Lecture Note on

Circuit and Network Theory

3rd Sem Electrical Engineering

Prepared by

Er Sachin kumar Satpathy

(Lecturer, Electrical dept)

B. I. T. Sambalpur

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(Fundamentals of Electrical Eng.)

* Introduction ⇒

⇒ Every elements in the surrounding are made up of sub atomic particles known as atoms.

⇒ So every materials are made up of infinite no. of atoms.

⇒ In an atom several sub atomic particles are found i.e. electrons and neucleus.

⇒ The electrons are revolving around the neucleus as planets are revolving around the sun, in a specific path known as orbit.

⇒ So, the electron possess specific energy while revolving around the neucleus.

⇒ Inside the neucleus we also found out sub-atomic particles like proton and neutron with some binding energy.

⇒ The electrons are made free by applying external energy.

⇒ Now the electrons are free from the rules of neucleus and moves to other near by atoms.

⇒ According to the scientist Rutherford, the electrons are -ve charge particles.

⇒ So, after free electrons from one atom neucleus moves towards neighbour atom.

⇒ The electron [illegible] discovered by J.J. Thomshon.

⇒ The atom which donate electrons to the other atoms is became +ve, known as +ve charge.

⇒ The atom which received electrons becomes -ve known as -ve charge.

⇒ So, +ve and -ve charge are atoms having deficient of electrons or access of electrons.

⇒ Loss of electrons of an atom +ve charge.

⇒ Gain of electrons of an atom -ve charge.

⇒ The energy which are able to released electrons from atoms are heat energy, Thermal energy, magnetic energy, chemical energy etc.

Current (I) ⇒

⇒ The current may be defined as flow of charge (electrons) per unit time.

⇒ Unit - Ampere.

⇒ charge unit → coloumb.

⇒ Current = $\frac{\text{Charge}}{\text{Time}}$

$$\boxed{I = \frac{q}{t}}$$

$\Rightarrow 1A = \frac{1C}{1s} = 1C/sec.$

'1A' is defined as the 1 coloumb of charge that displace or flow with 1 second.

$1KA = 10^3 A$
$1MA = 10^6 A$] Higher unit

Lower unit →

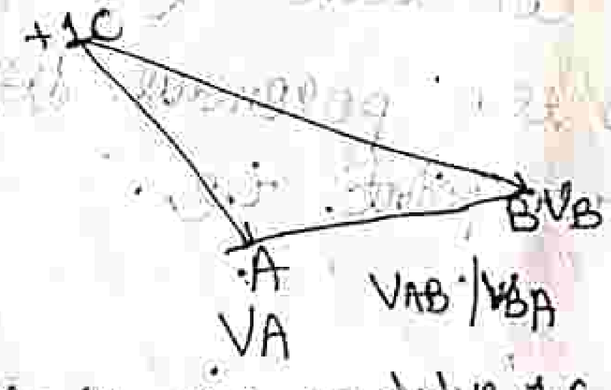
$1mA = 10^{-3} A$
$1\mu A = 10^{-6} A$

* potential ⇒ Dt: 08-08-20

⇒ It is the workdone to bring a unit +ve charge from infinity to a particular point.

⇒ It is denoted by 'V'.

⇒ Let; VA and VB are two potential.



⇒ Similarly the positive 1C charge moves to 'B' point and potential at 'B' point is 'VB'.

* Potential difference or voltage ⇒

⇒ It is defined as the difference of potential of two certain points.

$$V_{AB} = V_A - V_B$$

$$V_{BA} = V_B - V_A$$

⇒ Unit is 'Volt'.

⇒ Higher unit

$$1KV = 10^3 V$$

$$1MV = 10^6 V$$

⇒ Lower unit

$$1mV = 10^{-3} V$$

$$1\mu V = 10^{-6} V$$

⇒ Ohm's Law ⇒

⇒ At constant temperature the current flowing the conductor is directly proportional to the potential difference between two point. i.e.

$V \propto I$

⇒ $\boxed{V = IR}$

R = Resistance of conductors.

* Resistance (R)

⇒ It is defined as the property of materials which opposes the flow of charge ~~which~~ within certain potential difference.

⇒ Resistance may be defined as the rate of flow of 1A of current within the potential difference of 1V.

⇒ Unit → Ohm (Ω)

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

$$\Rightarrow \boxed{1\Omega = \frac{1V}{1A}}$$

⇒ Higher units

$$1M\Omega = 10^{6}\Omega$$

$$1K\Omega = 10^{3}\Omega$$

⇒ Lower units

$$1m\Omega = 10^{-3}\Omega$$

$$1\mu\Omega = 10^{-6}\Omega$$

Dt:-> 10.08.2020

Laws of Resistance :->

=> It is a property of a material which oppose flow of current or flow of charge. The material which obey this property is known as resistance.

=> The resistance seen in a material is directly proportional to the length of the material and inversely proportional to the cross-sectional area.

$R \propto l$ (Length)

$R \propto \frac{1}{a}$ (Crossectional Area)

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

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

ρ is equal the proportionality constant. (Respectively)

$\Rightarrow \rho = \frac{Ra}{l} = \frac{\Omega \times cm^2}{cm} = \boxed{\Omega\,cm}$

* **Resistance & Temperature relationship :**

Let R_0 = Resistance of material at 0°C.

R_t = Resistance of material at t°C.

$\boxed{R_t = R_0(1+\alpha t)}$! coefficient resistance

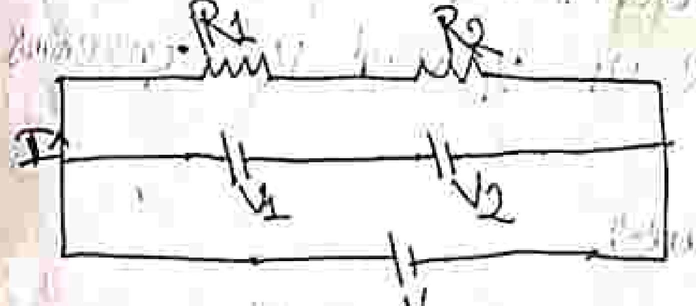
$\therefore \boxed{R_o > R_e}$

⇒ ~~If temperature~~

* **Resistance in series ⇒**

⇒ If one or more resistances are connected end to end position, then the connection is known as series connection.

⇒



⇒ Here, R_1 and R_2 are two resistances are connected in series across 'V' volt.

⇒ The current flow is 'I' and the voltage 'V' divided across 'R_1' and 'R_2' in 'V_1' and 'V_2'.

⇒ In series connection voltage should be divided but current flow is same.

so; $V = V_1 + V_2$

⇒ According to Ohm's law,

$V = IR_{se}$, $V_1 = I \times R_1$, $V_2 = I \times R_2$

where, R_{se} = Total series resistances.

Putting the above value,

$$V = V_1 + V_2$$

$$\Rightarrow IR_{se} = IR_1 + IR_2$$

Where; R_{se} = Total series Resistances.

$$\Rightarrow \cancel{I} R_{se} = \cancel{I}(R_1+R_2)$$

$$\Rightarrow \boxed{R_{se} = R_1+R_2}$$

* Voltage Division Rule:⇒

⇒ In voltage division rule we have to findout value of V_1 and V_2 in terms of V.

⇒ We know that;

$$V = I R_{se}$$

$$\Rightarrow V = I(R_1+R_2)$$

$$\Rightarrow \boxed{I = \frac{V}{R_1+R_2}}$$

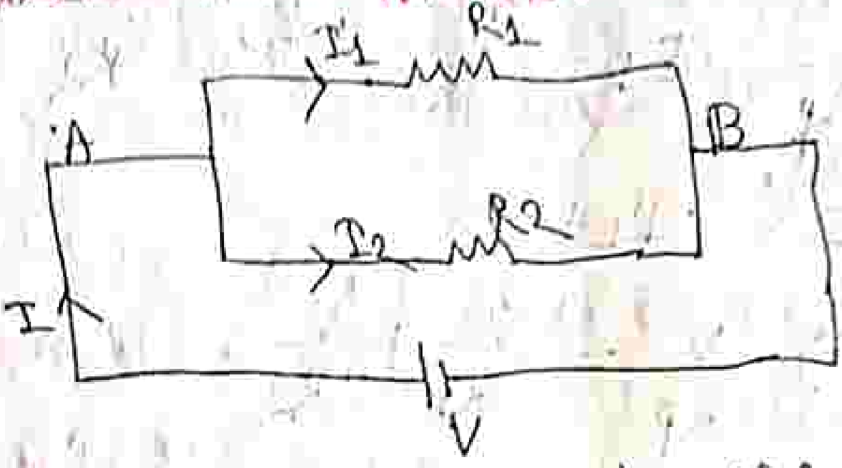
⇒ Again, we know that

$$V_1 = I R_1$$

$$\Rightarrow \boxed{V_1 = \frac{V}{R_1+R_2} \times R_1}$$

⇒ Similarly, $\boxed{V_2 = \frac{V}{R_1+R_2} \times R_2}$

Resistance in parallel:-



⇒ In parallel connection, the similar ends of resistances are groups in two distinct points and voltage is apply across it, this types of connection is known as parallel connection.

⇒ In this circuit diagram 'R1' and 'R2' are two resistances are connected in parallel across 'A' and 'B'. And the voltage 'V' is apply across it.

⇒ So, voltage 'V' appears 'R1' and 'R2' whereas the current taking by 'R1' and 'R2' are, 'I1' and 'I2' and the total current is 'I'.

⇒ In parallel connections, voltage across each resistances are same, whereas current is divided.

⇒ According to ohm's law;

$$I = \frac{V}{R_p}, \quad I_1 = \frac{V}{R_1}, \quad I_2 = \frac{V}{R_2}$$

$$\therefore \quad I = I_1 + I_2$$

$$\Rightarrow \frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2}$$

$$\Rightarrow \frac{\cancel{V}}{R_p} = \cancel{V}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{R_p} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\Rightarrow \cancel{\frac{1}{R_p} = \frac{R_1 R_2}{R_1 + R_2}}$$

$$\Rightarrow \frac{1}{R_p} = \frac{R_1 + R_2}{R_1 R_2}$$

$$\Rightarrow \boxed{R_p = \frac{R_1 R_2}{R_1 + R_2}}$$

∴ Where R_p = Total parallel resistance.

* Current Division Rules :-

⇒ In parallel circuit ~~...~~ we know that voltage across each resistances are same but current is divided.

⇒ so; we have to find out in terms of 'I_1' and 'I_2'.

$$\Rightarrow V = IR_p$$

$$\Rightarrow I = \frac{V}{R_p}$$

$$\therefore R_p = \frac{R_1R_2}{R_1+R_2}$$

$$I_1 = \frac{V}{R_1} = \frac{IR_p}{R_1}$$

$$\Rightarrow I_1 = \frac{I}{R_1} \times \frac{R_1R_2}{R_1+R_2}$$

$$\Rightarrow \boxed{I_1 = \frac{IR_2}{R_1+R_2}}$$

$\therefore$ Similarly

$$\boxed{I_2 = \frac{IR_1}{R_1+R_2}}$$

Dt:⇒ 13.08.2020

Faraday's Law ⇒

⇒ Faraday also known as for father of electricity.

1st Law ⇒ When there is change in position either magnet or conductor then an emf induced in the conductor.

2nd Law ⇒ It gives the magnitude of induced emf.

⇒ According to Faraday the emf ~~induced~~ induced is directly proportional to the change of flux. And inversely proportional to the change of time i.e

$\therefore\ e \propto \phi_2 - \phi_1$

where
ϕ_1 - Flux of time t_1
ϕ_2 - Flux of time t_2

$\Rightarrow e \propto \frac{1}{t_2 - t_1}$

$\Rightarrow e \propto \frac{\phi_2 - \phi_1}{t_2 - t_1}$

$\Rightarrow e \propto \frac{d\phi}{dt}$ (rate of change of flux w.r.t. time)

$\Rightarrow \boxed{e = \frac{N d\phi}{dt}}$ (N = No. of turns of the conductor)

* Lenz's law ⇒

⇒ Faraday predict only about induced emf but does not predict about direction of induced emf which can be later predicted by Lenz.

⇒ Statement ⇒ According to the Lenz, the direction of induced emf is such that it opposes the very cause by which it is produced.

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

* Fleming's Right Hand Rule ⇒

⇒ The three fingers of right hand ~~th~~ thumb, fore finger, middle finger are stretched in such a way that they are mutually perpendicular to each others such that the thumb represents relative motion of the conductor, fore finger represents the direction of magnetic field and the middle finger represents ~~direction~~ the direction of flow of current.

⇒ This principle is used in dc generator.

* Fleming's Left Hand Rule ⇒

⇒ The three fingers of left hand are stretched in such a way that they are mutually perpendicular to each other. If middle finger represents the flow of current in conductor, fore finger represents the direction of magnetic field then the thumb represents the motion of the conductor.

⇒ This law is applicable for DC motor.

* Inductance ⇒

⇒ It is the property of a material which does not allow sudden change of current.

⇒ It is denoted by letter 'L' or 'l'.

⇒ Unit is Henery.

⇒ It is wire wound having several numbers of turns. The function of inductor is to store energy (electrical energy).

⇒ Energy stored by inductor ⇒ $E = \frac{1}{2} LI^2$

where, I = current flow through the conductor, which obeys this is known as inductor.

L = Inductance of Inductor.

E = Energy

* Capacitance :⇒

⇒ It is the property of a material which does not allow sudden change of voltage.

⇒ It is denoted by 'C' or 'c'.

⇒ Unit is 'Farad'.

⇒ The material which obeys this property is known as capacitor. It about stored energy in capacitor. $E = \frac{1}{2} CV^2$

where; E = Energy

C = capacitance of the capacitor

V = Voltage

⇒ The charge stored in capacitor when voltage is applied so, charge stored by the capacitor is directly proportional to voltage.

i.e. $Q \propto V$

$\Rightarrow \boxed{Q = CV}$

Dt:- 20.08.2020

* Parameter ⇒ R-L-C

⇒ The various circuit elements of an electric circuit are called its parameter.

* Linear circuit ⇒ The circuit which have linear element whose value does not change whatever the current or voltage may be.

* Non-Linear Circuit ⇒

⇒ The circuit which have ~~[illegible]~~ element that change according to current or voltage are known as non-linear circuit.

* Bi-lateral Circuit ⇒

⇒ It is a circuit whose properties or charac-ristics are the same in either directio.

Ex- Transmission line.

* Uni-lateral Circuit ⇒

⇒ It is a circuit whose properties or charac-eristics change with the direction of operation.

* Active Network (CKT) ⇒

⇒ The network in which one or more sources are present is known as active network.

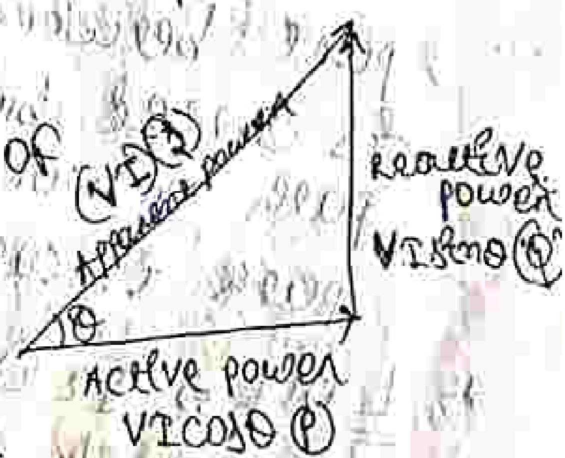
* Passive Network ⇒

⇒ In this types of network no emf sources are present.

* Power (P) :→ The rate of doing work, is called power.
⇒ It's unit is watt, Kilowatt, mega-watt.
⇒ symbol is 'P'.
⇒ $\boxed{P = VI}$, $\boxed{P = I^2R}$, $\boxed{P = \frac{V^2}{R}}$

→ There are three types of power; they are :-
1. Active power or True power or Real power.
2. Reactive power
3. Apparent power.

⇒ power triangle is a right angle triangle which represents the relationships between active, reactive and apparent power.



(a) Active power :→
⇒ Active power is a product of voltage, current and power factor.
⇒ VI cos θ , symbol is 'P'.
⇒ Unit is watt, KW, MW.

(b) Reactive power :→
⇒ The power which is consumed in reactance of the circuits.
⇒ VI sin θ , symbol is (Q).
⇒ Unit is VAR, KVAR, MVAR (∵ VAR = Volt Ampere ~~reactive~~ Reactive)

© Apparent power ⇒

⇒ It is a product of voltage and current taken by the load.

⇒ VI, symbol is S.

⇒ unit is VA, KVA, MVA.

Dt-24.08.2020

* **Node** ⇒

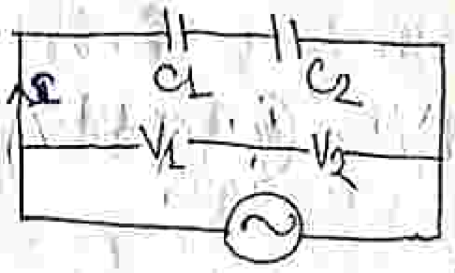
⇒ It is a junction in a circuit where two or more circuit elements are connected together that is called node point.

* **Branch** ⇒ It is a connecting link or part between any two node points that is called branch, that branch may one path or more than one path that one path is called branch.

* **Loop** ⇒ It is a closed path in a circuit in which no elements of node point is encountered.

* **mesh** ⇒ mesh is a loop in which no other loop is encountered.

* Capacitors are in series ⇒

⇒ 

⇒ In series connection current flow is same or voltage is divided.

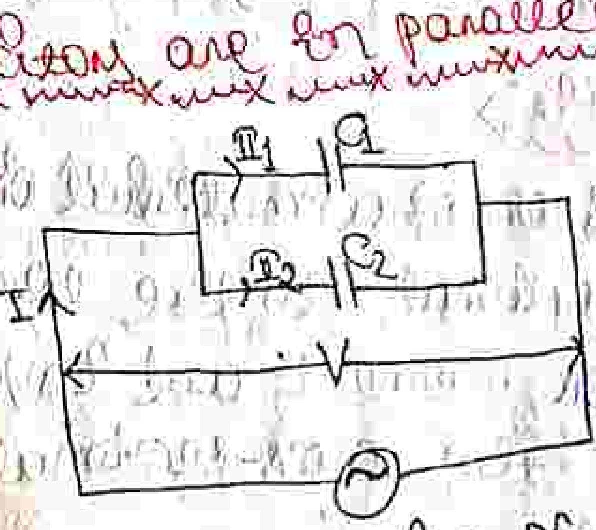
$$V = V_1 + V_2$$

$$\Rightarrow \frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\Rightarrow \boxed{C = \frac{C_1 C_2}{C_1 + C_2}}$$

* Capacitors are in parallel ⇒

⇒ 

⇒ In parallel connection of capacitor voltage flow is same or current is divided.

$I = I_1 + I_2$

$\Rightarrow Q = Q_1 + Q_2$

$\Rightarrow CV = C_1V + C_2V \quad (\because Q = CV)$

$\Rightarrow \boxed{C = C_1 + C_2}$

Dt:- 27.08.2020

* **Resistance:-**

⇒ It is defined as the property of materials which opposes the flow of current within certain potential difference.

* **Resistor:-** It is the material or elements which obey the resistance property.

⇒ Denoted by → R or r.

⇒ Unit → Ohm Ω

* **Laws of Resistance:-**

⇒ The resistance seen of a material or element is directly proportional to the length of the material or element and inversely proportional to the cross-sectional area of the element.

⇒ $R \propto l$ (l is the length of the element or material)

$\Rightarrow R \propto \frac{1}{a}$

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

where, "ρ" is known as proportionality constant or resistivity or specific resistance of the materials.

so, $\boxed{\rho = \frac{R \times a}{l}}$

$\Rightarrow$ unit, ohm metre

$\Rightarrow$ ohm.cm.

* Temperature co-efficient of the resistance :- $\Rightarrow$

$\Rightarrow$ The resistance of a material at a certain temperature is directly proportional to the change of temperature and also proportional to the initial resistance.

so, $\Delta R \propto R_0$

$\Rightarrow \Delta R \propto t_2 - t_1$

$\Rightarrow \Delta R \propto R_0 (t_2 - t_1)$

$\Rightarrow \Delta R = \alpha R_0 (t_2 - t_1)$

where, R_0 = Initial value of resistance of the materials.

ΔR = Change of Resistance

t_1 = Initial Temperature.

t_2 = Final Temperature

α = Proportionality constant

$\Delta t = (t_2 - t_1)$ = change of Temperature

R_t = Resistance of the material at increasing or decreasing temperature.

So, $R_t = R_0 + \Delta R$

$\Rightarrow R_t = R_0 + \alpha R_0 (t_2 - t_1)$

$\Rightarrow R_t = R_0 + \alpha R_0 \Delta t$

$\Rightarrow R_t = R_0 (1 + \alpha \Delta t)$

* Resistance are in series :-

$\Rightarrow$ If the terminal ends of resistances are connected at various distinct points then the connection form is known as series connection.

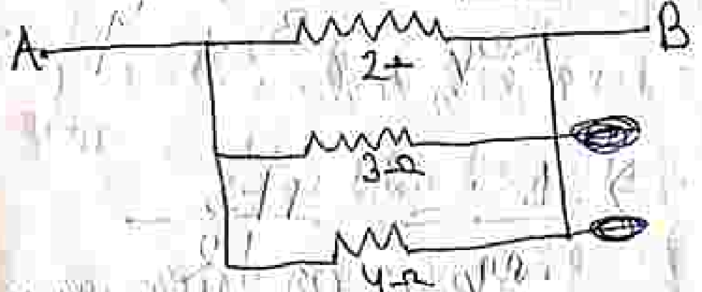
Here, 'R1' and 'R2' are connect in series across a voltage of 'V' volt.

Q1) Find the equivalent resistance between the terminal A and B ?

Soln.

$\therefore R_{eq} = R_1 + R_2 + R_3 = 2 + 3 + 4 = 9\Omega$

Q2)



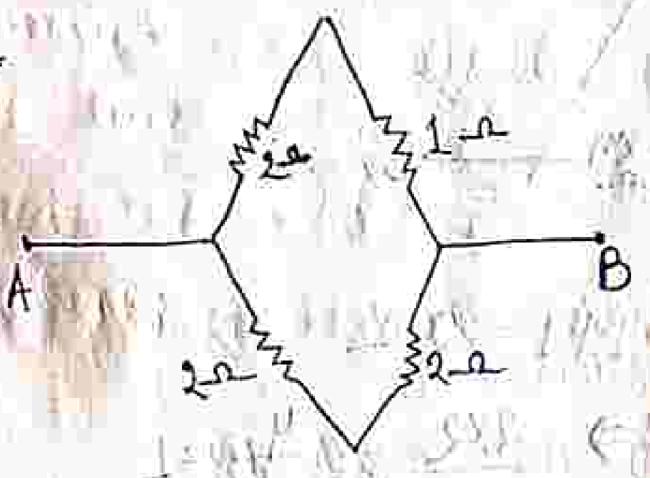
$\therefore R_{eq}$ for parallel $\Rightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$= \frac{1}{2} + \frac{1}{3} + \frac{1}{4}$

$= \frac{13}{12}$

$\boxed{\therefore R_{eq} = \frac{12}{13}\Omega}$

Q3)



Dt:29.08.2020

* Kirchoff's Law:⇒

(1) KCL (Kirchoff's current Law) or (Junction

⇒ In any electrical network, the algebraic sum of the current meeting at a point or (junction) is zero.

⇒ Incoming currents are taken as +ve and the outgoing currents are taken as -ve.

⇒ $I_1 + (-I_2) + (-I_3) + (I_4) + (-I_5) = 0$

⇒ $I_1 + I_4 - I_2 - I_3 - I_5 = 0$

⇒ $\boxed{I_1 + I_4 = I_2 + I_3 + I_5}$

⇒ Hence; Total incoming current = Total outgoing current.

⇒ From KCL; it is confirmed that total incoming current to the node is equal to the total outgoing current from node.

(2) KVL ⇒ [Kirchoff's voltage Law] (or Loop or mesh)

⇒ Statement ⇒ The algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network, plus the algebraic sum of the emfs. in that path is zero.

⇒ $\boxed{\Sigma IR + \Sigma e.m.f. = 0}$

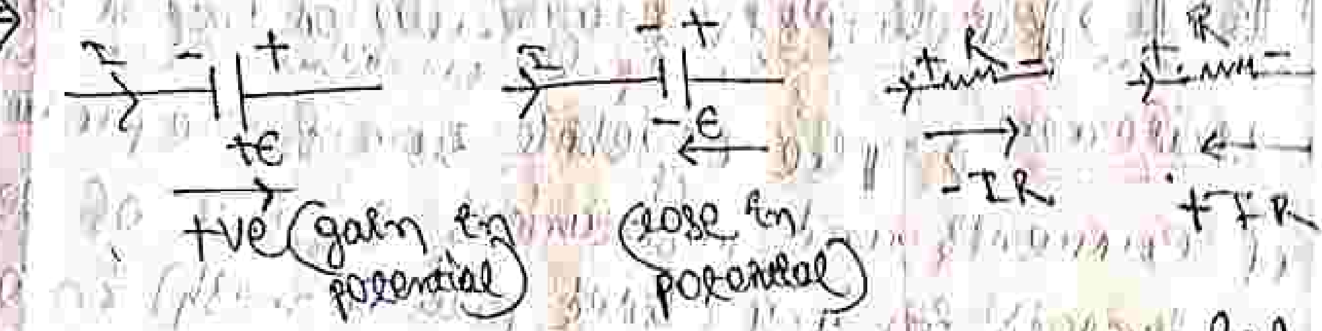
⇒ Step(1) ⇒ we have to considered the path in which we have to follow (Always in clockwise direction).

⇒ Step(2) ⇒ In this step we have to mentioned the current direction in each element and current sources.

⇒ Step(3) ⇒ Before applying KVL we must considered a direction in which we moves and show the element.

⇒ Step(4) ⇒ The direction must be left to right.

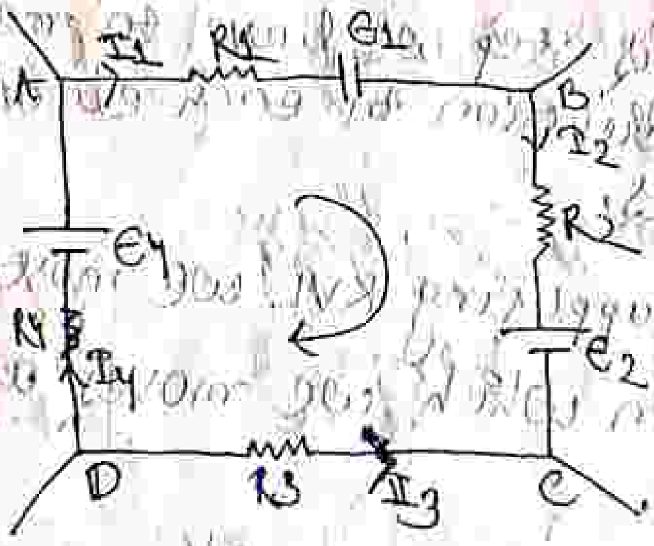
⇒ Step(5) ⇒ ~~The direction must be~~ During movement, there are 4 condition are:-

⇒ 

⇒ The algebraic sum of all the potential meeting across a close circuit or close loop is equal to zero.

$$\boxed{\Sigma V - \Sigma IR = 0}$$

⇒ Solve by KVL



(i) ABCDA is closed circuit so KVL is applied to the circuit.

(ii) We should now consider the path that we follow the path is always clockwise i.e. ABCDA.

so; $\Sigma E + \Sigma IR = 0$

$\Rightarrow -I_1R_1 - E_1 - I_2R_2 - E_2 + I_3R_3 - I_4R_4 + E_4 = 0$

$\Rightarrow -(I_1R_1 + E_1 + I_2R_2 + E_2 - I_3R_3 + I_4R_4 - E_4) = 0$

$\Rightarrow (E_1 + E_2 - E_4) + (I_1R_1 + I_2R_2 - I_3R_3 + I_4R_4) = 0$

New chapter (Superposition Theorem) Dt. 30.9.20

* Superposition Theorem :-

→ Statement :- In a linear, bilateral, active network containing more than one source, the current flowing through any circuit elements or resistance is determined by considering individual source one at a time, while other sources get ignore leaving behind its internal resistances.

* Steps

(1) To determined current across R_2 by superposition theorem.

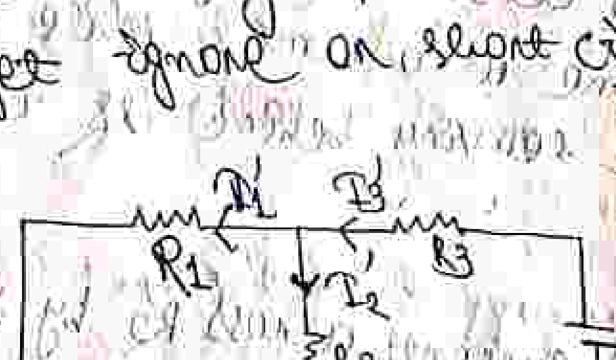
Step (1) considering V_1 source at that time V_2 source get ignore i.e V_2 source get short circuit.

$$I_1 = \frac{V_1}{Req(1)}, \quad Req(1) = (R_2 \| R_3) + R_1$$

∴ So, I_2 (According to current division rule).

$$I_2 = \frac{I_1 \times R_3}{R_2 + R_3}$$ (Direction up → Down)

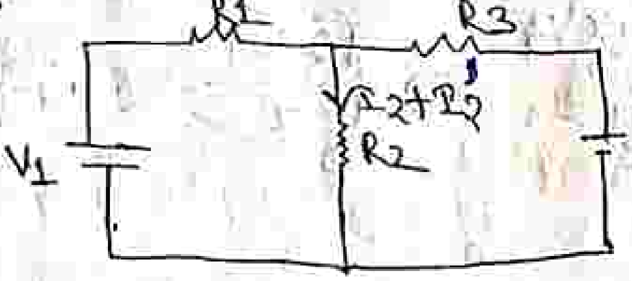
Step (2): considering V_2 source at that time V_1 get ignore or short circuited.



$$I_3' = \frac{V_2}{Req(2)}, \quad Req(2) = R_3 + (R_1 \| R_2)$$

$$I_2' = \frac{I_3' \times R_1}{R_1 + R_2}$$ (Direction is up → Down)

Step ③:-



I_2 (Total) $= I_2 + I_2'$ (as both the direction are same).

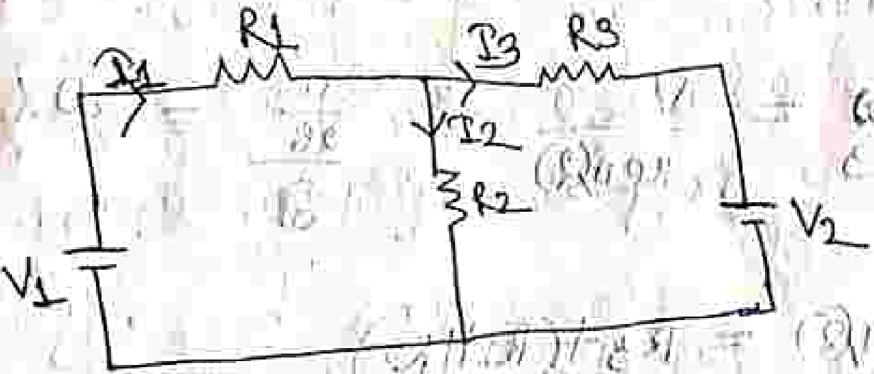
Q→01

$V_1 = 10V$, $V_2 = 20V$

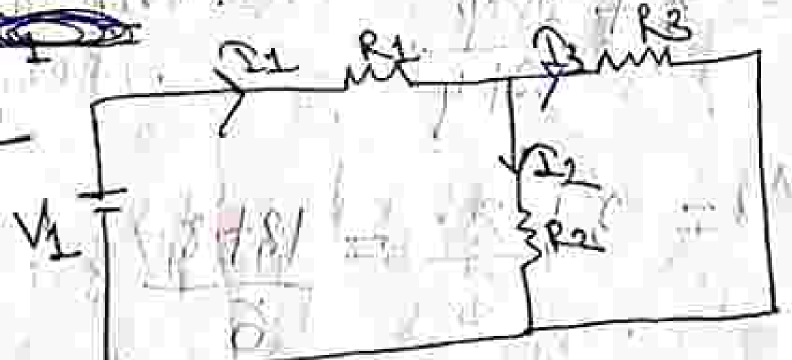
$R_1 = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 3\Omega$

Determine the current across I_2''?

Soln.



Step ①



$I_1 = \frac{V_1}{R_{eq(1)}} = \frac{10}{\frac{26}{7}} = \cancel{10} \times \frac{7}{\cancel{26}} = \frac{35}{13} A$

$R_{eq(1)} = (R_2 \| R_3) + R_1$

$= \frac{4 \times 3}{4+3} + 2 = \frac{12}{7} + 2 = \frac{26}{7}\Omega$

$$I_2 = \frac{\frac{3\cancel{8}^{5}}{13} \times 3}{\cancel{7}}$$

$$= \frac{15}{13}\ A$$

Step (2)

$$I_3' = \frac{V_2}{R_{eq(2)}} = \frac{20}{\frac{26}{6}} = 20 \times \frac{6}{26} = \frac{60}{13}$$

$$R_{eq(2)} = R_3 + (R_1 \parallel R_2)$$

$$= 3 + \frac{2 \times 4}{2+4}$$

$$= 3 + \frac{8}{6} = \frac{18+8}{6}$$

$$= \frac{26}{6}\ \Omega$$

$$I_2' = \frac{\frac{60}{13} \times 2}{2+4} = \frac{\frac{60 \times 2}{13}}{6} = \frac{20}{13}\ A$$

Step(3)

$\therefore I_2(\text{Total}) = I_2 + I_2' = \frac{15}{13} + \frac{20}{13} = \frac{35}{13}$ A. Ans

Dt. 07.09.2020

* Crammer's Rule ⇒

⇒ For a complicated circuit having more than one close loop a number of KVL equation obtained where we found a number of currents which are to be determine. So, where a number of unknown currents having a number of KVL equation to solve or find out current we use crammers rule. i.e.

$$a_{11}x + b_{12}y + c_{13}z = d_1$$

$$a_{21}x + b_{22}y + c_{23}z = d_2$$

$$a_{31}x + b_{32}y + c_{33}z = d_3$$

⇒ By representing in matrix form of the above equation.

we have;

$$\begin{bmatrix} a_{11} & b_{12} & c_{13} \\ a_{21} & b_{22} & c_{23} \\ a_{31} & b_{32} & c_{33} \end{bmatrix} = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \cdot \begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix}$$

⇒ For solving above matrix in cramer's rule we have to find out $\Delta, \Delta_1, \Delta_2$ & Δ_3, where;

$$\Rightarrow \Delta = \begin{vmatrix} a_{11} & b_{12} & c_{13} \\ a_{21} & b_{22} & c_{23} \\ a_{31} & b_{32} & c_{33} \end{vmatrix}$$

$$\Rightarrow \Delta_1 = \begin{vmatrix} d_1 & b_{12} & c_{13} \\ d_2 & b_{22} & c_{23} \\ d_3 & b_{32} & c_{33} \end{vmatrix}$$

$$\Rightarrow \Delta_2 = \begin{vmatrix} a_{11} & d_1 & c_{13} \\ a_{21} & d_2 & c_{23} \\ a_{31} & d_3 & c_{33} \end{vmatrix}$$

$$\Rightarrow \Delta_3 = \begin{vmatrix} a_{11} & b_{12} & d_1 \\ a_{21} & b_{22} & d_2 \\ a_{31} & b_{32} & d_3 \end{vmatrix}$$

Here

$$x = \frac{\Delta_1}{\Delta}$$

$$y = \frac{\Delta_2}{\Delta}$$

$$z = \frac{\Delta_3}{\Delta}$$

Q#1

$$3x + 2y + 7z = 4 \longrightarrow (1)$$

$$4x + 3y + 2z = 5 \longrightarrow (2)$$

$$3x + 5y + 3z = 7 \longrightarrow (3)$$

Ans

$$\Delta = \begin{vmatrix} 3 & 2 & 7 \\ 4 & 3 & 2 \\ 3 & 5 & 3 \end{vmatrix} = 3(9-10) - 2(12-6) + 7(20-9)$$

$$= -3 - 12 + 77$$

$$= 62$$

$$\Delta_1 = \begin{vmatrix} 4 & 2 & 7 \\ 5 & 3 & 2 \\ 7 & 5 & 3 \end{vmatrix} = 4(9-10) - 2(15-14) + 7(25-21)$$

$$= -4 - 2 + 28 = 22$$

$$\Delta_2 = \begin{vmatrix} 3 & 4 & 7 \\ 4 & 5 & 2 \\ 3 & 7 & 3 \end{vmatrix} = 3(15-14) - 4(12-6) + 7(28-15)$$

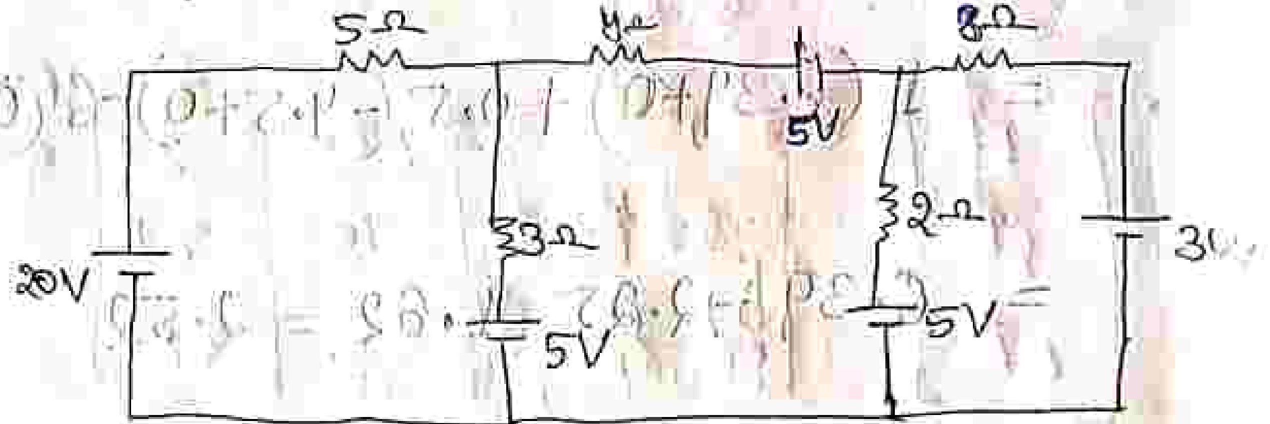
$$= 3 - 24 + 91 = 70$$

Dt:- 19.09.2020

*Imp

Mesh analysis:-

Q-1) Determine the current supplied by each battery in the circuit.

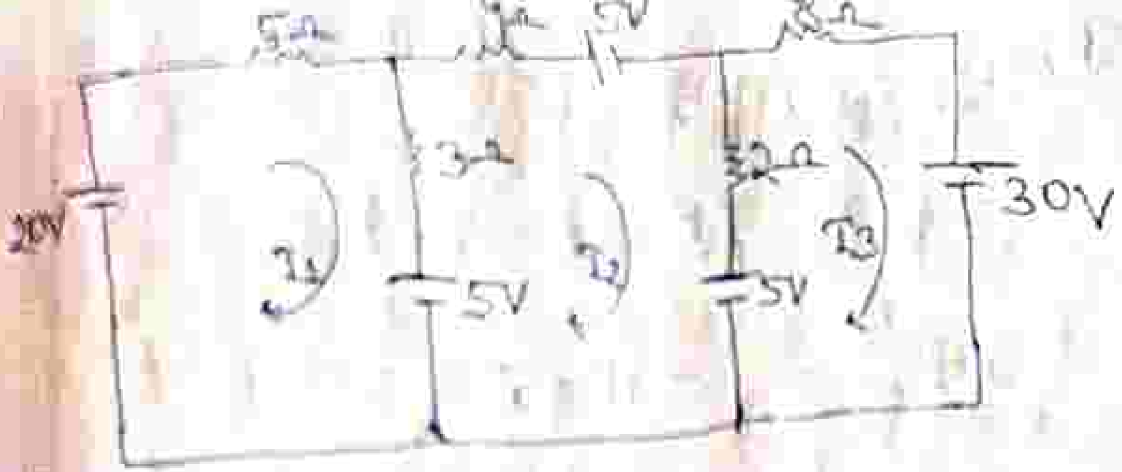


Soln.
In mesh analysis method we have to use of Ohm's law

i.e. $V = IR$

or, $[V] = [I][R]$

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix}$$



Resistance matrix :->

Self resistance :->

$R_{11} = 5+3 = 8\Omega$

$R_{22} = 4+2+3 = 9\Omega$

$R_{33} = 8+2 = 10\Omega$

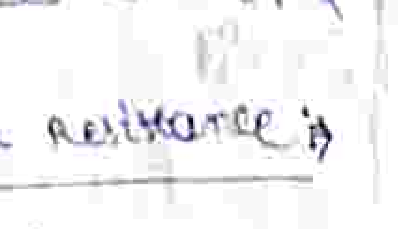
mutual resistance :->

$R_{12} = R_{21} = -3\Omega$

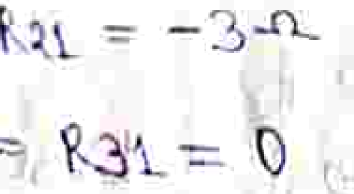
$R_{13} = R_{31} = 0$

$R_{23} = R_{32} = -2\Omega$

Emf matrix



$\Rightarrow E = E_1 + E_2$



$\Rightarrow E = E_1 - E_2 \,/\, E_2 - E_1$

so; $E_1 = 20 - 5 = 15V$

$E_2 = 5 + 5 + 5 = 15V$

$E_3 = -30 - 5 = -35V$

so;

$$\begin{bmatrix} 15 \\ 15 \\ -35 \end{bmatrix} = \begin{bmatrix} 8 & -3 & 0 \\ -3 & 9 & -2 \\ 0 & -2 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 8 & -3 & 0 \\ -3 & 9 & -2 \\ 0 & -2 & 10 \end{vmatrix} = 598$$

$$\Delta_1 = \begin{vmatrix} 15 & -3 & 0 \\ 15 & 9 & -2 \\ -35 & -2 & 10 \end{vmatrix} = 1530$$

$$\Delta_2 = \begin{vmatrix} 8 & 15 & 0 \\ -3 & 15 & -2 \\ 0 & -35 & 10 \end{vmatrix} = 1090$$

$$\Delta_3 = \begin{vmatrix} 8 & -31 & 15 \\ -3 & 9 & 15 \\ 0 & -2 & -35 \end{vmatrix} = -1875$$

$$\therefore I_1 = \frac{\Delta_1}{\Delta} = \frac{1530}{598} = 2.55A$$

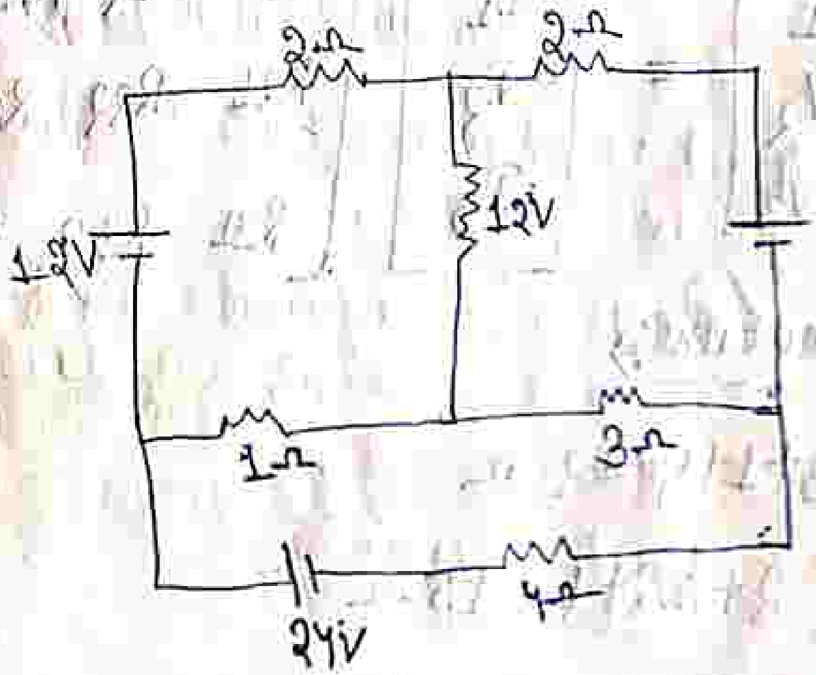
$$I_2 = \frac{\Delta_2}{\Delta} = \frac{1090}{598} = 1.82A$$

$$I_3 = \frac{\Delta_3}{\Delta} = \frac{-1875}{598} = -3.13A$$ (i.e. direction is observed)

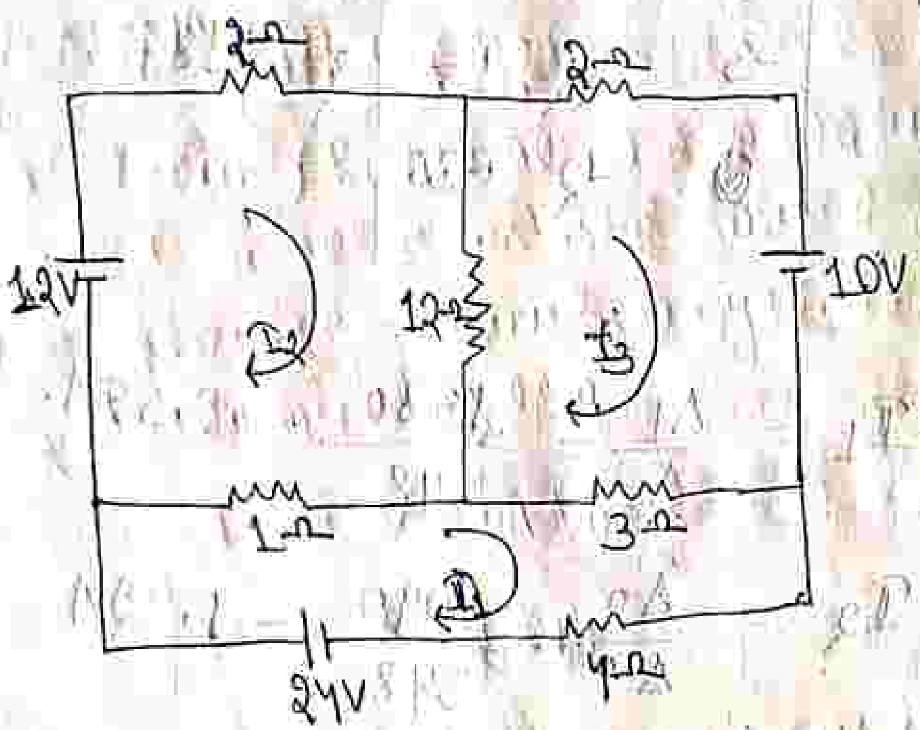
Q#02

Dt#21.09.2020

⇒ Determine the current in the 4Ω branch in the circuit.



Soln.



⇒ According to ohm's Law;

$$V = IR$$

$$\Rightarrow [V] = [I][R]$$

$$\Rightarrow \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix}$$

→ Resistance matrix ⇒

$$R_{11} = 3+1+4 = 8\ \Omega$$

$$R_{22} = 2+12+1 = 15\ \Omega$$

$$R_{33} = 2+3+12 = 17\ \Omega$$

$R_{12} = R_{21} = -1$, $R_{13} = R_{31} = -3$, $R_{23} = R_{32} = -1$

Voltage matrix ⇒

$V_1 = 24V$; $V_2 = 12V$; $V_3 = -10V$

so;

$$\begin{bmatrix} 24 \\ 12 \\ -10 \end{bmatrix} = \begin{bmatrix} 8 & -1 & -3 \\ -1 & 15 & -12 \\ -3 & -12 & 17 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 8 & -1 & -3 \\ -1 & 15 & -12 \\ -3 & -12 & 17 \end{vmatrix} = 8(255-144)+1(-17-36) -3(12+45) = 664$$

$$\Delta_1 = \begin{vmatrix} 24 & -1 & -3 \\ 12 & 15 & -12 \\ -10 & -12 & 17 \end{vmatrix} = 24(255-144)-12(-17-36) -10(12+45) = 2730$$

⇒ As I_1 current is flowing through 4Ω so;

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{2730}{664} = 4.1A \quad \text{Ans}$$

Dt:- 24.09.2020

* THEVENIN'S THEOREM :⇒

⇒ In a linear, bilateral, active network containing more than one source, the current flowing through any load resistance 'RL' is determined by the

$$\boxed{I_L = \frac{V_{TH} \text{ or } V_{OC}}{R_L + R_{TH}}}$$

⇒ which determine from Thevenin's equivalent circuit after thevenize the given circuit.

where; V_{TH}/V_{OC} = Thevenin's equivalent voltage across the load resistance after Thevenize the load resistance after removing the load resistance.

R_L = Load resistance across which current is to find out.

R_{TH} = Thevenin's equivalent resistance or total internal resistance of the circuit.

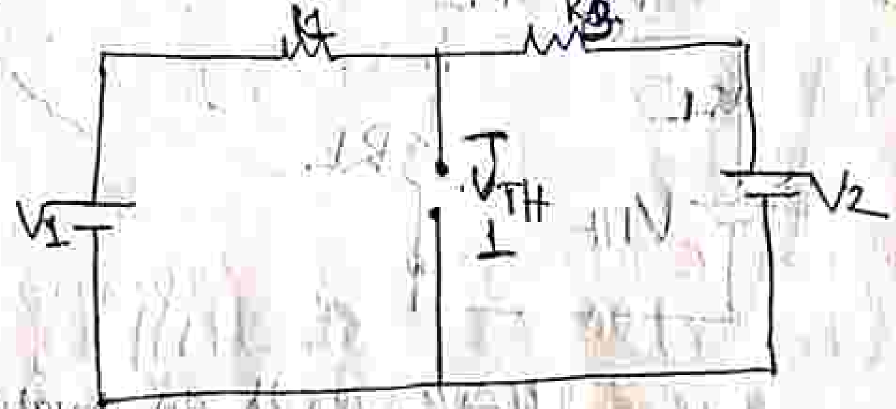
I_L = Load current.

Steps for Thevenize the circuit -

Step-(1) ⇒ we have to find out current across given R_L.
So the load resistance is R_L across which current is to be find out.

In the given circuit we have to find out current across R2. So $\boxed{R_L = R_2}$.

Step ⇒ (2) (VOC or VTH)
⇒ Removing the load resistance R_L in the circuit, now the voltage appear across open circuit terminal is V_{OC} or V_{TH}.

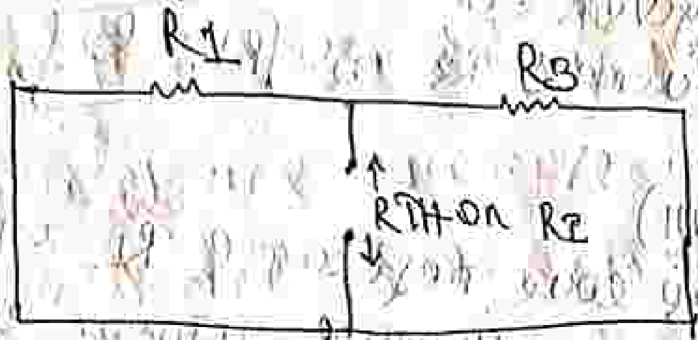


⇒ Here; V_{TH} or V_{OC} is find out by applying KVL or voltage division rule.

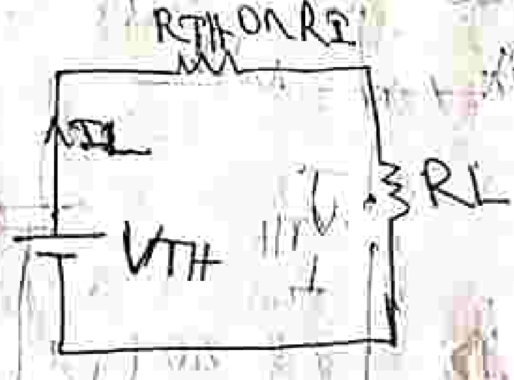
Step (3) (RTH or RI)

→ For finding out value of RTH or RI, all the sources are remove i.e. the voltage sources are short circuited and current sources are open circuited, RL terminal is open and we have to find out R across open circuit terminal to find out RTH.

$$\boxed{R_{TH} = R_1 \| R_3}$$



Step (4)



THEVENIN'S equivalent circuit

$$\boxed{I_L = \frac{V_{TH} \text{ or } V_{OC}}{R_{TH} + R_L}}$$

* Norton's Theorem :-

⇒ In a linear, bilateral, active network containing more than one source, the current through any resistance is find out by applying the relation ;

$$\boxed{I_L = \frac{I_N R_N}{R_N + R_L}}$$

where ; I_L = Load current which is to be find out.

R_N = Norton's equivalent resistance or total internal resistance.

R_L = Load resistance across which current is to be find out.

I_N = Norton's equivalent current or Norton's circuit current flowing through load resistance 'R_L' when 'R_L' replaced by ordinary conductor having negligible resistance.

* Steps for Nortanize a circuit :-

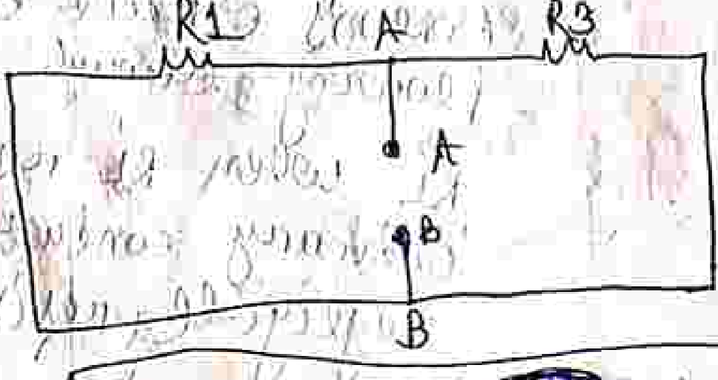
Step (1) ⇒ We have to find out first the load resistance 'R_L' across which current is to be find out.

So, the load resistance 'R_L' is the resistance across which the current is to be find out.

⇒ In the above circuit we have to find out current across R_2 so load resistance is $\boxed{R_L = R_2}$

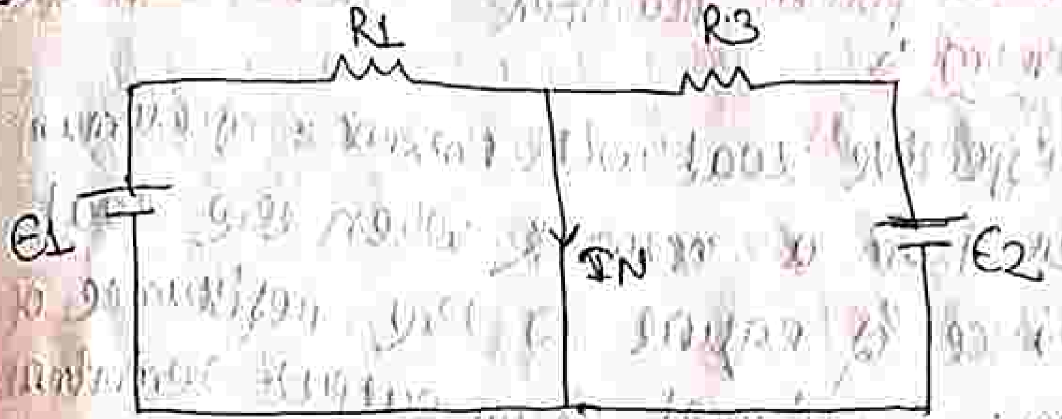
Step → ② (step for RN or RI)

⇒ For finding out the value of RN all the sources are remove i.e. the voltage sources are short circuited and current sources are open circuited.



So, $\boxed{RN \text{ or } RI = R1 \parallel R3}$

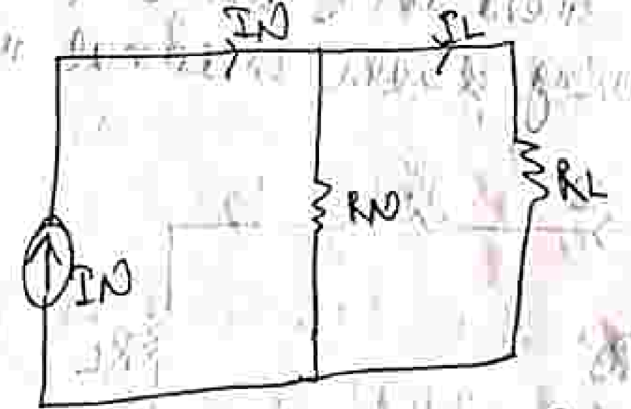
Step(3) → (Step for I_N)



⇒ So, the above circuit I_N can be find out by applying KCL or current division rule.

Step → (4) (Step for Norton's equivalent ckt)

⇒ After finding out I_N, R_N & R_L or design the Norton's equivalent circuit.



So applying current division rule.

$$\boxed{I_L = \frac{I_N \times R_N}{R_N + R_L}}$$

* Maximum Power Transfer Theorem :→ Dt→ 03.10.20..

⇒ A respective load will obstract maximum power from a network when the load resistance is equal to the resistance of a Network is viewed from output terminals of load resistance ; all energy sources are removed behind their internal resistance.

⇒ It means that maximum power transfer from source to load if R_L is equal to R_I when R_I is the internal resistance of the circuit viewed across open circuit terminal of the load resistance while source are ignore leaving their internal resistance.

⇒ In the circuit, V_s is equal to the generator voltage or source voltage.

R_s = source internal source

R = Resistance seen across the circuit

R_L = Load Resistance.

So $\boxed{R_I = R + R_S}$

where; R_I = Total internal resistance of the circuit.

So; In the circuit current flow is given by $\boxed{I = \dfrac{V_S}{R_I + R_L}}$

Power transfer to the load.

$$\boxed{P = I^2 R_L}$$

$$\Rightarrow P = \left(\frac{V_S}{R_I + R_L}\right)^2 R_L$$

So; maximum power will be transfer if;

$$\frac{dP}{dR_L} = 0 \quad (R_L \to 0 \ , P \to 0)$$

$$\Rightarrow \frac{d}{dR_L}\left(\frac{V_S^2 R_L}{(R_I + R_L)^2}\right) = 0$$

$$\Rightarrow \frac{\frac{d}{dR_L}(V_S^2 R_L)(R_I + R_L)^2 - \frac{d}{dR_L}(R_I + R_L)^2 \times V_S^2 R_L}{\{(R_I + R_L)^2\}^2}$$

$$\left(\because \frac{d}{dt}\left(\frac{a}{b}\right) = \frac{\frac{d}{dt}a \times b - \frac{d}{dt}b \times a}{b^2}\right.$$

$\Rightarrow V_S^2 (R_I + R_L)^2 - 2(R_I + R_L) \times V_S^2 R_L = 0$

$\Rightarrow \cancel{V_S^2} (R_I + R_L)^2 = 2(R_I + R_L) \times \cancel{V_S^2} R_L$

$\Rightarrow \dfrac{(R_I + R_L)^2}{R_I + R_L} = 2R_L$

$\Rightarrow R_I + R_L = 2R_L$

$\Rightarrow R_I = 2R_L - R_L$

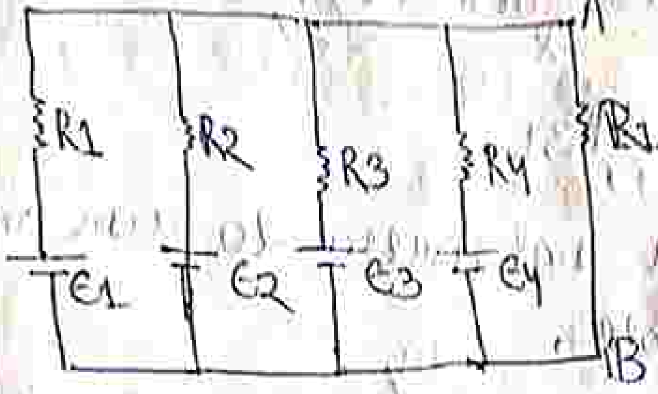
$\Rightarrow \boxed{R_I = R_L}$ This is the condition for maximum power transfer in Network.

i.e. when load resistance is equal to the total internal resistance of the circuit.

* Millman's Theorem $\Rightarrow$

$\Rightarrow$ This theorem is combination of both Thevenin's and Norton's theorem.

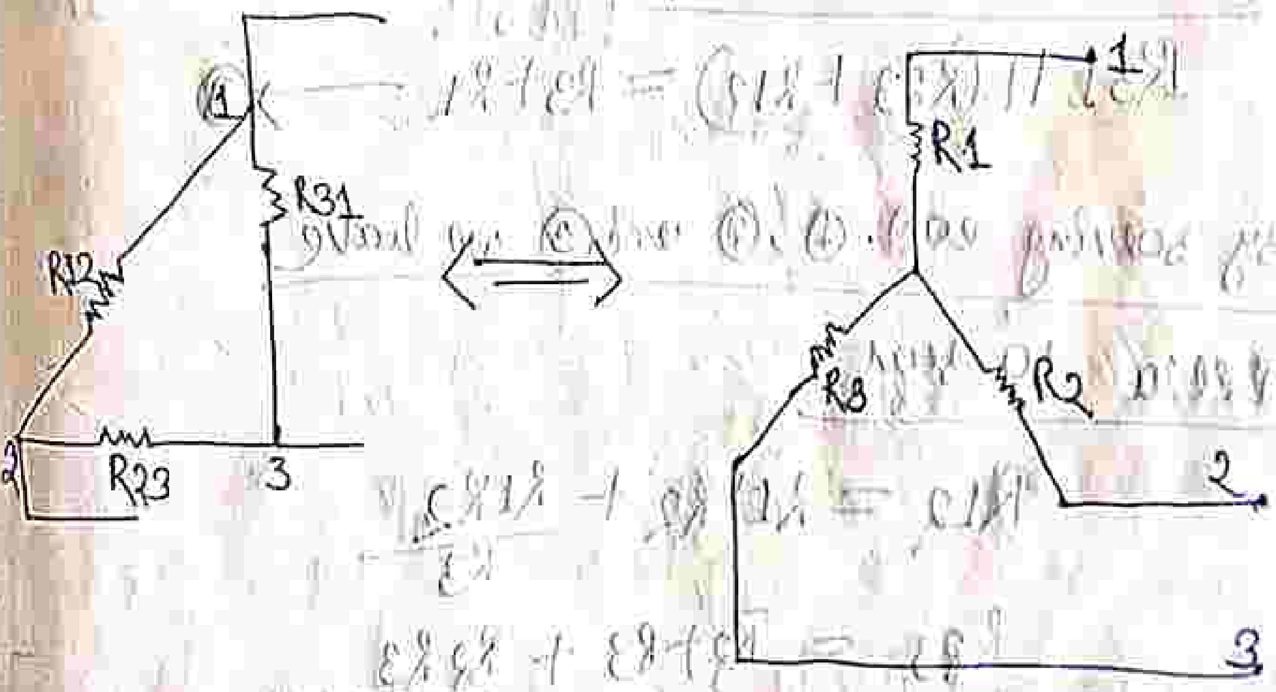
$\Rightarrow$ It is used to find out voltage across any network containing a number of parallel voltage source series with resistance.



$$\Rightarrow V_{AB} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_2} + \frac{E_3}{R_3} + \cdots + \frac{E_n}{R_n}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}}$$

$$\Rightarrow \boxed{V_{AB} = \frac{I_1 + I_2 + I_3 + \cdots + I_n}{G_1 + G_2 + G_3 + \cdots + G_n}}$$

* Star to Delta and Delta to star connection :⇒



* Star to Delta connection:⇒

$R_1 = R_{12} \times R_{31}$

⇒ Star to Delta and Delta to star connection are convertable.

* Resistance in between 1 & 2:⇒

In Delta

$R_{12} \parallel (R_{31} + R_{23}) = R_1 + R_2 \longrightarrow (1)$

Resistance betn. 2 & 3

$R_{23} \parallel (R_{12} + R_{31}) = R_2 + R_3 \longrightarrow (2)$

Resistance betn. 3 & 4

$R_{31} \parallel (R_{23} + R_{12}) = R_3 + R_1 \longrightarrow (3)$

* By solving eqn. (1), (2) and (3) we have:

Delta to star

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

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

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

Star to Delta connection ⇒

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

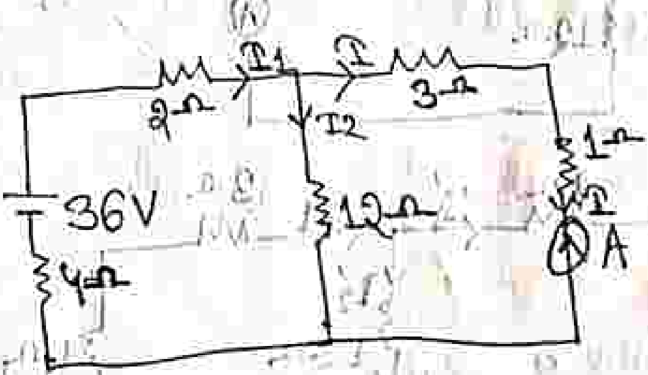
$$R_2 = \frac{R_{12} \times R_{23}}{R_{12}+R_{23}+R_{31}}$$

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

* Reciprocity Theorem ⇒

* In any linear, bilateral, active network if a source 'E' in any branch produces a current 'I' in other branch, then the same source emf (E) acting in the second branch produces the same current (I) in the first branch.

Ex: check the reciprocity of the following Network.



Soln. Let the current flowing in the Ameter is 'I' A.

Step-1 We have to find out current in Ammeter (A) due to present of 36V source in 1st branch.

$$So \; I_1 = \frac{V}{R_{eq}}$$

$$R_{eq} = \{(3+1)\|12\}+4+2$$

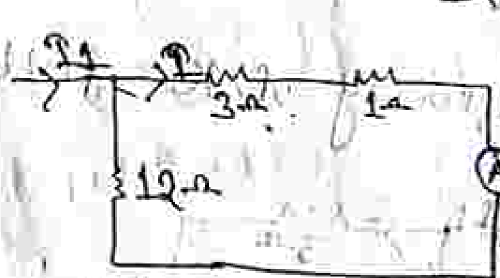
$$= 9\Omega$$

$$I_1 = \frac{36}{9} = 4A$$

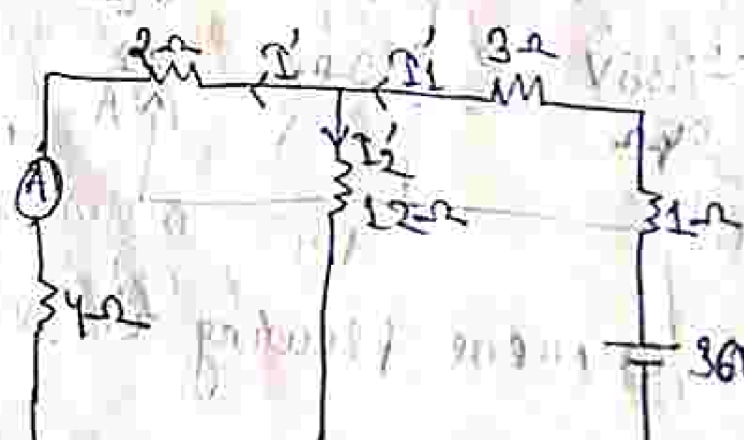
Now applying current division rule.

$$\Rightarrow I = \frac{I_1 \times 12}{12+3+1}$$

$$= \frac{4\times12}{12+3+1} = \frac{48}{16} = 3 \text{ Amp.}$$



Step-2



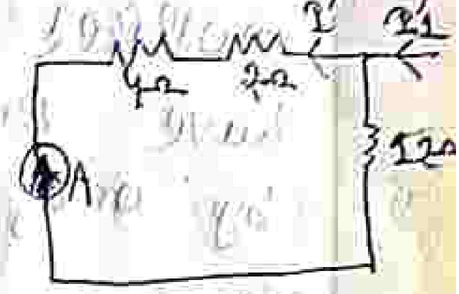
so; we first find out I_1' & then I

$$I_1' = \frac{V}{Req'}$$

$$Req' = \{(4+2)\|12\} + 3 + 1 = 8\,\Omega$$

$$I_1' = \frac{36}{8} = 4.5A$$

Now applying current division rules



$$I_2' = \frac{I_1' \times 12}{12+2+4}$$

$$= \frac{4.5 \times 12}{12+2+4} = 3A$$

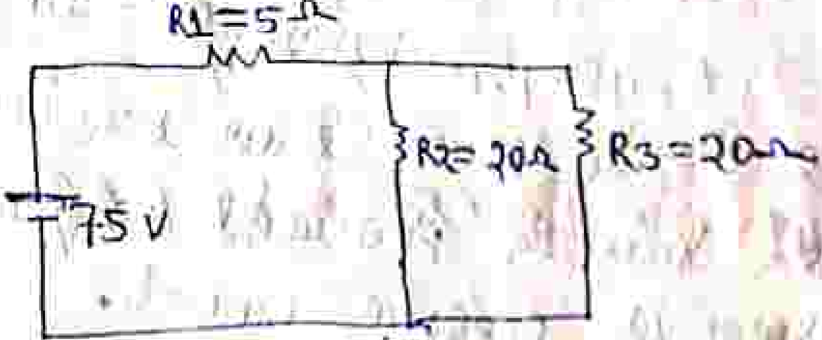
→ Hence it is proof that the source present both branch produced equal current respective opposite branch.

* Compensation Theorem :-

→ If the resistance of any branch of a network is changed from R to R ± Δ, when the current originally flowing is (I), the change of current at any other place in the network may be calculated by assuming that an emf of I×ΔR have been injected into the modified branch while all other sources have their emf ignore and are replaced by only their internal resistance.

Exp :-

Q→(1)

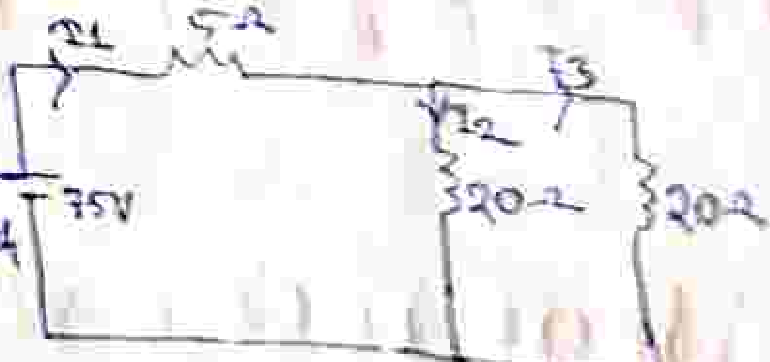


In the circuit if R3 increase by 30% then find out current change in other branch.

Soln.

Step (1)

First we have to find out each branch current.



$R_{eq} = (20 \| 20) + 5$

$= \frac{20 \times 20}{20+20} + 5 = \frac{400}{40} + 5$

$= \frac{40}{4} + 5 = \frac{40+20}{4} = \frac{60}{4} = 15\Omega$

$I_1 = \frac{V}{R_{eq}} = \frac{75}{15} = 5A$ (Left → Right)

$I_2 = \frac{I_1 \times R_3}{R_2 + R_3} = \frac{5A \times 20}{20+20} = 2.5A$ (U→D)

$I_3 = I_1 - I_2 = 5A - 2.5A = 2.5A$ (U→D)

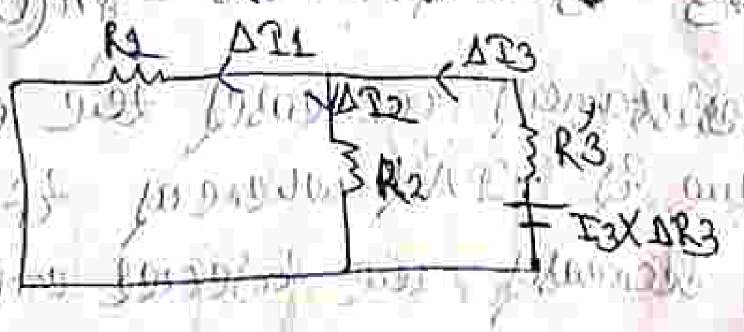
Step 2 ⇒ The resistance R_3 increase by 30%. so,

$\Delta R_3 = R_3 \times 30\% = 20 \times \frac{30}{100} = 6\Omega$, Hence

emf source inserted in the modified branch

$-I_3 R_3 = -2.5 \times 6 = -15V$

$R_3' = R_3 + \Delta R_3 = 20 + 6 = 26\Omega$



$\Rightarrow \Delta I_3 = \frac{I_3 \times \Delta R_3}{R_{eq}}$ & $R_{eq}' = \{(5 \| 20) + 26\}$

$= \frac{5 \times 20}{5+20} + 26 = 30\Omega$

so, $\Delta I_3 = \frac{2.5 \times 6}{30} = 0.5A$ (D→U)

Now applying current division rule :

$$\Delta I_1 = \frac{0.5 \times 20}{20+5} = 0.4A \,(R \to L)$$

$$\Delta I_2 = 0.5 - 0.4 = 0.1A \,(U \to D)$$

step → 3

(Thus : I_1N = I_1 current new)
($\Delta I_1 = I_1'$, $\Delta I_2 = I_2'$, $\Delta I_3 = I_3'$)

$$I_1N = I_1 - I_1' = 5 - 0.4 = 4.6A \,(L \to R)$$

$$I_2N = I_2 + I_2' = 2.5 + 0.1 = 2.6A \,(U \to D)$$

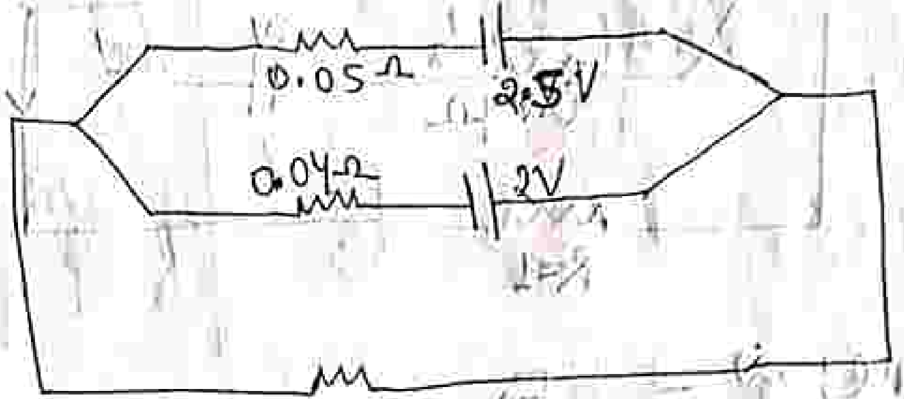
$$I_3N = I_3 - I_3' = 2.5 - 0.5 = 2A \,(U \to D)$$

*Note :→ If resistances increases the emf injected value is $-I\Delta R$ whereas if the resistances decreases the injected emf is $(+I\Delta R)$.

Dt:→15.10.2020

Q→01 / Imp

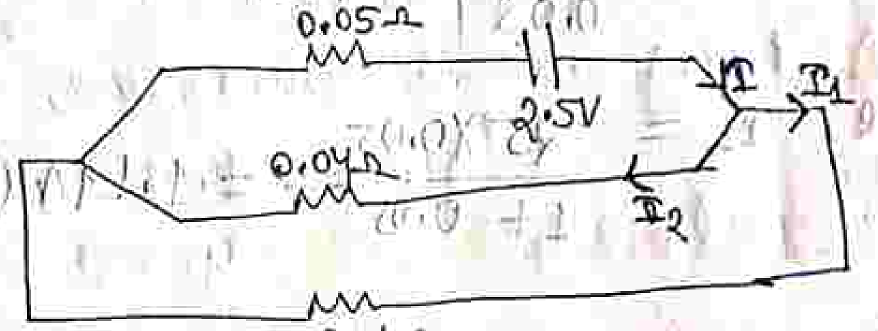
By using superposition theorem find out current in the resistance R.



$R_0 = 1\Omega$

Soln:

Step-1: Taking 2.5V source at that time 2V source ignore.



Here, $I = \frac{\epsilon_1}{Req}$ and $Req = (1 \| 0.04) + 0.05$

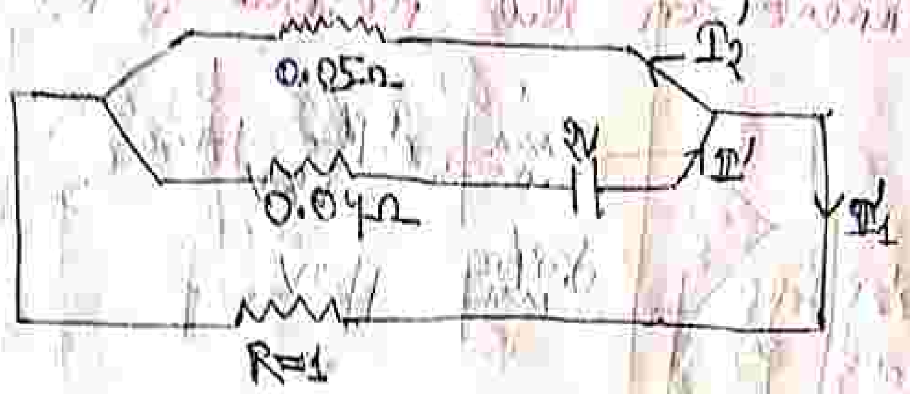
$= 0.08\Omega$

So, $I = \frac{2.5}{0.08} = 31.25A$

Now, $I_1 = \frac{31.25 \times 0.04}{1 + 0.04}$ (By using current division rule).

$= \frac{31.25 \times 0.04}{1 + 0.04} = 1.20A$ (R→L)

Step-2: Considering 2V source at a time 2.5V source is ignore.



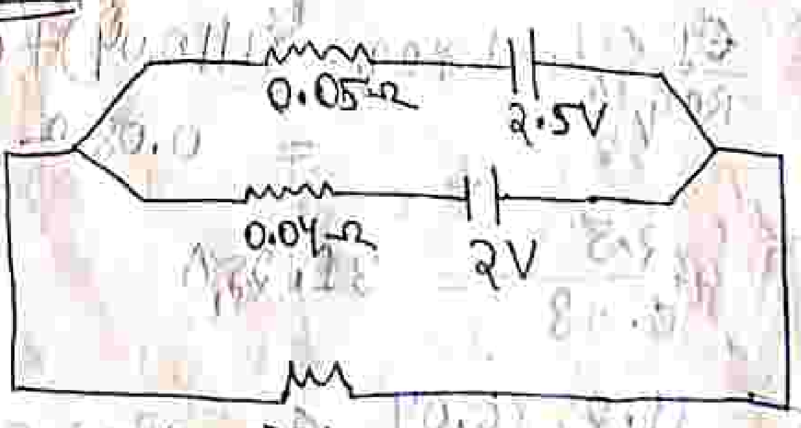
Here; $I' = \dfrac{E_2}{Req'}$ and $Req' = (0.05 \| 1) + 0.$

$= 0.08\,\Omega$

$$I' = \frac{2}{0.08} = 25A$$

Here; $I_1' = \dfrac{25 \times 0.05}{1 + 0.05} = 1.19A\ (R \to L)$

Step-3



Here; $I_{1T} = I_1 + I_1'$

$= 1.20 + 1.19$

$= 2.39A\ (R \to L)$

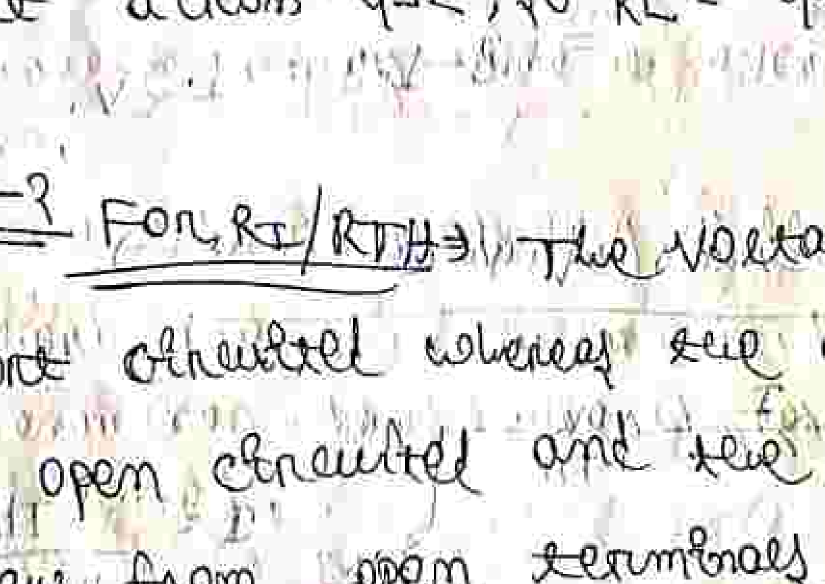
Q.3 (Q3) Find out current across 4-Ω resistance by using Thevenin's Theorem.

Soln.

Step-1

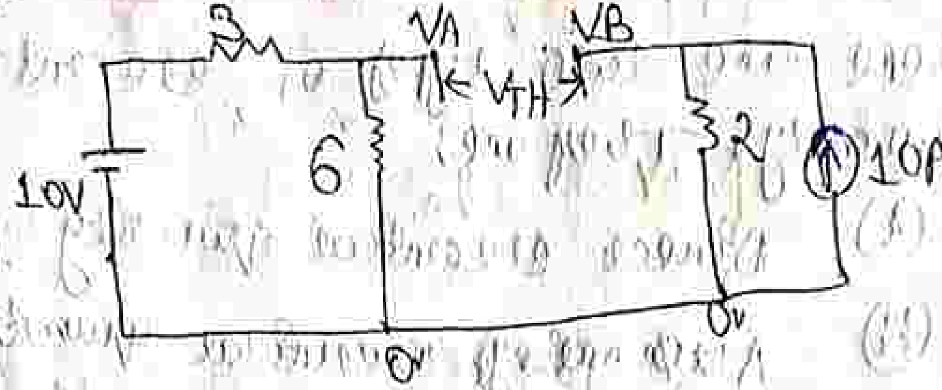
FOR RL ⇒ Here current is to be find out across 4-Ω, so RL = 4-Ω

Step-2 FOR RI/RTH ⇒ The voltage source be short circuited whereas the current source is open circuited and the resistance view from open terminals across RL.



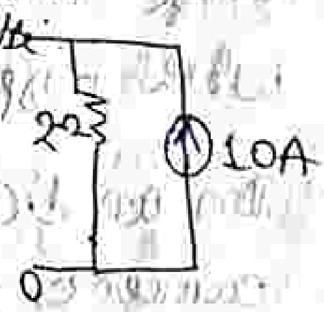
Now RTH or RI = $(3 \| 6) + 2$
$= 4\text{-}\Omega$

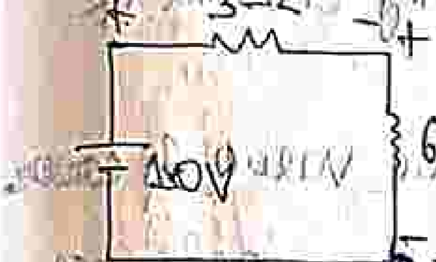
Step-3



So; Here $V_{TH} = V_A - V_B$

So, here; $V_B = 10 \times 2$
$(V = IR) = 20V$





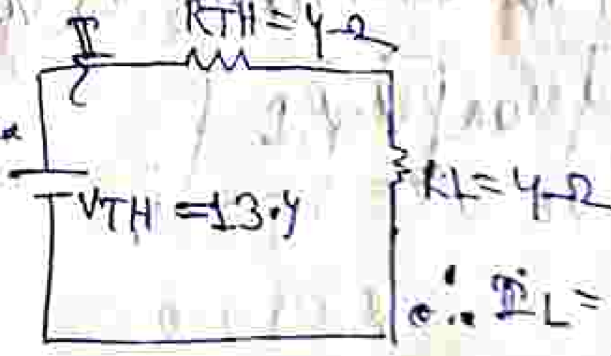
According to voltage division rule

$V_A = \frac{10 \times 6}{3+6} = 6.6V$ (with reference to 0V)

So; $V_{TH} = V_B - V_A = 20 - 6.6 = 13.4V$

Step-4

(Thevenin's equivalent circuit)



$\therefore I_L = \frac{V_{TH}}{R_L + R_{TH}} = \frac{13.4V}{4+4}$

$= \frac{13.4}{8} = 1.67A$

ॐ New Chapter Dt: 19. 10. 2020 AC Fundamentals

⇒ There are two types of electrical quantity. They are;

(i) Direct electrical quantity.

(ii) Alternating electrical quantity.

(i) Direct electrical quantity ⇒

⇒ The direct electrical quantity are those whose magnitude and direction doesnot cha[nge] with respect to time.

⇒ In an d.c. electrical quantity voltage an[d] current always same at every instant of time.

⇒ There is no frequency as the value is co[nstant]

⇒ There are no inductance and capacitan[ce] phenomenon (but there is resistance phenom[enon] is there).

⇒ So in this we ohm's law is valid i.e.,

$$\boxed{I = \frac{V}{R}} \quad \text{or} \quad \boxed{V \propto I}$$

Alternating electrical quantity ⇒

⇒ The alternating electrical quantity are those whose magnitude and directions get change with respect to time.

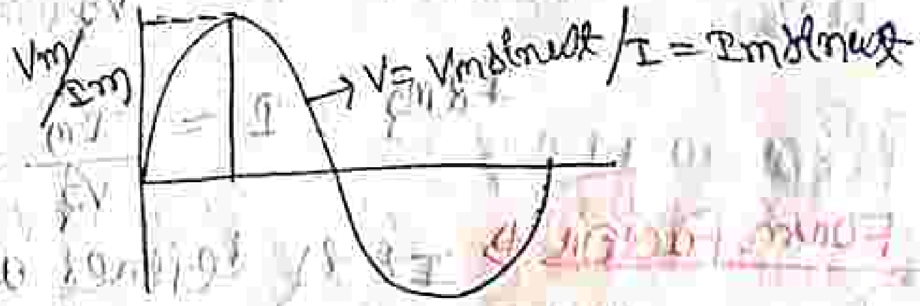
⇒ In an electrical quantity are ~~varied~~ varies according to the sinusoidal functions.

$V = V_m \sin\omega t$ or $E = E_m \sin\omega t$.

$I = I_m \sin\omega t$ where V_m, I_m and E_m are maximum value of A.C. electrical quantity; V, I and E are instantaneous of A.C. electrical quantity.

⇒ This is a frequency associated with A.C electrical quantity.

⇒ The wave form of AC electrical quantity are:



* **Average value** ⇒ The average value of A.C electrical quantities are those which when flowing through a given circuit transfer some charge as that of D.C.

So, $I_{av} = \frac{2I_m}{\pi} = 0.637 I_m$

$V_{av} = \frac{2V_m}{\pi} = 0.637 V_m$

$E_{av} = \frac{2E_m}{\pi} = 0.637 E_m$

* RMS value (Root mean square value) ⇒

⇒ RMS value of AC is that value of D.C which when flowing through a given circuit for a given time produce same heat as that of D.C.

$V_{RMS} = V = \frac{V_m}{\sqrt{2}} = 0.707 V_m$

$E_{RMS} = E = \frac{E_m}{\sqrt{2}} = 0.707 E_m$

$I_{RMS} = I = \frac{I_m}{\sqrt{2}} = 0.707 I_m$

* Form Factor ⇒ It is defined as the ratio of rms value of A.C. electrical quantity to average value.

⇒ It is denoted by KF.

$KF = \frac{\text{RMS value}}{\text{Average value}} = \frac{0.707 V_m \text{ or } I_m}{0.637 V_m \text{ or } I_m}$

$\Rightarrow$ $\boxed{K_F = 1.11}$ V.Imp

* Peak Factor :-

$\Rightarrow$ It is defined as the ratio of maximum value of an A.C. electrical quantity to R.M.S value of A.C electrical quantity.

$$K_P / K_C = \frac{\text{maximum value}}{\text{RMS value}}$$

$$= \frac{V_m / I_m / e_m}{0.707 V_m / I_m / e_m}$$

$\Rightarrow$ $\boxed{K_P / K_C = 1.414}$ V.Imp

Dt:- 22.10.2020

* AC through pure Resistance :-

$\Rightarrow$ Let the resistance R is connected across A.C. supply for $V = V_m \sin\omega t$ and current flowing is I.

According to Ohm's law we know that;

$$V = IR$$

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

So; Putting $V = V_m \sin\omega t$

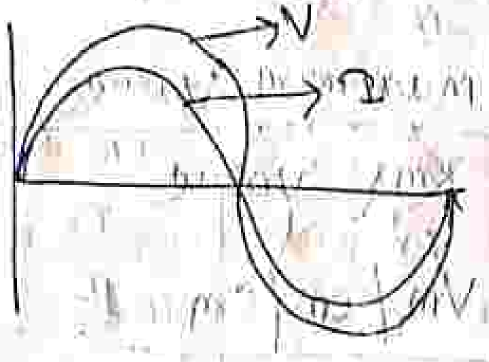
$$I = \frac{V_m \sin\omega t}{R} \Rightarrow \boxed{I = I_m \sin\omega t}$$

* at $\omega t = 0$ | at; $\omega t = \frac{\pi}{2} = 90°$ | at; $\omega t = 180°$ or

$V = 0$ | $V = V_m$ | $V = 0$

$I = 0$ | $I = I_m$ | $I = 0$

* Wave form:



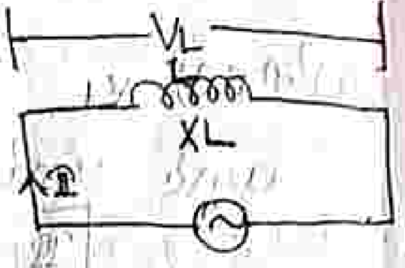
⇒ Here; in the pure resistance ckt. the voltage and current are vary simultaneously or both are vary at a time. so; voltage and current are in phase.

* Phasor Diagram:

Here $\phi = 0°$ (ϕ = angle between volt and current)

* A.C. Through pure Inductance :-

⇒ Inductance is the property of the material which doesnot allow sudden change of current.



$V = V_m \sin\omega t$

⇒ An inductance 'L' is connected across A.C. supply of $V = V_m \sin\omega t$ and the current flow is I.

⇒ Let the voltage drop across the inductors is 'V_L'.

$$\Rightarrow V_L = L\frac{dI}{dt}$$

$$\Rightarrow dI = \frac{V_L}{L}dt$$

Integrating both sides;

$$\int dI = \int \frac{V_L}{L}dt$$

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

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

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

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

($\because \sin(-\theta) = -\sin\theta$ odd function)

$$\Rightarrow I = \frac{V_m}{X_L} \sin\left(\omega t - \frac{\pi}{2}\right)$$

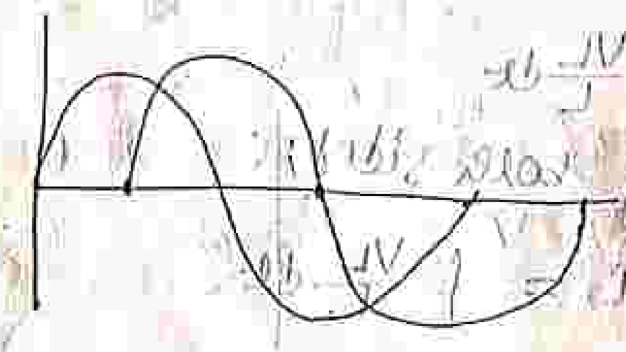
where; X_L = inductive reactance of the ckt and unit is ohm (Ω).

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

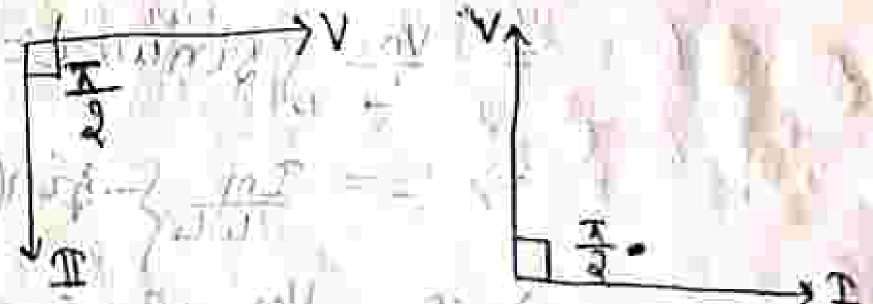
where; $I_m = \frac{V_m}{X_L}$

If, $\omega t = 0$	$\omega t = \frac{\pi}{2}$	$\omega t = \pi$ or $180°$
$V = 0$	$V = V_m$	$V = 0$
$I = -I_m$	$I = 0$	$I = I_m$

* Wave form:-



* Phasor Diagram:-



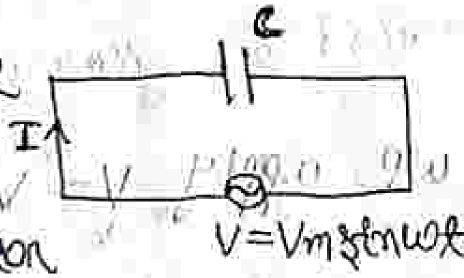
Dt: 02.11.2020

A.C through pure capacitive circuit :-

- capacitance is the property of the circuit or materials which doesnot allow sudden change of voltage.

- Here the 'C' capacitor is connected across A.C. supply of $V = V_m \sin\omega t$ and the current flowing is 'I'.

- We know that capacitors are store charge.



so charge store by capacitor

$$Q = CV$$

- But we again know that rate of transfer of charge is current flow.

$$I = \frac{dQ}{dt} = \frac{d}{dt}\{CV\}$$

$$\Rightarrow I = C\frac{d}{dt}V = C\frac{d}{dt}\{V_m \sin\omega t\}$$

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

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

$$= \frac{V_m}{\frac{1}{C\omega}}\cos\omega t$$

$$= \frac{V_m}{X_C}\cos\omega t$$

$$= \frac{V_m}{X_C} \sin\left(\frac{\pi}{2} + \omega t\right) \quad (\because \sin(90+\theta) = \cos\theta)$$

⇒ X_C is known as capacitive reactance and

$$X_C = \frac{1}{\omega C} \text{ \& unit is ohm } (\Omega)$$

so $I_m = \frac{V_m}{X_C}$, putting above value

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

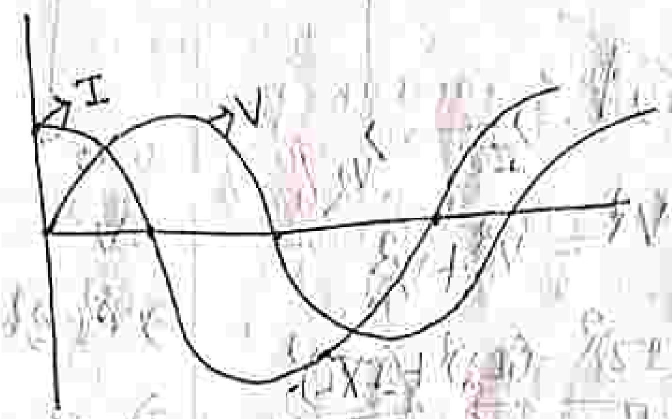
we apply $V = V_m \sin\omega t$ and current flow

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

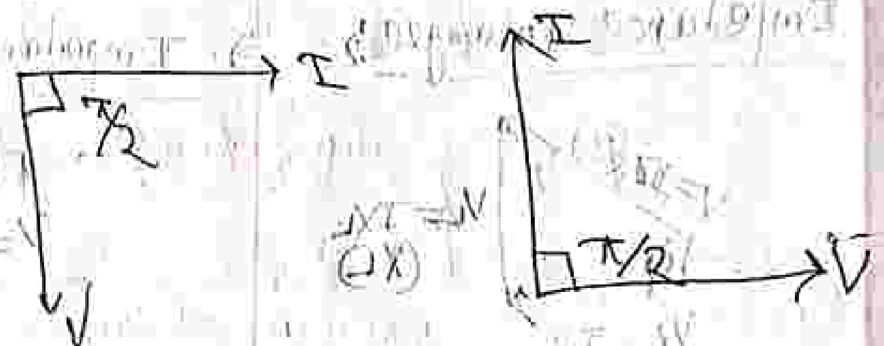
If $\omega t = 0$	If $\omega t = \frac{\pi}{2}$ or $90°$	If $\omega t = \pi$ or $180°$
$V = 0$	$V = V_m$	$V = 0$
$I = I_m$	$I = 0$	$I = I_m$

⇒ Here from this it is seen that the current travels ahead of voltage by $\frac{\pi}{2}$ or current leads the voltage by $\frac{\pi}{2}$ or $90°$.

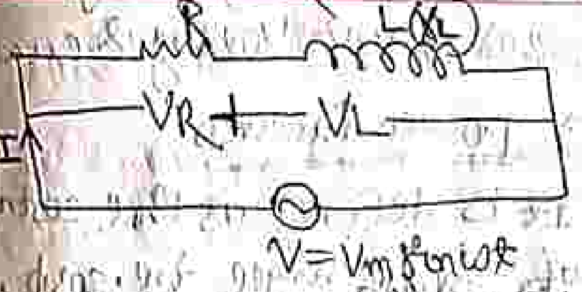
⇒ wave form

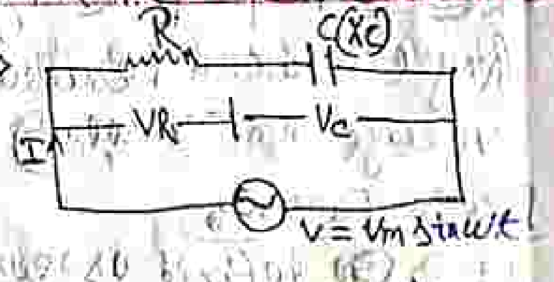


⇒ Phasor Diagram



R-L Series Circuit | R-C Series Circuit





⇒ Here, resistances 'R' and inductance 'L' having inductive reactance 'X_L' are connected in series across ac supply of $V = V_m \sin \omega t$ and the current flowing is 'I'.

⇒ $V_R = IR$ (Voltage Drop across 'R')

$V_L = IX_L$ (Voltage Drop 'L')

$V = IZ$ (Voltage Drop across ckt)

'Z' is impedance & unit is Ω of R-L series ckt.

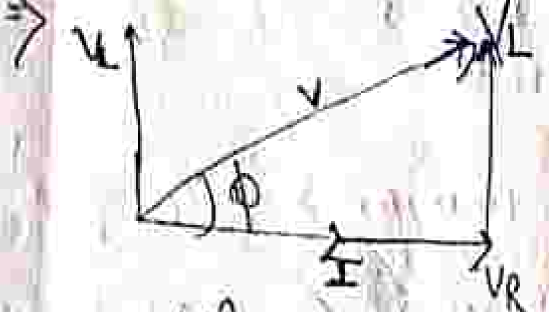
⇒ Here, resistances 'R' and capacitors 'C' having capacitive reactance 'X_C' are connected in series across ac supply of $V = V_m \sin \omega t$ and the current flowing is 'I'.

⇒ $V_R = IR$ (Voltage drop across 'R')

$V_C = IX_C$ (Voltage drop across 'C')

$V = IZ$ (Voltage drop across ckt)

'Z' is impedance & unit is Ω of R-C series ckt.

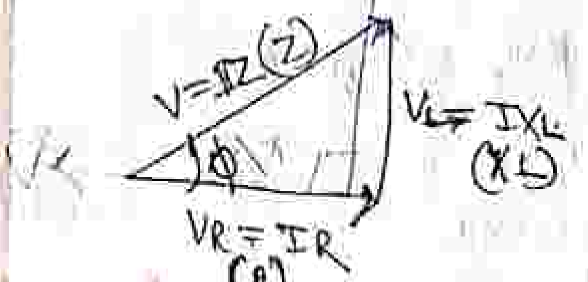


$V^2 = V_R^2 + V_L^2$

$\Rightarrow (IZ)^2 = (IR)^2 + (IX_L)^2$

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

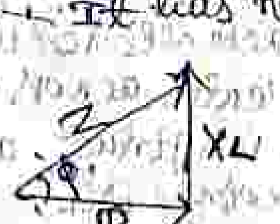
→ Impedance Triangle:



→ ~~Resultant~~ ϕ = phase angle (Angle between resultant voltage and current).

→ Power factor:

It is defined as the cosine of phase angle i.e. $\cos\phi$. It has no unit.

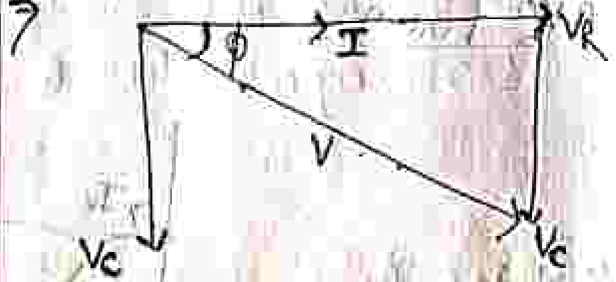


Here; $\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2+X_L^2}}$

→ power → Here power consumed by R-L series ckt; $P = VI\cos\phi$ where V & I are rms value of voltage & current.

$\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2+X_L^2}}$

→



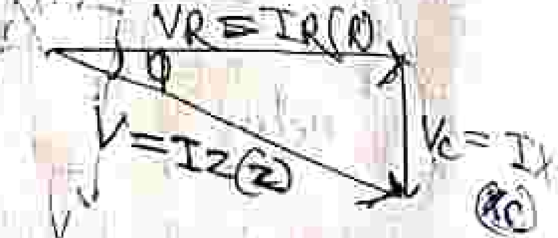
$V^2 = V_R^2 + V_C^2$

$\Rightarrow (IZ)^2 = (IR)^2 + (IX_C)^2$

$\Rightarrow Z^2 = R^2 + X_C^2$

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

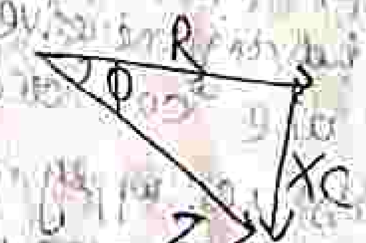
⇒ Impedance Triangle



⇒ ϕ = phase angle (Angle betn resultant voltage & current)

→ Power factor:

It is defined as the cosine of phase angle i.e. $\cos\phi$. It has no unit.



Here; $\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2+X_C^2}}$

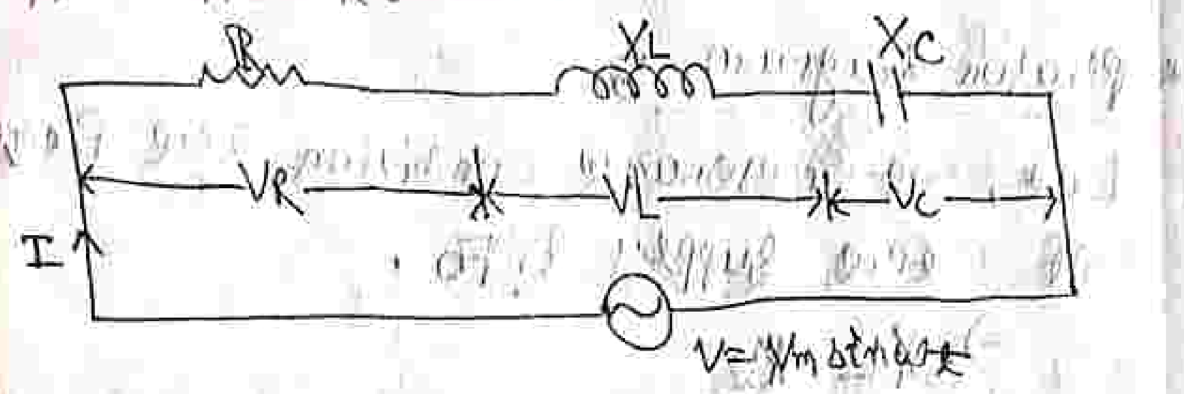
→ power

Here power consumed by R-C series ckt; $P = VI\cos\phi$ where V & I also rms value of voltage and current.

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

Dt:- 07. 11. 2020

* R-L-C series circuit ⇒



⇒ Here, resistance (R), inductive reactance (X_L) & capacitive reactance (X_C) are connected in series across ac supply of $V = V_m \sin\omega t$ and the current flowing is 'I'.

⇒ $V_R = IR$ (Voltage drop across resistance).

⇒ $V_L = IX_L$ (Voltage drop across inductance).

⇒ $V_C = IX_C$ (Voltage drop across capacitance).

⇒ The nature of circuit is depends upon the value of X_L & X_C, so there are three conditions arises ⇒.

(a) $X_L = X_C$

(b) $X_L > X_C$

(c) $X_L < X_C$

(a) $X_L = X_C$ ⇒ when inductive reactance is equal to capacitive reactance then the condition is called resonance condition.

i.e. $X_L = X_C$ so; $IX_L = IX_C \Rightarrow \boxed{V_L = V_C}$

⇒ At resonance condition, voltage across inductor & voltage across capacitor.

* Phasor diagram :-

Let, at resonance condition, the frequency of the supply is F_0.

$\Rightarrow X_L = X_C$

$\Rightarrow \omega_0 L = \frac{1}{\omega_0 C}$

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

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

⇒ Now, Angular Velocity = $\frac{\text{Angular displacement}}{\text{Time}}$

So, $\omega = \frac{\theta}{T}$ [Time → Time period (T), i.e. Time required to complete one cycle i.e. 360°]

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

$\Rightarrow \boxed{\omega = 2\pi F}$ [∵ Frequency = $\frac{1}{\text{Time period}}$]

[Frequency is reciprocal of time period].

Here, $2\pi F_0 = \frac{1}{\sqrt{LC}}$

$\Rightarrow \boxed{F_0 = \frac{1}{2\pi\sqrt{LC}}}$ [F_0 is resonant frequency]

⇒ At the resonance condition both the voltage V_L & V_C are cancel out each other. Hence only 'V_R' is dominance.

⇒ So; at resonance condition the entire R-L-C series circuits behaves as a resistive circuit.

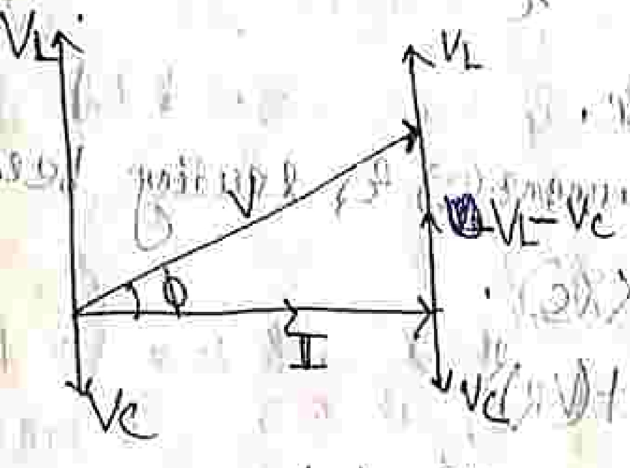
(ii) $X_L > X_C$

$\Rightarrow IX_L > IX_C$

$\Rightarrow V_L > V_C$

$\Rightarrow V_L - V_C > 0$

← <u>Phasor Diagram</u> ⇒



⇒ $V_L - V_C$ is on V_L side.

⇒ Nature of the current (I) is lagging behind the voltage $(X_L > X_C)$.

$\Rightarrow V^2 = (V_L - V_C)^2 + V_R^2$

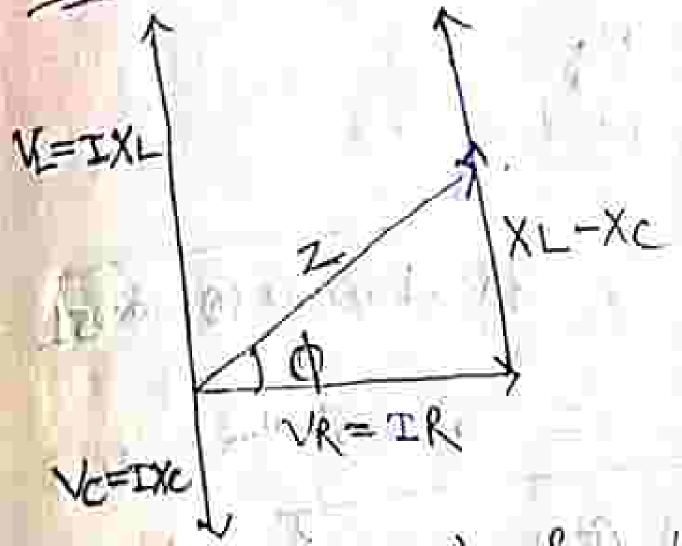
$\Rightarrow (IZ)^2 = (IX_L - IX_C)^2 + (IR)^2$

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

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

* $X_L > X_C$

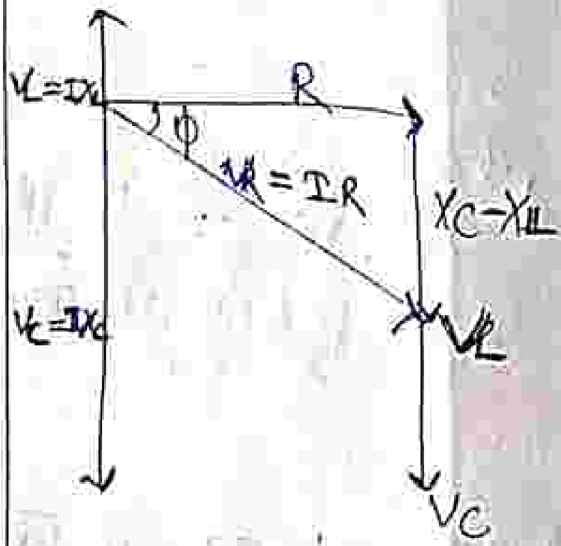
* power factor ⇒



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

* $X_L < X_C$

* power factor



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

* Problem

In a R-L-C series circuit R = 30 Ω, L = 15 mH and C = 51 μF. If the source voltage and frequency are 12V and 60Hz; what is the current and power factor of the circuit.

soln

Data given

R = 30 Ω

L = 15 mH = 0.015 H

C = 51 μF = 51×10^{-6}

V = 12 V

F = 60 Hz

$\therefore X_L = 2\pi F L$

$= 2\pi \times 60 \times 0.015$

$= 5.655\,\Omega$

$\therefore X_C = \frac{1}{2\pi F C} = \frac{1}{2 \times 3.15 \times 60 \times 0.000051}$

$= 5.65\,\Omega$

$\therefore Z = \sqrt{(30)^2 + (52 - 5.65)^2}$

$= 55.21\,\Omega$

$\therefore I = \frac{V}{Z} = \frac{12}{55.21} = 0.217A$ lag

$\therefore \cos\phi = \frac{R}{Z} = \frac{30}{55.21A} = 0.5$

dt:- 12.11.2020

* R-L-C Parallel Circuit:-

⇒ There are two methods for solving R-L-C Parallel circuit.

1. Vector or phasor method
2. Phasor algebra method

1. Phasor Algebra method:-

⇒ In this case to represent a circuit we use (j) denotor in the complex instead of (i).

⇒ The inductive reactance taken by +ve sign whereas the capacitive reactance taken as −ve sign. So a branch in the circuit written as $R+jX_L$ & $R-jX_C$.

⇒ The complex form is known as rectangular form but it can be represented by another form known as polar form or angle form.

$R+jX_L$ & $R-jX_C$ → Rectangular form.

$R\angle\theta$ or $R\angle-\theta$ → Polar form.

These both are inter-convertable.

⇒ Rectangular to polar

Rec   Pol

$Pol(R, X_L)$ or $Pol(R, -X_C)$

Ans ⇒ $Z\angle\theta$ Ans ⇒ $Z\angle-\theta$

⇒ Polar to Rectangular ⇒

$Rec(Z, \pm\theta)$

i.e. $Rec(Z, +\theta) = R+jX_L$

$Rec(Z, -\theta) = R-jX_C$

⇒ The addition and substraction of complex impedance done in Rectangular form.

$R_1+jX_{L_1} = Z_1\angle\theta_1$

$R_2+jX_{L_2} = Z_2\angle\theta_2$

Polyphase New chapter

* (φ) Phase is a path in which is a path of current flow but voltage seen in electrical circuit.

* Polyphase ⇒ It means more than one path for current flow but voltage is seen in electrical circuits only.

* Different Types of current ⇒

⇒ There is two types of current :-

1. Phase current.
2. Line current.

(1) Phase current ⇒ It is the current which is flowing ~~form~~ from one phase to neutral. It is denoted by the letter (I_{Ph}). Its unit is ampere.

$$[I_{Ph} = I_{RN} = I_{YN} = I_{BN}]$$

where; I_{Ph} = Current in phase.

I_{RN} = current between red phase and neutral.

I_{YN} = current between yellow phase and neutral.

I_{BN} = current between Blue phase and neutral.

(2) Line current ⇒ It is the current flowing between any two phases.

⇒ R to Y ; Y to B ; B to R.

⇒ $[I_{RY} = I_{YB} = I_{RB} = I_L]$

Different Types of voltage ⇒ There is two types of voltage. i.e. 1. Phase voltage
2. Line voltage

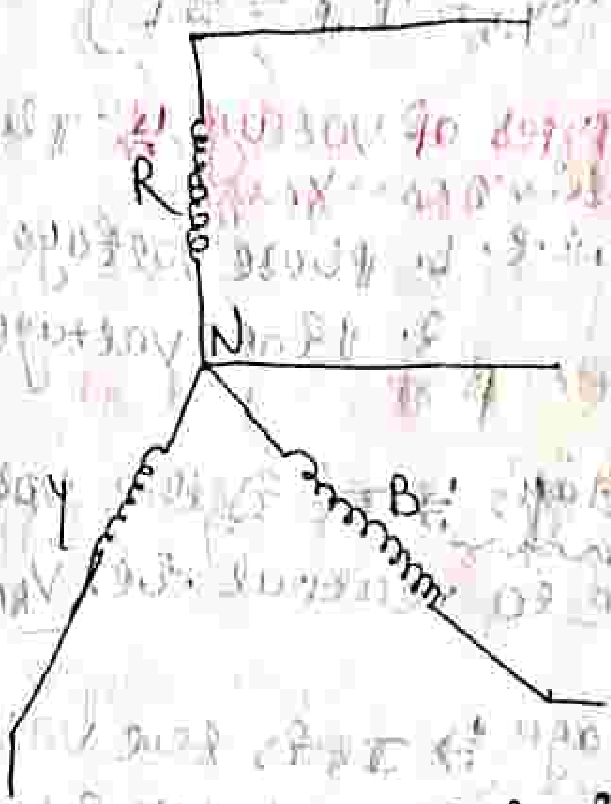
1. Phase voltage ⇒ It is the voltage lies been any phase to neutral i.e. $[V_{RN} = V_{BN} = V_{YN} = V_{ph}]$

2. Line voltage ⇒ It is the voltage lies between any two phases. i.e. $[V_{RY} = V_{YB} = V_{RB} = V_L]$.

⇒ In case of three phase circuit there are two types of configurations is possible. i.e.
(a) Star(Y) connections or star(Y) configuration.
(b) Delta (Δ) connections or Delta(Δ) configuration.

(a) Star connection ⇒ If the similar ends of three individual winding are connected in a single point and the output is taken by other three points of winding then the configuration is known as star(Y) connection or configurations.

⇒ As we know that the ac supply generated by ac generator or alternator so that the winding of alternator are star connection.



⇒ In this case the output is obtained is on the four wire system.

* Relations between different types of current (I_{ph}) or (I_L) ⇒

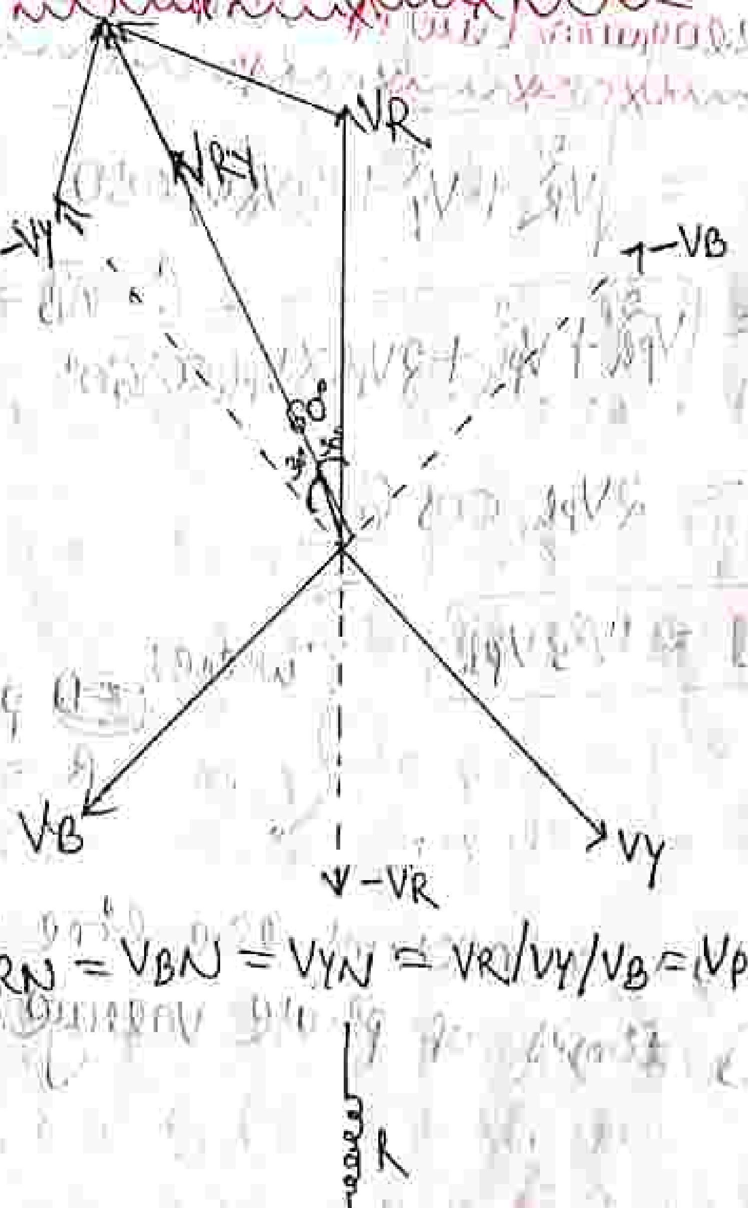
⇒ If the current flowing between R to N, Y to N and B to N then it is called phase current (I_{ph}).

⇒ Similarly the current flowing between R to Y, Y to B and B to R are known as line current (I_L).

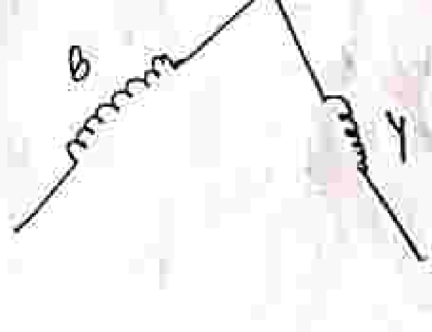
So, it is seens that each line is in series with its individual phase winding. Hence the line current in each line is the same as that the phase winding current to which the line is connected.

So here; $\boxed{I_L = I_{ph}}$

Relations between different voltage:-



$\Rightarrow V_{RN} = V_{BN} = V_{YN} = V_R / V_Y / V_B = V_{Ph}$



$$\Rightarrow \vec{V}_{RY} = \vec{V}_{YB} = \vec{V}_{BR} = \vec{V}_L$$

$$\Rightarrow \vec{V}_{RY} = \vec{V}_R - \vec{V}_Y$$

$$\Rightarrow \vec{V}_{YB} = \vec{V}_Y - \vec{V}_B$$

$$\Rightarrow \vec{V}_{BR} = \vec{V}_B - \vec{V}_R$$

* Parallelogram Law of Vector addition :-

$$\Rightarrow \vec{V}_{RY} = \sqrt{V_R^2 + V_Y^2 + 2V_R V_Y \cos\theta}$$

$$\left(\because \vec{AB} = \vec{A}^2 + \vec{B}^2 + 2AB\cos\theta \right)$$

$$\Rightarrow \vec{V}_L = \sqrt{V_{ph}^2 + V_{ph}^2 + 2V_{ph} \times V_{ph} \cos 60^\circ}$$

$$\Rightarrow \vec{V}_L = 2V_{ph} \cos \frac{60^\circ}{2}$$

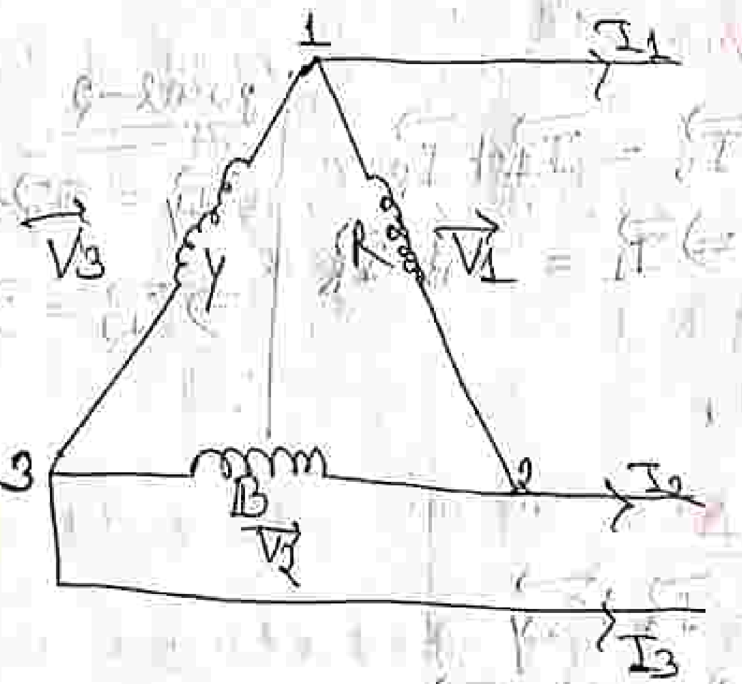
$$\Rightarrow \boxed{\vec{V}_L = \sqrt{3}\, V_{ph}}$$

where: $P = Q$

$$R = 2P\cos\frac{\theta}{2}$$

$\Rightarrow$ In star connection, the line voltage is $\sqrt{3}$ times of phase voltage.

* **Delta Connection:** In the delta connection the two dissimilar end of two windings are connected to a single point i.e. the three windings dissimilar end are connected three distinct points to ~~form~~ form a closed path.



* **Relation between different types of voltage:**

⇒ In delta connection among the 3 phases, two phases are acts as incoming and one phase is acts as neutral. So we say that the voltage between any two phase, it either V_{ph} or V_L. So $V_L = V_{ph}$.

* **Relation between line current and phase current:**

* Here the line currents are $I_1 = I_2 = I_3 = I_L$.
* Here $\vec{I_1}, \vec{I_2}, \vec{I_3}$ are line current, whereas I_R, I_Y and I_B.

$\Rightarrow \vec{I_1} = \vec{I_2} = \vec{I_3} = \vec{I_L}$

$\Rightarrow \vec{I_R} = \vec{I_Y} = \vec{I_B} = \vec{I_{Ph}}$

Applying KCL to point 1, 2, 3 $\Rightarrow$

<u>point-1</u>

$\vec{I_B} = \vec{I_1} + \vec{I_R}$

$\Rightarrow \vec{I_1} = \vec{I_B} - \vec{I_R}$

<u>point-2</u>

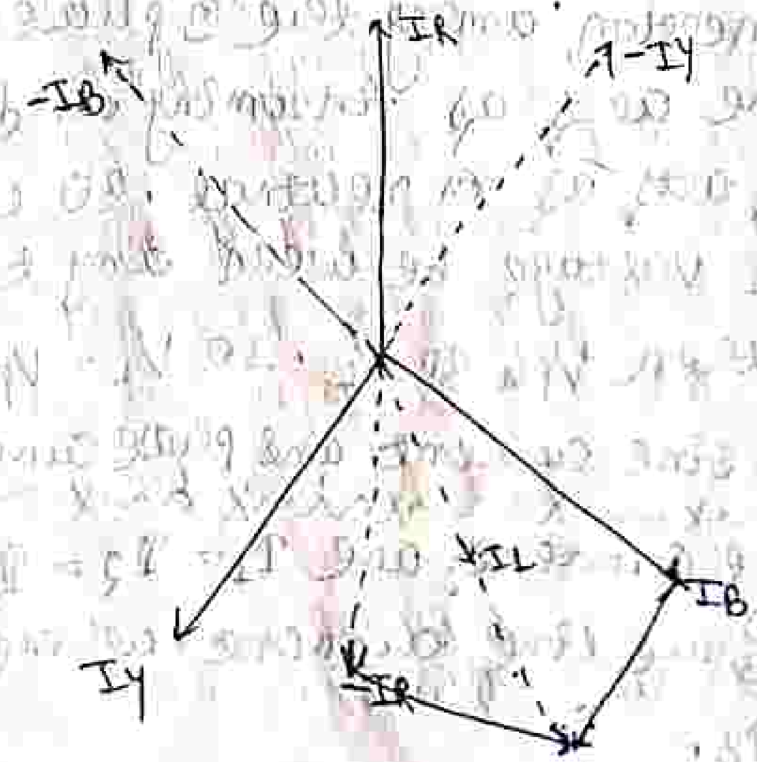
$\vec{I_Y} = \vec{I_2} + \vec{I_B}$

$\Rightarrow \vec{I_2} = \vec{I_Y} - \vec{I_B}$

<u>point-3</u>

$\vec{I_R} = \vec{I_3} + \vec{I_Y}$

$\Rightarrow \vec{I_3} = \vec{I_R} - \vec{I_Y}$



$$\Rightarrow \vec{I_L} = \sqrt{I_B^2 + I_R^2 + 2 I_B I_R \cos\theta}$$

$$\Rightarrow \vec{I_L} = \sqrt{I_{ph}^2 + I_{ph}^2 + 2 I_{ph} \cdot I_{ph} \cos 60^\circ}$$

Here; $P = Q$

so; $R = 2P\cos\frac{\theta}{2}$

$$\Rightarrow \vec{I}_L = 2\vec{I}_{ph} \cdot \cos\frac{60^\circ}{2}$$

$$\Rightarrow \vec{I}_L = 2\vec{I}_{ph} \cos 30^\circ$$

$$\Rightarrow \boxed{\vec{I}_L = \sqrt{3}\,\vec{I}_{ph}}$$

* 3ϕ power in both 'Y' and 'Δ' connections ⇒

⇒ As we know that the 1ϕ power $(P) = VI\cos\phi$ or $V_{ph} I_{ph} \cos\phi$; so; in both Δ & Y connections the 3ϕ power;

$$\Rightarrow 3\phi \text{ power} = 3 V_{ph} I_{ph} \cos\phi$$

⇒ In Δ ⇒ In Δ connection we know that;

$$V_L = V_{ph} \;\&\; I_L = \sqrt{3} I_{ph}$$

$$\text{so; } P(3\phi) = 3 V_{ph} I_{ph} \cos\phi$$

$$= 3 V_L \frac{I_L}{\sqrt{3}} \cos\phi$$

$$\Rightarrow \boxed{P(3\phi) = \sqrt{3} V_L I_L \cos\phi}$$

* In Y (star):-

Y connections we know that,

$I_L = I_{ph}$ and $V_L = \sqrt{3} V_{ph}$.

So; $P(3\phi) = 3 V_{ph} I_{ph} \cos\phi$

$= 3 \frac{V_L}{\sqrt{3}} I_L \cos\phi$

$\Rightarrow \boxed{P(3\phi) = \sqrt{3} V_L I_L \cos\phi}$

Both Y and Δ connections the power is constant.

New chapter, Filter circuit

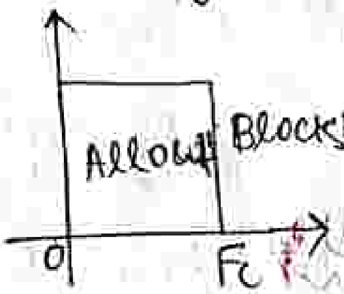
* Filter is an electrical circuit used for purifying the electrical energy. Mostly AC electrical energy, as it has associated with frequency. So we design such circuit by combining different circuits elements like R-L-C.
* Among of elements R-L and C, the inductance and capacitance are frequency sensitive element. As we know that $X_L = 2\pi f L$ and $X_C = \frac{1}{2\pi f C}$, from this relations it is concluded that $X_L \propto F$ and $X_C \propto \frac{1}{F}$.

→ So, by combining R-L-C circuit elements we have design such circuit which may allow or rejects particular frequency. So according to passing of different ranges of frequency the filters circuit are of four types ⇒

1. Low pass filter
2. High pass filter
3. Band pass filter
4. Band stop filter

(i) Low pass filter ⇒ According to the name suggest it allows only lower order frequency but attenuates (block) all other higher frequency. So it allow frequency from zero(0) to cut-off frequency (fc).

⇒

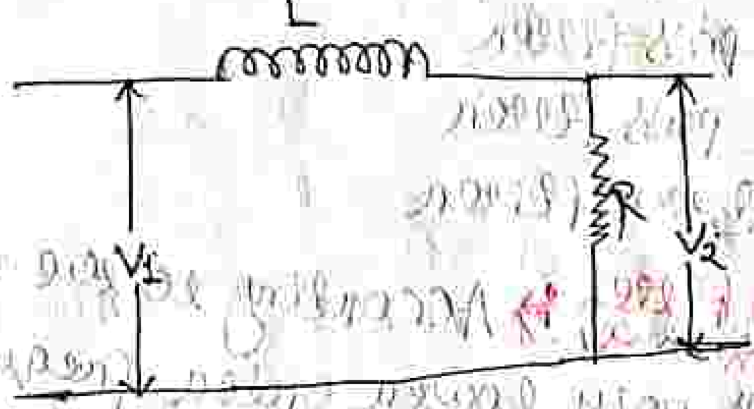


* Cut-off frequency ⇒ It is the frequency upto which or from which the frequency allow by the filter circuit allow or stop frequency response.

⇒ According to the circuit arrangement the low pass filter are of two types ⇒
(i) R-L low pass filter
(ii) R-C low pass filter

(i) R-L low pass filter ⇒

⇒ Here inductance (L) is connected in series instead parallel because at low frequency, the inductance offer low impedance. So; easily the lower frequency pass from input to output.

⇒ 

ω_c = cut-off angular velocity $= \frac{R}{L}$
(Taking laplace transform of above circuits)

$\Rightarrow 2\pi f_c = R/L$

$\Rightarrow f_c = \frac{R}{2\pi L}$

(ii) R-C low pass filter ⇒

⇒ Here the capacitance is connected in parallel instead of series, because at low frequency it effects a high impedance.

$\Rightarrow \omega_c = \frac{1}{RC}$ (Taking laplace transform)

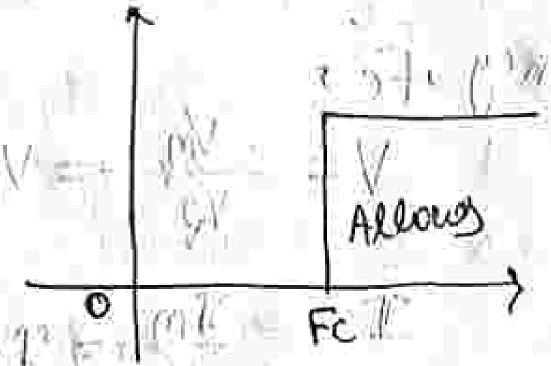
$\Rightarrow 2\pi f_c = \frac{1}{RC}$

$\Rightarrow \boxed{F_c = \frac{1}{2\pi RC}}$

(2) High pass filters ⇒

⇒ According to the name suggest it allows higher order frequency or attenuates towards lower order frequency.

⇒



⇒ It is also are two types below
(i) R-L high pass filters
(ii) R-C high pass filters

(i) R-L high pass filters ⇒

⇒ $\omega_L = \frac{R}{L}$

⇒ $2\pi F_L = R/L$

⇒ $\boxed{F_L = \frac{R}{2\pi L}}$

(ii) R-C high pass filters ⇒

⇒ $\omega_C = 1/\omega C$

⇒ $2\pi f_C = 1/RC$

⇒ $\boxed{F_C = \frac{1}{2\pi RC}}$

* Cut-off frequency (F_c) ⇒

⇒ It is the frequency at which magnitude of element parameter (V or I) is $\frac{1}{\sqrt{2}}$ times of maximum magnitude (RMS value).

At frequency, F_c,

$$V = \frac{V_m}{\sqrt{2}} = V_{RMS}$$

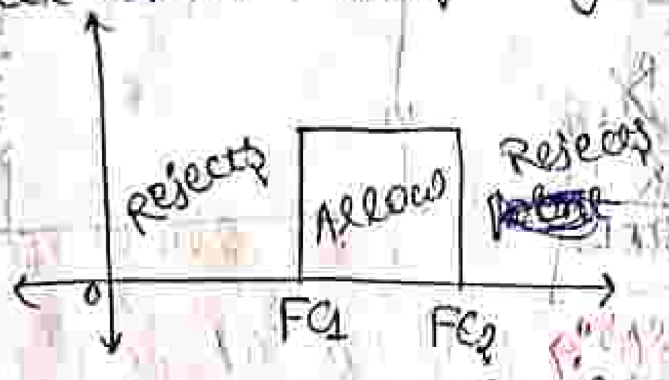
$$I = \frac{I_m}{\sqrt{2}} = I_{RMS}$$

⇒ But power = $\frac{1}{2}$ times of P_m (maximum power).

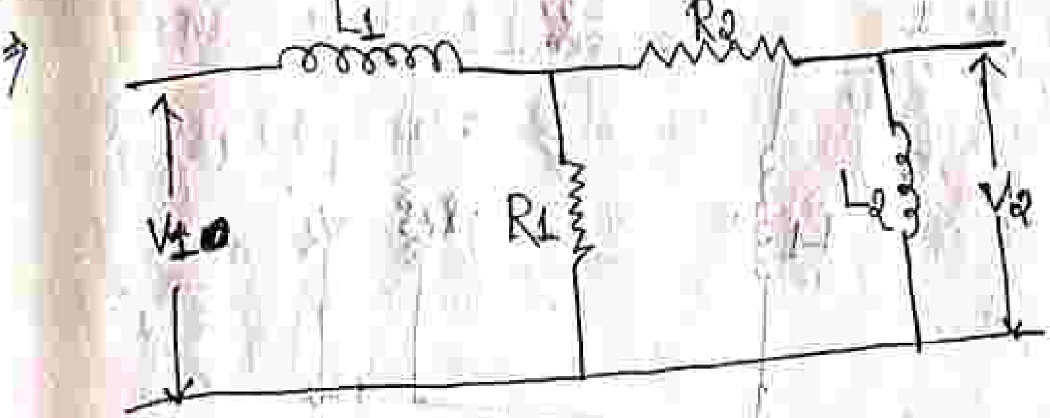
(3) "Band pass filter" (BPF) ⇒

⇒ It is the circuit which allow only particular band of frequency and rejects towards all others frequency.

⇒

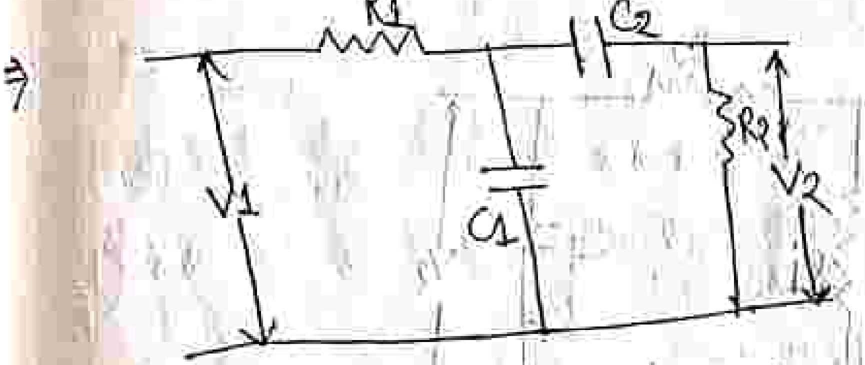


⇒ This filter circuit is obtained by cascading low pass filter with high pass filter i.e. the low pass filter allow frequency from 0 to F_{C2} and the high pass filter allows frequency from F_{C1} to infinity. So cascading both the band F_{C1} to F_{C2} is obtained.



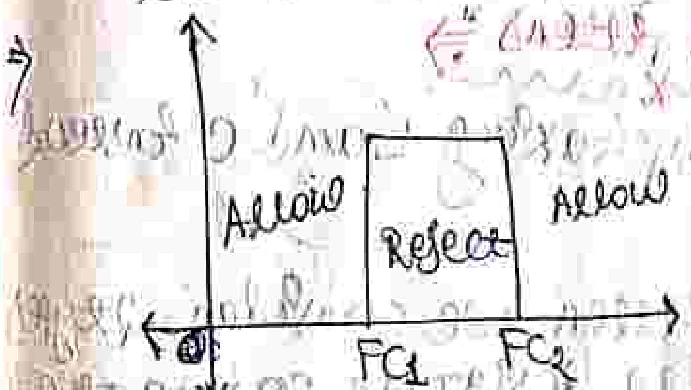
$F_{CL} = \frac{1}{2\pi R_1 C_1}$, $F_{CH} = \frac{R_2}{2\pi L_2}$

where,
F_{CL} = Low cut-off frequency
F_{CH} = High cut-off frequency



(4) Band stop filter (BSF) :-

⇒ It is the filter circuit which doesnot allow particular band of frequency except that particular band.

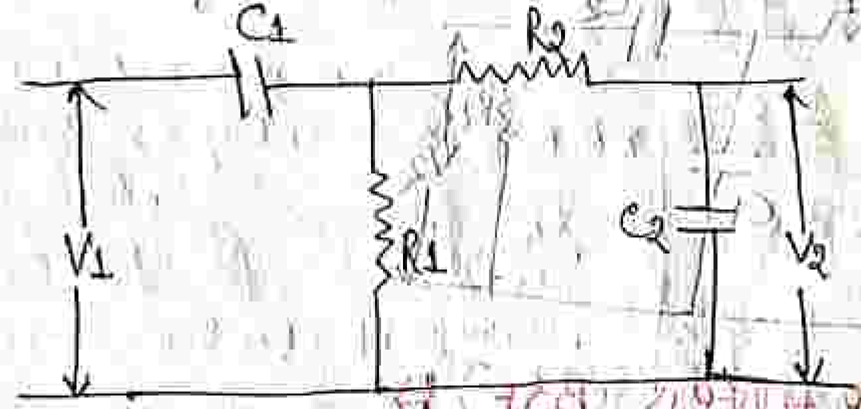


⇒ Band stop filter is obtained by cascading high pass filter with low pass filter.

⇒

$$F_{CL} = \frac{R_1}{2\pi L_1}$$

⇒



$$F_{CH} = \frac{1}{2\pi R_2 C_2}$$

Dt:⇒ 03.12.2020

* Constant (K) Types filters ⇒

(i) It can be design by taking 'L' and 'C' instead of R-L and R-C.

(ii) In this types of filter we consider 2 types of impedance while designing constant (K) type filter. The impedance are Z_1 and Z_2.

⇒ Z_1 = Series impedance.

⇒ Z_2 = Shunt impedance.

→ The product of Z_1 and Z_2 is a constant i.e.

$$\Rightarrow Z_1 \times Z_2 = K = (R_o)^2$$

where R_o is known as design impedance of particular frequency.

(iii) The filter circuit which obeys this above property is called constant k-types filter. So while designing the filter circuit is of two types of configurations are generally possible for every filter circuit i.e.

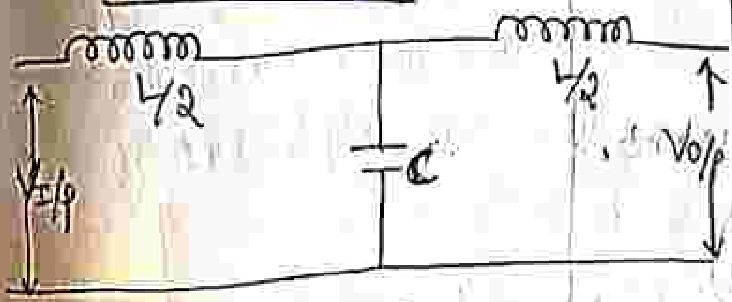
(1) T-type sections.

(2) π-type sections.

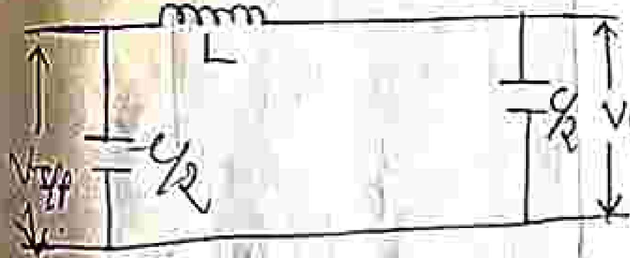
Low pass filters	High pass filters

Low pass filters

T-sections

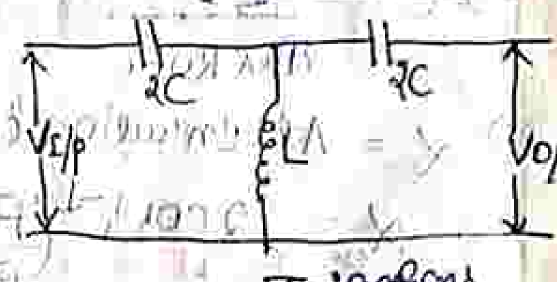


π-sections

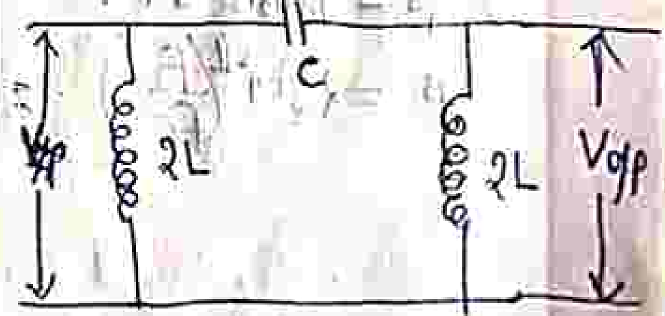


High pass filters

T-sections



π-sections



Low pass Filters	High pass Filters
$\Rightarrow Z_0(T) = R_0\sqrt{1-\left(\frac{F}{F_C}\right)^2}$	$\Rightarrow Z_0(T) = R_0\sqrt{1-\left(\frac{F_C}{F}\right)^2}$
$\Rightarrow R_0 = \sqrt{\frac{L}{C}}$	$\Rightarrow Z_0(\pi) = \frac{R_0}{\sqrt{1-\left(\frac{F_C}{F}\right)^2}}$
$\Rightarrow F_C = \frac{1}{\pi\sqrt{LC}}$	$\Rightarrow R_0 = \sqrt{LC}$
$\Rightarrow Z_0(\pi) = \frac{R_0}{\sqrt{1-\left(\frac{F}{F_C}\right)^2}}$	$\Rightarrow F_C = \frac{1}{4\pi\sqrt{LC}}$
$\Rightarrow Z_0(T)$ and $Z_0(\pi)$ are characteristics impedance of T and π sections.	$\Rightarrow L = \frac{R_0}{4\pi F_C}$
$\Rightarrow R_0$ = Design impedances.	$\Rightarrow C = \frac{1}{4\pi R_0 F_C}$
$\Rightarrow F_C$ = Cut-off frequency.	$\Rightarrow \alpha = 2\cosh^{-1}\left(\frac{F_C}{F}\right)$
$\Rightarrow L = \frac{R_0}{\pi F_C}$	$\Rightarrow \beta = 2\sin^{-1}\left(\frac{F_C}{F}\right)$
$\Rightarrow C = \frac{1}{\pi R_0 F_C}$	
$\Rightarrow \alpha$ = Attenuation constant.	
$\Rightarrow \alpha = 2\cosh^{-1}\left(\frac{F}{F_C}\right)$	
$\Rightarrow \beta$ = Phase shift	
$\beta = 2\sin^{-1}\left(\frac{F}{F_C}\right)$	

New chapter ⇒ Two port Networks Dt:- 08.12.2020

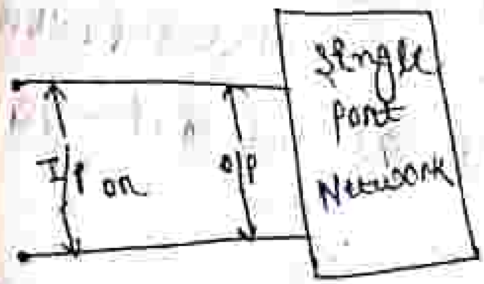
* Two port Network ⇒ In the two-port network we found input voltage and output voltage, resulting which flow a current between input to output.

⇒ So two port network is a network which performed specific task when input is given and at last it shows a specific output voltage.

⇒ There are two types of port networks are present :-

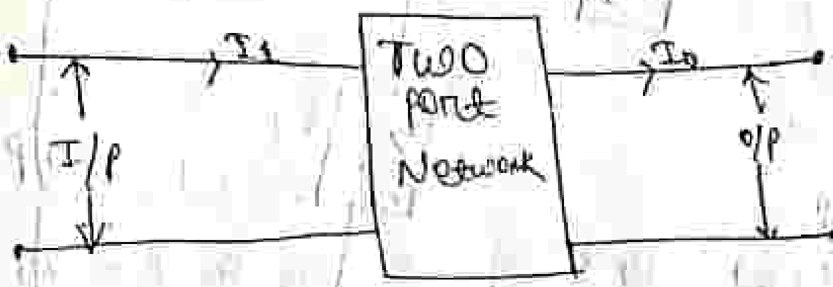
1. Single-port network
2. Two-port network

(1.) Single-port Network ⇒ Any active or passive network containing only two terminals or a pair of terminals which is acts as both input and output then it is called single-port network.



The pair of terminal is of either use as input or output it is represented by a rectangular box with two terminals.

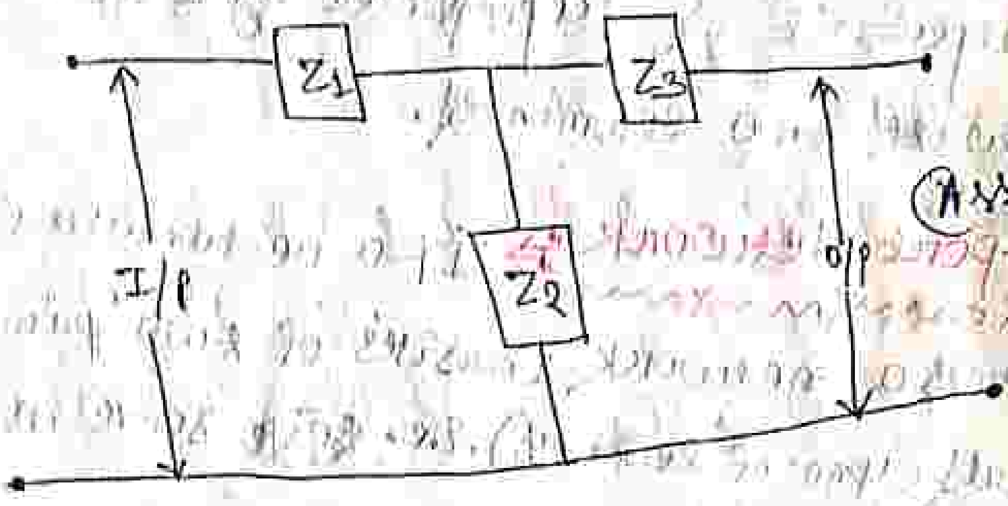
Two-port Network :- If a rectangular box that represents a network consists of two pairs of terminals (4 no: of terminals). i.e. serve as input pair and output pair.



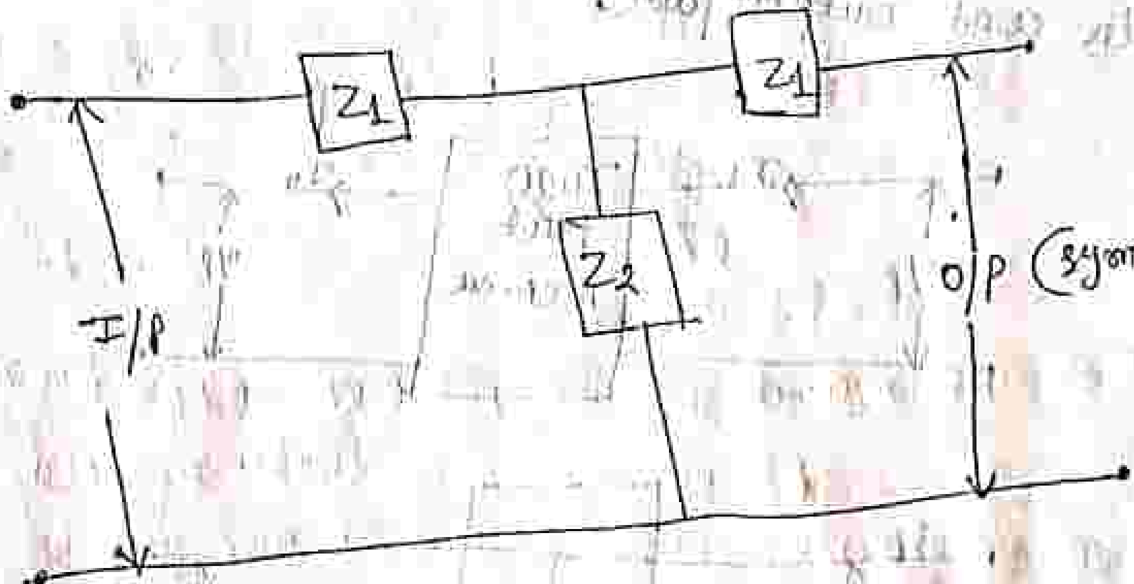
* Network configurations ⇒

⇒ There are several network configurations among which T and π are mainly used.

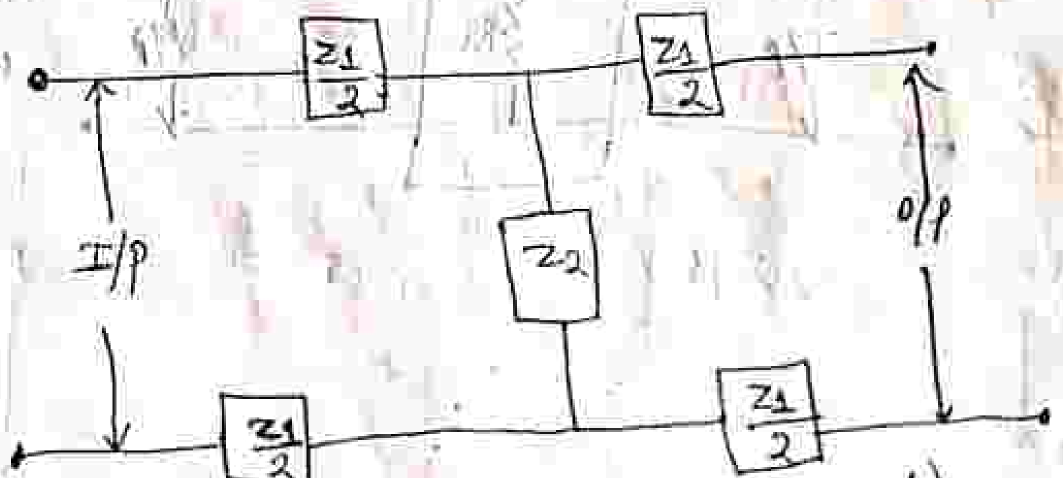
⇒ T-Sections ⇒



(Assymetric)

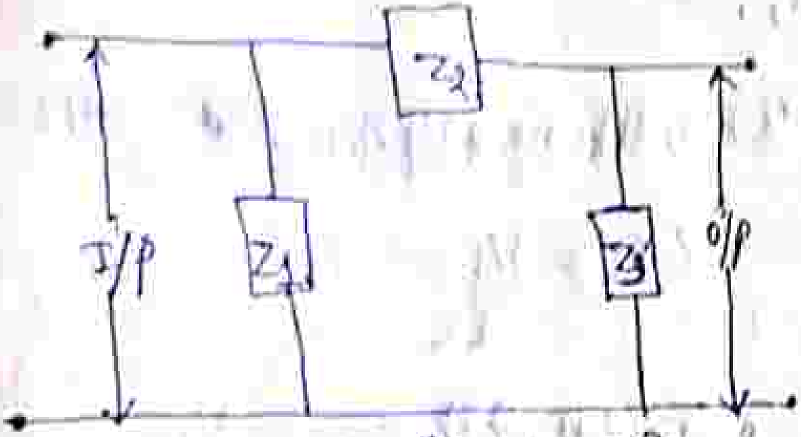


(Symmetric



(Symmetric Balanced)

→ π - section

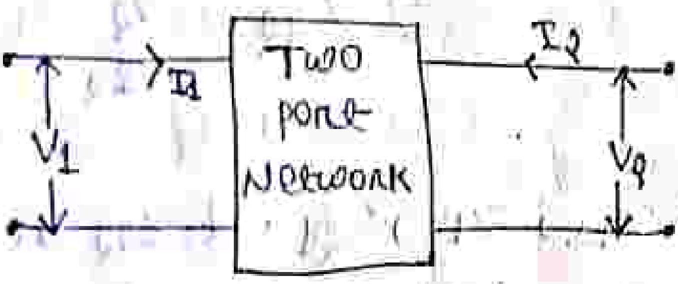


(Assymetric)

* Z-parameters or open circuit parameter or Impedance parameter

* parameter :

⇒ For a two-port network. V_1 and V_2 are input and output voltage and I_1 and I_2 are input and output current, so a two port network represented by a Z-parameters.



In matrix form;

$$\Rightarrow \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$\Rightarrow V_1 = I_1 Z_{11} + I_2 Z_{22} \longrightarrow (i)$$

$$\Rightarrow V_2 = I_1 Z_{21} + I_2 Z_{22} \longrightarrow (ii)$$

⇒ Let; the output terminal is open circuited, i.e. $I_2 = 0$.

~~so forma~~ so; from eqn (1); we get

$$Z_{11} = \frac{V_1}{I_1}$$

and from eqn.(2) $Z_{21} = \dfrac{V_2}{I_1}$

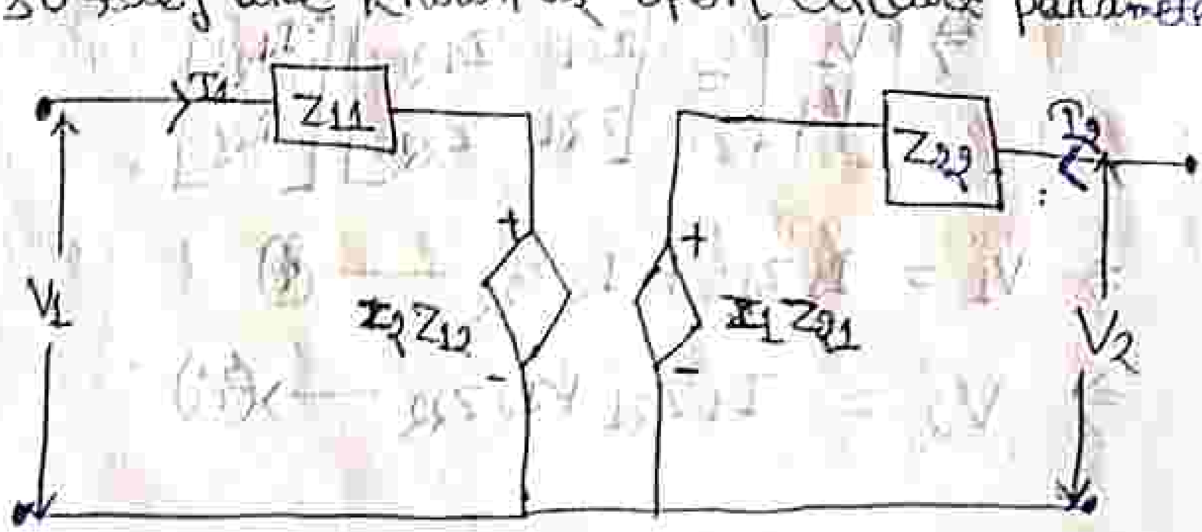
Let; the input terminal is open circuited. i.e. $I_1 = 0$.

so; from eqn.(1) ⇒ $Z_{12} = \dfrac{V_1}{I_2}$

and from eqn.(2);

$$\Rightarrow Z_{22} = \frac{V_2}{I_2}$$

⇒ Here; Z_{11}; Z_{12}; Z_{21} and Z_{22} are obtained by open circuited the terminal; so they are known as open circuit parameters.



Where; I_1Z_{21} and I_2Z_{22} are current control voltage source (CCVS) and Z_{11} and Z_{22} are input ~~and~~ output side impedances.

* Short circuit parameter or ~~Y-par~~ Y-parameters (Admittance) ⇒

⇒ The admittance is defined as the reciprocal of real port of the impedance. i.e. reciprocal of impedance also.

so; $\boxed{Y = \frac{1}{Z}}$

$$\Rightarrow Z = \frac{V}{I} \Rightarrow I = \frac{V}{Z} \Rightarrow \boxed{I = VY}$$

or $\boxed{Y = \frac{I}{V}}$

Here; in matrix form;

$$\Rightarrow [I] = [V] \times [Y]$$

$$\Rightarrow \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \times \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix}$$

In equation form;

$$I_1 = Y_{11}V_1 + Y_{12}V_2 \longrightarrow (i)$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2 \longrightarrow (ii)$$

Where; Y_{11} and Y_{12}, Y_{21} & Y_{22} are short circuit parameters or Y-parameter.

⇒ When output terminal is short circuited then $V_2 = 0$.

From eqn. ①; $I_1 = Y_{11} V_1$

$$\Rightarrow Y_{11} = \frac{I_1}{V_1}$$

From eqn. ②; $I_2 = Y_{21} V_1$

$$\Rightarrow Y_{21} = \frac{I_2}{V_1}$$

⇒ When input terminal is short circuited then $V_1 = 0$.

From eqn. ① ⇒ $I_1 = Y_{12} V_2$

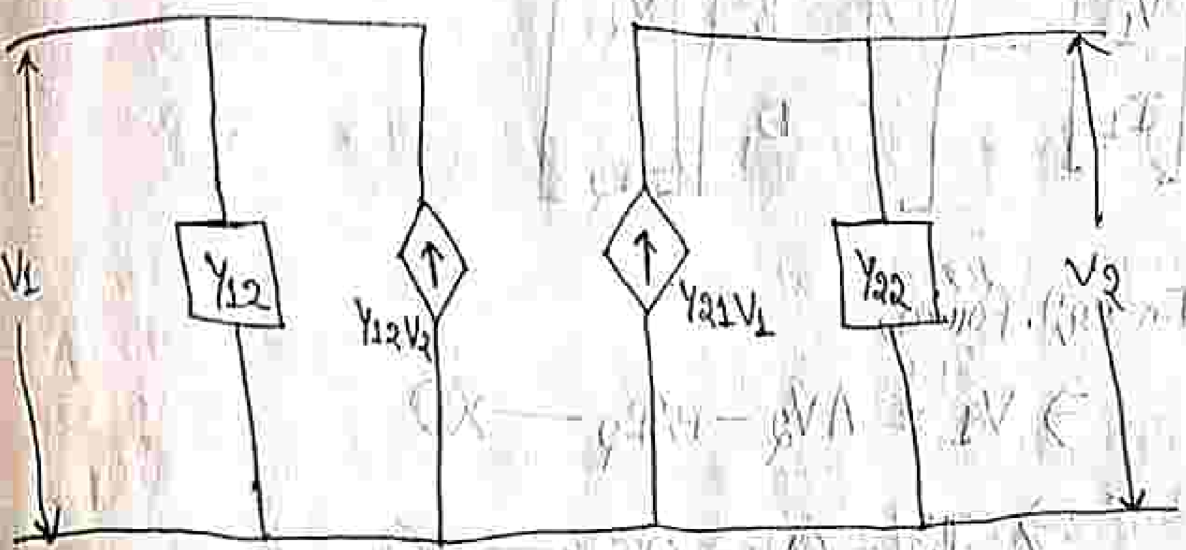
$$\Rightarrow Y_{12} = \frac{I_1}{V_2}$$

From eqn. ② ⇒ $I_2 = Y_{22} V_2$

$$\Rightarrow Y_{22} = \frac{I_2}{V_2}$$

where, Y_{11}, Y_{22} are input and output driving point admittance and Y_{12}, Y_{21} are reverse and forward transformation admittance.

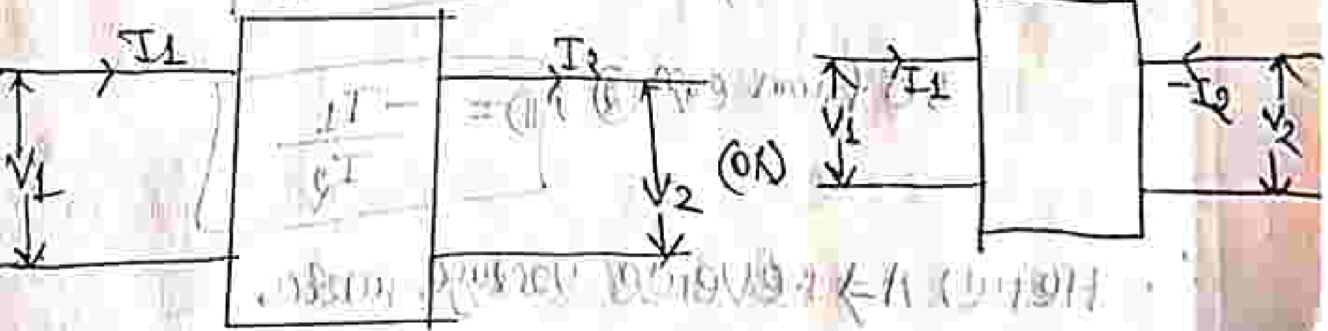
mathematically;



where, $Y_{12}V_2$ and $Y_{21}V_1$ are voltage control current source.

* ABCD parameters or mixed parameters or Transmission parameters:-

⇒ ABCD parameters are mostly used in analysed power transmission in a transmission line it is known as mixed circuit parameters or transmission parameters. Hence the input side is known sending ends and output side is known as receiving ends.



$$\Rightarrow \begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

⇒ In eqn. form;

$$\Rightarrow V_1 = AV_2 - BI_2 \longrightarrow (1)$$

$$\Rightarrow I_1 = CV_2 - DI_2 \longrightarrow (2)$$

⇒ When output side is open circuited;

so, $I_2 = 0$

So; from eqn. (1); $\boxed{A = \frac{V_1}{V_2}}$

So; from eqn. (2); $\boxed{C = \frac{I_1}{V_2}}$

⇒ When output is short circuited i.e. $V_2 = 0$

So from eqn. (1); $\boxed{B = \frac{-V_1}{I_2}}$

So from eqn. (2); $\boxed{D = \frac{-I_1}{I_2}}$

∴ Here; A ⇒ Reverse voltage ratio.

C ⇒ Transfer admittance.

B ⇒ Transfer impedance.

D ⇒ Reverse current ratio.

Dt:- 17.12.2020

* **Coupled Circuit:-** The coupled circuit is based on inductance i.e. the property of inductor. The inductance means the property of a material which opposes the ~~charge~~ change of sudden value of current. It is denoted by 'L'. Its unit is Henery(H).

⇒ Generally; inductors are nothing but a coil i.e. conductor having a number of turns. When current flow through the inductor or coil, flux is produced and that magnetic flux links with own conductor and emf is induced (according to Faraday's law).

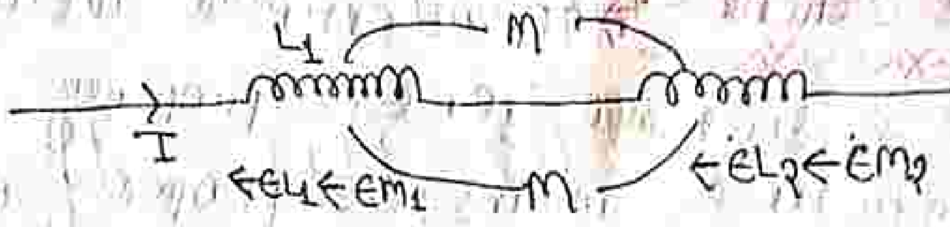
So; $\boxed{e = -N\frac{d\phi}{dt}}$ where; 'N' is the no. of turns of the coil.

⇒ Due to change of current across the inductor the emf is also induced in the coil. So again

$$\boxed{e = -L\frac{dI}{dt}}$$

where; 'L' is the co-efficient of self inductance and $\frac{dI}{dt}$ is the rate of change of current with respect to time.

* **Inductance are in series** ⇒



⇒ Here L_1 and L_2 are connected in series and the current flowing is I. Due to current flowing the flux are produced in both the inductors.

⇒ As both the inductors are closely coupled, so flux L_1 links with inductor L_2 and induces an emf, similarly for vice versa. so emf induced;
$$\boxed{e_{L_1} = -L_1 \frac{dI}{dt}}$$

$$\boxed{e_{L_2} = -L_2 \frac{dI}{dt}}$$ {self-inductance emf (e_{L_1} and e_{L_2})}

⇒ EMF induced in e_1;
$$\boxed{e_{m_1} = -M \frac{dI}{dt}}$$ (mutual induced emf in L_1)

⇒ EMF induced in e_2;
$$\boxed{e_{m_2} = -M \frac{dI}{dt}}$$ (mutual induced emf in L_2)

⇒ Here 'M' is the co-efficient of mutual inductance

⇒ Total applied voltages;

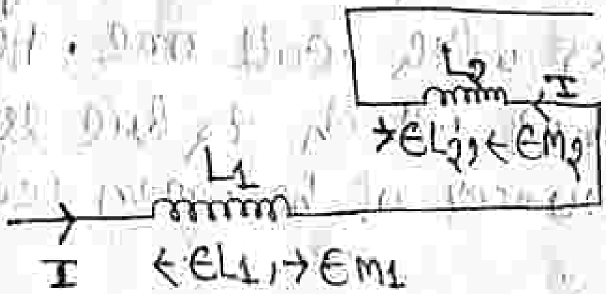
$$\Rightarrow E = E_{L_1} + E_{L_2} + e_{m_1} + e_{m_2}$$

$$\Rightarrow -L\frac{dI}{dt} = \left(-L\frac{dI}{dt}\right) + \left(-L_2\frac{dI}{dt}\right) + \left(-m\frac{dI}{dt}\right) + \left(-m\frac{dI}{dt}\right)$$

$$\Rightarrow -L = -L_1 - L_2 - m - m$$

$$\Rightarrow \boxed{L = L_1 + L_2 + 2m}$$

* Inductance are in series opposition ⇒



⇒ In case of series opposition the mutual induced emf in both the case oppose the self induced emf. As the direction of current in both the inductor are opposite.

Hence; $E_{L_1} = -L_1\frac{dI}{dt}$, $e_{m_1} = m\frac{dI}{dt}$

$E_{L_2} = -L_2\frac{dI}{dt}$, $e_{m_2} = m\frac{dI}{dt}$

⇒ Total induced emf;

$$\Rightarrow E = E_{L_1} + E_{L_2} + e_{m_1} + e_{m_2}$$

$$\Rightarrow -L\frac{dI}{dt} = \left(-L_1\frac{dI}{dt}\right) + \left(-L_2\frac{dI}{dt}\right) + \left(m\frac{dI}{dt}\right) + \left(m\frac{dI}{dt}\right)$$

$\Rightarrow -L = -L_1 - L_2 + M + M$

$\Rightarrow -L = -L_1 - L_2 + 2M$

$\Rightarrow \boxed{L = L_1 + L_2 - 2M}$

* ~~Mutual~~

* Mutual Inductance $\Rightarrow$ If two coils are placed nearer to each other (closely coupled) then flux of the coil one links with coil two or more simultaneously flux of coil two links with coil one. Hence an emf is induced, which is due to the mutual inductance of between the two coils.

* Co-efficient of coupling $\Rightarrow$

$\Rightarrow$ It is denoted by 'K'. It is defined as the fraction of total flux that links with other coil or the ratio of mutual inductance actually present between the two coils to the maximum possible flux.

Sol $\Rightarrow \boxed{K = \dfrac{\phi_{12}}{\phi_{11}}}$ (for coil-1)

$\Rightarrow \boxed{K = \dfrac{\phi_{21}}{\phi_{22}}}$ (for coil-2)

→ As ϕ_{12} and ϕ_{21} are less than ϕ_{11} and ϕ_{22} ; so the value of 'K' is less than 1. i.e. $(K < 1)$.

→ we know that ; $M = N_1 \frac{d\phi_{21}}{dI_2}$

$$\Rightarrow \boxed{M = N_1 \frac{\phi_{21}}{I_2}} \longrightarrow (1)$$

→ Similarly ; again ; $M = N_2 \frac{d\phi_{12}}{dI_1}$

$$\Rightarrow \boxed{M = N_2 \frac{\phi_{12}}{I_1}} \longrightarrow (2)$$

→ multiplying eqn (1) and (2) we get ;

$$\Rightarrow M^2 = N_1 \frac{\phi_{21}}{I_2} \times N_2 \frac{\phi_{12}}{I_1}$$

$$\Rightarrow M^2 = N_1 \cdot N_2 \frac{\phi_{21}}{I_2} \cdot \frac{\phi_{12}}{I_1}$$

$$\Rightarrow M^2 = K^2 \left(\frac{N_1 \phi_{11}}{I_1}\right) \cdot \left(\frac{N_2 \phi_{22}}{I_2}\right)$$

$$\Rightarrow M^2 = K^2 \cdot L_1 \cdot L_2$$

$$\Rightarrow \boxed{M = K\sqrt{L_1 \cdot L_2}}$$

Here ;

$$\Rightarrow e_{L_1} = -L_1 \frac{dI_1}{dt} \quad ; \quad e_{L_1} = -N_1 \frac{d\phi_{11}}{dt}$$

$$\Rightarrow -L_1 \frac{dI_1}{dt} = -N_1 \frac{d\phi_{11}}{dt}$$

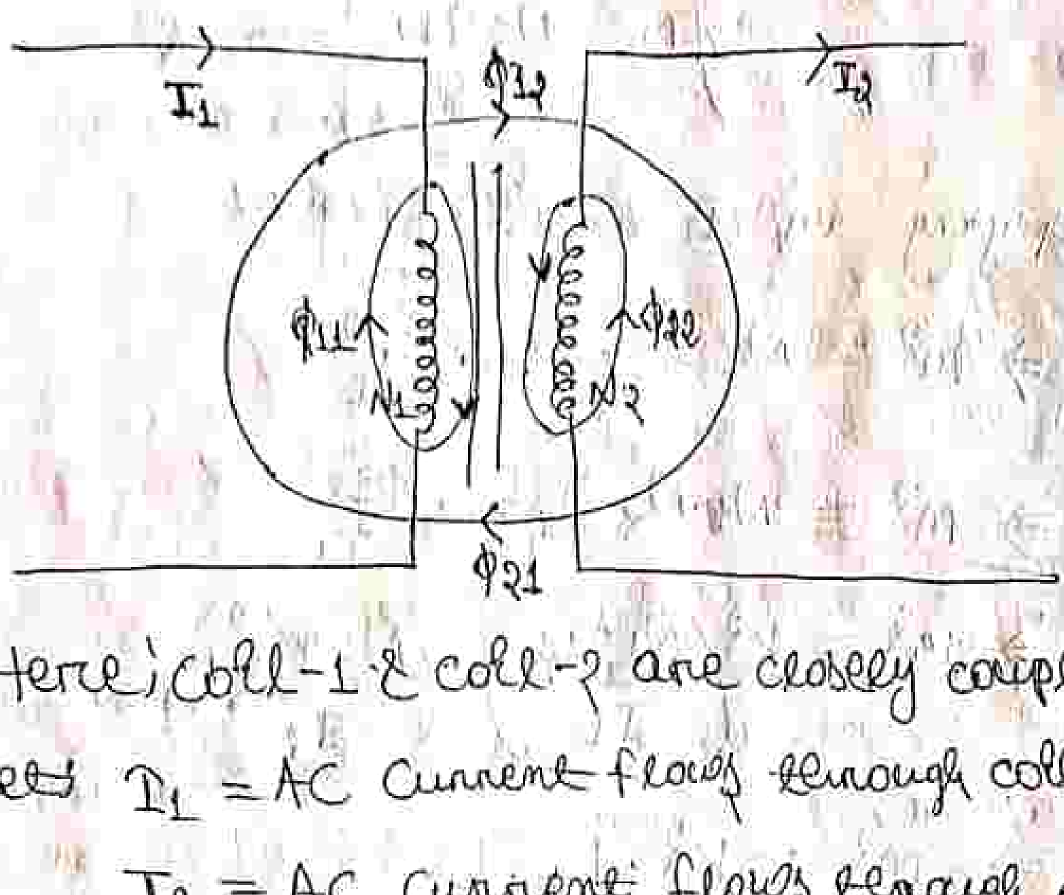
$$\Rightarrow L_1 = N_1 \frac{d\phi_{11}}{dI_1} = N_1 \frac{\phi_{11}}{I_1}$$

$\therefore$ Similarly;

$$\Rightarrow L_2 = N_2 \frac{d\phi_{22}}{dI_2}$$

$$= N_2 \frac{\phi_{22}}{I_2}$$

$\Rightarrow$



$\Rightarrow$ Here; coil-1 & coil-2 are closely coupled.

Let I_1 = AC current flows through coil-1.

I_2 = AC current flows through coil-2.

$\Rightarrow$ ϕ_{11} = self leakage flux of coil-1.

$\Rightarrow$ ϕ_{22} = self leakage flux of coil-2.

$\Rightarrow$ ϕ_{12} = Mutual leakage flux of coil-1 links with coil-2.

⇒ ϕ_{21} = mutual flux of coil-2 links with coil-1.

⇒ N_1 = No: of turns of coil-1.

⇒ N_2 = No: of turns of coil-2.

⇒ EM_1 = EMF induced in coil-1 due to flux coil-2.

$$\Rightarrow \boxed{EM_1 = -N_1 \frac{d\phi_{21}}{dt}} \longrightarrow (1)$$

again; $$\Rightarrow \boxed{EM_1 = -M \frac{dI_2}{dt}} \longrightarrow (2)$$

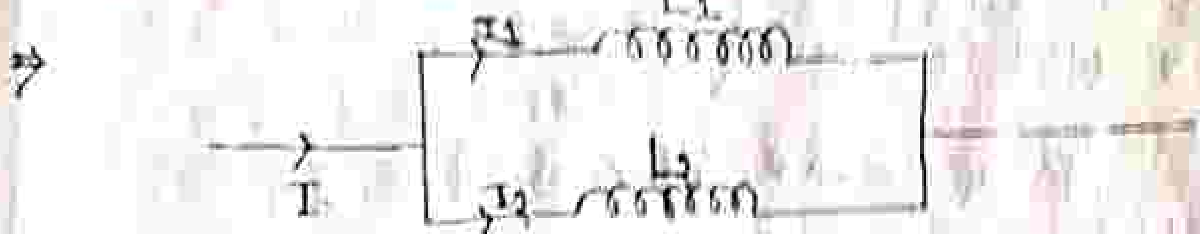
Equating both the equations;

$$\Rightarrow -N_1 \frac{d\phi_{21}}{dt} = -M \frac{dI_2}{dt}$$

$$\Rightarrow \boxed{M = N_1 \frac{d\phi_{21}}{dI_2}}$$

Similarly, for the 2nd coil; $\boxed{M = N_2 \frac{d\phi_{12}}{dI_1}}$ (By taking EM_2).

* Inductance are in parallel :-

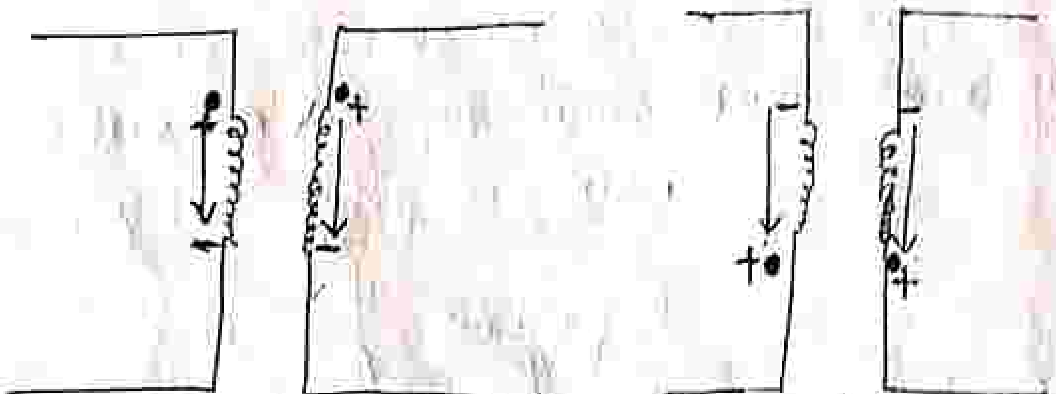


⇒ When; L_1 and L_2 are parallel with same direction of current flow I_1, I_2 then the net inductance ; $L = \boxed{\dfrac{L_1L_2 - M^2}{L_1+L_2-2M}}$

⇒ If the current direction is opposite then;

$$\boxed{L = \frac{L_1L_2 - M^2}{L_1+L_2+2M}}$$

* **Dot convention :-** To determine polarity of induced voltage in the coupled coil we used dot convention so, according to the polarity of induced emf in the coil dot marks should be given. on each coil a dot is placed at the terminal which are instantly same polarity on the basis of mutual inductance.

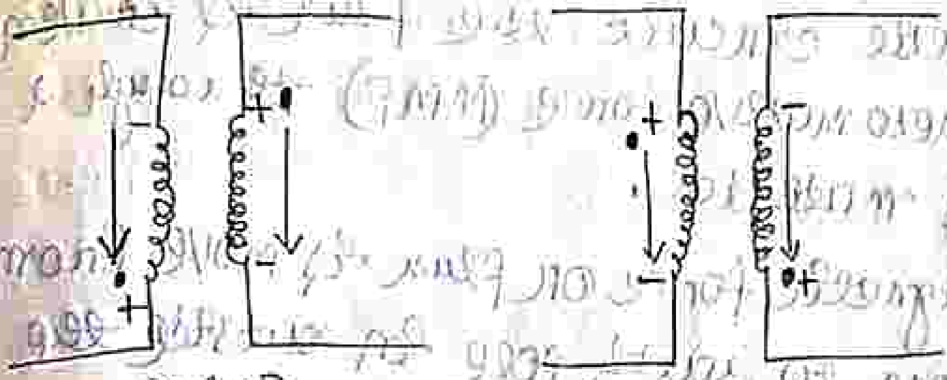


M(+ve)

M(+ve)

⇒ On the basis of dot convention we decided the value of 'M' i.e. either +ve or -ve.

⇒ When the current through each of the mutual coupled coil are going away or going towards the dot then in both the case 'M' is +ve.

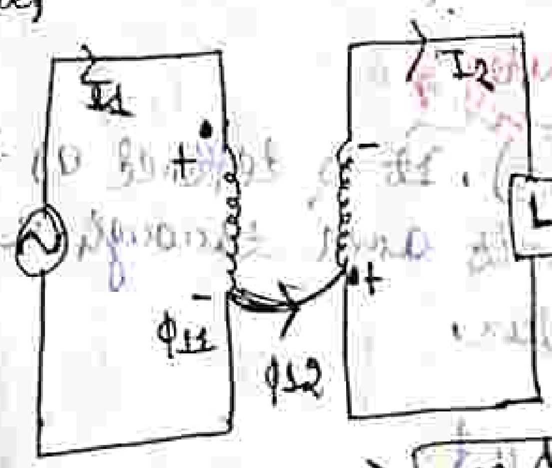


M(+ve) M(+ve)

⇒ When the current flowing through the two coil either leaving the dot in 1 coil and about to enter in other coil and vice-versa then in both the case mutual inductance(M) is (-ve).

⇒ Hence the dot point is given to both the coil of same polarity.

+ Dot convention is used in case of transformers i.e. for example;



$$\Rightarrow \boxed{-M\frac{d\phi_{12}}{dt}}$$

* Magnetic Circuits ⇒

⇒ The magnetic circuit is analogous to electric ckt. The difference is that in case of electrical circuit the emf drives ~~....~~ current through a conductor whereas in case of magnetic circuit the flux is driven by magneto motive force (MMF) through a magnetic material.

⇒ The magnetic force or flux is move from north pole to south pole in outside the magnet whereas it moves from south poles to north poles inside the magnet.

* **Magnetic Force** ⇒ It is denoted by (H). It is defined as the strength of magnetic field at any point within a magnetic field is equal to the force experience by an unit north poles of 1 weber placed at that point.

⇒ Unit is Newton/webers.

* **Magnetic Flux Density** ⇒

⇒ It is denoted by (B). It is defined as the flux passing per unit area through a plane right angles to flux.

so, $B = \frac{\phi}{A}$ weber/m²

where ϕ ⇒ Total no. of flux strikes the plane.

A ⇒ Area of cross-section of the plane.

* Relation Between magnetic force and magnetic flux Density (B and H) :⇒

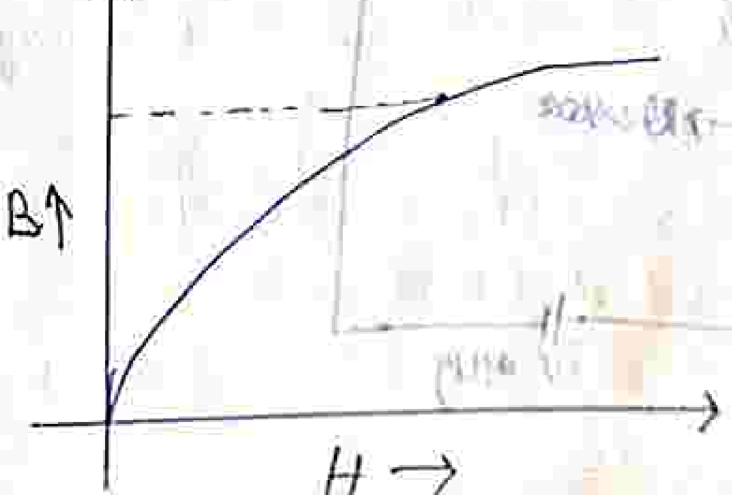
⇒ It is seen that when a magnetic material get magnetised through a magnetic field then the material get magnetised and flux is produced.

⇒ The flux travels through that material from one point to other point (N→S) through that materials.

⇒ As the flux is travels that material having certain cross-sectional area, hence flux density be seen across that materials.

⇒ If we increase the magnetising force as, we see that the flux density (B) across the material is also be increases.

⇒ This variation of flux density with magnetising force is upto point of saturation (if magnetising force increases flux density also increases upto point of saturation). After of saturation if further magnetising force increases the flux density remain constant, the variation is just like a straight-curve lines.



⇒ The flux density (B) and the magnetic force a variation is depends upon types of material. So, according to the variation the materials are of three types. They are ⇒

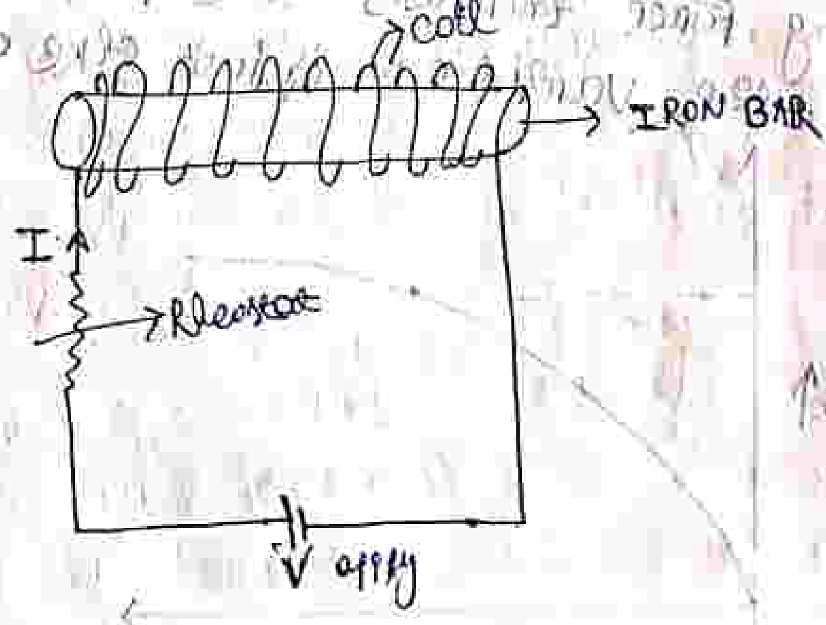
1. Ferro magnetic materials.
2. Dia magnetic materials.
3. para magnetic materials.

⇒ The B-H curve holds better in case of ferro magnetic materials.

* Hysteresis Loop ⇒

⇒ According to B-H characteristics of materials we see that there are three types of materials i.e. ferro, para, dia magnetic. Among these ferro-magnetic materials is suitably show magnetic behaviour. So a ferro-magnetic material should be taken for study B-H characteristics.

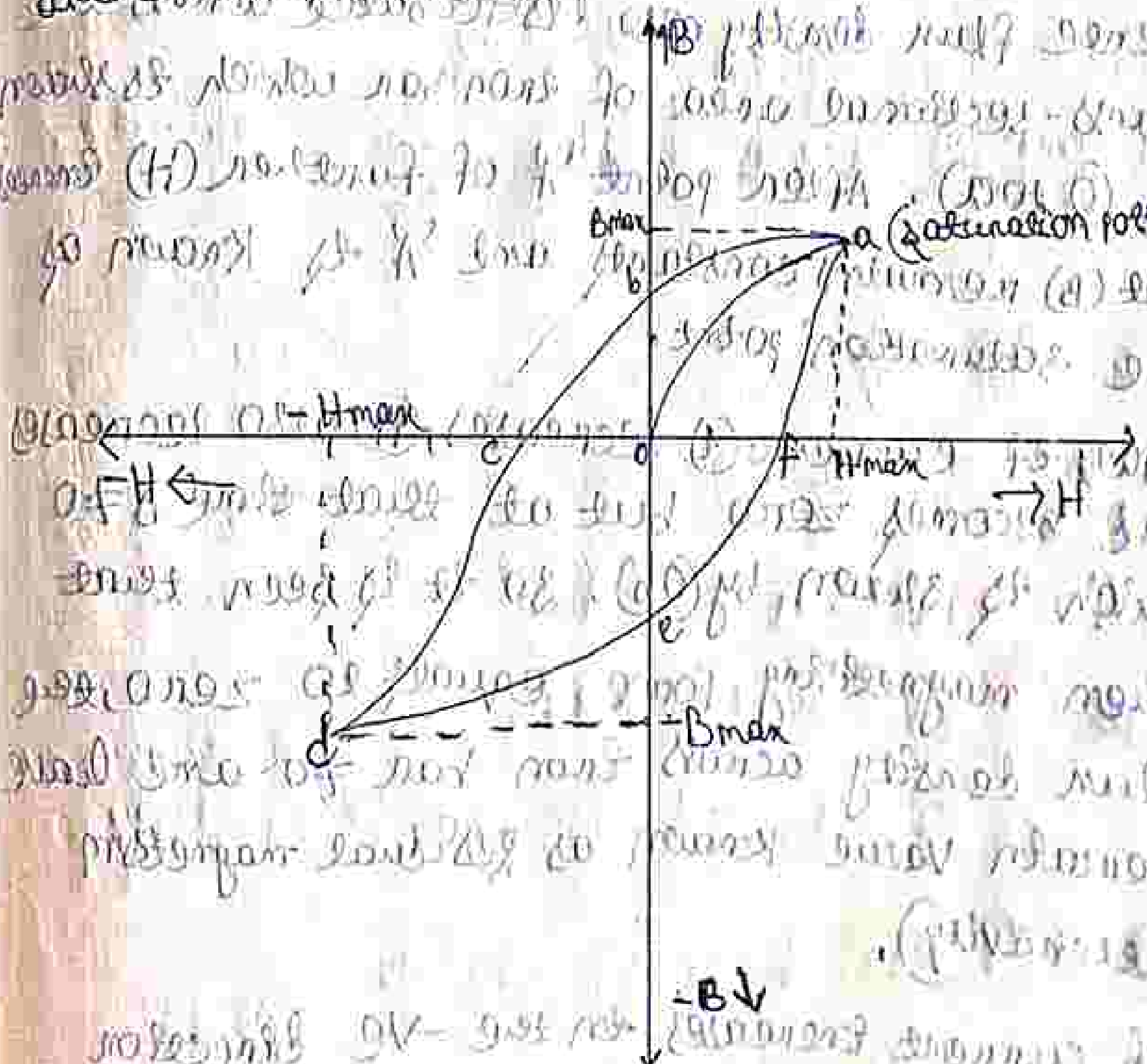
Let us considered an iron bar A.



⇒ Here, iron bar is wound by a coil having several no. of turns. A supply voltage is fed by means of a rheostat to control the current flow through the coil.

⇒ When current flow through the coil/winding a magnetising force is created and which magnetise the iron bar.

⇒ As iron bar has certain cross-sectional area so flux density distribution occurs inside the iron bar i.e. magnetic flux travels within the certain cross-sectional area, which shows a behaviours.



⇒ Hysteresis predicted about lagging of flux density (B) behind the magnetising force (H). So hysteresis loop may be defined as lagging magnetic flux density (B) behind the magnetising force (H) which is shown in figure.

⇒ By varying the rheostat (R) the current through coil is vary. So magnetising force also vary. If current increases then magnetising force also increases and which magnetised the iron bar.

⇒ Hence flux density also distributed across the cross-sectional area of iron bar which is shown by (O to a). After point 'A' of further (H) increase but (B) remains constant and 'A' is known as +ve saturation point.

⇒ Now, if current (I) decreases, (H) also decreases and becomes zero but at that time $B \neq 0$ which is shown by (Ob). So it is seen that when magnetising force equals to zero, the flux density across iron bar $\neq 0$ and have certain value known as Residual magnetism (Retentivity).

⇒ If current increases in the -ve direction (reverse direction) so (H) also increases in the -ve direction (opposite direction) and when

H = oc and at that time B = zero that is known as D-magnetising force of magnetic material.

⇒ Now, if further (H) increases in the reverse direction (B) also increases in the reverse direction which is shown by 'cd' and after point-d, if further (H) increases (B) remains constant. So (d) is known as -ve saturation point.

⇒ If further the current direction is changes i.e. flow as that of previous one then H and B both vary and when H = 0, B = oe known as negative residual magnetism or -ve retentivity.

⇒ If further (H) increases (B) also vary and when H = of, B = 0 and the variation is shown by 'ef' and 'fa'.

⇒ If this points are joined (oabcdefa) then it is seen like loop known as hysteresis loops.