) line current

iv) phase current.
v) total power consumption & powerfactor.

ans. given, $Z_p = 5 - j10$
$R = 5\,\Omega$, $X_C = -10\,\Omega$.
$V_L = 400\,V$, $f = 50\,Hz$.

(i) $V_L = 400\,V$.

(ii) $V_p = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94\,V$

(iii) $I_L = I_p = \frac{V_p}{Z_p} = \frac{230.94}{11.18\,\Omega}$
$= 20.65\,A$.

$Z_p = \sqrt{R^2 + (10)^2}$
$= (5)^2 + 100$
$= \sqrt{125}$
$= 11.18\,\Omega$

(iv) $I_p = 20.65\,A$

(v) power consumption ⇒ $P = 3 I_p^2 R_p$.
$P = 3 \times (20.65)^2 \cdot 5$
$= 6400\,W$

powerfactor $= \frac{R_p}{Z_p} = \frac{5}{11.18} = 0.44$.

Q. A 3 phase load consists of 3 similar inductive coil of resistance $50\,\Omega$ and inductance $= 0.3\,H$. The supply is $415\,V$, $f = 50\,Hz$ calculate
i) The line current
ii) power factor.
iii) The total power when the load is star connected.

ans given $R = 50\,\Omega$
$L = 0.3\,H$
$V_L = 415\,V$, $f = 50\,Hz$.

(i) $I_L = \frac{V_p}{Z_p} =$

$V_p = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239.6\,V$.

$Z_p = \sqrt{R^2 + X_L^2}$

$2\pi fL = 2 \times 3.141 \times 50 \times 0.3 = 94.23\ \Omega$

$Z_p = \sqrt{50^2 + 94.23^2}$

$= \sqrt{2500 + 8879.29}$

$= \sqrt{11379.29} = 106.67\ \Omega$

$I_L = \frac{V_p}{Z_p} = \frac{293.6}{106.67} = 2.24\ A$

ii) $\cos\phi = \frac{R_p}{Z_p} = \frac{50}{106.67} = 0.46$

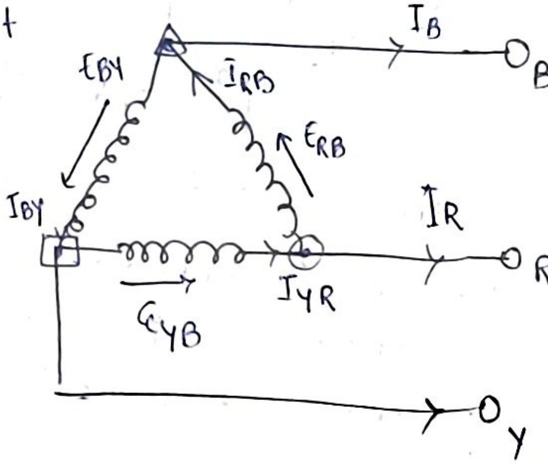
iii) $P = 3 I_p^2 \cdot R_p$

$= 3 \times (2.24)^2 \times 50) = 752.64\ W$

⇒ Mess or Delta connection :-

when the starting end of one coil is connected to the finishing end to the another coil, the mess or delta connection is obtained.

- Here is the given circuit I_R, I_Y, I_B are the line currents and I_{YR}, I_{RB}, I_{BY} are the phase currents



Applying KCL at point ⊙,

$I_R + I_{RB} - I_{YR} = 0$.

$\Rightarrow I_R = I_{YR} - I_{RB}$.

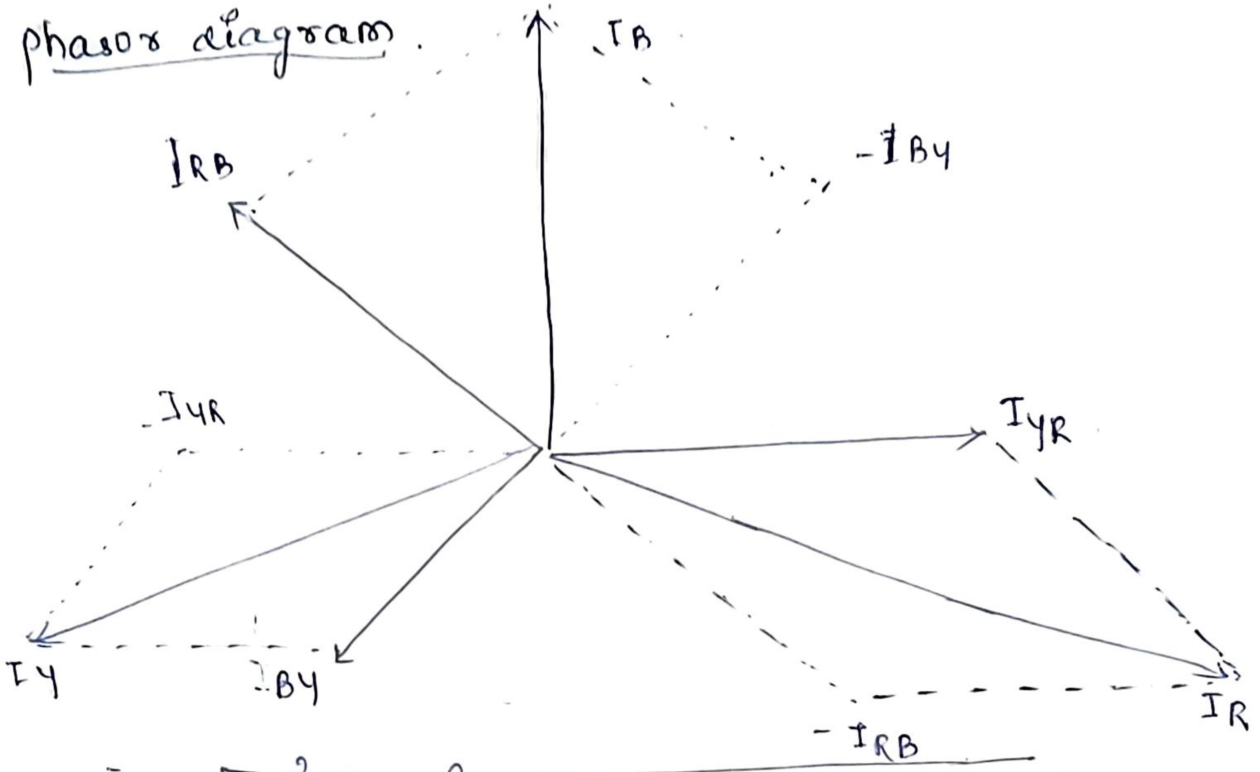
Applying KCL at point △

$I_B = I_{RB} - I_{BY}$

Applying KCL at point ⊡

$I_Y = I_{BY} - I_{YR}$

phasor diagram



$$I_R = \sqrt{I_{YR}^2 + I_{RB}^2 + 2 \cdot I_{YR} \cdot I_{YR} \cdot I_{RB} \cdot \cos 60^\circ}$$

$I_{YR} = I_{RB} = I_{BY} = I_p$ (phase current)

$I_R = I_Y = I_B = I_L$ (line current).

so, $I_L = \sqrt{I_p^2 + I_p^2 + 2 I_p^2 \cdot \frac{1}{2}}$

$I_L = \sqrt{3 I_p^2} = \boxed{\sqrt{3}\, I_p = I_L}$

line current = $\sqrt{3}$ phase current.

since in Δ connected system, only one phase is included betn any pair of line outers, potential diff betn the line outers called the line voltage = phase voltage

i.e $\boxed{V_L = V_P}$

$\therefore$ line voltage = phase voltage.

25.11.24

→ Power calculation in Δ connection

active power in a single phase circuit.
→ $VI\cos\phi$

active power in 3 phase circuit =
$= 3VI\cos\phi = 3V_pI_p\cos\phi = 3E_pI_p\cos\phi$.

when ϕ is the phase angle betn current & voltage so, $\boxed{\cos\phi = \frac{R}{Z}}$

- Active power for 3 phase, line to line voltage,

$= 3V_pI_p\cos\phi$

$= 3\frac{V_L}{\sqrt{3}}I_L\cos\phi$

$= \sqrt{3}V_L \cdot I_L\cos\phi$

$\because \sqrt{3}V_p = V_L$

$V_p = \frac{V_L}{\sqrt{3}}$

$\therefore I_p = I_L$

Apparent power -(S) = $3V_pI_L = \sqrt{3}V_LI_L$

Reactive power - (Q) $3V_pI_p\sin\phi = \sqrt{3}V_LI_L\sin\phi$.

→ In balanced system, the resultant emf in the closed circuit will be zero, i.e

$$\boxed{E_{RY} + E_{YB} + E_{BR} = 0}$$

(Note) → There will be no circulating current in the mesh if no load is connected to the lines.

Q. A balanced star connected load of $(12+j9)\Omega$ per phase are connected in Δ, 400 V, 3 phase supply. find (i) line current.
(ii) power factor.
(iii) power drawn.
(iv) Reactive volt ampere.

(v) total volt ampere. (apparant power).

ans. given,

$Z_p = 12 + j9$ (inductive)

$R = 12\,\Omega$

$X_L = 9\,\Omega$

$V_L = 400$ v

$I_p = \frac{V_p}{Z_p} = \frac{400}{15} = 26.66$ A.

$Z_p = \sqrt{R^2 + X_L^2}$
$= \sqrt{12^2 + 9^2}$
$= \sqrt{144 + 81}$
$= \sqrt{225} = 15$

(i) $I_L = I_p\sqrt{3} = \sqrt{3} \times 26.66$
$= 46.17$ A.

(ii) $\cos\phi = \frac{R_p}{Z_p} = \frac{12}{15} = 0.8$

(iii) Power drawn (P) $= 3 V_p I_p \cos\phi$.
$= 3 \times 400 \times 26.66 \times 0.8$
$= 25593.6$ watt.

(iv) $Q = 3 V_p I_p \sin\phi$.

$\cos\phi = 0.8$

$\phi = \cos^{-1} 0.8 = 36.56$.

$\sin\phi = \sin 36.56 = 0.59$.

$Q = 3 \times 400 \times 26.66 \times 0.59$
$= 19200$ VAR.

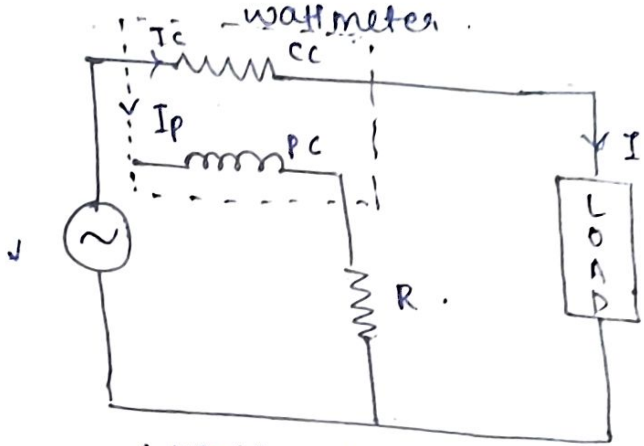
(v) Total volt ampere (S) $= 3 V_p I_p$
$= 3 \times 400 \times 26.66$
$= 31{,}992$ VA.

(AQ.10) 95

3 impedances each of (3 - j4) Ω are connected to a Δ 3 phase 430 V, 50 Hz balanced supply. Calculate the line & phase current in Δ connected load and power delivered to the load.

→ **Measurement of Power in 3 phase circuit :-**

wattmeter consists of a low resistance coil called current coil (CC) which is inserted in series with the line carrying current to be measured and a high resistance coil called pressure coil (Pc) which is connected in series with a high resistance betn the 2 points across which potential diff is to be measured.



(watt meter connection coil)

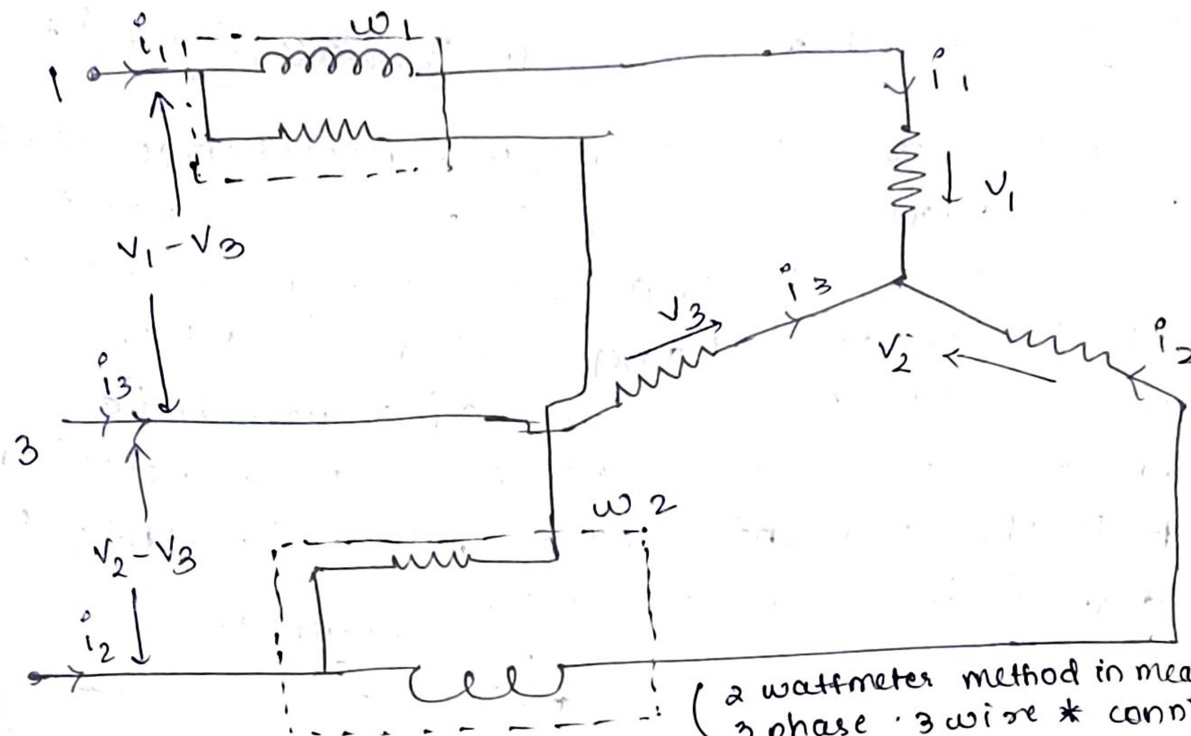
Two wattmeter Method :-

- the current coils of 2 wattmeter are inserted in any 2 lines and pressure coil is connected from its own current coil to the line without a current coil.

v_1, v_2, v_3 and i_1, i_2, i_3 are the voltages and currents of the 3 loads connected across 3 different phases.

Instantaneous power (P) $= v_1 i_1 + v_2 i_2 + v_3 i_3$ → (1)

(a) <u>Star connected system</u> :-



(2 wattmeter method in measuring 3 phase 3 wire * connⁿ)

$i_1 + i_2 + i_3 = 0$ (Applying KCL at neutral point).

$i_3 = -(i_1 + i_2)$

Now put the value of i_3 in eqⁿ (1),

$P = v_1 i_1 + v_2 i_2 - v_3 (i_1 + i_2)$

$= i_1 (v_1 - v_3) + i_2 (v_2 + v_3)$

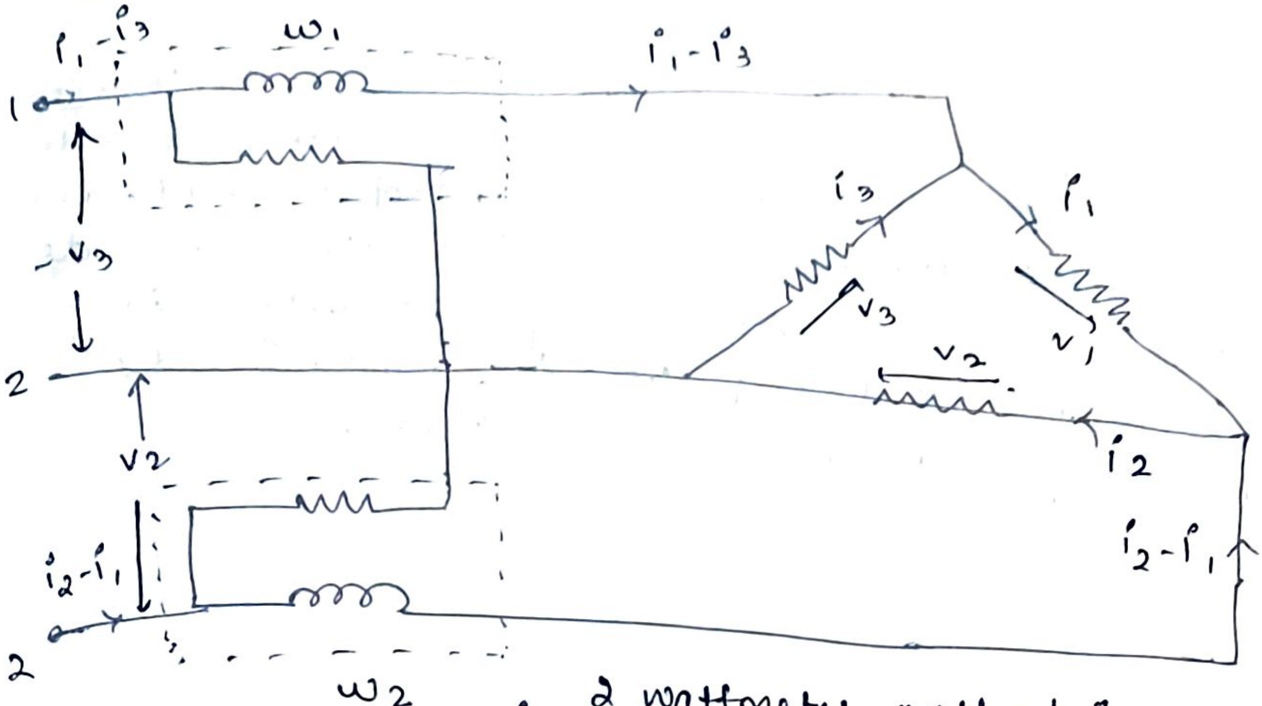
$P = w_1 + w_2$

Since i_1 is the instantaneous current flowing through the current coil and $v_1 - v_3$ is the instantaneous potential diff across pressure coil of wattmeter, which is $(v_1 - v_3) i_1$

Similarly, $W_2 = (V_2 - V_3) i_2$

- Hence, the total power in a 3 phase 3 wire star connected load is the algebric sum of 2 wattmeter.

(b) Δ connected system -



(2 wattmeter method in measuring 3 phase wire connⁿ in Δ connⁿ)

$$V_1 + V_2 + V_3 = 0.$$

$$V_1 = -(V_2 + V_3)$$

putting value in eqⁿ 1,

$$P = -(V_2 + V_3) i_2 + V_2 i_2 + V_3 i_3$$

$$= -V_2 i_2 - V_3 i_2 + V_2 i_2 + V_3 i_3$$

$$= V_2 (i_2 - i_1) - V_3 (i_1 - i_3)$$

$$P = W_2 + W_1$$

⇒ Total power is the algebric sum of 2 wattmeter readings.

$W_1 = V_L I_L \cos(30° - \phi)$

$W_2 = V_L I_L \cos(30° + \phi)$

$\phi = \tan^{-1}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)\sqrt{3}$ → ϕ = phase angle.

$\tan\phi = \sqrt{3}\left[\frac{W_1 - W_2}{W_1 + W_2}\right]$

28/11/24

Q. Two wattmeters connected to measure the total power in a 3 phase balanced circuit, one measure 4800 W, while the other reads backwards. On reversing the letter it is found to read 400 W. what is the total power and power factor.

(i) $W_1 = 4800\ W$

$W_2 = -400\ W$

$P = W_1 + W_2$

$= 4800 - 400 = 4400\ W$

(ii) $\phi = \tan^{-1}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)\sqrt{3}$

$= \tan^{-1}\left(\frac{~~4400~~ 5200}{4400}\right)\sqrt{3}$

$= \tan^{-1}\frac{52}{44}\sqrt{3}$

$=$ ~~tan⁻¹ 1.181~~

$\phi =$ ~~49.74 × 1.73~~ $=$ ~~86.051~~ 63.88

power factor $= \cos 63.88$

$= 0.44$

In a 2 wattmeter method, power measured was 30 kW at 0.7 powerfactor lagging. find the reading of each wattmeter.

$P = 30\,kW = 30{,}000\,W$, $\cos\phi = 0.7$

$P = \sqrt{3}\, V_L I_L \cos\phi$ $\qquad \phi = \cos^{-1} 0.7 = 45.57$

$$V_L I_L = \frac{30 \times 10^3}{\sqrt{3} \times 0.7} = 24743.6\ VA.$$

$W_1 = V_L I_L \cos(30 - \phi) = 24743.6 \cos(30 - 45.57)$
$= 238351\ W$

$W_2 = V_L I_L \cos(30 + \phi) = 24743.6 \cos(30 + 45.57)$
$= 6165\ W.$

Module - IV

Transformer.

It is a static device which transforms electrical energy from one circuit to another circuit with different voltage level but at constant frequency.

(To be read later).

Working Principle :-

— x — x — x — x — x —

100

Module - III

Magnetic Circuit

⇒ Faraday's first law :-

- whenever a relative displacement occurs between a conductor and a magnetic field then an emf induced in that conductor
- emf induced in the conductor in two ways
  (i) By rotating a conductor in a constant magnetic.

or

  (ii) By rotating the magnetic field outside the constant conductor.

⇒ Faraday's second law :-

- the emf induced in the conductor is $\propto$ to the rate of change of flux linkages in it

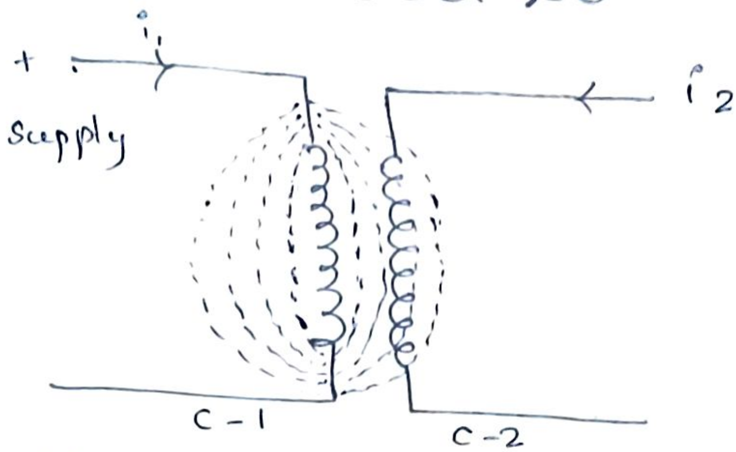
$$e \propto \frac{d\phi}{dt}$$

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

ϕ = flux, t = time, n = no. of turns

- The negative sign is present over there because the induced emf is in opposite dir^n to the supply voltage.

⇒ Self emf and Mutual induced emf.



There are 2 coils in the circuit diagram i.e coil.1 and coil.2.

- when we are giving supply to C_1 current will be flows in it due to which there will be some flux linkage in C_1 and C_2 due to which emf will induced in C_1 and C_2
- The emf induced in C_1 due to current I_1 is known as self induced emf.
- The emf induced in C_2 due to current I_1 is known as mutual induced emf.

self induced emf (e) = $-L\frac{di}{dt}$.

$L = \frac{N\phi}{i}$ — N → no. of turns.

$$L = \frac{N^2 \mu_0 \mu_r a}{l} \text{ Henry.}$$

l → length of the conductor

where, L = self inductance.

ϕ = flux

permeability (μ) = $\mu_0 \times \mu_r$.

μ_0 → absolute permeability = $4\pi \times 10^{-7}$ H/m.
μ_r → relative permeability
(for air or vaccum
$\mu_r = 1$)
i = current
a = area of cross section of the conductor.

Dt - 2/12/24

Mutual induced emf (e_m) = $-M \frac{di_1}{dt}$

$$M = \frac{N_1 N_2 a \mu_0 \mu_r}{l} \text{ Henry.}$$

where, M = mutual inductance
i_1 = current flowing in C_1
N_1 = no. of turn in C_2
N_2 = no of turn in C_2

- the magnitude of emf induced is proportional to the component of the velocity in a dir^n ⊥r to the dir^n of the magnetic feild and the induced emf is given by

$$e = BLV \sin\theta \text{ V.}$$

The dir^n of this induced by fleming's right hand rule.
B = flux density wb/m² or Tesla.
l = length of conductor.
v = velocity in m/s.

=> **Coefficient of coupling :-**
when 2 coils are placed near other, all the flux produced by one coil doesnot link with the other coil and only a certain

portion of flux produced by one coil links with the other coil which is less than unity (1) and known as coefficient of coupling (K)

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

L_1 - coefficient of self inductance of C_1.

L_2 = coefficient of self inductance of C_2.

M = coefficient of mutual inductance.

Q. A coil has 400 turns. find the induced voltage in it if the flux changes from 0.2 m wb to 1 m wb in 0.2 sec.

$d\phi = 1 \times 10^{-3} - 0.2 \times 10^{-3}$

$= 0.8$ m wb. or 0.8×10^{-3} wb.

$dt = 0.2$ sec.

$N = 400$.

so, $e = N \frac{d\phi}{dt} = 400 \frac{0.8 \times 10^{-3}}{0.2}$

$= 400 \times \frac{0.0008}{0.2}$

$= 400 \times 0.004$

$= 1.6$ V.

Q. find the induced emf in a conductor of length 150 cm moving at an angle of 30° to the dirn of magnetic field of B = 1.2 wb/m² with a velocity of 60 m/s.

$B = 1.2$ wb/m²

$l = 1.5$ m.

$v = 60$ m/s

$\theta = 30°$

$\Rightarrow e = BLV \sin 30$.

$= 1.2 \times 1.5 \times \cancel{60}^{30} \times \frac{1}{\cancel{2}}$

$= 54$ V

-) A coil having an inductance of 60 mH is carry a current of 90 A. Calculate the self ind. emf in the coil, when the current is

(i) Reduced to 0 in 0.03 sec. (6 mark)

(ii) Reversed in 0.03 sec.

$L = 60 \times 10^{-3}$ H. $= 0.06$ H.

$i = 90$ A.

(i) $di = 90 - 0 = 90$ A.

$dt = 0.03$ sec.

$e = L \frac{di}{dt} = 0.06 \times \frac{90}{0.03}$

$= 180$ V.

(ii) current $= -90$ A.

$di = 90 - (-90) = 180$ A.

$dt = 0.03$

$e = L \frac{di}{dt} = 0.06 \times \frac{180}{0.03}$

$= 360$ V.

Q. A coil of 300 turns, wound on a core of non-magnetic material has an inductance of 10×10^{-3} H. Calculate.

(i) the flux produced by the current of 5A

(ii) the avg value of emf induced when a current of 5 A is reversed in 2 m sec.

given. $N = 300$.

$L = 10$ mH

$L = 10 \times 10^{-3}$ H

$L = 0.01$ H.

(i) $i_1 = 5A$.
$\phi = ?$
so, $L = \frac{N\phi}{i}$

$\phi = \frac{Li}{N} = \frac{0.01 \times 5}{300} = 0.1667$ wb

(ii) $i_2 = -5A$ (as it reversed).
at t or $dt = 8 \times 10^{-3}$ sec $= 0.008$ sec.

$e = L\frac{di}{dt} = 0.01 \times \frac{5-(-5)}{0.008}$

$= 0.01 \times \frac{10}{0.008}$

$= 12.5$ V.

Q. Two coils having 100 and 50 turns respectively are wound on a core with $\mu = 4000\mu_0$ effective core length $= 60$ cm and effective core area $= 9\,cm^2$. find the mutual inductance betn the coils.

given, $N_1 = 100$.
$N_2 = 50$.

$\mu = 4000\mu_0 = 4000 \times 4\pi \times 10^{-7} = 0.005024$.

$l = 60$ cm $= \frac{60}{100} = 0.6$ M.

$a = 9\,cm^2 = 9 \times 10^{-4}$

$M = \frac{N_1 N_2 a \mu}{l}$

$= \frac{100 \times 50 \times 9 \times 10^{-4} \times 4000 \times 4\pi \times 10^{-7}}{0.6}$

$= 37.7$ mH.

Q. If 2 coils having self inductances of 60 mH and 80 mH and the mutual inductance between them is 40 mH then find coefficient of coupling.

given, $L_1 = 60$ mH $= 60 \times 10^{-3}$

$L_2 = 80$ mH $= 80 \times 10^{-3}$

$M = 40$ mH

$$K = \frac{M}{\sqrt{L_1 L_2}} = \frac{40}{\sqrt{60 \times 80}}$$

$$= \frac{40}{69.28} = 0.577.$$

(A-11) A solenoid has 1200 turns and carries a current of 2A. The iron core has a length of 0.4 m and A = 80 cm^2, the relative permeability (μ_r) = 1000. Calculate the self induced emf in the solenoid, if the current is switched off in 0.01 sec.

given, $N = 1200$

$i = 2A$.

$l = 0.4$ m.

$a = 80$ cm^2 $= 80 \times 10^{-4}$ ~~= 0.0~~ m^2

$\mu_r = 1000$

$dt = 0.01$ sec.

$$e = L \frac{di}{dt} =$$

$$L = \frac{N^2 \mu_0 \mu_r a}{l}$$

$$= \frac{(1200)^2 \times (4\pi \times 10^{-7}) \times 1000 \times 80 \times 10^{-4}}{0.4}$$

$= 36.19$ H.

$e = L \frac{di}{dt}$, switch off = 0 A

$= 36.19 \left(\frac{2-0}{0.01}\right)$

$= 7238$ V.

DT - 5/12/24

difference betn electric & Magnetic circuit.

Electric	magnetic
- flow of current	- flow of flux.
- Resistances opposes the flow of current	- reluctance opposes the flow of flux.
- emf induced here ($emf = I_1R_1 + I_2R_2 + \dots$)	- Here mmf (magneto motive force) induced. ($Mmf = \phi_1 S_1 + \phi_2 S_2 + \dots$)
- current $I = \frac{emf}{resistance}$	- flux (ϕ) $= \frac{MMf}{reluctance}$.
- Reciprocal of resistance is conductance.	- Reciprocal of reluctance is permeance
- conductivity $= \frac{1}{resistivity}$	- Permiability $= \frac{1}{reluctivity}$
- current density (J) $= \frac{current}{area} = \frac{I}{A}$.	- flux density (B) $= \frac{flux}{Area} = \frac{\phi}{A}$.

→ **Magnet** :-

- It is an object which attracts iron, nickel, cobalt etc.

⇒ Magnetism :-

The power of a magnet by which it attracts certain substances.

⇒ Magnetic material :-

(i) **Paramagnetic matial :-** The materials which are not strongly attracted by magnet are called as paramagnetic material.

ex - Aluminium, tin, platinum, magnesium.

(ii) **Diamagnetic material :-** The material which are repelled by magnets are called as diamagnetic material.

ex - Zinc, mercury, lead, sulphure, copper, Ag. Bismuth, wood etc.

(iii) **ferromagnetic material :-** The material which are strongly attracted by magnet is known as ferromagnetic material.

ex - Iron, nickle, cobalt, steel and some of their alloyes.

⇒ Reluctance (S)

- It opposes the flow of flux and it is the ratio of mmf to the flux.

i.e $S = \frac{mmf}{\phi}$; $mmf = NI$

unit = $\frac{\text{Ampere x turn}}{\text{weebree}} = \frac{AT}{wb}$

$S = \frac{l}{\mu A}$ ($\mu = \mu_0 \mu_r$)

⇒ **Permeability (μ) :-**

- The ability of a material to conduct magnetic flux through it is called permeability of the material.

$$\boxed{\mu = \frac{B}{H}}$$

B → flux density
H → Magnetising force or magnetic field strength.

$\therefore B = \mu H$
$\therefore B \propto H$.

⇒ **Relative permeability (μ_r) :-**

$\mu = \mu_0 \mu_r$

$$\therefore \boxed{\mu_r = \frac{\mu}{\mu_0}}$$

- It is the ratio of permeability to absolute permeability.

⇒ - **flux density (B) :-**

- It is the ratio of flux per area.

$$\boxed{B = \frac{\phi}{A}}$$

ϕ → flux
A → Area.

unit $= \frac{wb}{m^2}$ = Tesla.

⇒ **Magnetising force / Magnetic field strength (H) :-**

$$\boxed{H = \frac{NI}{l}}$$

n = no. of turn.
i = current.
l = length of the conductor.

$H \propto I$
$H \propto \frac{1}{l}$

Q. A coil of 300 turns and resistance of 10 Ω is wound uniformly over a steel ring of mean circumference of 30 cm and Area is 9 cm². It is connected to a 20 v supply. If the relative permeability of the ring is 1500 then find magnetising force, reluctance, mmf, flux.

given, $N = 300$

$R = 10\ \Omega$

$l = 30cm = 0.3\ m.$

$A = 9\ cm^2 = 9 \times 10^{-4}\ m^2$

$V = 20\ V.$

$\mu_r = 1500.$

•) $H = \frac{NI}{l} = \frac{300 \times \frac{V}{R}}{l}$

$= \frac{300 \times \frac{20}{10}}{0.3} = \frac{300 \times 2}{0.3} = 2000\ \frac{AT}{m}$

•) Reluctance (S) $= \frac{l}{\mu A}$

$= \frac{0.3}{4\pi \times 10^{-7} \times 1500 \times 9 \times 10^{-4}}$

$= 1.769 \times 10^{7}\ AT/Wb.$

•) flux $= \phi = \frac{mmf}{S}$

$= \frac{600}{1.769 \times 10^{-7}}$

$=$

c) B-H curve / magnetisation curve / saturation curve or magnetic hestoricis :-

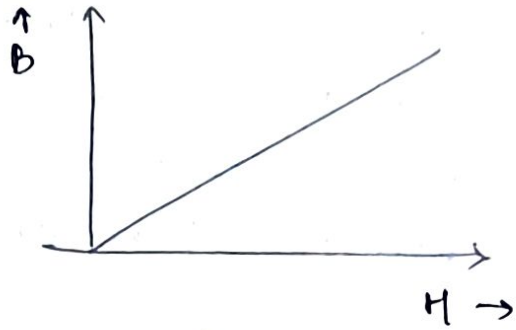
$\mu = \frac{B}{H}$

$\mu H = B$

$\boxed{B \propto H}$ ——— (1)

The relation betn magnetic flux density (B) and magnetising force (H) is known as B-H curve

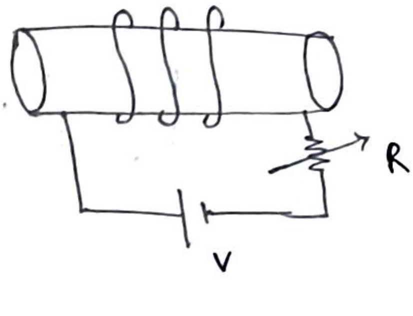
for non magnetic material the B-H curve is given below -



→ for Magnetic material :-

- let us take a non-magnetic conductor or iron bar and magnetised it within a field of a solenoid.

$H = \frac{NI}{l}$



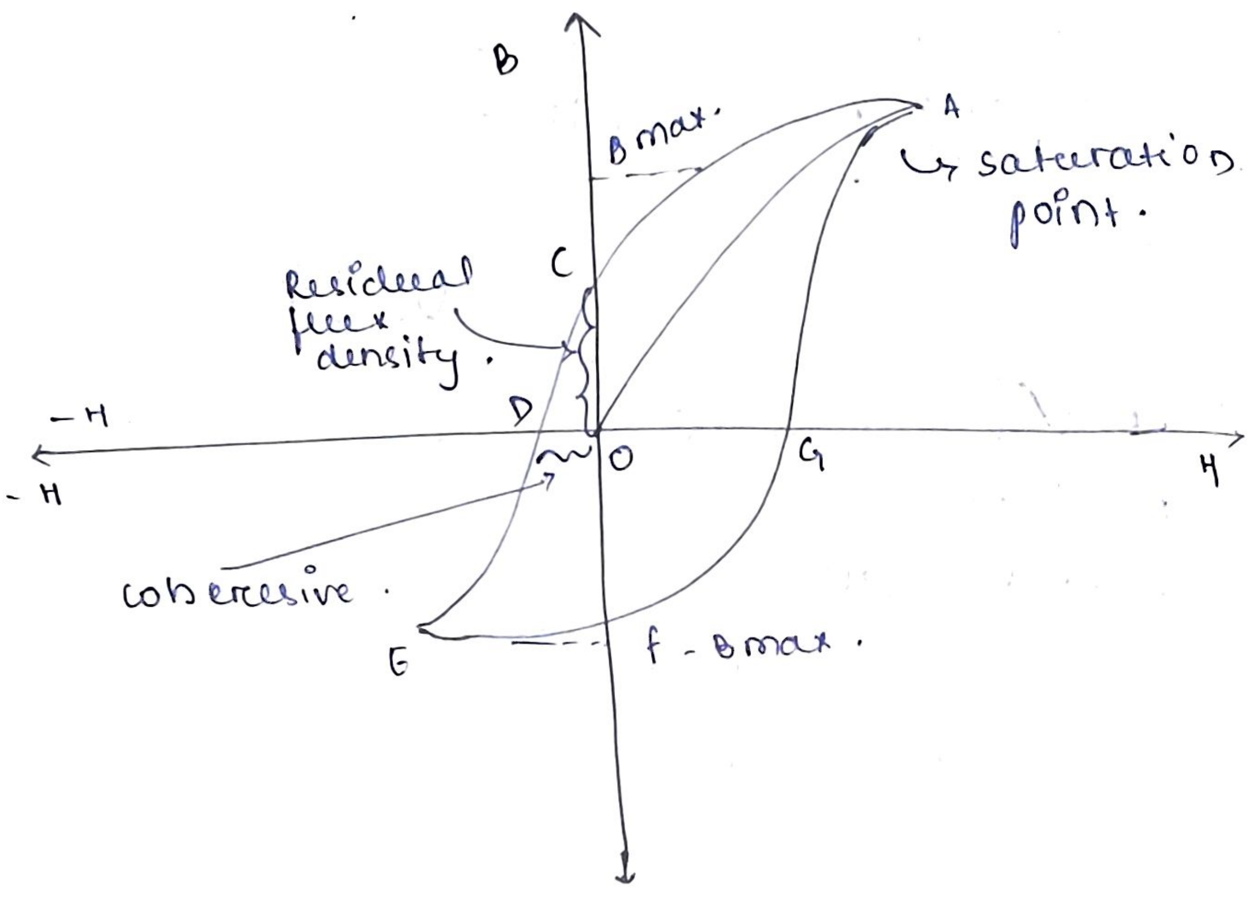
$H \propto I$

and $B \propto H$ (from (1))

so, $B \propto H \propto I$.

- The field $H = \frac{NI}{l}$ produced by the solenoid is called magnetising force.

- The value of x can be increased or decreased by increasing or decreasing the current through the circuit.
- Let H be increased from 'o' to a maximum value and noted the flux density and the graph will come betn H and B is $\overline{OA}$.
- If 'H' is now decreased (by gradually decreasing the current), flux density 'B' will not decrease along $\overline{AO}$ but it will decreasing along $\overline{AC}$ and hence,
  $H=0$, $B \neq 0$ $(B = \overline{OC})$, It means that on removing H the iron bar is not completely demagnetised. This value $B = \overline{OC}$ is called residual flux density or remanant.



- Remanent or residual flux density measures the retentivity or remanance.

Retentivity :-

- It is defined as the ability of a material to retain magnetism after the external effect has been removed.
- To demagnetised the iron bar we have to apply the magnetising force in the reverse direction.
- When H is reversed then B is reduced to 0 (H = $\overline{OD}$). These value of H is known as coheresive and it is the measure of coheresivity of the material.

Coheresivity :-

- It is the intensity of the applied magnetic force required to reduce the magnetisation of the material to zero, after the magnetisation of the sample has been driven to saturation.
- After the magnetisation has been reduced to zero, the value of H is further increased in reverse dirn and the iron bar again reaches in a magnetic saturation.
- By taking H back from its corresponds negative saturation we will get a similar graph EFGA.
- The closed loop ACDEFGA is a hypothesis loop.

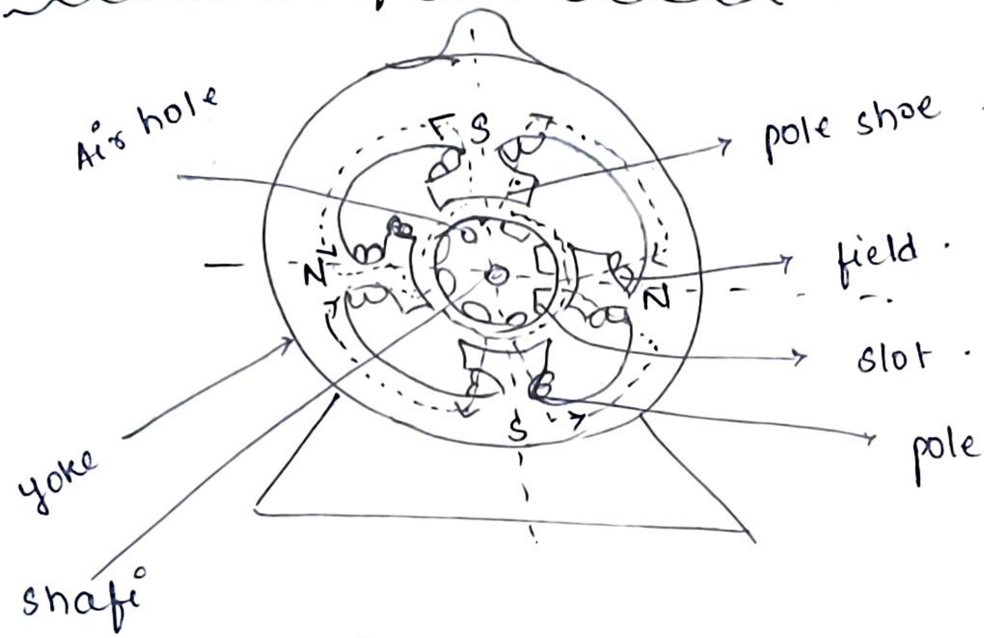
04.12.24

Module - III — Cont.....

DC - Machine :-

- In a rotating electrical machine, there are a stator part and a roter part. The stationary part is known as stator and the rotating part is known as rotor.
- A same DC machine can either be used force generator operation and motor operation.

Construction of a DC-machine :-



- In a DC machine, a stator consists of field system or main magnetic circuit and the rotor consist of armature assembly or main electrical circuit.

→ Commutator or splitring.

- It is used to convert AC produced in the armature conductor to unidirectional direct current (DC)
- It is a cylinder made of hard drum pure copper segments insulated from eachother with mica insulation.

- Its main funⁿ is to convert AC voltage induced in the armature winding to DC voltage across the terminal.

Process **Brushes :-**

- These are made of carbon or graphite in a rectangular prism form and pressed over the commutator segment with suitable spring.
- Carbon provides a self-lubricating surface and it has high resistance, high melting point and it reduces armature reaction.
- Its funⁿ is to provide a conducting path from the rotating commutator segments to the stationary terminal.

Pole core and Pole shoe :-

- Pole is divided into 2 part (i) pole core
  (ii) pole shoe.

(i) **Pole core :-**

- It is a rectangular prism made of laminated silicon steel. where silicon reduces histeresis loss and lamination reduces eddy current loss.
- Its main funⁿ is to support the field winding, forms a magnetic circuit and creates magnetic flux.

(ii) **Pole shoe :-**

- The outermost part of the pole is known as pole shoe. It is an enlarged section on either side of the pole.

- Its main funⁿ is to reduce the reluctance of the magnetic path and supports the field coil.

⇒ Lap winding :-

no. of parallel path (A) = no. of Poles (P) ~~= no of brushes (B)~~

⇒ Wave winding :-

no of parallel path (A) = 2 ~~= no of Brushes (B)~~

⇒ DC generator :-

- It is a rotating electrical machine which converts mechanical energy into electrical energy.

⇒ Working Principle :-

An electrical generator is a machine which converts mechanical energy into electrical energy and the energy conversion is based on the principle of production of dynamically induced emf.

whenever a conductor cut magnetic lines of force then dynamically induced emf is produced in the conductor according to faraday's law of electromagnetic induction. This emf causes a current to flow if the conductor circuit is closed.

Emf eqⁿ of a DC generator ★ Imp.

E_{avg} = avg induced emf per conductor

E_g = generated emf in any parallel path.

P = no. of poles.

Z = total no. of conductor.

ϕ = flux per pole.

N = speed in revolution per min (RPM)

A = no. of parallel paths

In one complete revolution total flux cut by each conductor = $(P \times \phi)$ wb

- Total time taken by each conductor to complete one revolution $= \frac{1}{N}$ min

$= \frac{60}{N}$ sec.

- So avg rate of flux cut by each conductor,

$$= \frac{\text{total flux cut}}{\text{total time taken}} = \frac{P \times \phi}{\frac{60}{N}} = \frac{NP\phi}{60} = E_{avg}$$

- No. of conductors in series with each parallel path $= \frac{Z}{A}$

- Now, total generated emf in any parallel path (E_g) $= E_{av} \times \frac{Z}{A}$

$$= \frac{P\phi N}{60} \times \frac{Z}{A} = \boxed{\frac{P\phi Z N}{60A}} = E_g$$

$$E_g = \left(\frac{PZ}{60A}\right)\phi N$$

($\frac{PZ}{60A}$ → constant.)

$$\boxed{E_g \propto \phi N}$$

Different types of DC generator :-

- ~~Sepf excit~~ separately excited DC generator.
- Self excited DC generator
  - series
  - shunt
  - compound

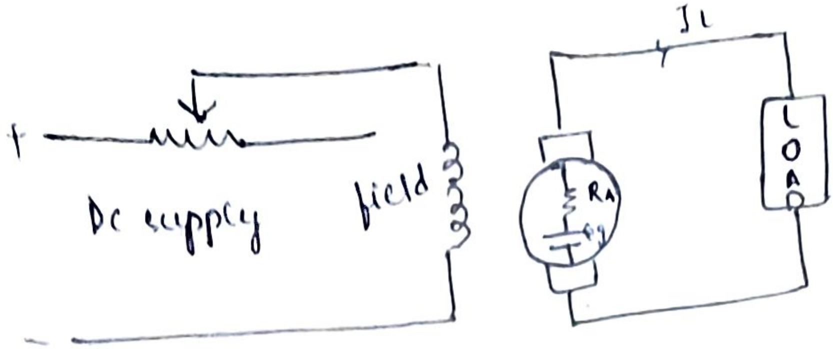
According to the relative positions of field coil in the circuit w.r.t armature binding compounde machines are 2 types
(i) short shunt compound generator
(ii) long shunt compound generator

According to the load characterstic compound generators are divided into 3 types
(i) under compound
(ii) flat or level compound.
(iii) Over compound.

Depending upon the relative dirn of current flowing in series and shunt field winding, compound machine are divided in 2 types
(i) cummulative compound.
(ii) differential compound.

Separately excited DC generator:

In this generator the field coil is generated or connected to a separate DC source for its excitation.

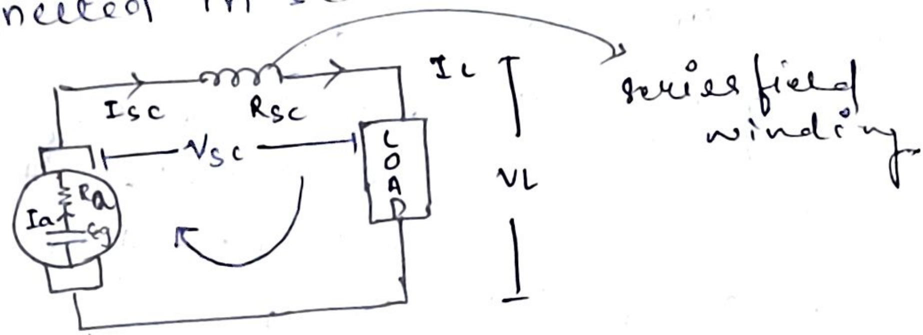


Self excited DC generator.

- In this type generator the exciting current is taken from the armature circuit of the self machine
- There are 3 types of self excited generator

(i) Series generator :-

- field winding is of few turns and thicker wires.
- Its resistance is approx nearer to armature resistance.
- In this type of generator the field winding is connected in series with armature.



Eg - generated emf
Ia - armature current
Ra - armature resistance.
Isc - series field current
Rsc - series field resistance
IL - load current.
VL - voltage across the load.
Vsc - voltage across series field.
RL - load resistance
Va - armature voltage

Applying KVL,

$e_g - I_a R_a - V_{BD} - V_{SC} - V_L = 0$

$e_g = I_a R_a + V_{BD} + V_{SC} + V_L$

V_{BD} - Brush contance voltage drop.

$V_{SC} = I_{SC} \times R_{SC}$

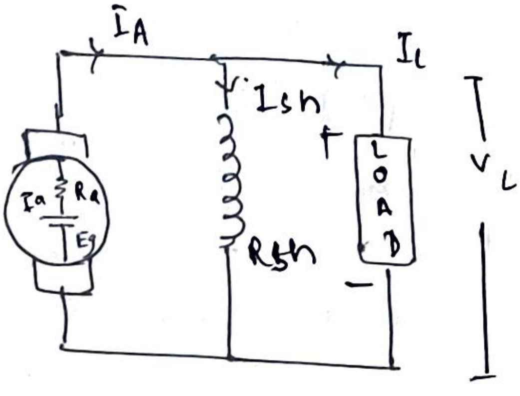
$V_a = I_a \cdot R_a$

$V_L = I_L R_L$

$\boxed{I_a = I_S = I_L}$

(ii) Shunt generator :-

- In this type generator the field winding is connected parallel with the armature.
- field winding is of many torns with thinner wire.
- Its resistance is much more greater than armature resistance.



$I_{sh} \rightarrow$ Shunt field current

$R_{sh} \rightarrow$ shunt field resistance

$V_{sh} \rightarrow$ voltage across shunt field.

Applying KVL,

$E_g - I_a R_a - V_{BD} - V_{sh} = 0$

$V_{sh} = V_L$

$E_g = I_a R_a + V_{BD} + V_{sh}$

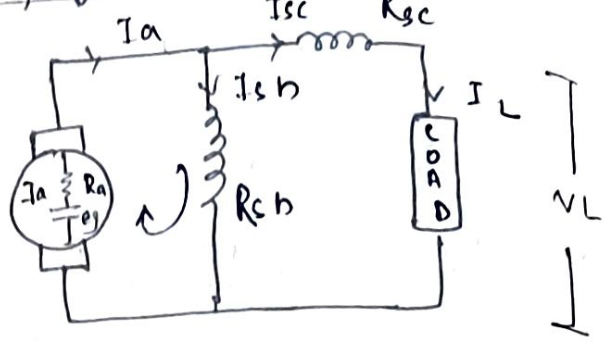
$I_a = I_{sh} + I_L$

* $\boxed{V_{sh} = I_{sh} \cdot R_{sh}}$.

(iii) Compound generator

In this type of generator 2 separate field coils are provided on each pole. One for series field and another for shunt field. So the machine is known as compound machine.

→ Short shunt compound generator :-



$V_{sh} = I_{sh} \cdot R_{sh}$

$$V_{sh} = I_{sc} R_{sc} + V_L$$

Applying KVL,

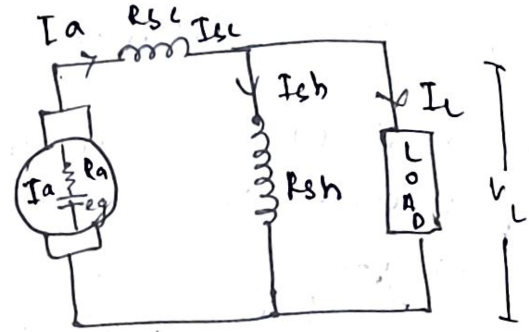
$E_g - I_a R_a - V_{BD} - V_{sh} = 0$

$E_g = I_a R_a + V_{BD} + V_{sh}$

$$I_a = I_{sh} + I_L$$

$$I_L = I_{sc}$$

→ Long shunt compound generator :-



$V_{sh} = V_L$

applying KVL,

$E_g - I_a R_a - V_{BD} - I_{sc} R_{sc} - V_{sh} = 0$

$E_g = I_a R_a + V_{BD} + I_{sc} R_{sc} + V_{sh}$

$I_a = I_{sc} = I_{sh} + I_L$

Q. Calculate the flux per pole required on full load for a 50 kW, 400 V, 8 poles, 600 RPM DC shunt generator with 256 conductors arranged in a lap connected winding. The armature winding resistance is 0.1 Ω, the shunt field resistance is 200 Ω and there is brush contact voltage drop of 1 V at each brush on full load.

= 50 KW   Ra = 0.1 Ω
= 400 V   Rsh = 200 Ω, 1 V.
= 8
= 600
256

ce it is given lap winding, so
A = P = 8.
is given brush contact voltage drop is 1 V
at each brush, so, total brush drop

$V_{BD} = 2 \times 1 = 2\,V.$

$e_g = \frac{P\phi Z N}{60} \Rightarrow$

$E_g = I_a R_a + V_{BD} + V_{sh}$ → $V_{sh} = V_L = 400\,V$

$R_a = 0.1$

$I_a = I_{sh} + I_L$

$V_{sh} = I_{sh} \cdot R_{sh}$

$I_{sh} = \frac{V_{sh}}{R_{sh}} = \frac{400}{200} = 2\,A.$

$I_L = \frac{P_{o/p}}{V_L}$

$= \frac{50 \times 10^3}{400} = 125$

$I_a = 2 + 125 = 127\,A.$

$e_g = I_a R_a + V_{BD} + V_{sh}.$

$= 127 \cdot 0.1 + 2 + 400.$

$= 414.7\,V.$

∴ $e_g = \frac{P\phi Z N}{60A} \Rightarrow \phi = \frac{60\, e_g A}{P Z N}$

$= \frac{60 \times 414.7 \times 600}{8 \times 256 \times 600}$

$= 0.162$ wb.

Q. 20kW compound generator works on full load with a terminal voltage of 230 V. The armature, series and shunt field resistance are 0.1 Ω, 0.05 Ω, 115 Ω respectively. Calculate the generated emf when the generator is connected with short shunt.

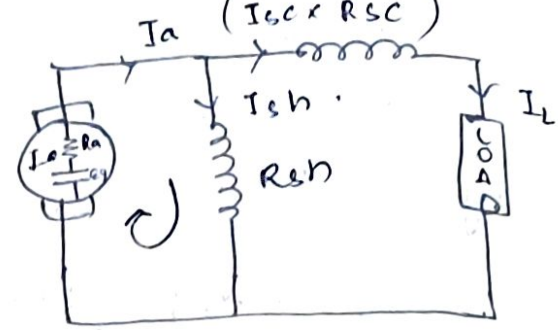
given, $P_{o/p} = 20\,kW$

$V_L = 230\,V$

$R_a = 0.1\,\Omega$

$R_{se} = 0.05\,\Omega$

$R_{sh} = 115\,\Omega$



Applying KVL,

$E_g - I_a R_a - I_{sh} R_{sh} = 0$

$E_g = I_a R_a + I_{sh} R_{sh}$

$I_L = \frac{P}{V} = \frac{20 \times 10^3}{230} = \frac{2000}{23} = 86.95\,A$

$\therefore I_L = I_{sc} = 86.95\,A$

$V_{sh} = I_{se} R_{se} + V_L$

$I_{sh} \times R_{sh} = (86.9 \times 0.05) + 230$

$= 234.3\,V$

$I_{sh} = \frac{234.34}{115} = 2.03$

$I_a = I_{sc} + I_{sh}$

$= 86.95 + 2.03$

$= 88.93$

$E_g = I_a R_a + I_{sh} R_{sh}$

$= (88.93 \times 0.1) + (2.03 \times 115)$

$= 242.34\,V$

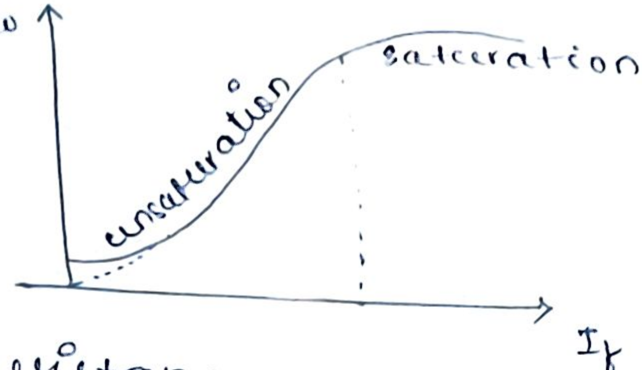
⇒ Different generator characteristic

(1) open circuit or noload or magnetisation characterstic (OCC) :-

- The relationship betn no load induced emf (E_0) and field current (I_f) is known as open circuit characteristic (OCC) when the generator is running at rated speed.

⇒ critical resistance

The value of field resistance with which the generator will build up some voltage is known as critical resistance.



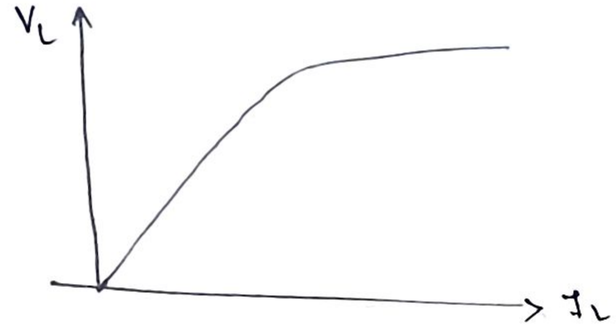
⇒ Critical speed :-

for a definite value of field resistance the speed at which the generator builds up a few voltage is known as critical speed.

(2) load characterstic :-

- The relationship betn the terminal voltage or load voltage (V_L) and load current (I_L) of the generator running at rated speed is known as external or load characterstic.

- for series generator :-



- forchent generator.

(3) Internal / total characterstic :-

- It is the relationship betn induced emf (E_g) and armature current (I_a) when the machine is on load and running at constant speed.

⇒ Different losses in a DC machine :-

(i) copper loss

- It is equal to resistance of the conducting circuit multiplied by square of the armature current.

$W_{cu} = I_a^2 R_a$ watt.

- different copper losses are taking place in a DC machine such as

(i) Shunt field cu loss (constant)
(ii) series field cu loss.
(iii) armature circuit cu loss.
(iv) Brush contact copper loss.

- The copper loss are taking place due to the current flowing through the conducting circuit which have finite resistance.

(ii) Iron loss / core loss :-

- This losses are taking place in the magnetic circuit or core material.

- Due to rotation of armature core these losses are taking place continuously in the core.
- these losses are of 2 types
  - (a) histeresis loss
  - (b) eddy current loss

(a) Histeresis loss (Wh)

- These losses are taking place due to reversal of magnetism and to reduce these losses silicon steels are used

(b) eddy current loss (We)

- It takes place in the core material which links with alternating flux. Due to the alternating flux links with the core, emf is induced in the core material according to ~~3rd~~ to faraday's law of electro magnetic induction.
- this induced emf circulates a current in the core material which is known as eddy current. and due to this eddy current there will be eddy current Loss.
- To reduce this eddy current loss the amature core should be provided with lamination or laminated.

(iii) Mechanical loss :-

- these Losses are taking place due to the friction of the moving part.
- Due to wind friction, there will be windage loss
- these losses are depends on the speed of rotation

(iv) stray loss or rotational loss :-

the combination of core loss and mechanical loss is known as stray loss

(v) constant or standing loss -

combination of stray loss and shunt field copper loss is known as constant loss.

→ condition for max. efficiency :-

constant loss (W_c) = variable loss (Cu loss)

$$\Rightarrow W_c = I_a^2 R_a$$

$$\Rightarrow \boxed{I_a = \sqrt{\frac{W_c}{R_a}}}$$

→ Armature reaction :-

the effect of armature flux on main flux is called as armature reaction

⇒ commutation :-

the reversal of current in a coil as the coil passes over the brush axis is called as commutation :-

⇒ Parallel operation of a DC generator :-

- It is necessary to meet the load demand in access of a capacity of the running generator.

⇒ condition for parallel operation :-

- the polarity of the generators should be same
- the terminal voltage must be same

———— x ————

DC Motor :-

It is a rotating electrical machine which converts electrical energy into mechanical energy.

Principle of operation :-

- When ever a current carrying conductor is placed in a magnetic field it experiences a mechanical force and it will move in a direction of the force experiment.
- The dirn of force is given by fleming's left hand rule.
- The magnitude of force is given by, $F = BIL$
  - B = flux density
  - I = current flowing through the conductor.
  - l = length inside the conductor inside the magnetic field.
- Since the armature conductor are revolving in the magnetic field emf induced in the armature conductor & the dirn of emf induced in direct opposition to the supply voltage. So induced emf is called back emf or counter emf.

Significance of back emf :-

This back emf provides an opposition property to the flow of current which is responsible for conversion of electrical energy into mechanical.

- Back emf makes to DC motor self regulating machine.

$$E_b = \frac{P \phi Z N}{60 A}$$

$E_b = \left(\frac{PZ}{60A}\right)\phi N$

$\left(\frac{PZ}{60A}\right)$ → constant func^n

⇒ $E_b \propto \phi N$

⇒ $N \propto \frac{E_b}{\phi}$

⇒ **Shunt motor :-**

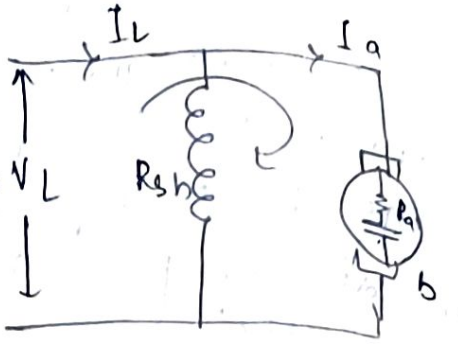
Applying KVL,

$V - I_aR_a - E_b = 0$

$$\boxed{E_b = V - I_aR_a}$$

$I_aR_a = V - E_b$

$$\boxed{I_a = \frac{V - E_b}{R_a}}$$



$I = I_a + I_{sh}$

$V_{sh} = I_aR_a + E_b$

$V - I_aR_a - E_b = 0$

⇒ $E_b = V - I_aR_a$

Multiplying 'I_a' in both sides,

$I_aE_b = VI_a - I_a^2R_a$.

$V \cdot I_a$ = electrical input to the armature

$E_b \cdot I_a$ = Mechanical power develop or electrical power converted to the mechanical power

$I_a^2R_a$ = Copper loss in the armature.

⇒ **Torque :-**

It is known as twisting moment and if 'F' is the tangential force in Newton and it is acting at a radial distance of 'R' meter from the axis of the rotation than torque

$T = F \times R$ Nm.

- for circular motion power developed =

= torque × angular

= $(T \times \omega)$ watt.

Mechanical powere ~~drop~~ developed by the armature running at N Rp then $P = E_b I_a = \omega T$

$\Rightarrow E_b I_a = \frac{2\pi N}{60} \times I_a$

$\omega = \frac{2\pi N}{60}$ radian / sec.

$T = T_a$ = armature term

$T_a = E_b I_a \times \frac{60}{2\pi N}$

$$\boxed{T_a = 9.55 \frac{E_b I_a}{N}}$$

$T_a = 9.55 \frac{P \phi Z N}{60 A} \times \frac{I_a}{N}$

$\Rightarrow T_a \propto \phi I_a$

⇒ cond^n for maximum power :-

back emf $\boxed{E_b = \frac{V}{2}}$

the mechanical powere develop by the motor is maximum when the back emf is equal to half of the supply voltage.

Speed Regulation :-

It is defined as the ratio of change in speed from no load to full load as a fraction of full load speed.

$$\% SR = \frac{\text{No of load speed} - \text{full load speed}}{\text{full load speed}} \times 100$$

⇒ Characteristic of DC motor :-

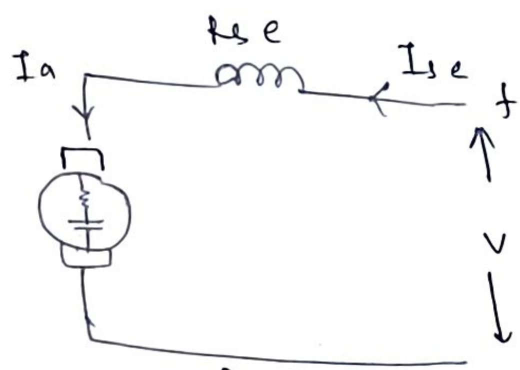
(a) series motor :- (T_a Vs I_a)

$T_a \propto \phi I$

ϕ is the flux which is proportional to the field current

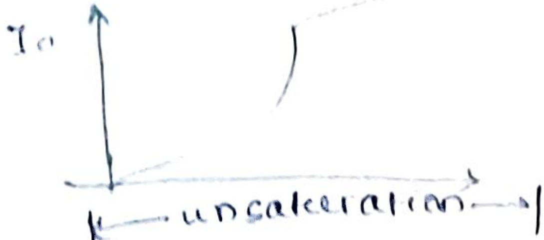
$T_a \propto I_a \cdot I_a$

$T_a \propto I_a^2$

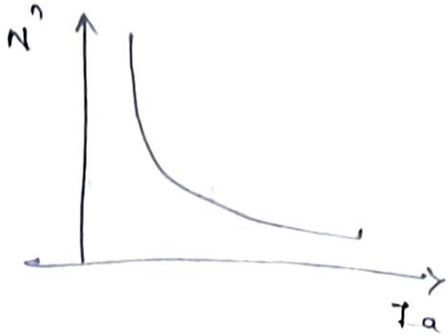


series motor

$I_{se} = I_a$.



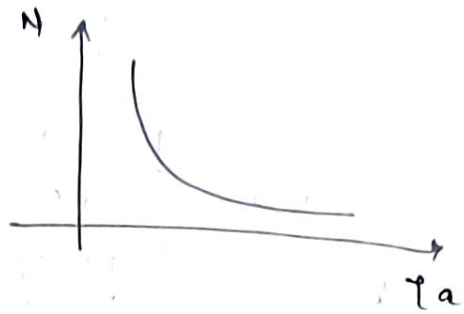
(b) N v/s Ia



$N \propto \frac{E_b}{\phi}$

$N \propto \frac{1}{\phi}$ and $N \propto \frac{1}{I_a}$.

(c) N v/s Ta



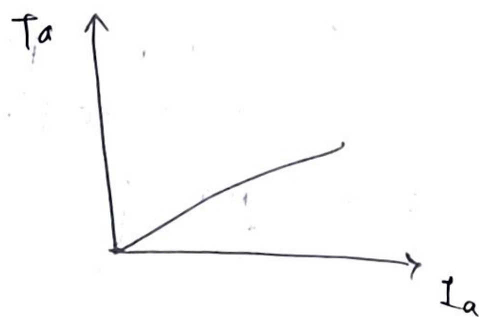
$N \propto \frac{E_b}{\phi}$ $\qquad T_a \propto \phi I_a$

$\Rightarrow N \propto \frac{1}{\phi}$ $\qquad \Rightarrow T_a \propto I_a$

$\Rightarrow N \propto \frac{1}{I_a}$ $\qquad \Rightarrow N \propto \frac{1}{T_a}$

⇒ Shunt motor characteristics :-

(a) Ta v/s Ia



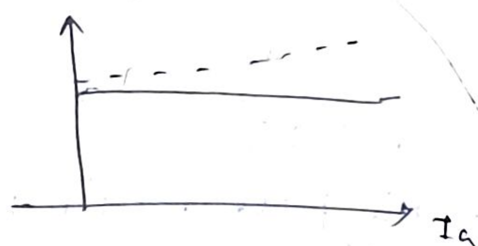
$T_a \propto \phi I_a$.

ϕ is proportional with the field current (I_{sh}) but In case of shunt motor I_{sh} is constant

Then $T_a \propto I_{sh} \cdot I_a$

$T_a \propto I_a$

(b) N v/s Ia



$N \propto \frac{E_b}{\phi} \Rightarrow N \propto V - I_a R_a$

$\phi \propto I_{sh}$

(c) N v/s Ta

$N \propto \frac{E_b}{\phi}$

$N \propto V - I_a R_a$

$N \propto V - I_a R_a$ $(T_a \propto I_a)$

DT - 16/12/24

Q. A 120 V DC shunt motor having armature resistance of 0.2 Ω field circuit resistance of 60 Ω, draw a line current of 40 A at full load and the brush voltage drop is 3 V and rated full load speed is 1800 rpm calculate.

(i) Speed at half load.

(ii) Speed at 125 % of full load.

$V = 120\,V$

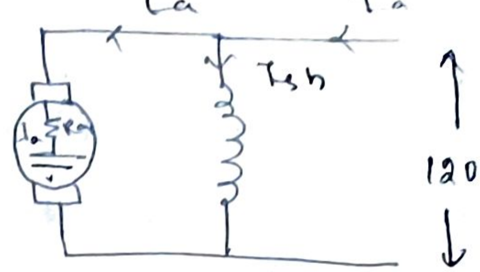
$R_a = 0.2\,\Omega$

$R_{sh} = 60\,\Omega$

$I_L = 40\,A$

$V_{BD} = 3V$

$N = 1800\,RPM$



$E_b = V - I_a R_a - V_{BD}$ ⇒ $I_a = I_L + I_{sh}$

$I_{sh} = \frac{V_{sh}}{R_{sh}} = \frac{120}{60} = 2A.$

$I_a = 40 + 2 = 42.$

$E_b = 120 - (38 \times 0.2) - 3 = 109.4\,V.$

<u>cond^n-1</u> (half load)

In case of a shunt motor if the load changes then the armature current will changes and there will be no change in shunt field current.

→ If load will be half then Ia will be half.

$N_1 = ?$

$I_{a1} = \frac{I_a}{2} = \frac{38}{2} = 19\,A.$

$E_{b1} = V - I_a \times R_a - V_{BD}$

$= 120 - (19 \times 0.2) - 3$

$= 113.2\,V$

$N \propto \frac{Eb}{\phi}$ —— (1)

$N_1 \propto \frac{Eb}{\phi}$ —— (2)

$\Rightarrow \frac{1}{2} \Rightarrow \frac{N}{N_1} = \frac{Eb}{Eb_1}$

$N_1 = \frac{N \times Eb_1}{Eb} = \frac{1800 \times 113.2}{109.4} = 1862.52$.

<u>cond^n-2</u> - (125 % full load)

$N_2 = ?$

$Ia_2 = 125\%$ of Ia $= \frac{125}{100} \times 38 = 47.5$

$Eb_2 = V - Ia_2 Ra - V_{BD}$

$= 120 - (47.5 \times 0.2) - 3 = 107.5$ v.

$\frac{N_1}{N_2} = \frac{Eb}{Eb_2} \Rightarrow N_2 = \frac{N \times Eb_2}{Eb} = \frac{1800 \times 107.5}{109.4}$

$= 1768$ RPM.

Q. A 200 V DC series motor runs at 1000 RPM and takes 20 A combines resistance of armature and field is 0.4 Ω calculate the resistance to be inserted in series so, as to reduce the speed to 800 RPM. Assuming the torque to vary as square of the speed & linear magnetisation core.

ans. $V = 200$ V

$N = 1000$ RPM.

$I_L = 20$ A $= Ia = Isc$

$Ra + Rsc = 0.4 \Omega$

$N_1 = 800$ RPM.

$\boxed{Ta \propto N^2}$ → given —— (1)

$Eb = V - IaRa - Isc\,Rsc$

$= V - Ia(Ra + Rsc)$

$= 200 - (20 \times 0.4)$

$= 192$ V

$T_a \propto \phi I_a$

In case of series motor ϕ is $\propto$ with the series field current

i.e $\phi \propto I_{sc} \Rightarrow \phi \propto I_a$

$$\boxed{T_a \propto I_a^2} \quad \text{--- (2)}$$

from eq^n (1) & (2) we get

$N^2 \propto I_a^2$ --- (3)

$N_1^2 \propto I_{a_1}^2$ --- (4)

$$\frac{eq^n (3)}{eq^n (4)} = \frac{N^2}{N_1^2} = \frac{I_a^2}{I_{a_1}^2} = \frac{1000^2}{800^2} = \frac{20^2}{I_{a_1}^2} = I_{a_1} = 16A.$$

in case of series motor flux ϕ is proportional with the series field current.

$$N \propto \frac{E_b}{\phi}$$

$\phi \propto I_{sc} = \phi \propto I_a$

$$N \propto \frac{E_b}{I_a} \quad \text{--- (3)}$$

similarly. $N_1 \propto \frac{e_{b_1}}{I_{a_1}}$ --- (4).

eq^n (3) divided by eq^n (4) $\frac{eq^n 3}{eq^n 4} \Rightarrow \frac{N_1}{N_2} = \frac{\frac{E_b}{I_a}}{\frac{E_{b_1}}{I_{a_1}}}$

$$\Rightarrow \frac{N}{N_1} = \frac{e_b}{I_a} \times \frac{I_{a_1}}{e_{b_1}}$$

$$\Rightarrow \frac{1000}{800} = \frac{192}{20} \times \frac{16}{E_{b_1}}$$

$e_{b_1} = 125.44 V$.

$e_{b_1} = V - I_aR_a - I_aR_{sc} - I_aR_{ext}$

$= V - I_a(R_a + R_{sc} + R_{ext})$.

$= 125.44 = 200 - 16 (0.4 + R_{ext})$.

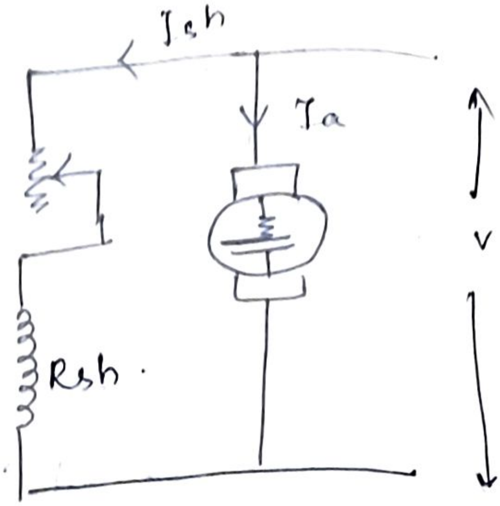
→ Speed control of DC motor :

for shunt motor :

method- 1 .

(i) field flux control or field control method :-

→ In this method A variable resistance is connected in series with the shunt field current decreas



$N \propto \frac{Eb}{\phi}$

$N \propto \frac{1}{\phi}$

$\phi \propto Ish$

$\uparrow N \propto \frac{1}{Ish} \downarrow$

As the shunt field current decreses the speed will be increase.

- In this method the speed can be increase, beyond the base speed or rated speed.

(ii) Armature resistance control method :-

In this method a suitable variable resistance is added in series with the armature

$N \propto \frac{Eb}{\phi} \Rightarrow N\phi \propto Eb$

$N \propto \frac{V - Ia\,(Ra + Rext)}{\phi}$

- In this method armature resistance can be increased by adding and enter resistance (Rext) due to which the voltage drop $V - Ia\,(Ra + Rext)$ (decreases) which is $\propto$ with speed (N) which is also decrease.

So in this method the speed can be reduced the from the rated or base value.

) **Ward Leonard method**

In this method, we can increase or decrease the speed from a base value

Starter :-

Dt - 19/12/24.

It is a device by means of which something is started from rest.

Every DC motor a starter is necessary

Q. **Why necessity of a starter in case of DC motor ?**

Armature current $(I_a) = \frac{V - E_b}{R_a}$ = starting current.

Just at the time of start, $N = 0$, so $E_b = 0$ ie $(E_b \propto \phi N)$. So armature current drawn from the supply will be $\frac{V}{R_a}$, as ~~...~~ R_a being very small the starting armature will be dangerously very high.

As the armature starts rotating it increase and the armature current reduces to limit the starting current to a safe value. So a starter is used.

- It consists mainly a variable resistance to be connected to the armature circuit.

⇒ **Different types of DC motor starter :-**

1) Three point starter.
2) four point starter
3) DOL (direct on line) starter.
4) Auto-transformer starter.

⇒ ~~Three phase induction motor :-~~

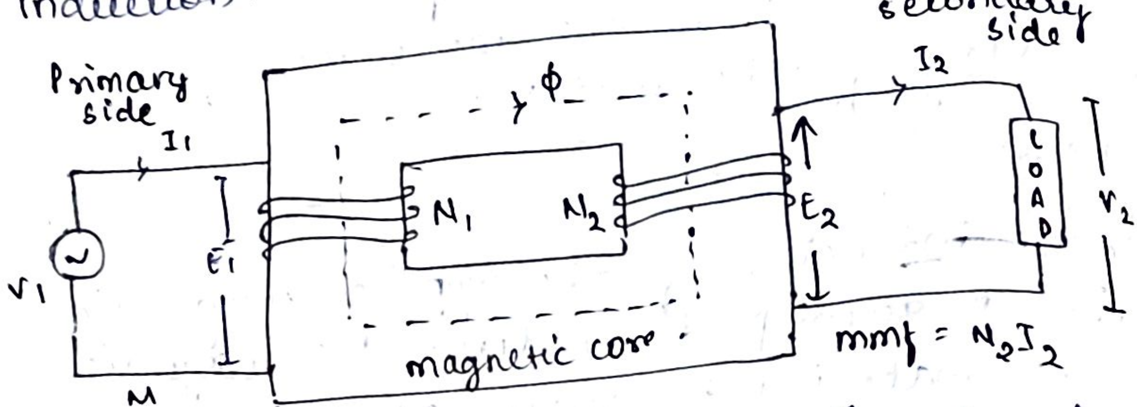
x

Transformer :-

It is a static device which transforms electrical energy from one circuit to another circuit at a different voltage level but at constant frequency.

Working Principle :-

The principle of operations is based on production of statically induced emf by mutual induction according to faraday's law of electromagnetic induction.



- Generally there will be 2 windings in a transformer mounted on a core of magnetic materials, one winding when connected to a suitable ac supply an AC current flowing in the winding (primary) which will setup alternating flux in the core.
- this alternating flux links with both the winding so, alternating voltage will be induced in both the winding.
- the first winding which is connected to the supply is known as primary winding and the second winding which is connected with a load-

circuit is known as secondary winding.

- The Induced emf in the primary is known as self induced emf and the induced emf in the secondary is known as mutual induced emf.
- The dirn of these induced emf will be same but in antiphase to the supply voltage.
- The magnitude of these induced emf depends on the number of turns. i.e

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

(phasor dia).

⇒ Main Parts of a Transformer :-

1) Protective cover
2) Conservator.
3) explosion vent.
4) Breather
5) Buchholz-relay
6) Main tank.
7) Diaphragm.

(☆ imp)

⇒ emf equation of a transformer :-

- N_1, N_2 are the number of turns in primary and secondary coil.
- E_1, E_2 are the induced emf in primary and secondary.
- f = frequency.
  V_1 = supply voltage.
  ϕ = instantaneous flux varying sinusoidally in wb.

ϕ

$\phi = \phi_{max} \sin\omega t$

- when the primary is supplied from a AC voltage an alternating current flows through the primary winding and which will setup alternating flux in the magnetic core, due to which emf induced in both the windings.
- The instantaneous emf induced per turn.

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

$$e = -\frac{d}{dt}(\phi_m \sin\omega t)$$

$$= -\phi_m \cdot \cos\omega t \cdot \omega$$

$$= -\phi_{max} \cdot \omega \cdot \sin\left(\frac{\pi}{2} - \omega t\right)$$

$$= -\phi_{max} \cdot \omega \cdot -\sin\left(\omega t - \frac{\pi}{2}\right)$$

$$e = \phi_{max}\,\omega \sin\left(\omega t - \frac{\pi}{2}\right)$$

(*) e will max when ωt = 180° or π rad/sec.

$$\boxed{e_{max} = \phi_{max}\,\omega}$$

$$E_{rms} = \frac{E_m}{\sqrt{2}} = \frac{\phi_{max}\,\omega}{\sqrt{2}}$$

$$= \frac{\phi_m \times 2\pi f}{\sqrt{2}}$$

$$\boxed{E_{rms} = 4.44\, f\, \phi_m \ \text{V}}$$ → for single turn.

⇒ Emf in primary ie $E_1 = 4.44\, f\, \phi_m N_1$ V

Emf in secondary ie $E_2 = 4.44\, f\, \phi_m N_2$ V

i.e. $E_1 \propto N_1$

$E_2 \propto N_2$

⇒ Voltage Transformation Ratio (K)

$$E_1 = 4.44 f \phi N_1 \quad \text{——— (1)}$$
$$E_2 = 4.44 f \phi N_2 \quad \text{——— (2)}$$

eqⁿ (2) / eqⁿ (1).

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K.$$

→ Turns Ratio ($\frac{1}{K}$)

- $\frac{1}{K} = \frac{N_1}{N_2} = \frac{E_1}{E_2}$
- for an ideal transformer,
  $V_1 = E_1$ and $E_2 = V_2$
- Neglecting looses in a transformer total power input = total power output i.e.

$$V_1 I_1 = V_2 I_2$$

$$\Rightarrow \frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

- The ratio of secondary induced emf to primary induced emf is known as transformation ratio.

⇒ Step-Up Transformer :-

when, $N_2 > N_1$ or $E_2 > E_1$, then the transformer is known as step up transformer.

⇒ step-down transformer :-

when $N_2 < N_1$ or $E_2 < E_1$, then the transformer is known as step-down transformer.

⇒ Ideal Transformere-

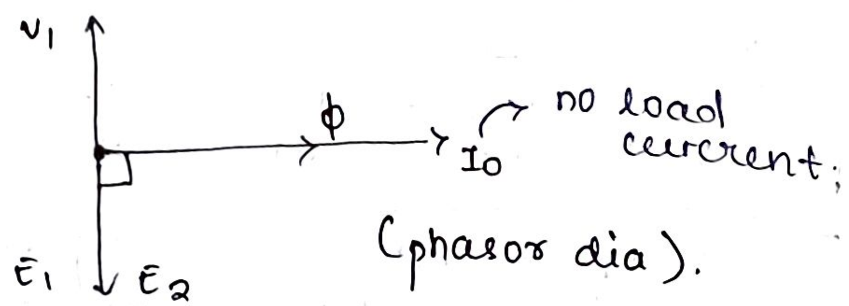
1. No iron loss
2. No magnetic leakage.
3. No copper loss.
4. Absence of magnetsing characteristic.

⇒ Practical transformer:-

1. These above 4 things are present in practical transformer.

⇒ Transformer on no load (for ideal trans.)

1. A transformer with no looses and no leakage is known as ideal transformere.
2. Here the two coils are purely inductive coil.

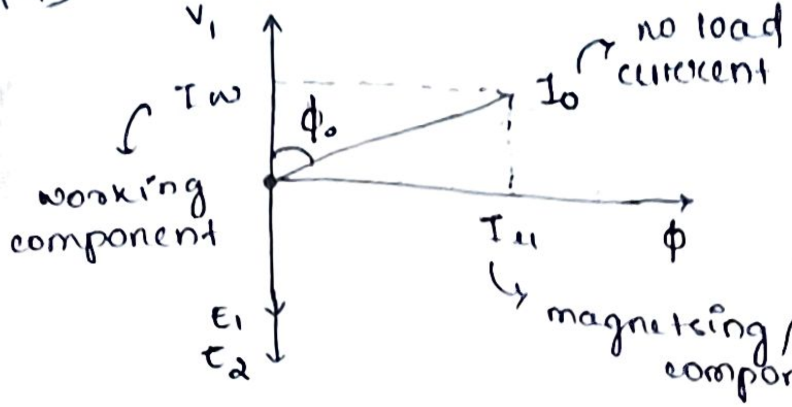


(phasor dia).

(•) The no load current is known as magnetising current and its only purpose is to magnetised the core only.

⇒ Practical transformer on no load :-

- The no load current will lag the supply voltage by an angle less than 90° because the coil have some resistances present.
- This current can be resolved into two mutually ⊥r component, one along the dir^n of supply voltage and other in 90° to the supply voltage.



$I_w = I_0 \cos \phi_0$

$I_\mu = I_0 \sin \phi_0$

$I_0 = \sqrt{I_w^2 + I_\mu^2}$

I_w = It supplies Eddy current loss, histerisis loss and small amount of copper loss in the primary.

I_μ = It establises the magnetic flux in the transformer core.

→ why rating of a trasformer is in KVA.?

- copper loss of a transformer depends on current and Iron loss or core loss depends on voltage, so total transformer looses depends on voltage and current and not on phase angle between voltage and current i.e it is Independent of load power factor. this is why the rating of a transformere is in (KVA) but not in KW.
  ↳ kilo volt ampere.

Q. A 25 KVA lose less transformer has 500 turns on the primary and 40 turns on the secondary winding. the primary is connected to 3000 V, 50 Hz supply. Determine :-

(i) Primary & secondary current at full load.

(ii) Secondary emf

(iii) The transformation ratio.

(iv) Max. flux in the core.
(v) also determine which type of transformer is it
(No load current can be neglected).

ans given, Power output = 25 KVA
$P(N_1) = 500$
$S(N_2) = 40$
$V_1 = 3000$ V.
$f = 50$ Hz.

(iii) $K = \frac{40}{500} = 0.08$

(ii) $V_1 = E_1 = 3000$ V.
$V_2 = E_2 =$

$K = \frac{N_2}{N_1} = \frac{E_2}{E_1} = \frac{V_2}{V_1}$

$0.08 = \frac{E_2}{E_1} = \frac{E_2}{3000}$

$E_2 = 3000 \times 0.08 = 240$ V.

$V_2 = E_2 = 240$ V.

(o) In a loss less transformer power input = power output.

(i) $I_2 = \frac{P\,o/p}{V_2} = \frac{25 \times 10^3}{240} = 104.17$ A.

$I_1 = \frac{P\,o/p}{V_1} = \frac{25 \times 10^3}{3000} = 8.33$ A.

(iv) $E_1 = 4.44 f \, \phi_m \cdot N_1$

$\phi_m = \frac{3000}{4.44 \times 50 \times 500} = 0.027$ Wb.

(v) as $E_1 > E_2$, $N_1 > N_2$, $V_1 > V_2$, $I_2 > I_1$
↳ step down transformer.

⇒ Voltage Regulation :-

The change in voltage from no load to full load is known as voltage regulation and it is expressed as a percentage of full load voltage.

$$\% \, VR = \frac{V_0 - V_2}{V_2} \times 100$$

V_0 = no load v
V_2 = full load v.

or It is defined as the ratio of no load voltage to full load voltage as a fraction of full load voltage.

⇒ Testing on a Transformer :-

1. Open circuit test :-

- The no load test or the open circuit test will be done at low voltage side (LV)
- from open circuit test we can find core loss or iron loss and no load powerfactor. ($\cos \phi_0$)

2. Short circuit test :-

- This test is done at the high voltage side (HV)
- ~~This~~ from this test we can find copper loss and equivalent resistance, reactance reffered to the meter inside.

⇒ Looses and efficiency :-

- Loss
  - Cu loss (variable loss) (I^2R)
  - Core loss or Iron loss
    - Hysteresis loss
    - Eddy current loss

Dt - 11/12/24

→ **Efficiency :-**

W_{cu} = copper loss

W_i = iron loss

Input = output + losses

$$\text{efficiency } \eta = \frac{\text{output of a transformer}}{\text{Input of a transformer}}$$

→ **All day or Energy efficiency -**

$$\text{energy efficiency} = \frac{\text{energy output of the transformer}}{\text{energy output of the transformer + losses}}$$

- when it is calculated for a day is a day called as all day efficiency.

⇒ **Condition for maximum efficiency :-**

Variable loss = constant loss

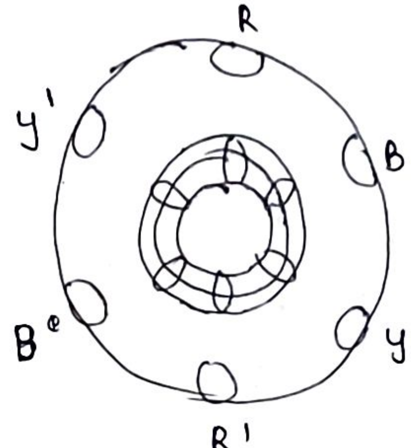
Variable loss ↓ copper loss

constant loss ↓ Iron loss / core loss.

Three Phase Induction Motor :-

=> Principle of Operation :-

When polyphase or 3 phase AC is applied to the polyphase stator windings a sincronausly rotating magnetic field will setup in the air gap.



- At the time of start, the roter is stationary hence the rotor has a relative speed equal to sincronous speed in the opposite dir^n, so there will be induced emf in the rotor conductors according to faraday's law of electromagnetic induction.
- As the roter conductors forms a close circuit windings or as shorting either con^n of the rotor, As a result there will be induced current in the rotor conductores.
- Now comes the motor principles current carring rotor conductors find themselves in a rotating magnitic field, so a torque is developed and the rotor starts rotating in the dir^n of the rotating field. This is according to lenz's law or fleming's left hand rule.
- As the current necessary for motor action emf is induced in the rotor conductore changes the name is inductor motor.

-) Constructional details.

In every polyphase Induction motor it has 2 main parts (i) stationary part → stater.
(ii) rotating part → roter.

(i) Stater :-

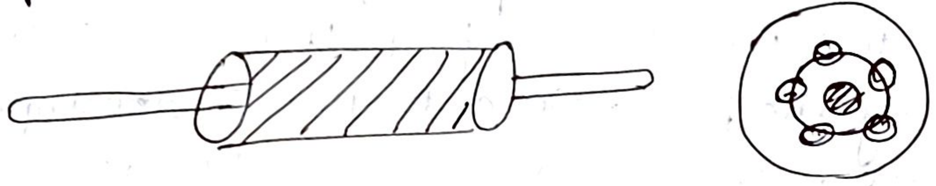
It is similar to that of AC generator or alternator having strator frame, strator core and stator winding.

(ii) Roter :-

In poly-phase induction motor, the rotor consⁿ is of 2 types (a) squirrel cage rotor
(b) slipring or phasewound rotor.

(a) squirrel cage rotor -

- It is a solid cylinder with slots or holes round the peri-ferri, the slots are little twisted which is known as skewed.
- Each slot contain single solid conductor lightly insulated. These conductors are permananty short circuited at both ends.

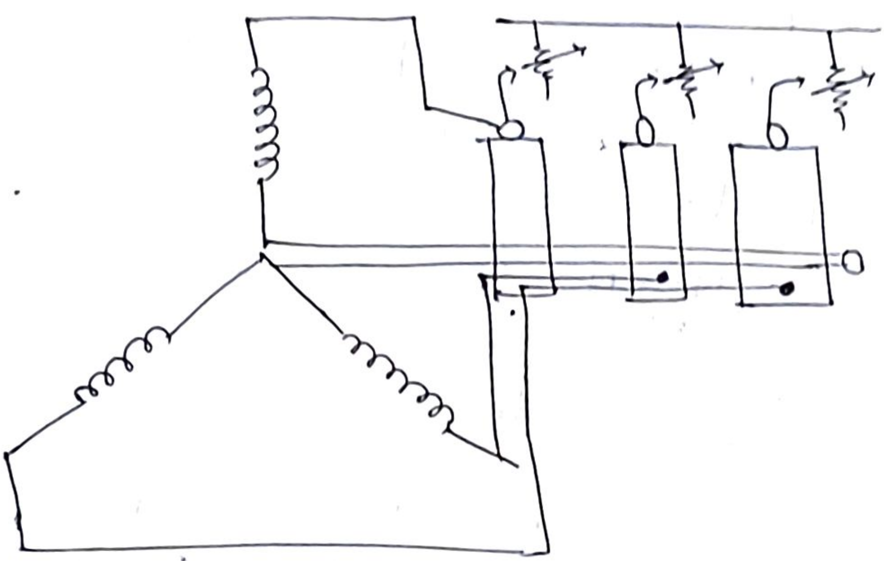


- No external impedence can be inserted to the rotor circuit and skewing is done for noiseless operation and prevent magnetic locking.

(b) slipring or phase wound rotor :-

- In this type rotor there is a regular 3 phase supply with proper size insulted conductor.

- This winding is always star connected
- The 3 open ends are connected to 3 slipring mounted on one side of the shaft.
- for the slipring connections are taken to the terminal box through brushes on the slip rings.
- these terminals are connected to one external star connected impedance (generally variable resistance). So the rotor is known as slipring or phase wound rotor.
- Acc. to the type of rotor, polyphase induction motors are named as squirrel phase inducⁿ motor or phase wound or slipring induction motor.



Dt - 20/12/24

→ Synchronous speed : (N_s)

$$N_s = \frac{120f}{P}$$

f → frequency

N_s → synchronous speed / stator speed

P → no. of pole.

→ **Slip (s) :-**

- In case of induction motor the rotor always run at below or less than the synchronous speed.
- The difference betn synchronous speed and the actual speed of the rotor is known as slip or relative speed of the motor. This is also known as absolute slip.
- This absolute slip when expressed as a fraction of synchronous speed, it is known as fractional ~~speed~~ slip.
- fractional slip when multiplied by 100, it gives %age slip.

  ⊙ slip speed = relative speed = $N_s - N$

  N_s = synchronous / stator speed.

  N = rotor speed.

  ⊙ fractional slip = $\frac{N_s - N}{N_s}$

  ⊙ % slip = $\frac{N_s - N}{N_s} \times 100$.

- Is an induction motor run with the rotor speed = stator speed or synchronous speed?

ans No, because when $N_s = N$ at that time, relative speed ($N_s - N = 0$) so at that time current will be zero, Hence Torque (τ) is equal to 0. so the motor can't be started.

(Note) → At starting or standstill condition slip = 1 (because at starting rotor speed = 0) $s = \frac{N_s - N}{N_s} = \frac{N_s - 0}{N_s} = 1$.

Relationship betⁿ frequency of rotor emf and frequency of stator emf :-

$$S = \frac{f_{r}}{f}$$

$$f_{r} = S \times f$$

f_{r} = frequency of the rotor emf
f = frequency of the stator emf.
S = slip.

Q. Calculate the synchronous speed, % slip, slip speed and slip of a 3 phase Induction motor excited by 50 Hz source. The rotor speed is 1440 RPM (N)

given, $f = 50$ Hz.
$N = 1440$ RPM.

$$N_s = \frac{120f}{P}$$

let $P = 2$, $N_s = \frac{120 \times 50}{2} = 3000$ RPM

i) $P = 4$, $N_s = \frac{120 \times 50}{4} = 1500$ RPM $N_s > N$

(as this synchronous slip is just above the rotor speed so the no. of pole $P = 4$ is suitable)

ii) $\% \text{ slip} = \frac{N_s - N}{N_s} \times 100$

$$= \frac{1500 - 1440}{1500} \times 100$$

$$= \frac{060}{1500} \times 100 = 4\%.$$

iii) slip speed $= N_s - N$
$= 1500 - 1400 = 60$ RPM.

(iv) $\text{slip} = \frac{N_s - N}{N_s} = \frac{1500 - 1440}{1500} = 0.04.$

152

⇒ The frequency of the emf in the stator of a 4 pole induction motor is 50 Hz and that in the rotor is 1.5 Hz. what is the slip and at what speed the motor is running.
↳ ~~synchronous~~ rotor (N)

given, $P = 4$

$f = 50 Hz$

$f_r = 1.5 Hz$

i) $slip (s) = \frac{f_r}{f} = \frac{1.5}{50} = 0.03$

ii) $N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$ RPM.

$s = \frac{N_s - N}{N_s}$

$0.3 = \frac{1500 - N}{1500} \Rightarrow N = 1455$ RPM.

⇒ A 3 phase, 4 pole, 50 Hz induction motor is running at ~~14500~~ 1455 ~~RM~~ RPM. find the slip and slip speed.

given ⇒ $P = 4$

⇒ $f = 50 Hz$

⇒ $N = 1455$ RPM

$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$ RPM

(i) slip speed $= N_s - N$

$= 1500 - 1455 = 45$ RPM

(ii) $slip (s) = \frac{N_s - N}{N_s} = \frac{1500 - 1455}{1500} = \frac{45}{1500}$

$= 0.03$

Q. A 3 phase 400 volt, 50 Hz supply is given to 3 phase Induction motor with 4 pole and runs at 1440 RPM. Determine the speed of the rotor flux, frequency of the rotor current & slip.

given, $f = 50\ Hz$.
$P = 4$ pole.
$N = 1440$ RPM.
$V = 400$ volt.

(i) $N_s = \frac{120 f}{P} = \frac{120 \times 50}{4} = 1500$ RPM.

(ii) $S = \frac{N_s - N}{N_s} = \frac{1500 - 1440}{1500} = 0.04$.

$S = \frac{f_r}{f} \Rightarrow f_r = S \times f$.
$f_r = 0.04 \times 50$
$= 2\ Hz$.

(A-12) A 4 pole, 3 phase induction motor operates from a supply whose frequency is 50 Hz. calculate
(i) the speed at which the magnetic field of stator is rotating.
(ii) the speed of the rotor when the slip is 0.04
(iii) The frequency of rotor current when slip is 0.03.
(iv) the frequency of rotor current at standstill.

ans. given, $P = 4$ pole.
$f = 50\ Hz$.

(i) $N_s = \frac{120 f}{P} = \frac{120 \times 50}{4} = 1500$ RPM.

(ii) $s = N_s - N / N_s$

~~$0.04 = 1500 - N$~~

~~$N = N_s - s$~~

~~$= 1500 - 0.04 = 1499.96$~~

$0.04 \times 1500 = N_s - N$

$60 = 1500 - N$

$N = 1500 - 60 = 1440$ RPM

(iii) $s = \frac{f_r}{f} \Rightarrow 0.03 = \frac{f_r}{50}$

$f_r = 50 \times 0.03$

$= 1.5$

(iv) at standstill, $s = 1$.

so, $s = \frac{f_r}{f} \Rightarrow f_r = s \times f$.

$= 50 \times 1$

$= 50$ Hz

——— x ———

3 Phase AC generator or Alternator :-

working principle.

- Alternator is a synchronous AC generator.
- The basic principle of operation is based on production of dynamically induced emf in the armature circuit by relative motion of the armature conductors in a uniform magnetic field.
- the relative motion of the conductor can be either rotating the ~~set~~ conductor in a stationary magnetic field or rotating the magnetic field within stationary conductors.

⇒ **Pitch factor :- (K_c or K_p)**

- It is defined as the ratio of coil voltage of a short ~~field~~ ~~co~~ pitched coil to coil voltage of a full pitched coil.

$$K_p = \cos\frac{\alpha}{2} \quad , \quad \beta = \frac{180^\circ}{n}$$

→ short pitch angle or chording angle.

- It is less than 1, where α = the phase angle betⁿ the induced emf in the two sides of the coil.

$$\beta = \frac{180^\circ}{n} \rightarrow n = \text{no. of slots per pole.}$$

→ **distribution factor :- (K_d)**

It is defined as the ratio of vector sum of coil side voltage of distributed winding to arithmatic sum of coil side voltage of concentrated winding.

$$K_d = \frac{\sin \frac{m\beta}{2}}{m \sin \frac{\beta}{2}}$$

m = no. of slots per pole per phase.
β = slot angle = $\frac{180°}{n}$
n = no. of slots per pole.

→ winding factor :-
- It is the product of pitch factor and distribution factor.

$$K_w = K_p \times K_d$$

Dt - 21/12/24

Q. A 6 pole AC generator is running and producing the frequency of 60 Hz. Calculate the revolution per min of the generator. If the frequency is reduced to 20 Hz, How many no. of poles will be required if the generator is to be run at the same speed.

ans given, P = 6 pole.
f = 60 Hz

(i) $N = \frac{120f}{P} = \frac{120 \times 60}{6} = 1200$ RPM.

Now, f = 20 Hz.

$N = \frac{120f'}{P'}$ ⇒ $1200 = \frac{120 \times 20}{P}$

⇒ $P = \frac{120 \times 20}{1200} = 2$.

$$P = 2$$

EMf eqⁿ of alternator (6 M) *

P = no. of pole.
ϕ = flux per pole.
Z_{ph} = No. of conductors connected in series per phase.
N = Speed of the rotor in RPM. (revolution per min)
T_{ph} = No. of turns per phase connected in series.
$= \frac{Z_{ph}}{2}$.
f = frequency of generated emf. $= \frac{PN}{120}$
$\Rightarrow PN = 120f$
E_0 = No load induced emf.

In one complete revolution of the rotor total flux cut by each conductor is $= P\phi$ wb.

Total time taken to complete one revolution $= \frac{1}{N}$ min $= \frac{60}{N}$ sec.

Avg rate of flux cut by each conductor

$$= \frac{\text{total flux cut}}{\text{total time taken}} = \frac{P\phi}{\frac{60}{N}} = \frac{P\phi N}{60}$$

but acc. to faraday's law of electromagnetic induction avg. rate of flux cut by the conductor is = avg induced emf.

so, avg induced emf per conductor $= \frac{P\phi N}{60}$ volt.

avg induced voltage per phase $= \frac{P\phi N \times Z_{ph}}{60}$ volt.

$\Rightarrow E_{RMS}$ = form factor × E_{avg}

$\Rightarrow E_{RMS} = E_0 = 1.1 \times E_{avg}$

$\Rightarrow E_0 = 1.1 \times \frac{P\phi Z_{ph} N}{60}$

$E_0 = \frac{1.11}{60} \times 120f \times \phi \times 2\,T_{ph}$

$= \frac{1.11 \times 120 \times 2}{60} \times f\,\phi\,T_{ph}$

$E_0 = 4.44\,f\,\phi\,T_{ph}$ → per phase value.

→ for a short pitch distributed winding.

$E_0 = 4.44\,K_w\,f\,\phi\,T_{ph}$

$E_{ph}/E_{op}/E_0 = 4.44\,(K_p \times K_d)\,f\,\phi\,T_{ph}$ volt per phase.

→ for a star connected 3 phase alternator no load terminal induced,

$$E_{0L} = \sqrt{3} \times E_{0P}$$

→ for maximum induced emf,

$K_p = 1$ $K_d = 1$

Q. Calculate the distribution factor for a 3 phase distributed single layer winding of the armature of an alternator. The alternator has 2 poles and a total of 18 slots

3-ϕ.

$P = 2$.

slot = 18

$M = \frac{\text{no. of slot per pole}}{\text{phase}} = \frac{18/2}{3} = 3$.

$\beta = \frac{180°}{n}$ → no of slot per pole.

$\beta = \frac{180}{9} = 20°$ $(n = \frac{18}{2} = 9)$

$$K_d = \frac{\sin \frac{M\beta}{2}}{M \sin \frac{\beta}{2}}$$

$= \frac{\sin \frac{3 \times 20}{2}}{3 \sin \frac{20}{2}} = \frac{\sin 30}{3 \sin 10} = 0.96$.

Q. An alternator has 9 slots per pole. The coil span is 8 slots, find the pitch factor for fundamental frequency.

9 slots per pole.
coil span = 8 slots.

$$K_p = \cos\frac{\alpha}{2}$$

$$\alpha = 180^\circ - \text{coil span}$$

$$\text{coil span} = \frac{180 \times \text{coil span in terms of slot}}{\text{no. of slots per pole}}$$

$\Rightarrow$ coil span $= \dfrac{180 \times 8}{9}$ (180 ÷ 9 = 20)

$= 160^\circ$

$\alpha = 180^\circ - 160^\circ$
$= 20^\circ$

$K_p = \cos\dfrac{\alpha}{2} = \cos\dfrac{20}{2} = \cos 10^\circ = 0.98$.

Q. A 4 pole alternator has an armature with 25 slots and 8 conductors per slot and rotates at 1500 RPM and flux per pole is 0.05 wb. Calculate the emf generated, if winding factor is 0.96 and all conductors are connected in series.

$P = 4$
slots $= 25$
conductor per slot $= 8$
$N = 1500$ RPM
$\phi = 0.05$ wb
$K_w = 0.96$

• $f = \dfrac{PN}{120}$
$= \dfrac{4 \times 1500}{120} = 50$ Hz

• Total cond. (Z_{ph})
$= 25 \times 5 = 200$.

• $T_{ph} = \dfrac{Z_{ph}}{2} = 100$.

$\Rightarrow E_0 = 4.44\, K_w\, f\, \phi\, T_{ph}$ V.
$= 4.44 \times 0.96 \times 50 \times 0.05 \times 100$.
$= 1065.6$ V.

wiring, grounding and Noise.

when a signal is generated from a transducer, it should be properly connected to the measurment system without disturbing its inherient property. these includes proper wiring, grounding and noise reduction in the signal.

(i) **Grounding** :- It is done by connecting the negative part of the signal to the ground.

- It provides safety from electric of shock by giving a low resistance path to the earth from the device in operation.
- Depending upon the soil resistivity, it is done by pipe, rod, plate earthing.

(ii) **Noise** :- It is an undesirable signals along with the signals to be measured.

- It is caused due to coupling of a noise source.

→ different coupling mechanism are

(i) conducting coupling
(ii) Inductive coupling.
(iii) capacitive coupling.

- Noise can be reduced by using filters, shielding or twisted pair of wire.

:) **Signal conditioning** :- It is the next step to noise reduction for effective measurement.

- It is done by amplification, filtering and isolation.
- filtering can be done by using active filter or passive filter.

:) **Residential wiring** :-

step-1 - Preparation of building plan to a suitable scale.

step-2 - Preparation of a chart for the devices to be connected.

step-3 - Calculation of total connected load.

step-4 - Calculation of sub-circuit per IE ratio.

step-5 - Preparation of wiring diagram.

step-6 - Selection of types of wiring.

step-7 - Preparation of item list.

:) **Commonly used items** :-

- service main
- energy meter
- Main switch.
- sub-main
- distribution board.
- miniature circuit breaker.
- fuse
- main conductor
- continuous earth conductor
- Grounding or earthing
- switch Board.
- light or fan point.
- conduit.

162 Types of wiring :

Batten wiring :-

i) - It uses wooden batten mounted on the wall
- this wiring is economical.
- It exposed over the surface.
- In this wiring repairing work is easy.

ii) clear wiring :-
- It uses wooden cleat mounted at regular intervals on the wall.
- It exposed to the surrounding.

(iii) Cashing / caping wiring :-
- It uses wooden or plastic channel with covering mounted on the wall.
- It is costly.
- Better outlook, than batten and cleat wiring.

(iv) conduit wiring :-
- It is of two types :-
(a) surface conduit wiring.
(b) Conceated conduit wiring.

(a) surface conduit wiring :-
- GI pipes mounted on the wall by this wiring
- similar to cashing or caping wiring.
- used for industrial wiring.

(b) concealed conduit wiring :-

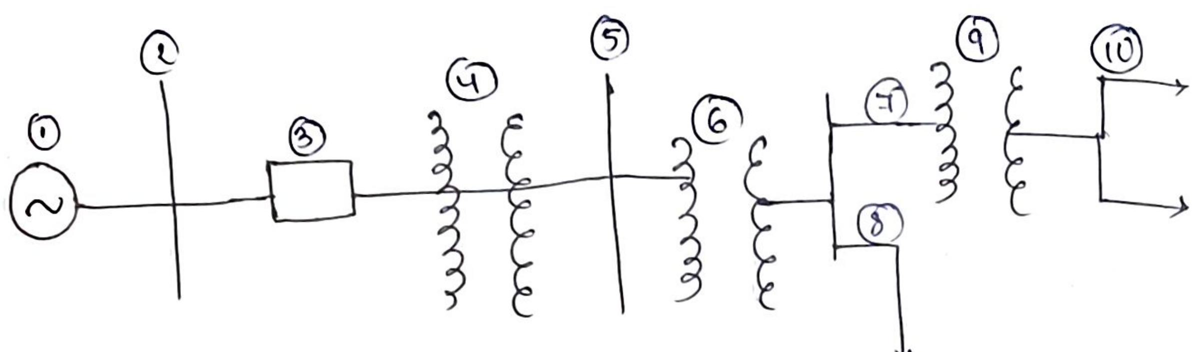
- conduit pipes are embedded inside the wall during construction of the house.
- It is costly.
- has a good out look.

⇒ **Distribution of AC Power :-**

Types of distribution system used for domestic supply

(i) Single phase two wire
(ii) Three phase four wire.
(iii) Three phase system is used for generator.

→ layout of transmission and distribution network :-



1) Alternator or generator (11 kV)
2) Generator bus
3) circuit breaker / makes
4) stepup transformer / generator transformers
   (33 kV (11×3), 66 kV (11×6), 132 kV (11×12)).
5) Station bus
6) step down transformer (down to 11 kV)
7) feeder
8) Bulk consumer
9) distribution transformer (local substation)

10 → 440 V for 3 phase
   → 230 V for 1 phase.

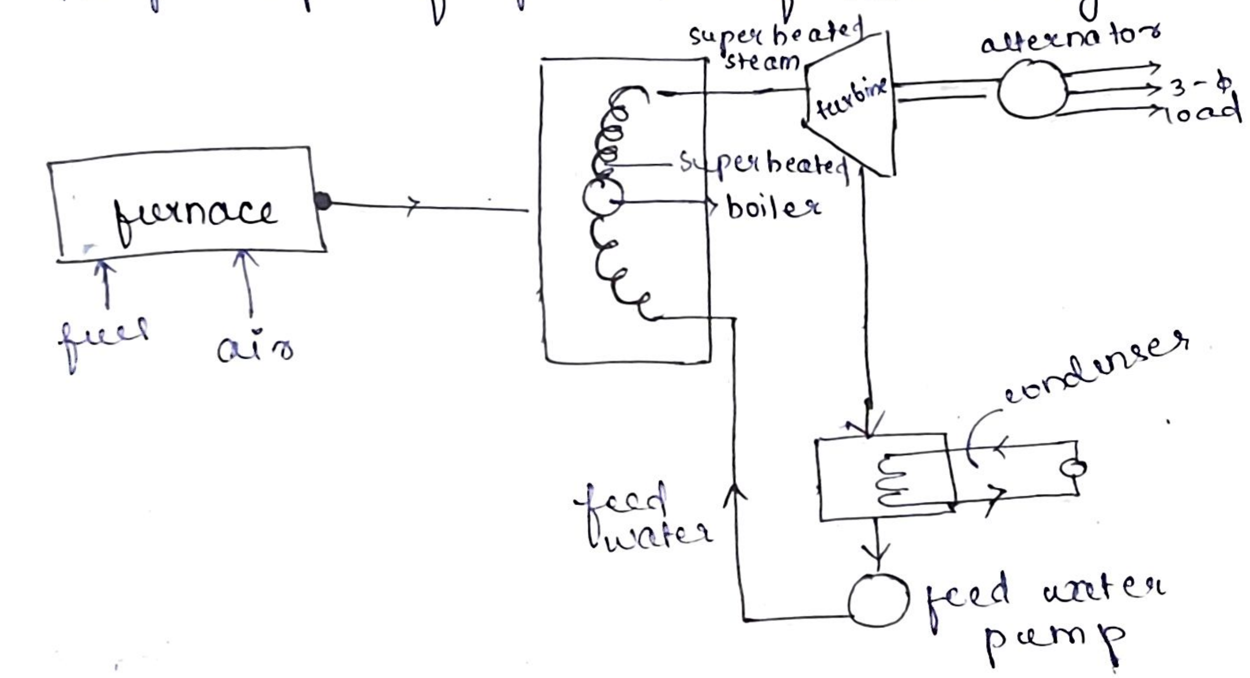
1(c) Generations of AC power.

The three different generating plants are-

(i) Thermal / steam power plant
(ii) Hydro / hydroelectric power plant
(iii) Nuclear power plant.

(i) Thermal Power plant:- It uses burning fossil fuels (coal) to get heat energy.

- This heat energy heats water to produce super heated steam.
- The superheated steam passes through the steam turbine and converted into kinetic energy (mechanical).
- This kinetic energy rotates the turbine shaft and mechanical energy is converted to electrical energy by the alternator.
- Thus in this case the prime mover is steam driver and the entire process is based on the principle of operation of rankine cycle.



⟩ Site selection :-

- The availabity of water (river / canal) should be nearest to the plant.
- Transportation facility should be better
- cost of land should be minimum.
- The plant should be near to the load center
- distence from the populated area as huge amount of smokes are coming out from this power plant.

advantages :-

- low initial cost.
- fuel used is cheap.
- It requires less space than hydroelectric power plants.

disadvantages :-

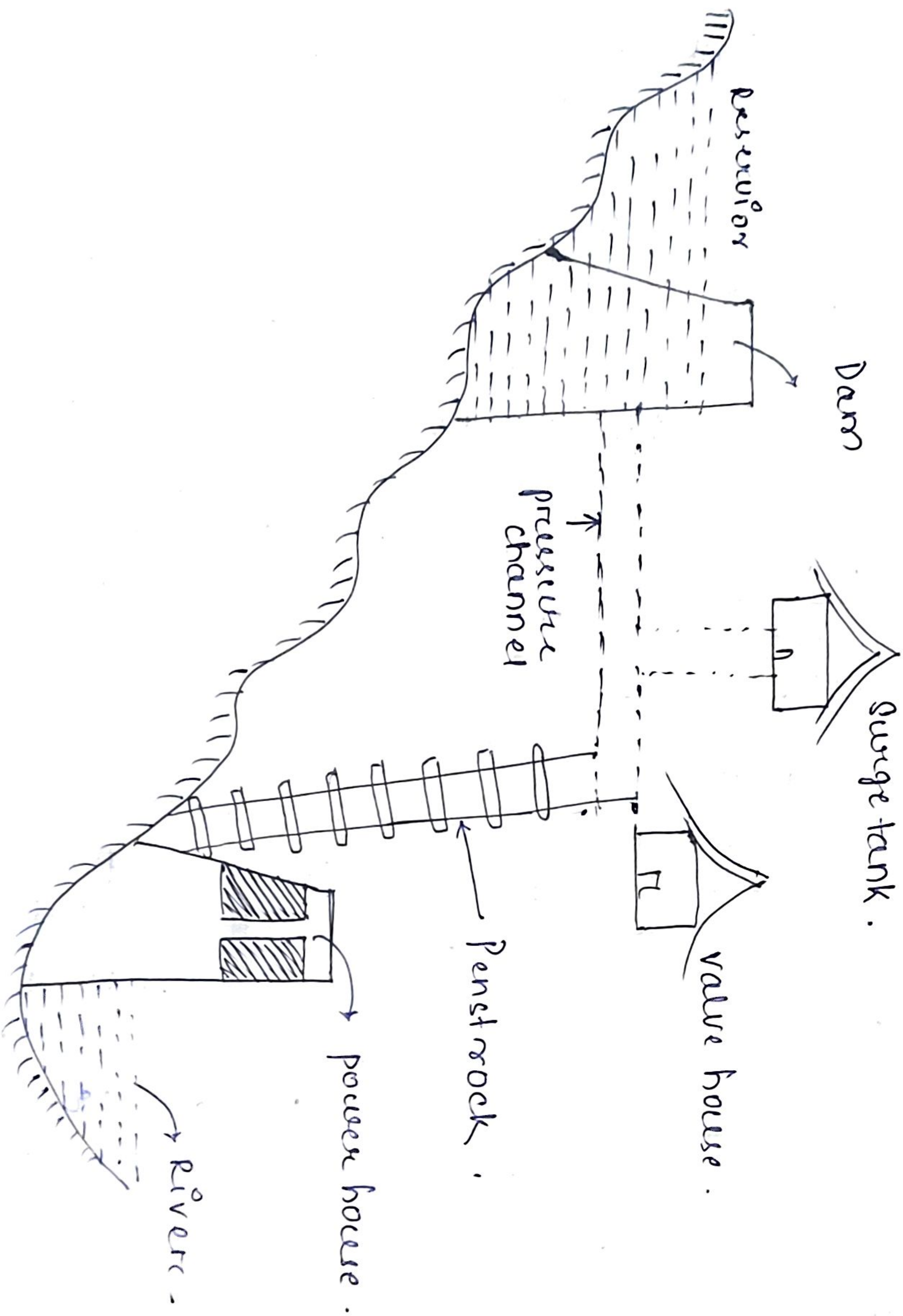
- It pollutes atmosphere due to smoke
- Running cost is higher than hydro-electric power plant.
- less efficiency (30-35 %)
- Maintance cost is high.

⇒ site selection for hydroelectric power plant.

→ Availability of water should be more as huge amount of water is required.
- To transportation of heavy machineries, rail an rate facility should be available.
- cost and type of the land should be low.
- there are a wide variation in water supply from a river or canal during the

166 year so storage of water should be necessary.

Hydroelectric power plant :-



Main components

(i) Dam/Reservoir :- It is a barrier which stores water.
- Dams are build of concrete.

(ii) Surge tank :- It is a secondary reservoir in form of an open vessel used to prevent irregularities of flow of water to the turbine.

(iii) Penstock :- These are open-closed conduit and are made of concrete or steel.

(iv) Water turbine :- These are used to convert flowing water mechanical energy.

(v) Alternator :- It converts the mechanical energy from the water turbine into electrical energy.

⇒ Working

- When the water from the reservoir is allowed to get released through pressure channel and it reaches to the value house.
- The value house control the amount of water flow to the turbine through the penstock
- Inside the power house, the water turbine converts the potential energy of water into kinetic energy that is in form of mechanical energy which acts as a prime mover for the alternator which converts it into electrical energy.

169 Advantages:-

- It requires no fuel as water is the generation of electrical energy.
- Running cost is very less.
- Simple in construction and requires less maintanance.
- Quite neat and clean.

Disadvantages:-

- High capital cost.
- Generation depends on avg rainfall around the year.
- High cost of transmission, as these plant is nearer to hilly area.

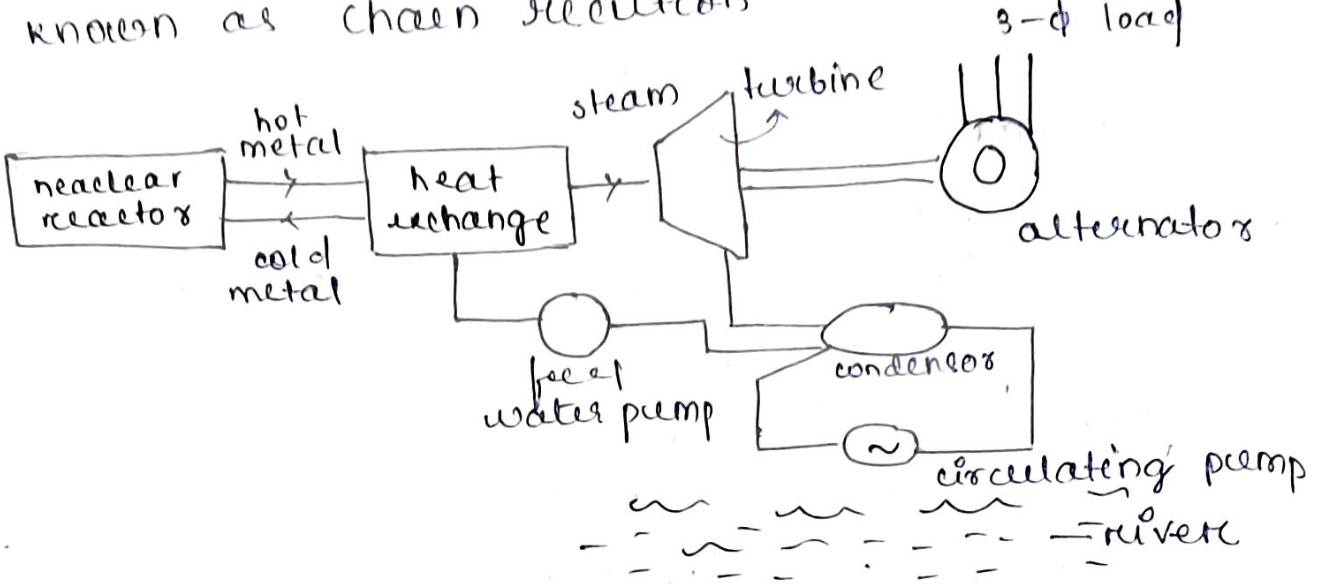
=) Nuclear Power Plant :-

Site selection :-

- Availabity of water should be better as huge amount of water is required
- disposal of waste from this power plant are radioactive, so to avoid health hazards, it must be kept in deep
- The plant should be distance far away from populated area
- Transportation facility should be adequate for transport of heavy machinery.

→ fission Reaction :-

When a Uranium U_{235}, atom is broken by a slow neutron, it will split into two or more fragments which is known as nuclear fission. This continuous process of nuclear fission is known as chain reaction.



Nuclear fuel :-

1) Uranium, U^{235}
2) plutonium, Pu^{239}
3) Thorium, Th^{232}

different components :-

1) Nuclear reactor :- Nuclear fuel U^{235} is subjected to nuclear fission inside it.

2) Heat exchanger :- The nuclear reactor gives up heat to the heat exchanger which is utilized to given steam to the turbines. and after giving of heat feed to the reactor.

3) Steam turbine :- the dry and super heated steam from the heat exchanger is fed to the steam turbine which convert the heat energy of steam to mechanical energy.

4) Alternator :- It is one type of generator which converts mech. energy to electrical energy.

Working Principle :-

- As discussed earlier, the chain reaction produces huge amount of heat inside the nuclear reactor and required a lot of control for this reaction. The heat of reactor is carried to the heat exchanger which also heats the water injected into this heat exchanger. And after the water gets converted into steam with ~~light~~ high temperature.
- The turbine converts heat into mechanical energy and this is converted into electrical energy by the alternator.

Advantages

- There is saving in fuel so transportation requires less space.
- Economical for producing electrical energy.

Dis-Advantages

- fuel is expensive and difficult to discover.
- Capital cost is high.
- experienced work man is required for plant.