03-04-23

FUNDAMENTALS OF ELECTRICAL ENGINEERING

Electrical Engineering involves transforming the energy from one form to another form (OR) one point to another point.

This so called technology is started with invention of electricity. And it is continued with further invention of electronics. Every engineer should study about electrics & electronics engg. This course will improve the analytical and imagination skills which is important for every engineer.

Syllabus:

UNIT-1:

Basics of Electrical Circuits :-

Charge, Current, Voltage, Power, Passive Components, Source transformation, types of Sources, Resistors, Inductors, Capacitors (RLC) in series & parallel combination, Basics of Circuit Laws, Star-delta transformations.

UNIT-1

BASICS OF ELECTRICAL CIRCUITS

* **Charge (Q) :-**

Charge is a electrical property of atomic particles that causes it to experience a force when it is placed in a electromagnetic field.

mathematically charge is represented with

$$Q = It$$

unit is coulombs.

$1C = 6.24 \times 10^{18}\ \bar{e}$

* **Current (I) :-**

The flow of charge is called current. The strength of current is given by rate of flow of charge, or charge per second.

$$I = Q/t$$

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

* **Electrical potential or Voltage (V) :-**

The capacity of charged body to do work is called electric potential or voltage.

$$V = \frac{W}{Q} \quad ; \quad v = \frac{dw}{dq}$$

Units of electric potential is volts (V).

* **Potential Difference (P.D) or Electromotive Force (EMF) or Voltage or Electric potential :-**

The difference b/w the potentials of two charged bodies is called P.D.

* **Energy (E):** The total work done in a electrical circuit is called Energy.

As we know that, $V = \frac{W}{Q}$

$$W = VQ = VIt$$

E (or) $W = VIt$ Units are Joules (J) or watt-sec.

Watt-sec is not enough to represent energy so, $1000W = 1kW$

$3600\ sec = 1\ hr$

$$1\ kW\text{-}hr = 36 \times 10^5\ W\text{-}sec$$

* Power (P) :-

The rate at which work is done in an electrical circuit is called Power.

$$P = \frac{\text{work done (in a electrical circuit)}}{\text{time}}$$

$$= \frac{VIt}{t}$$

$$= VI$$

(or)

$$P = \frac{\text{work done}}{\text{coulomb}} \times \frac{\text{coulomb}}{\text{time}}$$

$$P = \frac{W}{q} \times \frac{q}{t} = \frac{V}{t} \times I = V \times I$$

$$P = VI$$

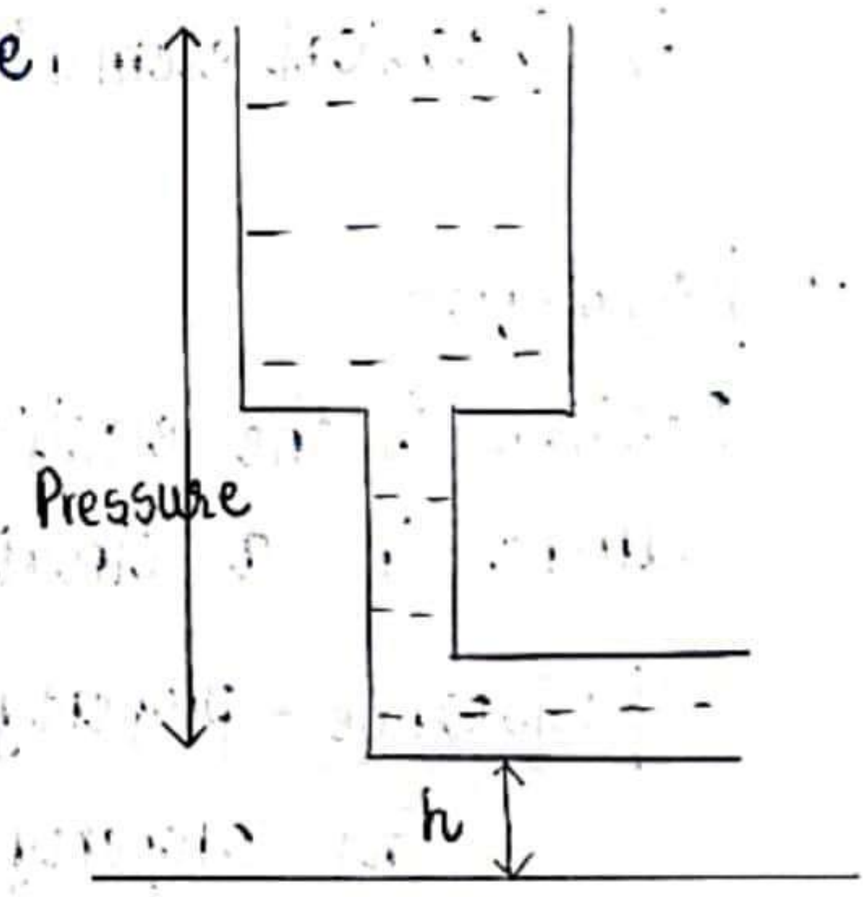
Units of power is Watt (W) or kilowatts (kW)

Consider a water tank at a certain height from the ground

Charge is represented by → water amount

Voltage " " " → water pressure

Current " " " → water flow



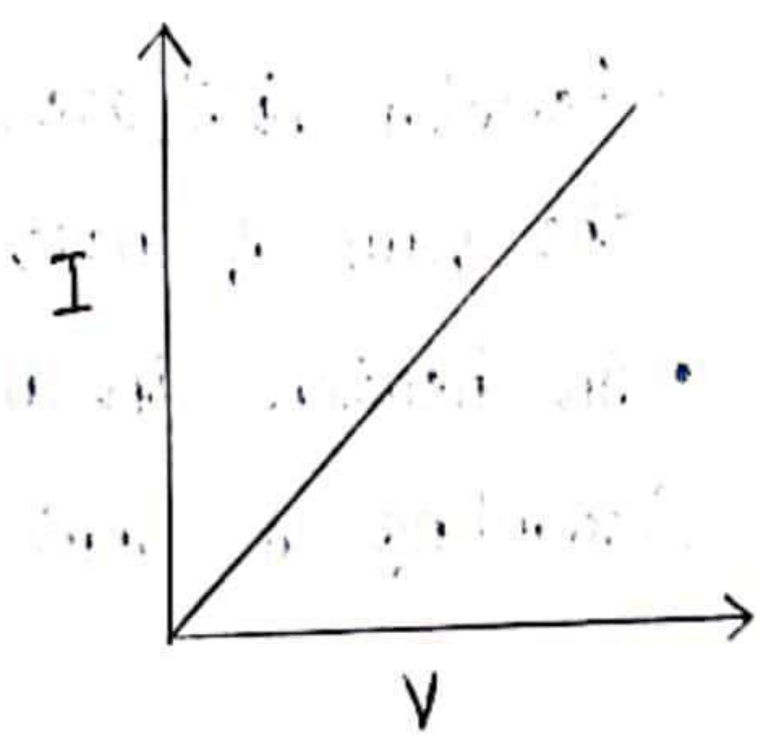
* Ohm's Law :-

Ohm's law states that at constant temperature, Voltage is directly proportional to current flowing through that material or conductor.

$$V \propto I$$

$$V = IR \text{ (at constant temp)}$$

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



* Electrical Power (P) :-

$$P = VI$$

$$P = I^2 R$$

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

Units watts or kilowatts

* Electrical Circuit or Network :-

A physical Electrical Circuit or Network is a system of interconnected components.

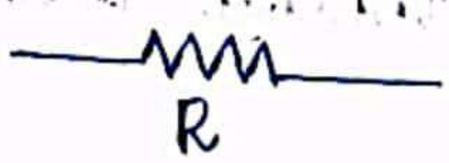
- Components :-
  1) Energy sources (Voltage or current sources) - Active components
  2) Electrical elements (Resistor (R); Inductor (L); Capacitor (C)).
     RLC - passive components

* Resistor :-

Resistor is the electrical component that opposes the flow of current in a circuit.

Resistance :- property of material that opposes the flow of current (or) property of Resistor.

→ Units are ohms (or) (Ω)

→ Symbol is 

→ Resistor dissipates or consumes the electrical energy in the form of heat.

- In heaters in household (nichrome is used)

→ According to Ohm's Law,

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

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→ The power absorbed | consumed by the resistor ; $P = VI$ watts.

→ The total energy consumed by the resistor;

$$E = \int_0^t P\,dt$$

$$E = Pt$$

$$= VIt$$

$$E = VIt$$

$$\Downarrow$$

$$E = I^2 Rt$$

(OR)

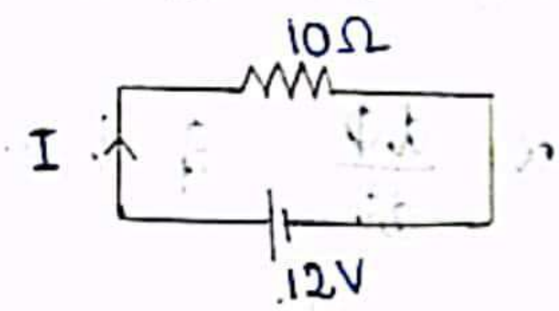
$$E = \frac{V^2}{R} t$$

units: Joules (or) kW.

Q) A 10 ohm resistor is connected across a 12V battery then calculate the current flowing through the resistor.

Sol: $I = \frac{V}{R} = \frac{12}{10} = 1.2A$ (According to Ohm's Law).

$I = 1.2A$



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* The conductor twisted into the form of a coil is called Inductor.

* Inductor (L) or Inductance :-

The ability of inductor to oppose the change in current is called as inductance. It is denoted by 'L'.

→ The unit of Inductance is Henry 'H'.

→ Symbol –

→ Inductor stores energy in the form of magnetic field.

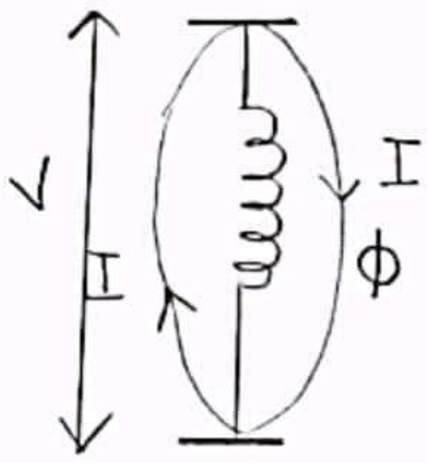
The current flowing through inductor changes w.r.t time, as the magnetic flux produced by the current also changes, then it causes voltage to be induced across the inductor i.e, according to Faraday's law of electromagnetic induction rate of change of flux linkages / links with & voltage to be induced across the conductor.

$V \propto \frac{d\phi}{dt}$ & $i \propto \phi$

$\frac{d\phi}{dt}$ – rate of change of flux.

$\Rightarrow V \propto \frac{di}{dt}$

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



L – proportionality constant (or) Inductance.

V – Voltage across the inductor

The current through the inductor is $di = \frac{1}{L} \cdot V \cdot dt$

Integrating on both sides,

$$\int_0^t di = \int_0^t \frac{1}{L} V \cdot dt$$

$$= \frac{1}{L}\int_0^t V\,dt$$

$$i(t) - i(0) = \frac{1}{L}\int_0^t V\,dt$$

$$i(t) = \frac{1}{L}\int_0^t V\,dt + i(0)$$

The current flowing through the inductor depends on the integral of the voltage across the inductor & initial current.

If $i(0) = 0$ then the above eq becomes;

$$i(t) = \frac{1}{L}\int_0^t V\,dt$$

Power absorbed by the inductor is

$$P = VI$$

$$P = Li\frac{di}{dt} \text{ watts}$$

Total energy stored in the inductor is

$$E = \int_0^t Li\frac{di}{dt}\,dt$$

$$= L\int_0^t i\,di$$

$$= L\left[\frac{i^2}{2}\right]_0^t \quad \left[\text{w.k.t } i(0) = 0;\ i(t) = I\right]$$

$$\Rightarrow E = \frac{1}{2}LI^2$$

$$\therefore E = \frac{1}{2}LI^2 \text{ Joules or KWh.}$$

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* Capacitor (C) :-

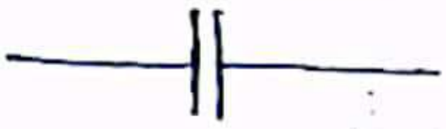
Two conducting surfaces (plates) are seperated by an insulating medium. This is called as a Capacitor.

* Capacitance :-

The ability of capacitor to store the charge is called capacitance. (or) The ability of capacitor to oppose the sudden change in voltage.

→ Capacitor stores energy in the form of electrostatic field.

→ Units of capacitance is Farads. (F).

→ Circuit symbol — 

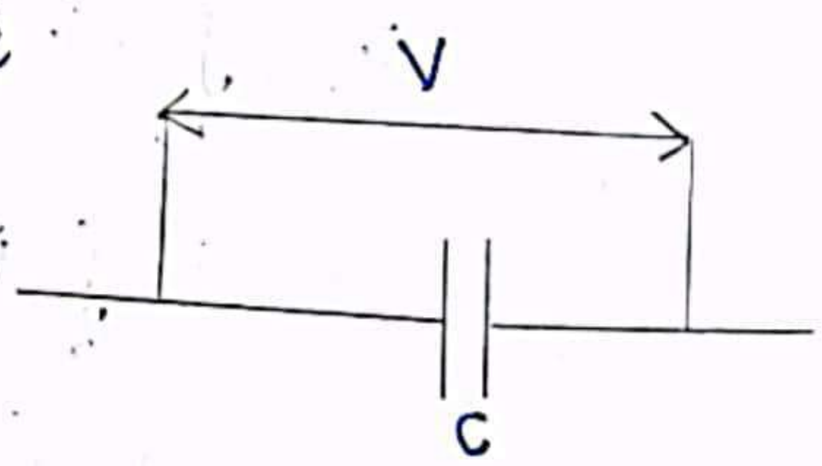
The charge (q) stored in the capacitor is directly proportional to voltage applied to the capacitor.

$$q \propto V$$

$$\Rightarrow \quad Q = CV$$

C – proportionality constant (or) Capacitance

Differentiating the above eq w.r.t time



$$\frac{dq}{dt} = C \frac{dv}{dt}$$

$$\Rightarrow \quad i = C \frac{dv}{dt}$$

i – current flowing through the capacitor.

Voltage across the capacitor is

$$dv = \frac{1}{C} \cdot i \, dt$$

Integrating on both sides

$$\int_0^t v = \frac{1}{C} \int_0^t i \, dt$$

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$$\Rightarrow V(t) = \frac{1}{C}\int_0^t i\,dt + V(0)$$

The voltage across the capacitor depends upon the integral of the current flowing in the capacitor and initial voltage.

If initial voltage $V(0) = 0$, then the above eq becomes

$$V(t) = \frac{1}{C}\int_0^t i \cdot dt$$

Power absorbed by the capacitor is,

$$P = VI$$

$$\Rightarrow P = C \cdot V \cdot \frac{dV}{dt} \text{ watts}$$

Total energy stored in the capacitor,

$$E = \int_0^t P \cdot dt$$

$$= \int_0^t C \cdot V \cdot \frac{dV}{dt} \cdot dt$$

$$= \int_0^t C \cdot V \cdot dV$$

$$= C \left[\frac{V^2}{2}\right]_0^t \quad \left[\text{w.k.t } V(0) = 0 \text{ \& } V(t) = V\right]$$

Energy equation when initial voltage $V(0) = 0$ becomes,

$$E = \frac{1}{2}CV^2 \text{ Joules (or) Kwatts-hr (KWh)}$$

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* Classification of Elements :—

Elements are classified into four types.

1) Active & Passive Elements
2) Linear & Non-Linear Elements.
3) Unilateral & Bilateral elements
4) Lumped & Distributed elements

1) Active & Passive Elements :-

Active elements are the elements which are able to deliver the power.

Ex: voltage supply & Current Source.

Passive elements are the elements which are able to consume/ store the energy.

Ex: Resistor, Inductor & Capacitor.

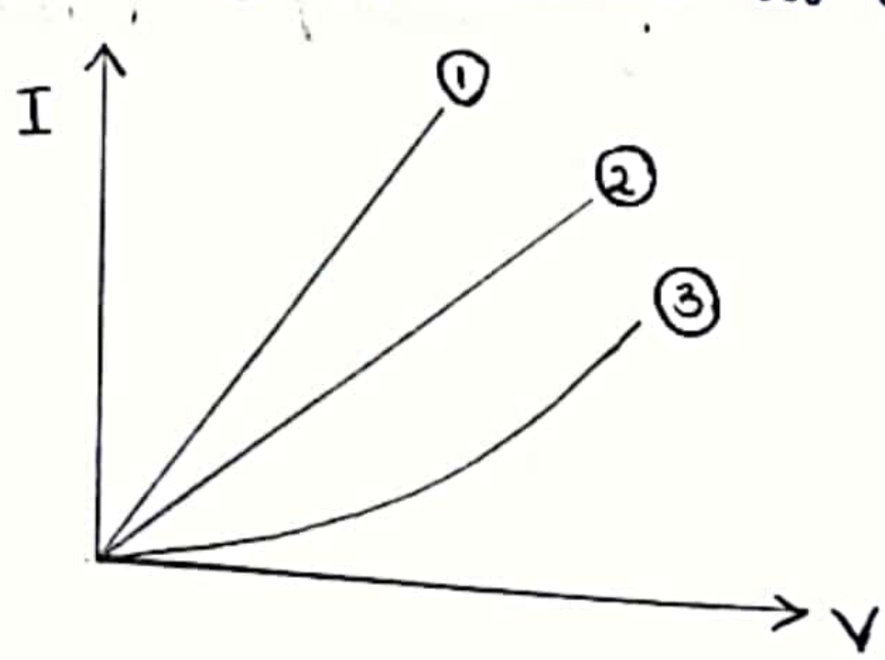
Resistor → Consumes energy

Inductor & Capacitor → Stores energy

2) Linear & Non-Linear Elements :-

Linear elements are the elements that show a linear relationship between the voltage & current as shown in curve ① & ②.

Non-Linear elements are the elements that do not show a linear relationship between the voltage & current as shown in curve ③



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3) Unilateral & Bilateral Elements :-

Unilateral element has different relations b/w the voltage & current for the flow of current in two possible directions.

Ex: Silicon diode, lightening arrestors.

In bilateral elements voltage and current relation is same for the flow of current in either directions.

Ex: RLC.

4) Lumped & Distributed elements :-

Lumped elements are the elements which are smaller in size physically & seperable for analytical purpose.

Ex: RLC

Distributed elements are the elements which are not electrically separable for analytical purpose.

Ex: Transmission Line (It has distributed resistance, distributed inductance & distributed capacitance).

* Sums :-

Q) If 70J of energy is available for every 30 secs of charge then what is the voltage.

A:

$E = 70J$

$Q = 30C$

$V = E/Q = 70/30 = 2.33\,V$ ($\because E = W = 70J$).

Q) 5 coloumbs of charge is flowing in a given point in a wire in 2 secs. How many ampheres of current is flowing?

A:

$Q = 5C$

$t = 2\,sec$

$i = \frac{q}{t} = \frac{5}{2} = 2.5\,A$

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Q) What is the power in watts if energy of 50J is used in 2secs.

A:

$P = ?$

$W = E = 50J$

$t = 2 secs$

$P = \frac{W}{t} = \frac{50}{2} = 25 Watts$

Q) A current in a 2H inductor varies at a rate of 2 A/s. Find the voltage & magnetic energy stored in the inductor after 2 sec

A:

$V = L\frac{di}{dt} = 2(2) = 4V$

$E = \frac{LI^2}{2} = \frac{1}{2} \times 2 \times 16 = 16J$

$L = 2H$

$I = 2\frac{A}{sec} \times 2sec$

$= 4A$

Q) A capacitor having a capacitance of 2mF is charged to a voltage of 1000V. Find the charge & energy stored in a capacitor.

A:

$Q = CV$

$= 2 \times 10^{-6} \times 1000$

$= 2 \times 10^{-3} C$

$Q = 2mC$

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

$= \frac{1}{2} \times 2 \times 10^{-6} \times 10^6$

$= 1$

$\therefore E = 1J$

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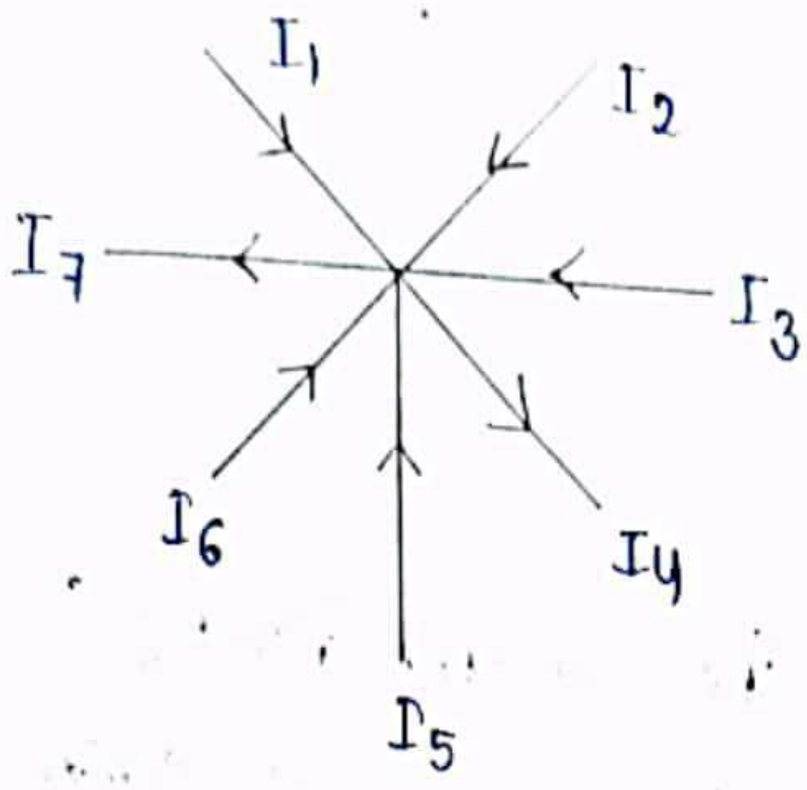
* KIRCHOFF'S LAWS :—

1) Kirchoff's Current Law (KCL) :-

It states that the algebraic sum of current meeting at a junction or node is equal to zero.

$$\Sigma i = 0$$

⇒ Ex:



⇒ $I_1 + I_2 + I_3 + I_5 + I_6 = I_4 + I_7$

- Consider the incoming current is +ve and outgoing as -ve.

Sum of incoming currents = Sum of outgoing currents

$(I_1 + I_2 + I_3 + I_5 + I_6 = I_4 + I_7)$.

2) Kirchoff's Voltage Law (KVL) :-

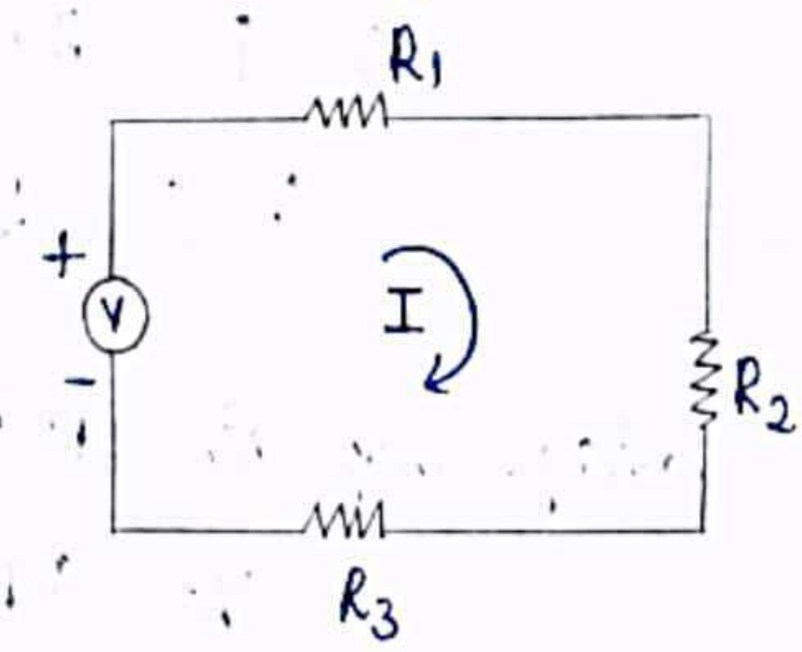
It states that the algebraic sum of all branch voltages in a closed path / loop / mesh is zero.

$$\Sigma V = 0$$

Consider current entering as +ve & current leaving as -ve.

$$-(IR_1 + IR_2 + IR_3) + V = 0$$

$$V = I(R_1 + R_2 + R_3).$$

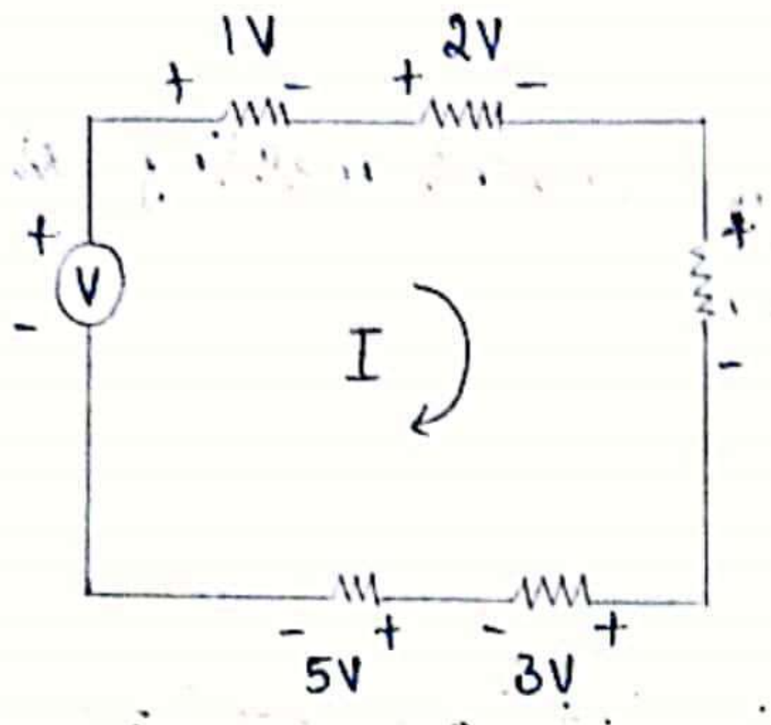


Active elements always deliver power.

Applied voltage must be equal to sum of voltage drop across each element.

* Sums :—

Q)

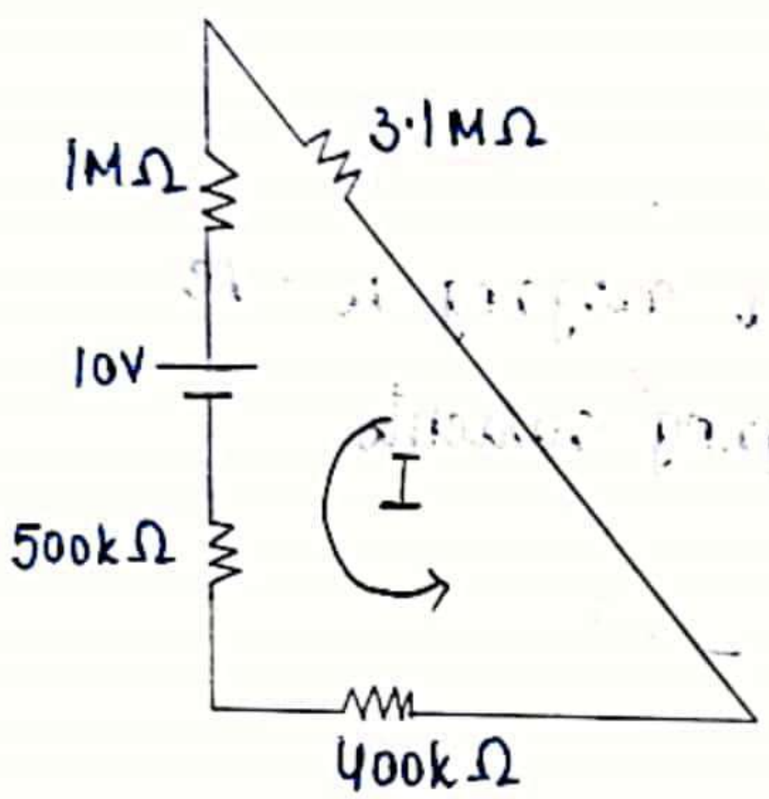


Find $V_1 = ?$

$V_1 = ?$ A: $V_1 = (30-1-2-5-3)\ V$

$V_1 = 19V$

Q)



Determine the current flowing & calculate voltage drop at each resistor.

A:

$$10 = I(10^6 + 500\times10^3 + 400\times10^3 + 3.1\times10^6)$$

$$= I(10^6 + 5\times10^5 + 4\times10^5 + 31\times10^5)$$

$$= I(50\times10^5)$$

$$\Rightarrow I = 2\times10^{-6} A$$

$$\therefore I = 2\mu A$$

Voltage drop at $1M\Omega$,

$$V = IR$$

$$= 2\times10^{-6}\times1\times10^6$$

$$V = 2V$$

voltage drop at $3.1M\Omega$,

$$V = IR$$

$= 2\times10^{-6} \times 3.1\times10^{6}$

$V = 6.2\,V$

voltage drop at $400\,k\Omega$,

$V = 2\times10^{-6}\times 4\times10^{5}$

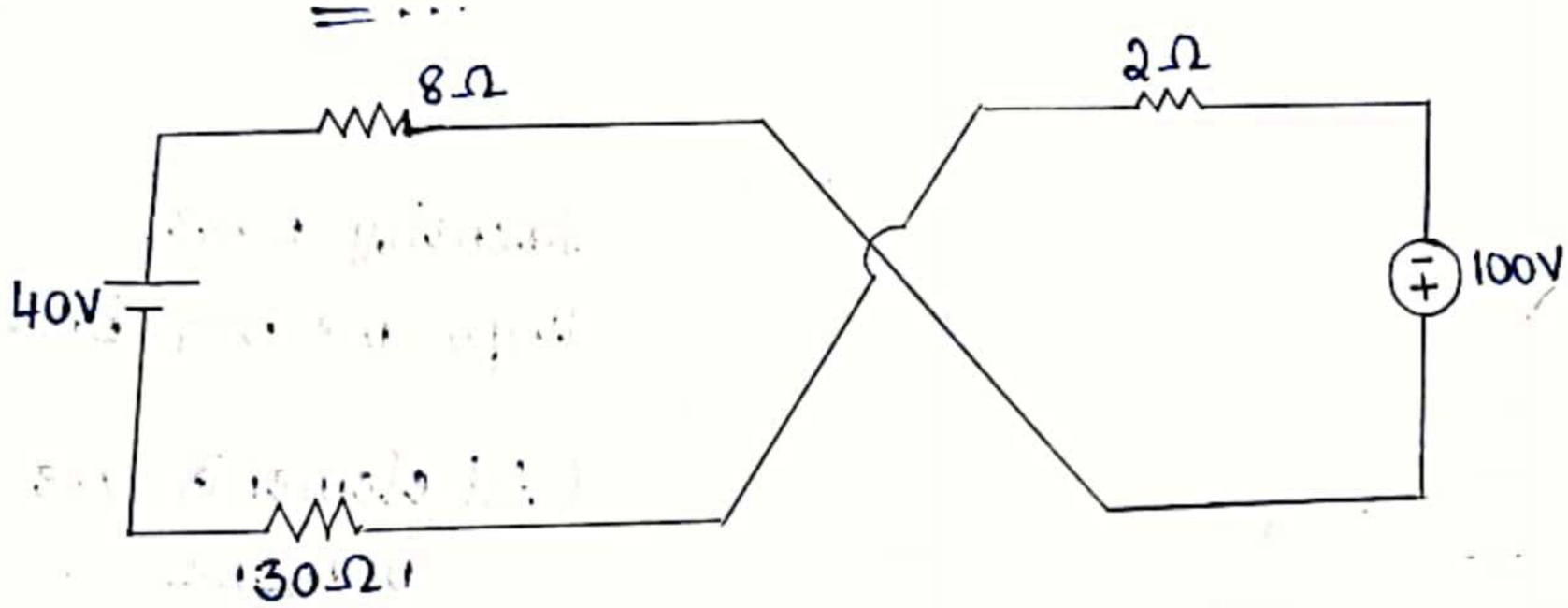
$V = 0.8\,V$

voltage drop at $500\,k\Omega$,

$V = 2\times10^{-6}\times 5\times10^{5}$

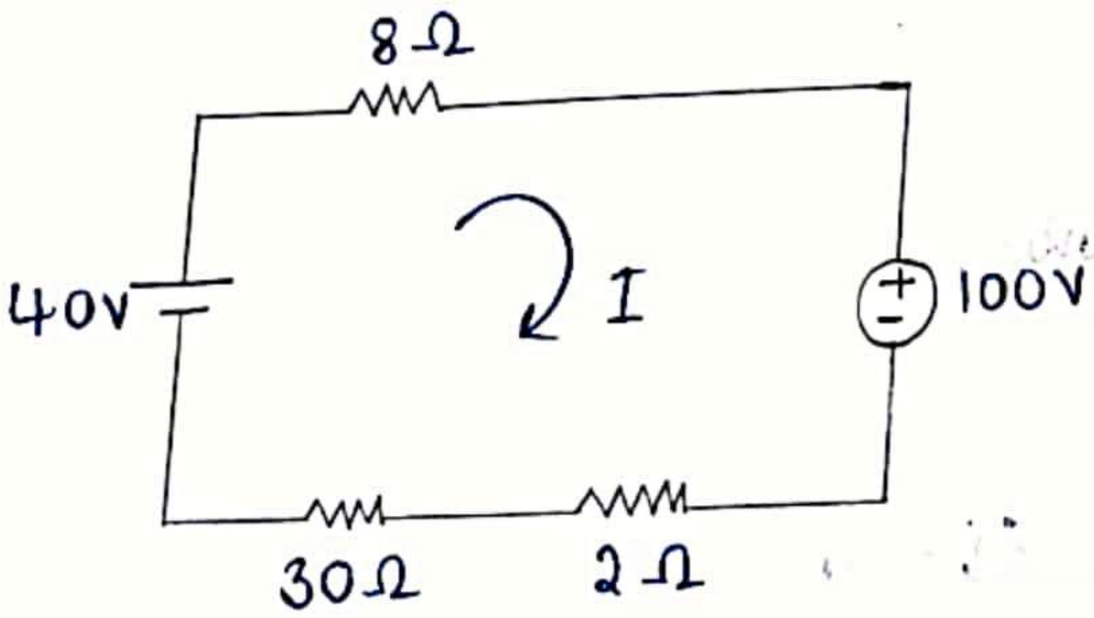
$V = 1\,V$

Q)



Find the current & voltage drop across $30\,\Omega$ resistor.

A:



A: $-60 = I(8+2+30)$

$I = -1.5\,A$

voltage drop across $30\,\Omega$,

$V = IR$

$= -1.5\times30$

$= -45\,V$

$I = 1.5\,A$, $V = 45\,V$

* Node / Junction :—

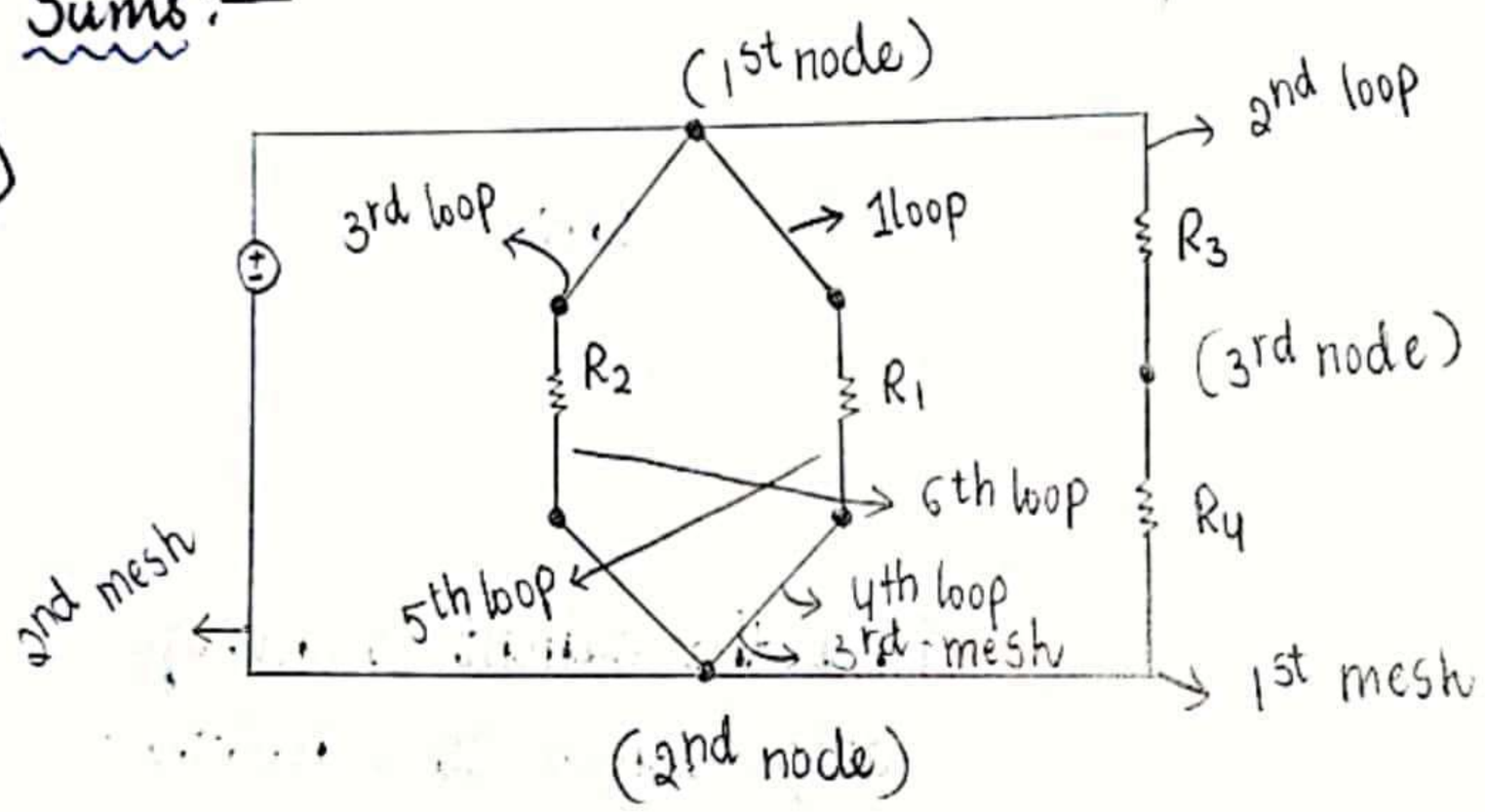
Q. The point at which two or more elements have a common connection.

- **Loop** :- Loop is a closed path in a network, i.e, starting & terminating point should be the same.
- **Mesh** :- Mesh is also a closed path in a network that does not contain any internal loops within it.
- **Branch** :- Branch is a one simple element and nodes at both ends of the element.

Q

* Sums :—

Q)



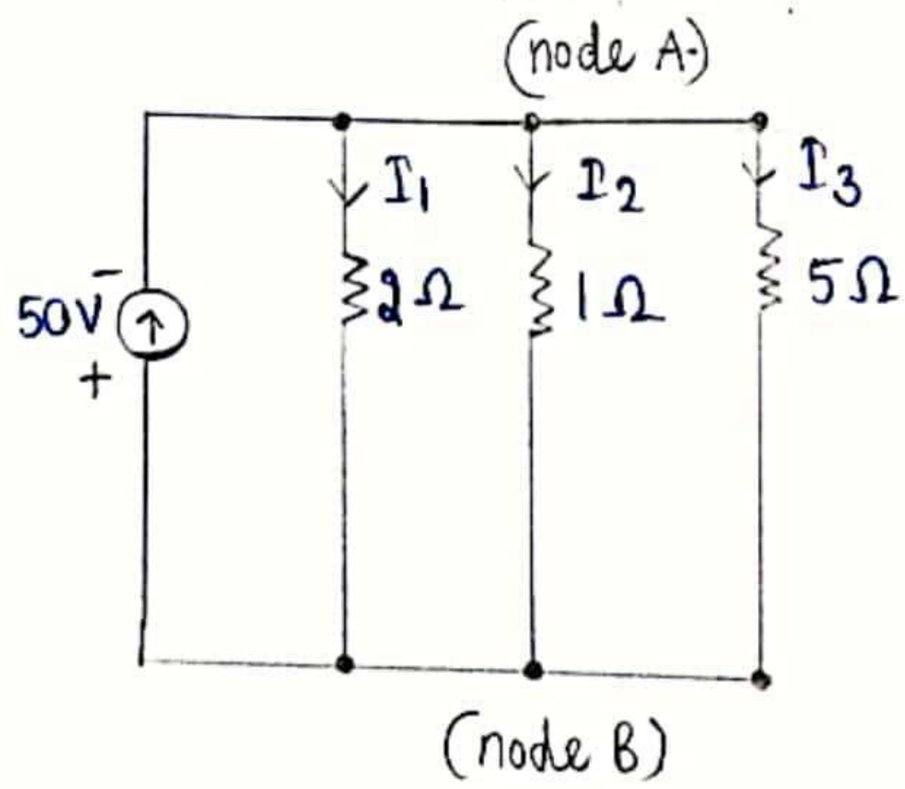
Identify nodes, loops, mesh & branch.

(All elements are branches).

A:

Q) Determine currents in all resistors.

A:



$$\Sigma i = 0$$

$$50 = I_1 + I_2 + I_3$$

$$V_{AB} = V = IR$$

$$\therefore I = V/R$$

$$50 = \frac{V}{2} + \frac{V}{1} + \frac{V}{5}$$

$$\Rightarrow 50 = V(0.5 + 1 + 0.2)$$

$$\Rightarrow V = \frac{50}{1.7} = 29.41V$$

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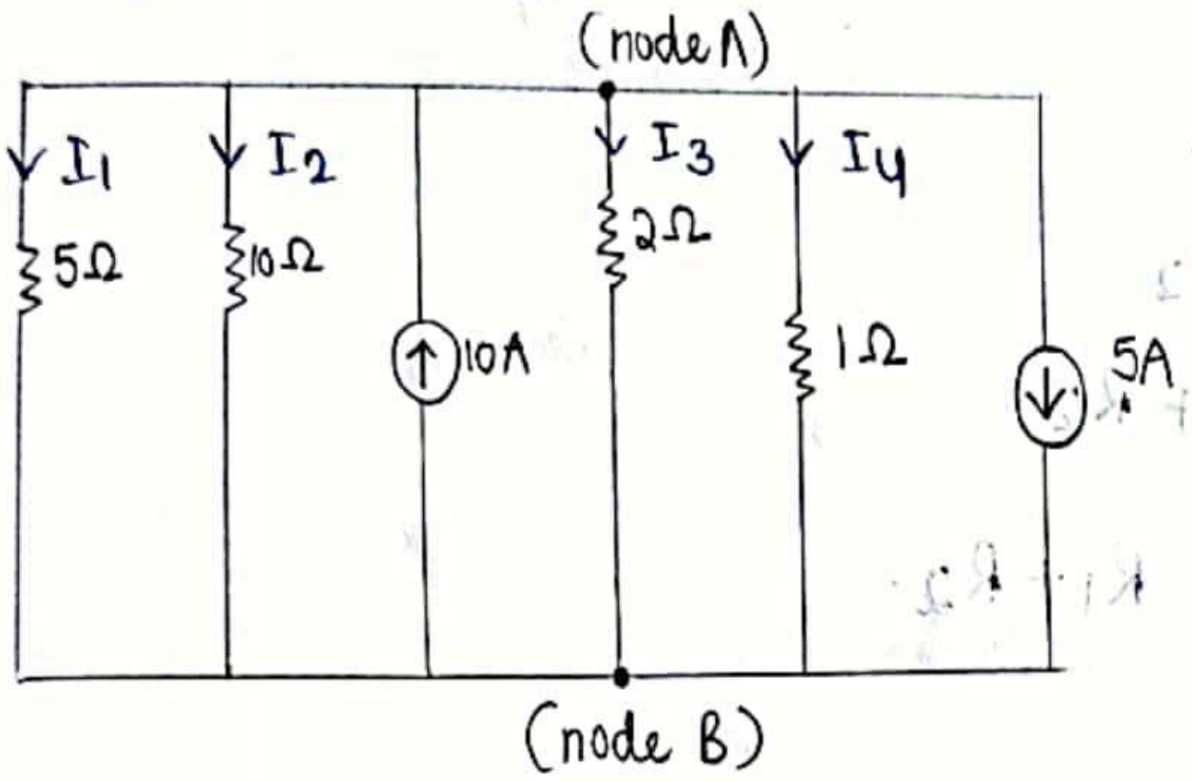
$$I_1 = \frac{V}{R} = \frac{29.41}{2} = 14.7\,A$$

$$I_2 = \frac{V}{R} = \frac{29.41}{1} = 29.41\,A$$

$$I_3 = \frac{29.41}{5} = 5.88\,A$$

Q) Find the voltage across $10\,\Omega$ resistor.



A: $10 - 5 = \frac{V}{5} + \frac{V}{10} + \frac{V}{2} + V$

$$5 = V(0.2 + 0.1 + 0.5 + 1)$$

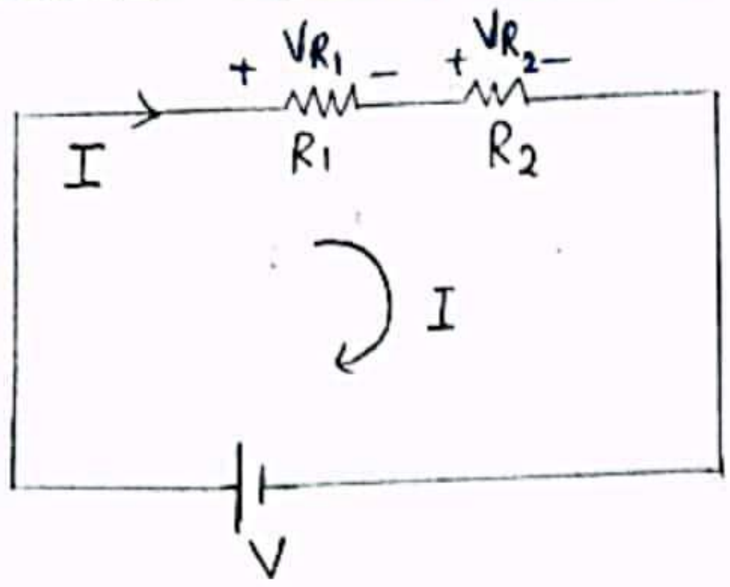
$$V = \frac{5}{1.8} = 2.77\,V$$

$$\therefore V_{across\ 10\Omega} = 2.77\,V$$

$(V_{AB} = V_{10\Omega})$

* Resistors in Series :—

→ In series circuit current is same ; voltage is divided



Here two resistors R_1 & R_2 are connected in series.

$$V = V_{R_1} + V_{R_2}$$

$$= IR_1 + IR_2$$

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

$$R = R_{eq} = R_{eff} = R_1 + R_2.$$

In Series network,

Effective Resistance

$$R_{eq} / R_e = R_1 + R_2 + R_3 + \dots + R_n$$

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* Voltage drop across any resistor equals to applied voltage × $\frac{\text{concerned resistance}}{\text{Total resistance}}$.

* Voltage Division Rule :-

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

$$V_{R_1} = IR_1$$

$$I = \frac{V}{R_{eq}} = \frac{V}{R_1 + R_2}$$

$$V_{R_1} = \frac{V}{R_1 + R_2} \cdot R_1 \quad ; \quad V_{R_2} = IR_2 = \frac{V}{R_1 + R_2} \cdot R_2$$

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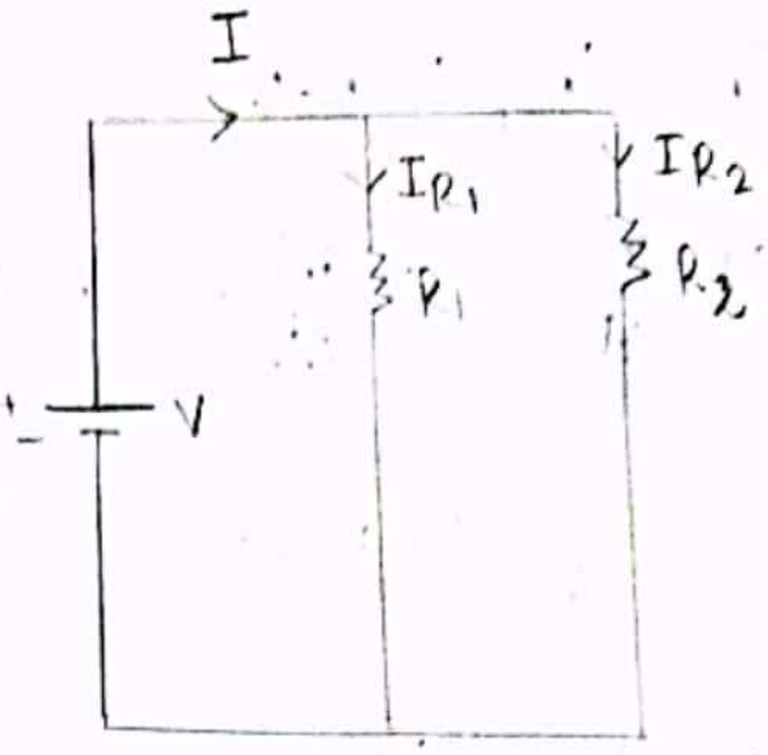
* Resistors in Parallel :—

→ In parallel circuit, voltage is same & current is divided.

$$I = \frac{V}{R_{eq}} \; ; \; I = I_{R_1} + I_{R_2}$$

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

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



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

* Current Divison Rule :—

Current is divided

$$I_{R_1} = \frac{V}{R_1}$$

$$V = I R_{eq}$$

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

$$I_{R_2} = \frac{V}{R_2} = \frac{I \cdot \frac{R_1 R_2}{R_1 + R_2}}{R_2} = \frac{I \cdot R_1}{R_1 + R_2}$$

* In current divison rule current flowing through any resistor = Total current × $\frac{\text{opposite resistance}}{\text{Total resistance}}$

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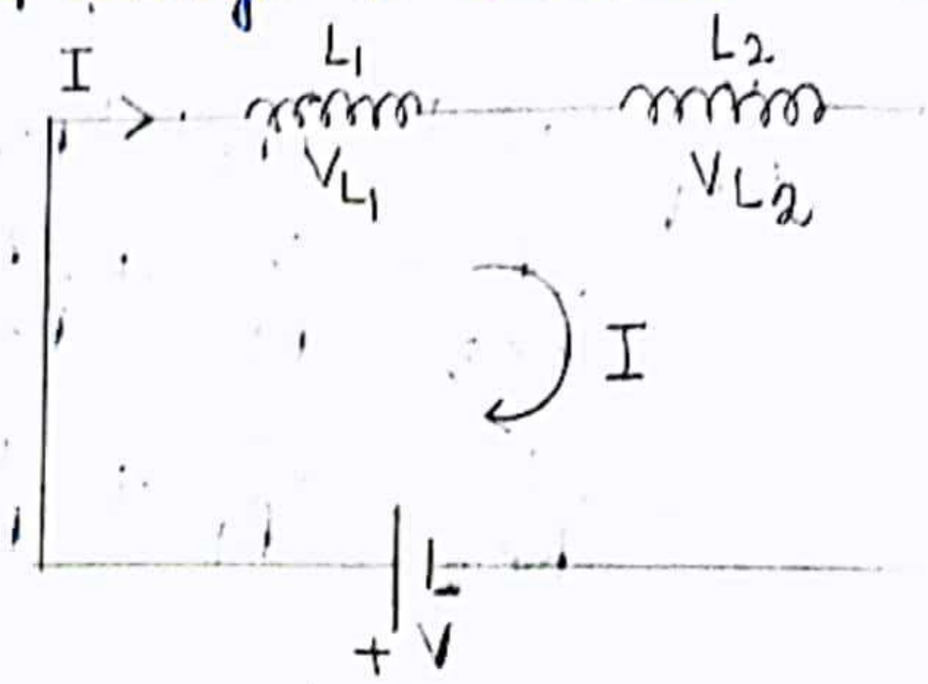
* Inductors in Series :—

In series circuit, current is same & voltage is divided.



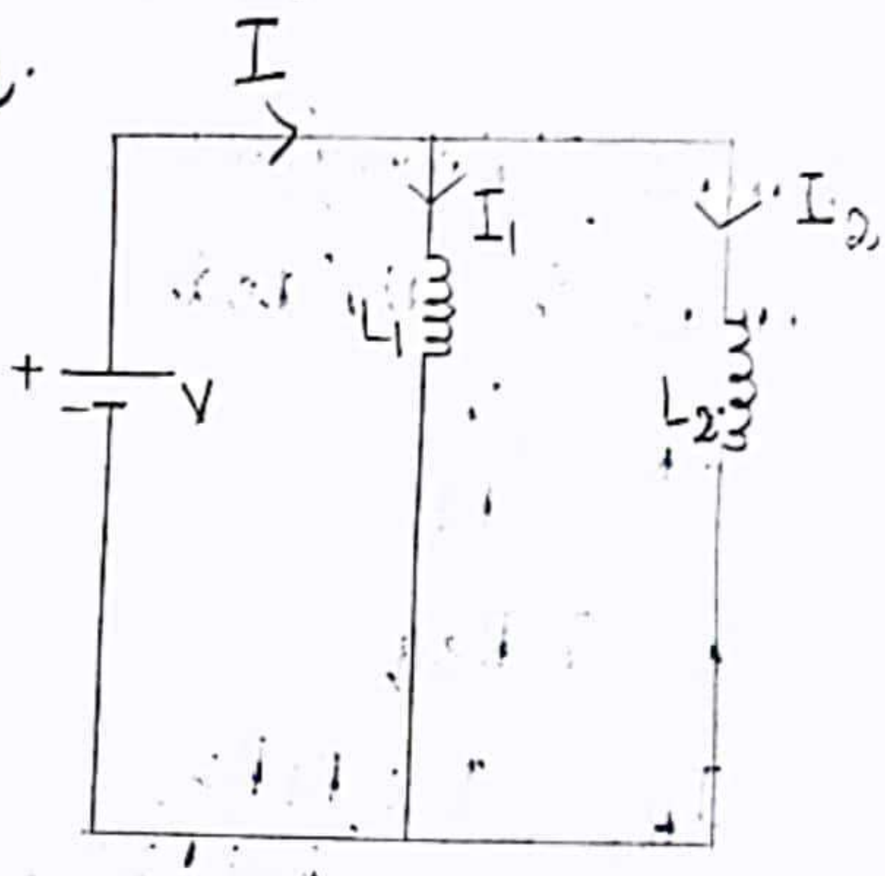
$$V = V_{L_1} + V_{L_2}$$

$$L_{eq}\frac{di}{dt} = L_1\frac{di}{dt} + L_2\frac{di}{dt}$$

$$\Rightarrow L_{eq} = L_1 + L_2$$

* Inductors in Parallel :—

Voltage is same & current is divided.



$$I = I_{L_1} + I_{L_2}$$

$$\frac{1}{L_{eq}}\int v\,dt = \frac{1}{L_1}\int v\,dt + \frac{1}{L_2}\int v\,dt$$

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

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

$$\Rightarrow L_{eq} = \frac{L_1 L_2}{L_1 + L_2}$$

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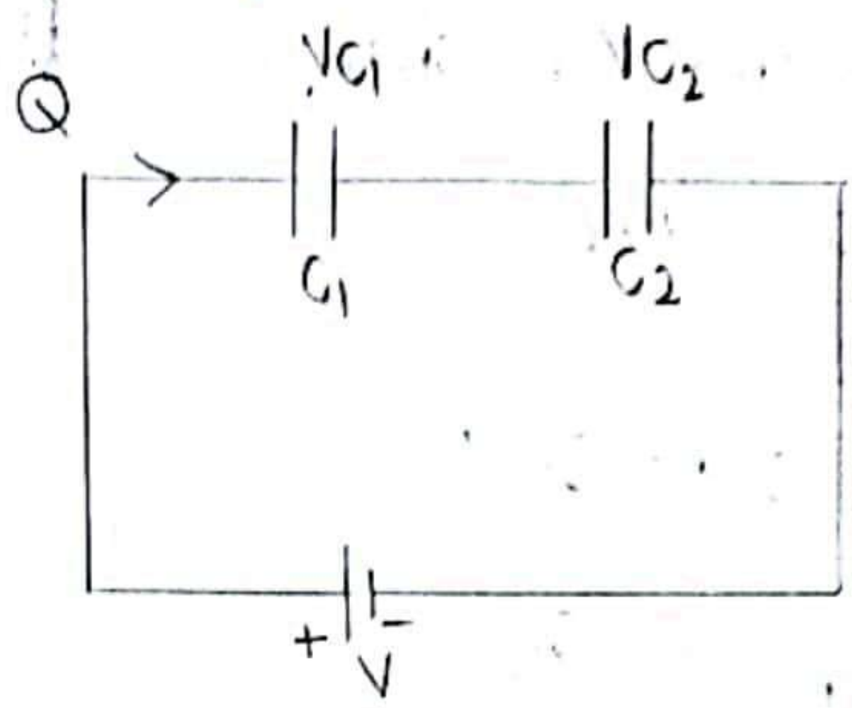
* Capacitors in Series:—

In capacitors series circuit, charge is same & voltage is dividing.



$$Q = CV$$

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

$$V = V_{C_1} + V_{C_2}$$

$$\frac{Q}{C_{eff}} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\Rightarrow C_{eff} = \frac{C_1 C_2}{C_1 + C_2}$$

$$V_{C_1} = \frac{Q}{C_1} \quad ; \quad Q = C_{eq} V$$

$$= \frac{C_1 C_2}{C_1 + C_2} \times V$$

$$\Downarrow$$

$$= \frac{\frac{C_1 C_2}{C_1 + C_2} \times V}{C_1}$$

$$\Rightarrow V_{C_1} = V \frac{C_2}{C_1 + C_2}$$

$$= \cdots$$

$$V_{C_2} = \frac{Q}{C_2} = \frac{\frac{C_1 C_2}{C_1 + C_2} \times V}{C_2}$$

$$\Rightarrow V_{C_2} = \frac{C_1}{C_1 + C_2} \times V$$

$$= \cdots$$

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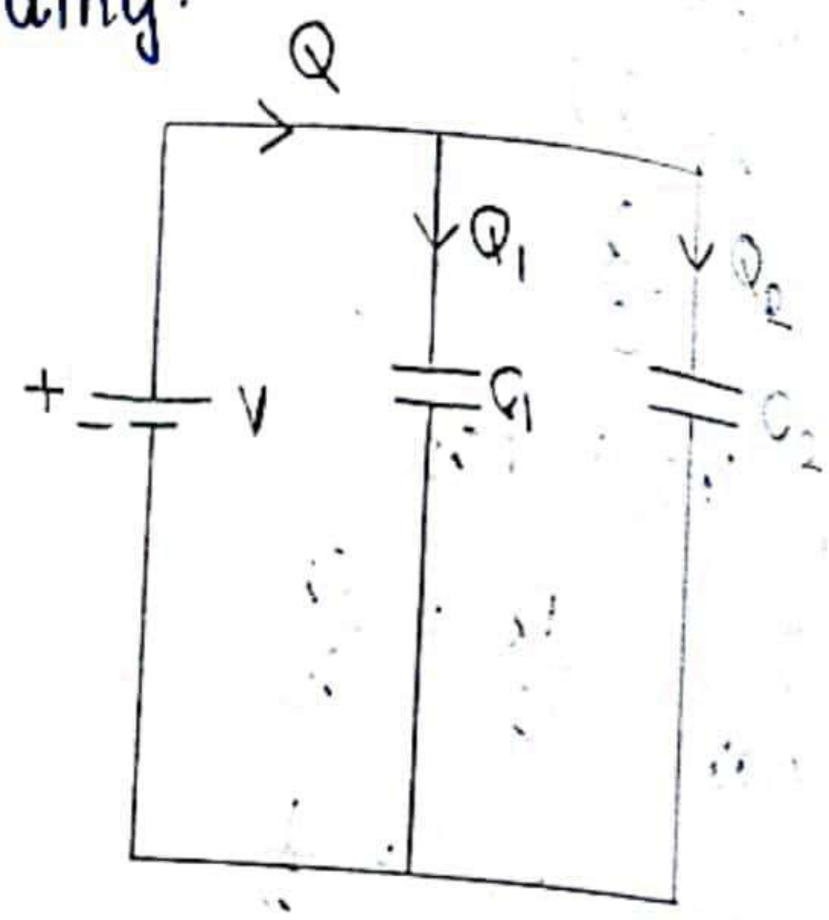
*. Capacitors in Parallel :—

Voltage is same & charge is dividing.



$$Q = Q_{C_1} + Q_{C_2}$$

$$Q = CV$$

$$C_{eq} V = C_1 V + C_2 V$$

$$\Rightarrow C_{eq} = C_1 + C_2$$

$$Q_{C_1} = C_1 \cdot V$$

$$= \frac{Q}{C_1 + C_2} \cdot C_1$$

$$Q = CV$$

$$V = \frac{Q}{C_{eq}} = \frac{Q}{C_1 + C_2}$$

$$\Rightarrow Q_{C_1} = Q \cdot \frac{C_1}{C_1 + C_2}$$

$$Q_{C_2} = C_2 \cdot V$$

$$= \frac{Q}{C_1 + C_2} \cdot C_2$$

$$\Rightarrow Q_{C_2} = Q \cdot \frac{C_2}{C_1 + C_2}$$

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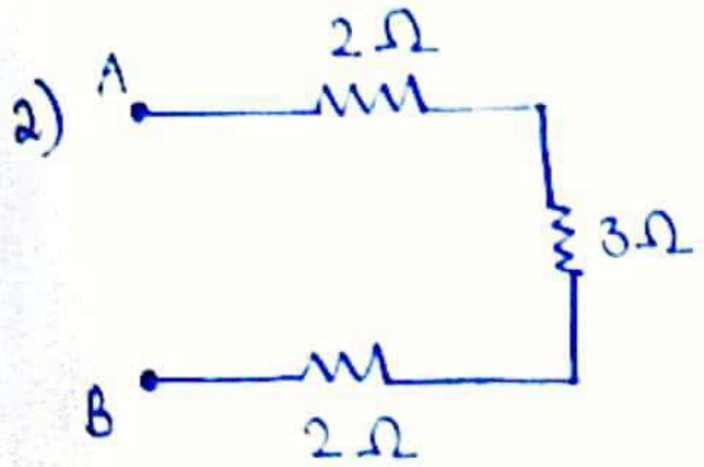
* Problems on Series and Parallel Circuits :—

1)

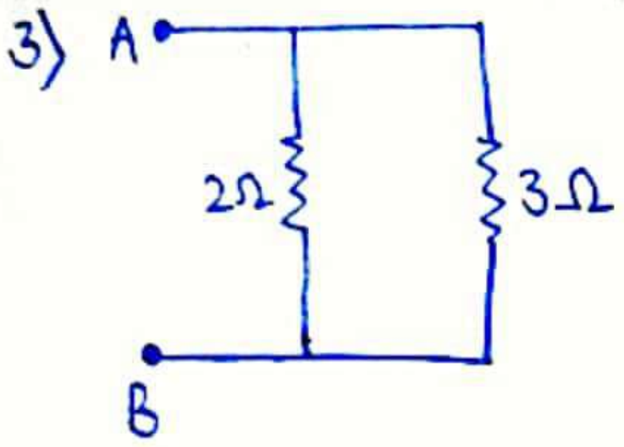
$R_{eq} = R_1 + R_2 = 2+3 = 5\Omega$

2)



$R_{eq} = 2+3+2 = 7\Omega$

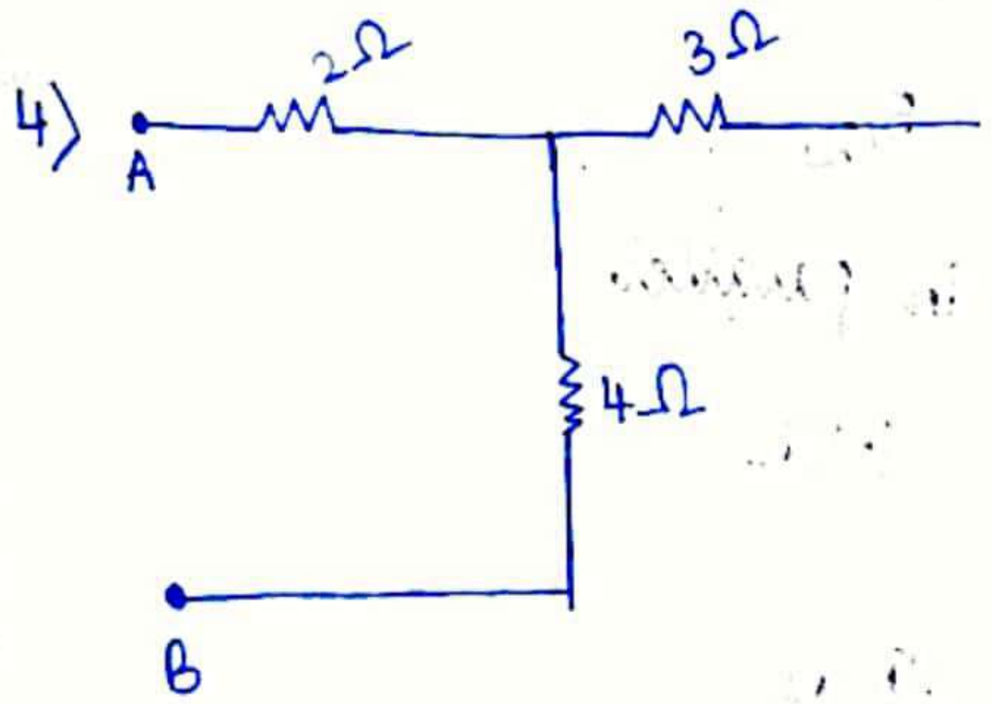
3)



It is based on the connection among the elements looking from source side

$R_{eq} = R_{ab} = \frac{2\times3}{2+3} = \frac{6}{5} = 1.2\Omega$

4)



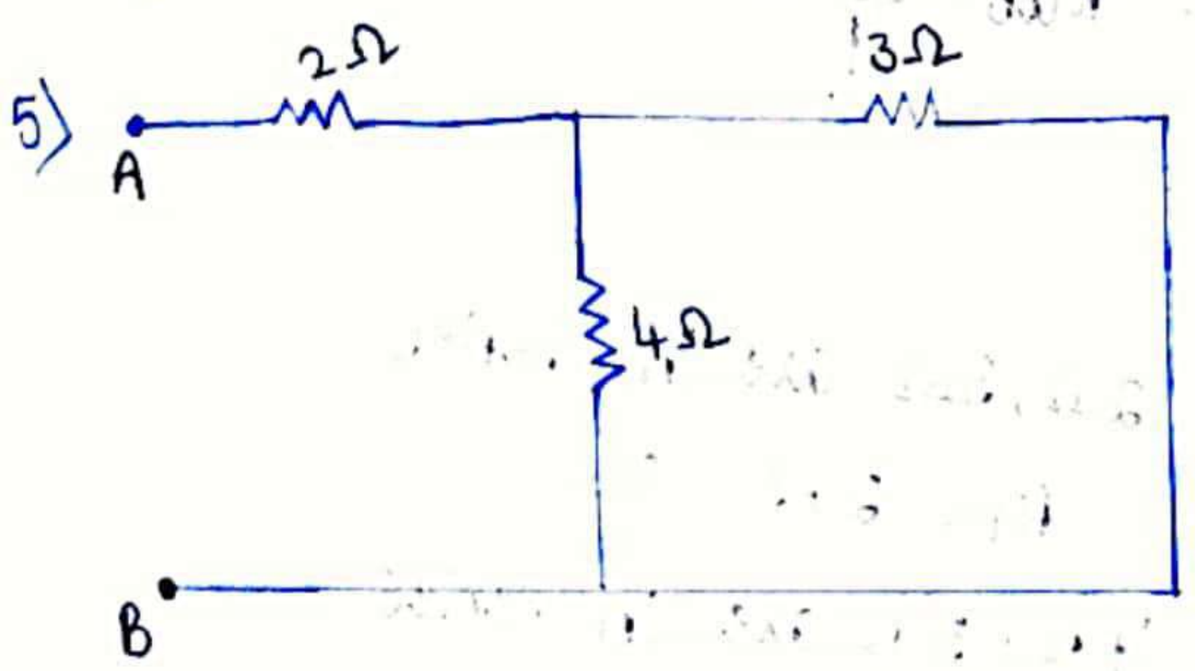
No current passes through 3Ω

$R_{eq} = R_1 + R_2$

$= 2\Omega + 4\Omega$

$R_{eq} = 6\Omega$

5)

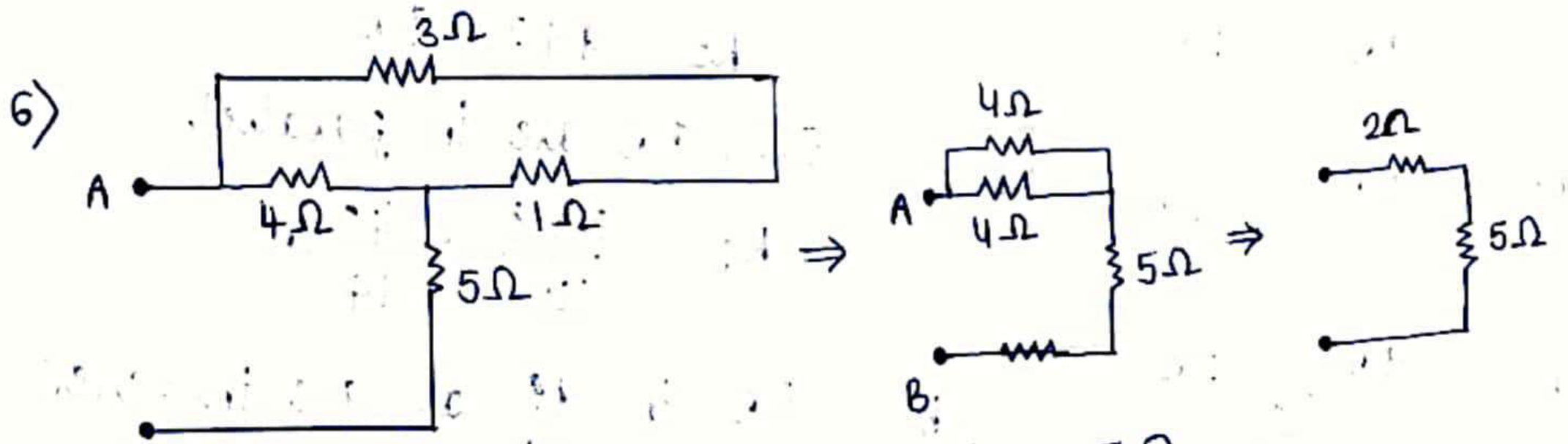


$R_{eq} = \frac{3\times4}{3+4} + 2$

$= \frac{12}{7} + 2 = \frac{26}{7}$

$R_{eq} = 3.71\Omega$

6)



$R_{eq} = 7\Omega$

* Capacitors in Parallel :—

$$C_{eq} = C_1 + C_2$$

* Capacitors in Series :—

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

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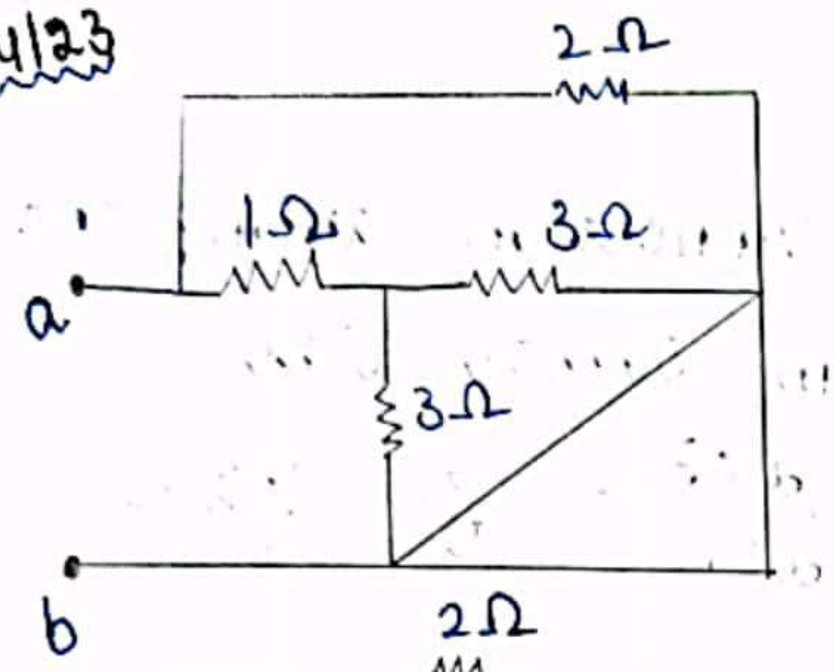
Q)

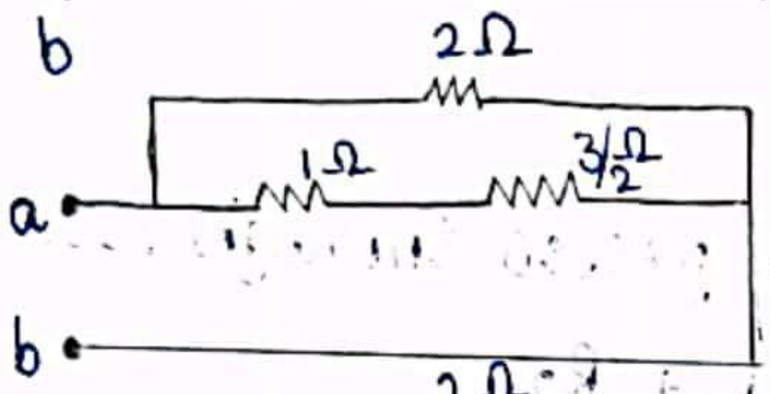


$R_{ab} = ?$

$3\Omega, 3\Omega$ are in parallel

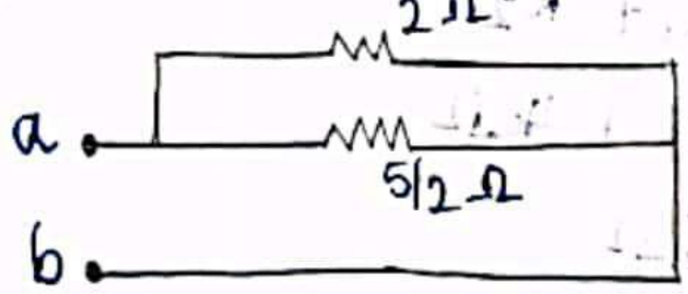
$$\frac{1}{R} = \frac{1}{3} + \frac{1}{3}$$

$$R = 3/2\,\Omega$$



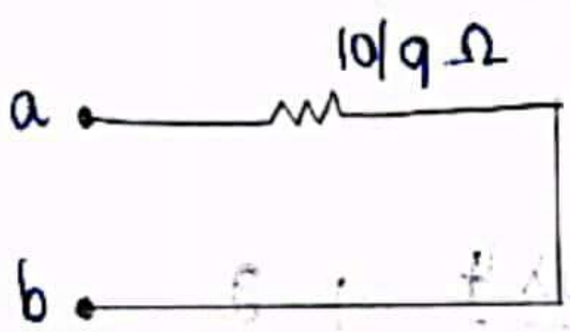
$\frac{3}{2}\Omega, 1\Omega$ are in series

$$R = \frac{3}{2} + 1 = 5/2$$



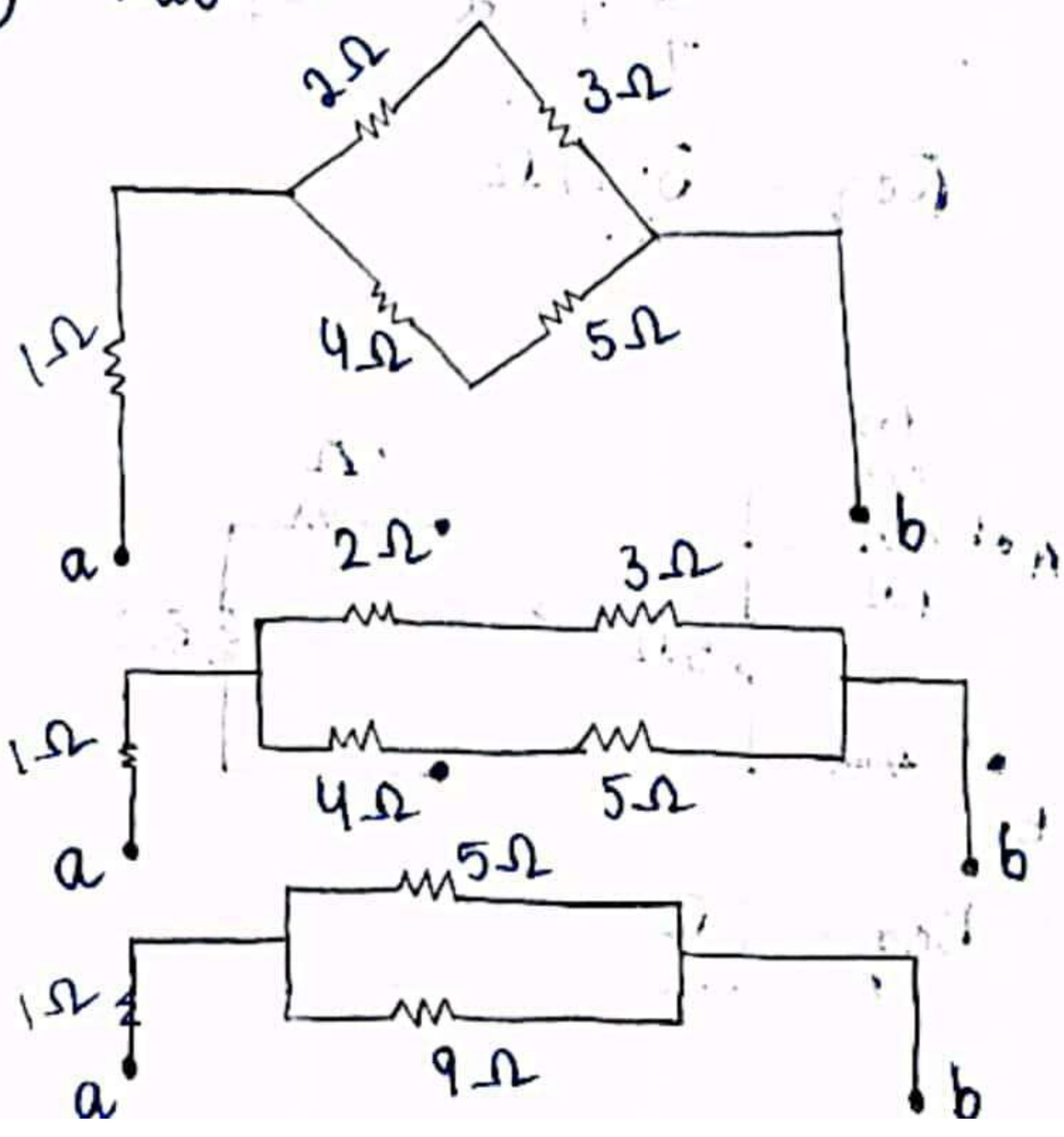
$\frac{5}{2}\Omega, 2\Omega$ are in parallel

$$R = \frac{10}{9}\,\Omega = 1.1\,\Omega$$



$$\therefore R_{ab} = \frac{10}{9}\,\Omega$$

Q) $R_{ab} = ?$



$2\Omega, 3\Omega$ are in series

$$R_1 = 2 + 3 = 5\,\Omega$$

$4\Omega, 5\Omega$ are in series

$$R_2 = 4 + 5 = 9\,\Omega$$

$5\Omega, 9\Omega$ are in parallel

$$R_3 = \frac{5 \times 9}{14} = \frac{45}{14}\,\Omega$$

1Ω & $\frac{45}{14}\,\Omega$ are in series

$$R_{ab} = 1 + \frac{45}{14} = \frac{59}{14}$$

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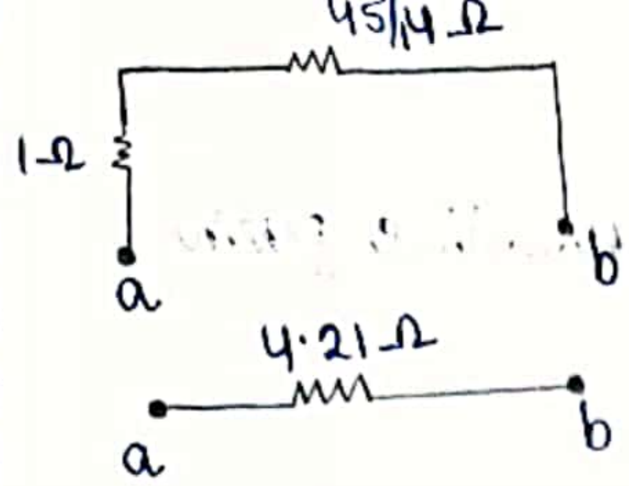
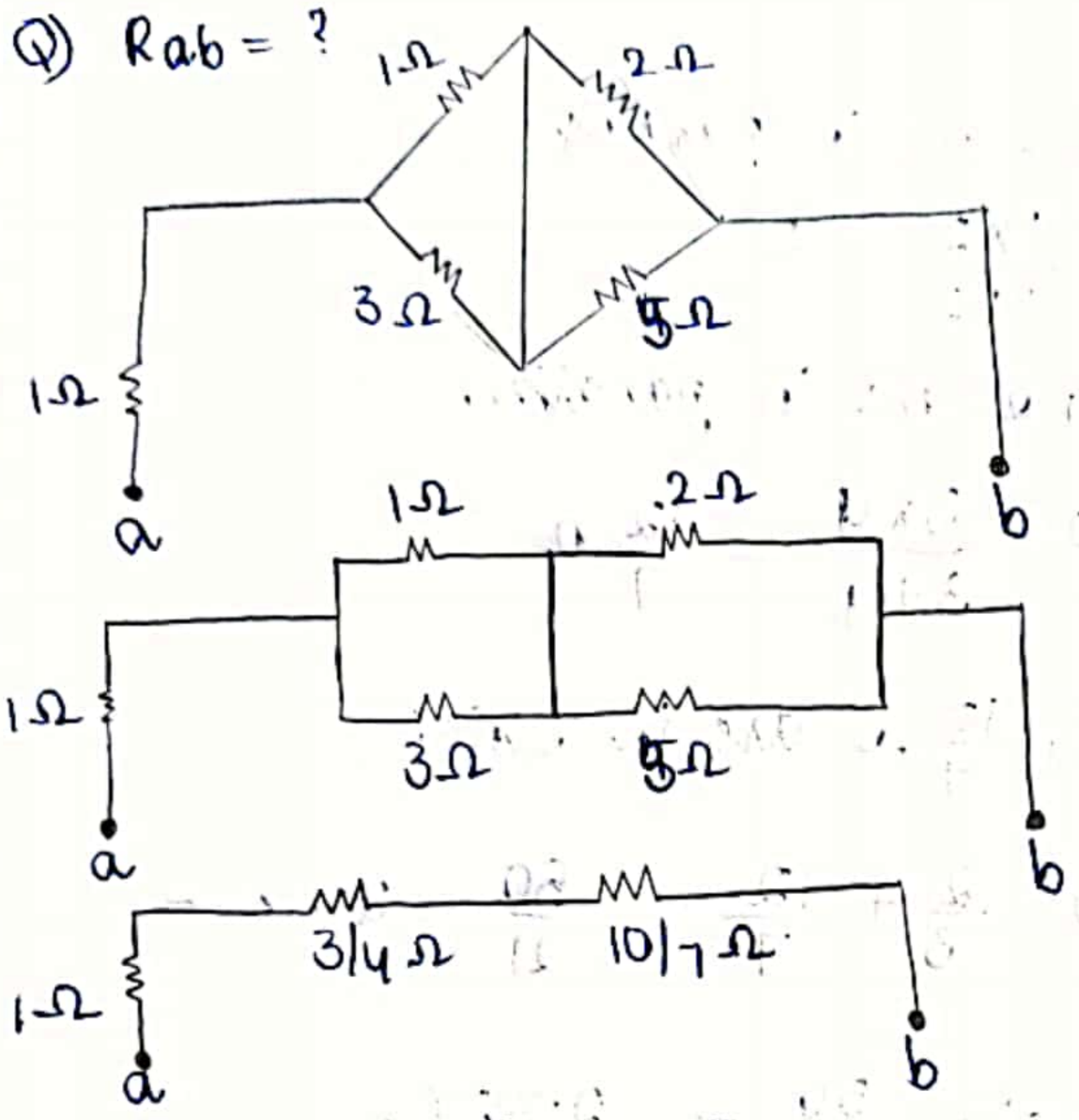


$\therefore R_{ab} = \frac{59}{14}$ or $4.21\,\Omega$

Q) $R_{ab} = ?$



1Ω, 3Ω are in parallel

$R_1 = \frac{1\times3}{1+3} = \frac{3}{4}\,\Omega$

2Ω, 5Ω are in parallel

$R_2 = \frac{2\times5}{2+5} = \frac{10}{7}\,\Omega$

$\frac{3}{4}\,\Omega$, $\frac{10}{7}\,\Omega$ are in series

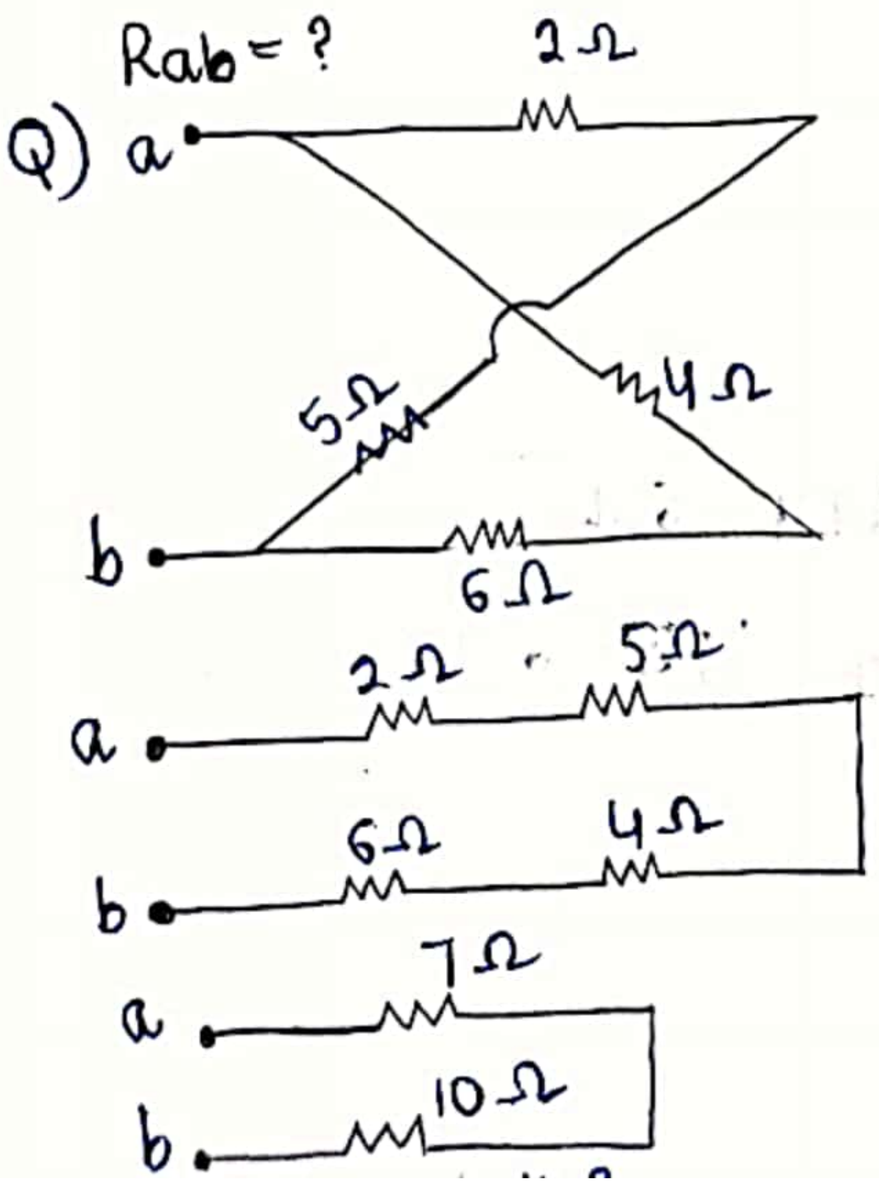
$R_3 = \frac{3}{4} + \frac{10}{7} = \frac{61}{28}\,\Omega$

1Ω, $\frac{61}{28}\,\Omega$ are in series

$R_{ab} = 1 + \frac{61}{28} = \frac{89}{28} = 3.17\,\Omega$

$\therefore R_{ab} = \frac{89}{28}$ or $3.17\,\Omega$

Q) $R_{ab} = ?$



2Ω, 5Ω are in series

$R_1 = 2+5 = 7\,\Omega$

6Ω, 4Ω are in series

$R_2 = 10\,\Omega$

7Ω, 10Ω are in parallel

$R_{ab} = \frac{10\times7}{10+7} = \frac{70}{17} = 4.11$

$\therefore R_{ab} = \frac{70}{17}$ or $4.11\,\Omega$

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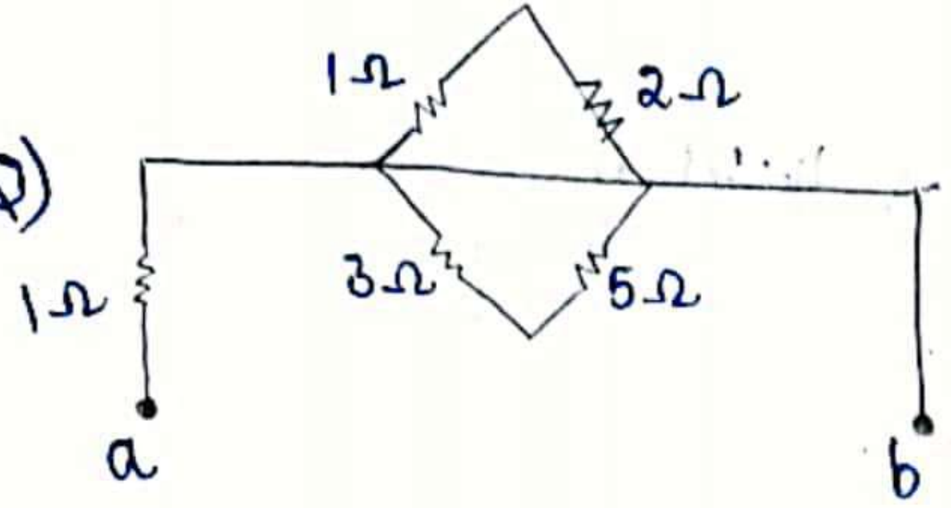
Q)

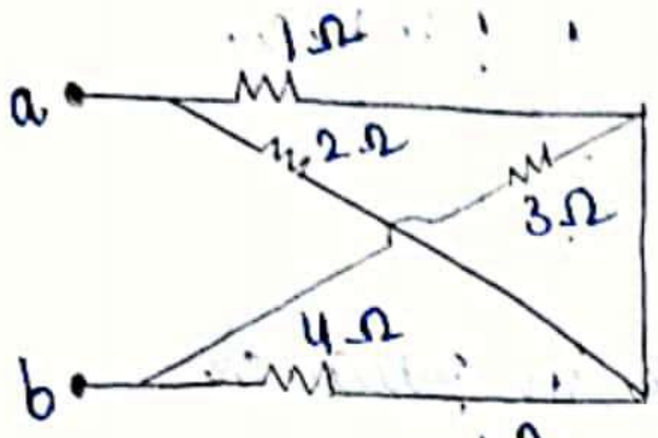


$R_{ab} = ?$

Current chooses low resistive path

$\therefore R_{ab} = 1\Omega$

Q) $R_{ab} = ?$

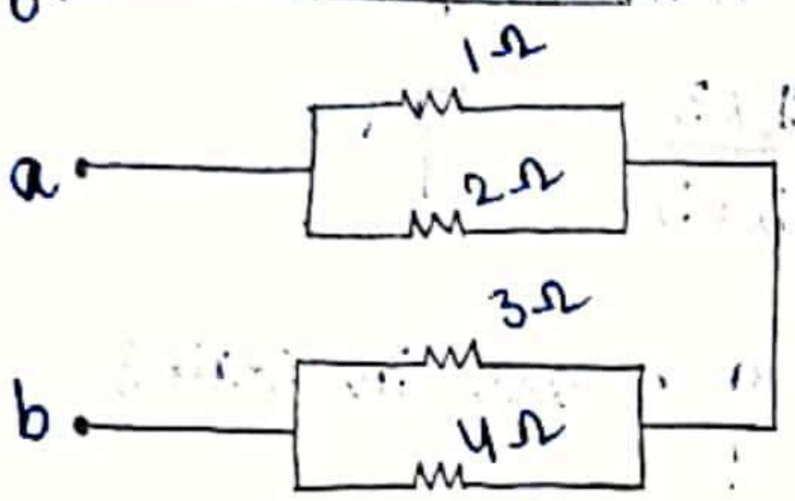


$1\Omega, 2\Omega$ are in parallel

$R_1 = \frac{1\times 2}{1+2} = \frac{2}{3}\Omega$

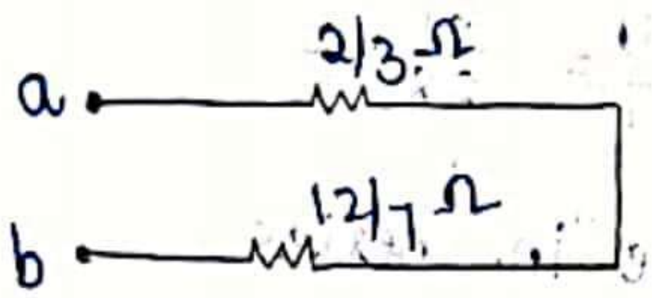
$3\Omega, 4\Omega$ are in parallel

$R_2 = \frac{3\times 4}{3+4} = \frac{12}{7}\Omega$

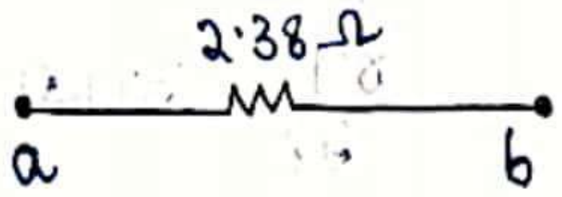


$\frac{2}{3}\Omega, \frac{12}{7}\Omega$ are in series

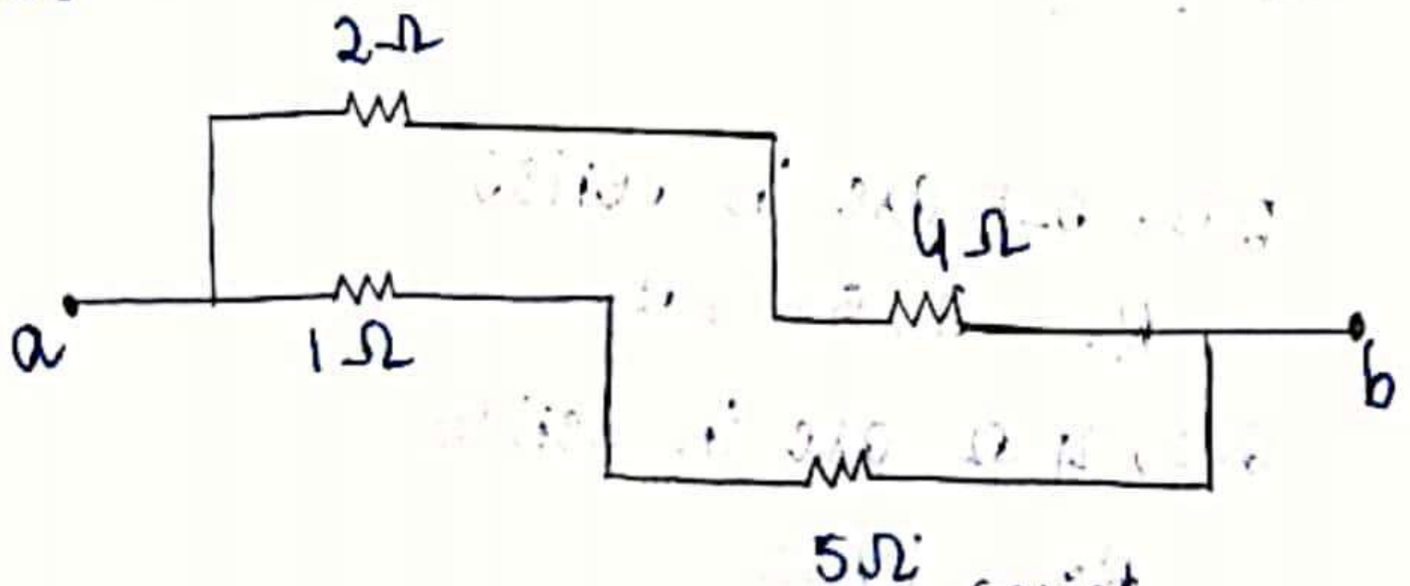
$R_{ab} = \frac{2}{3} + \frac{12}{7} = \frac{50}{21} = 2.38\Omega$



$\therefore R_{ab} = \frac{50}{21}$ or 2.38Ω



Q) $R_{ab} = ?$



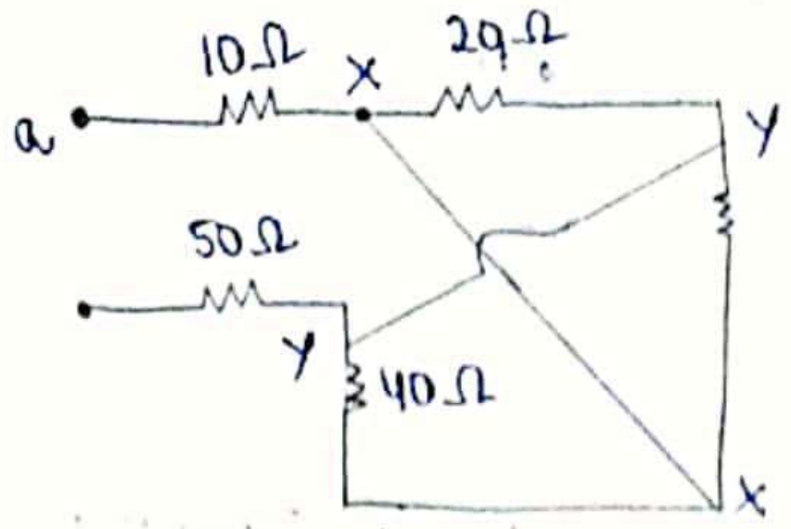
$2\Omega, 4\Omega$ are in ~~parallel~~ series, $R_1 = 2+4 = 6\Omega$

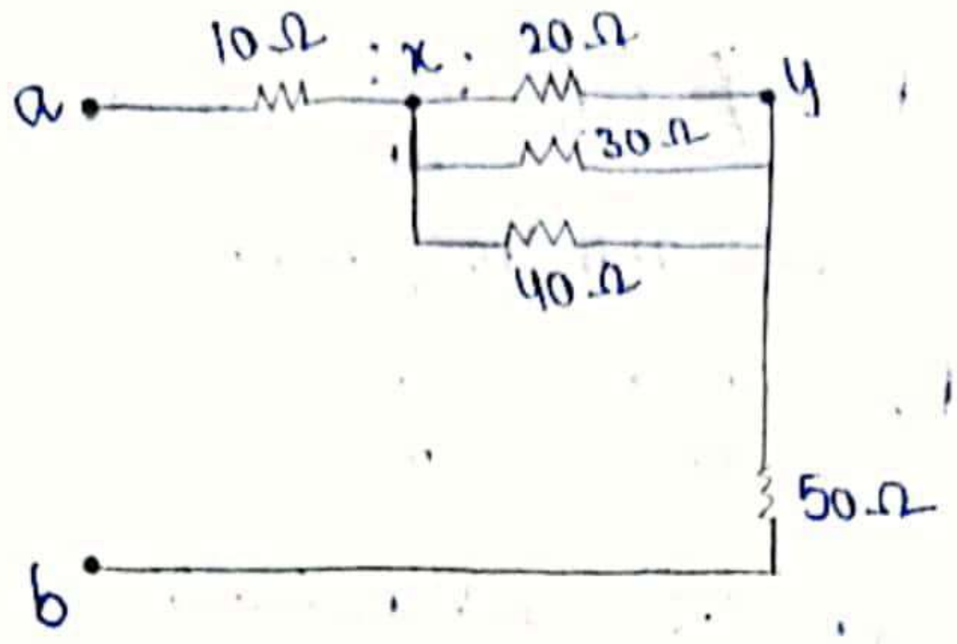
$1\Omega, 5\Omega$ are in ~~parallel~~ series $R_2 = 1+5 = 6\Omega$

$6\Omega, 6\Omega$ are in parallel

$\therefore R_{ab} = 3\Omega$

Q) Rab = ?





20Ω, 30Ω, 40Ω are in parallel

$R_1 = \frac{120}{30}\,\Omega$

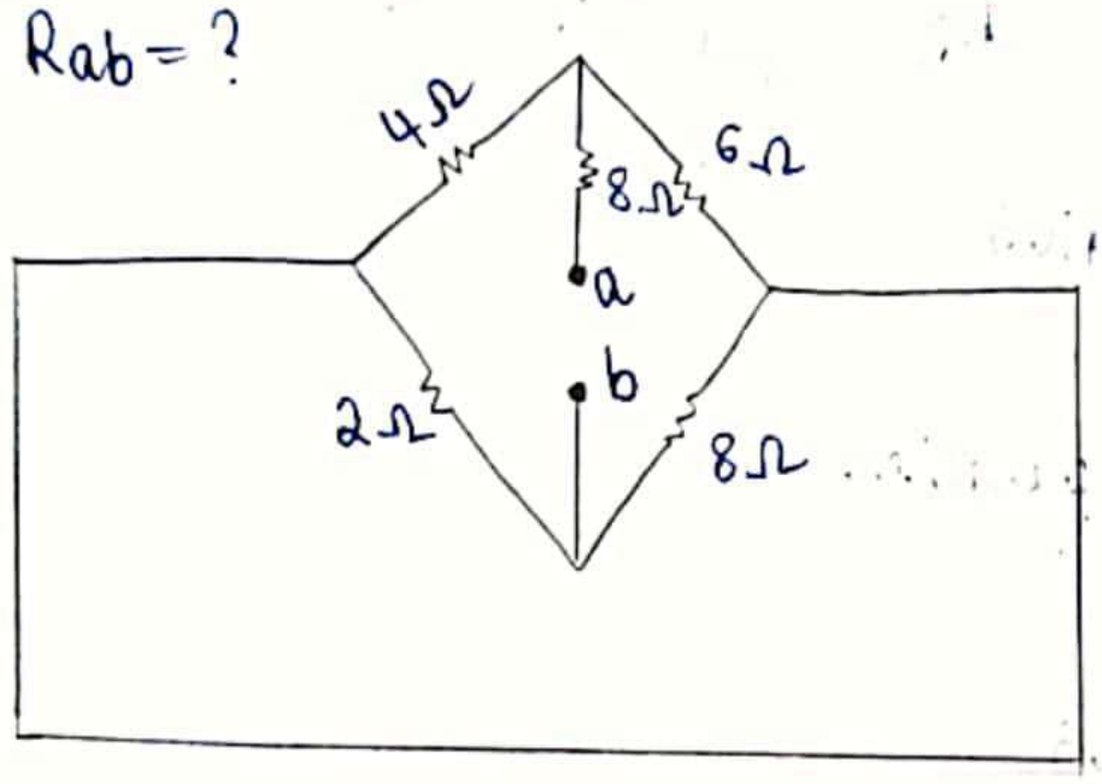
10Ω, $\frac{120}{30}\,\Omega$, 50Ω are in series

$R_{ab} = 10 + \frac{120}{30} + 50$

$= 69.23$

$\therefore R_{ab} = 69.23\,\Omega$

Q) Rab = ?

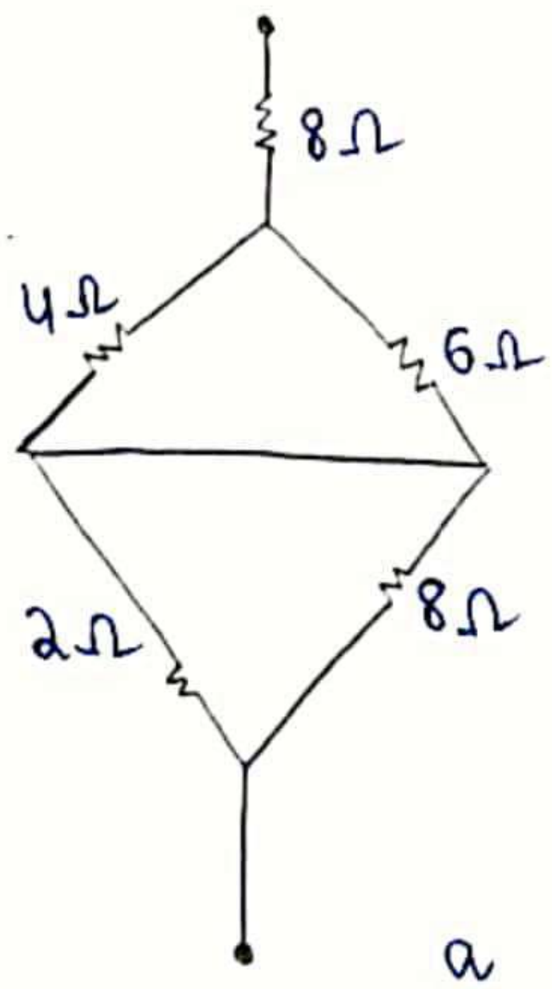


4Ω, 6Ω are in parallel

$R_1 = \frac{6 \times 4}{10} = 2.4\,\Omega$

2Ω, 8Ω are in parallel

$R_2 = \frac{2 \times 8}{10} = 1.6\,\Omega$

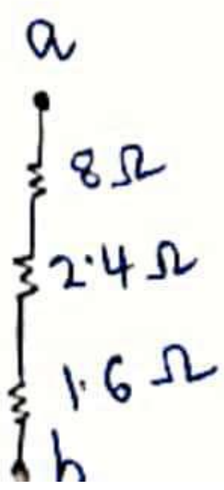


8Ω, 2.4Ω, 1.6Ω are in series

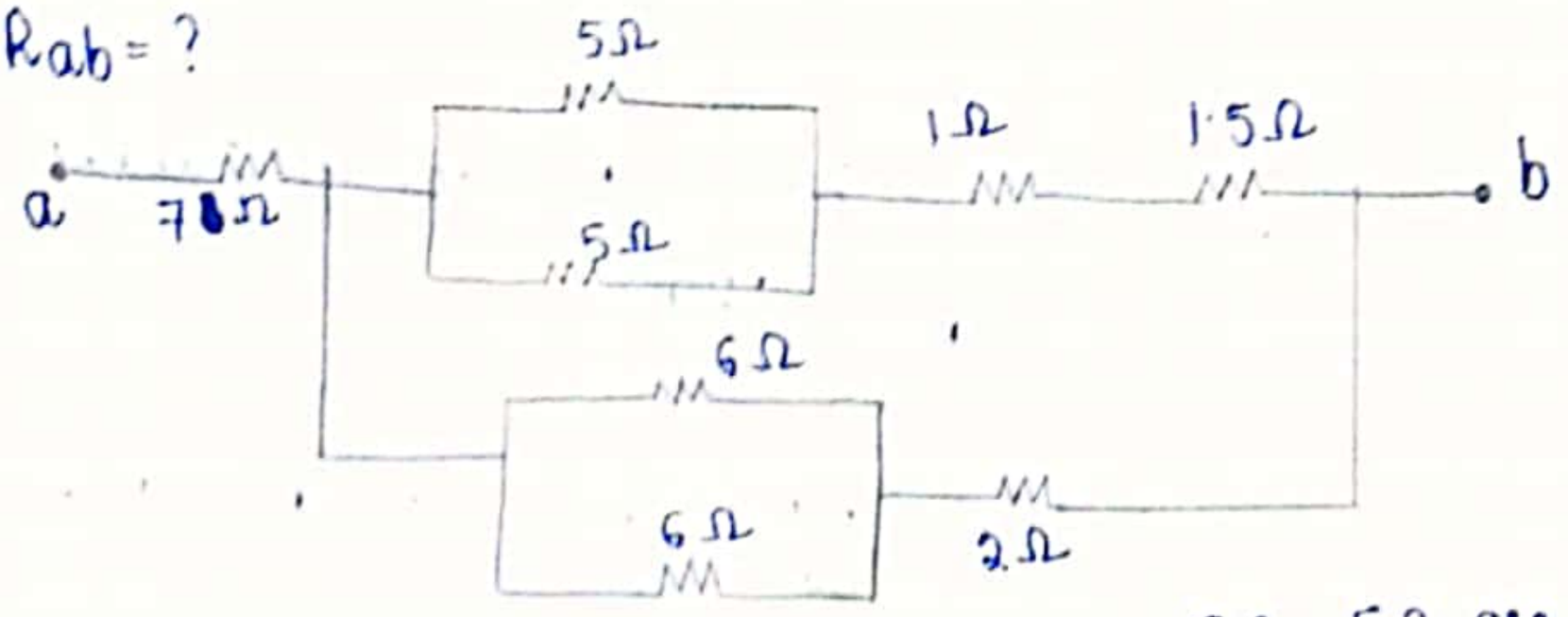
$R_{ab} = 8 + 2.4 + 1.6$

$= 12\,\Omega$

$\therefore R_{ab} = 12\,\Omega$

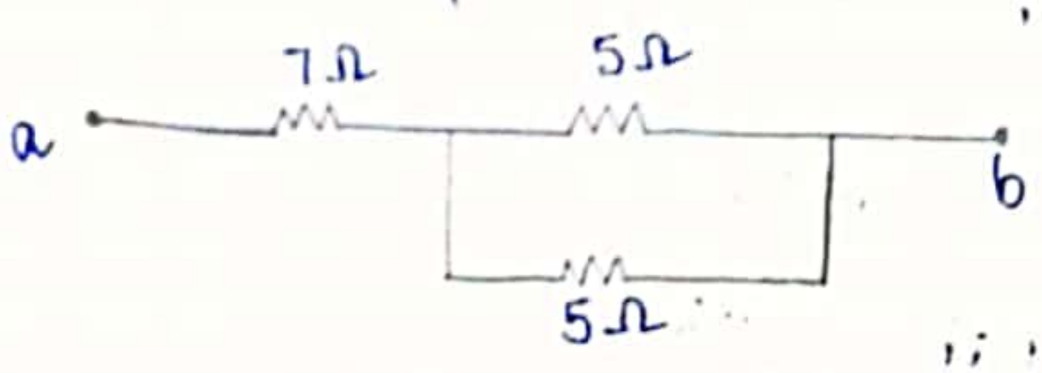


Q) $R_{ab} = ?$



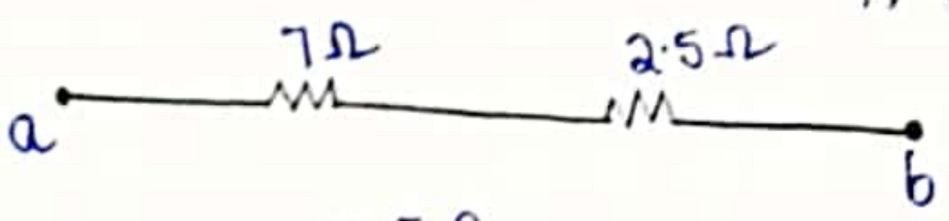
5Ω, 5Ω are in parallel

$R_1 = \frac{5 \times 5}{10} = 2.5\Omega$



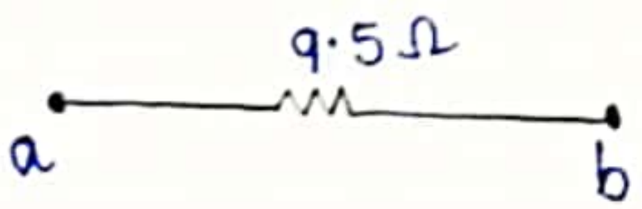
6Ω, 6Ω are in parallel

$R_2 = \frac{6 \times 6}{12} = \frac{36}{12} = 3\Omega$



$\frac{5}{2}\Omega$, 1Ω, 1.5Ω are in series

$R_3 = \frac{5}{2} + 2.5 = 5\Omega$



3Ω, 2Ω are in series

$R = 5\Omega$

5Ω, 5Ω are in parallel

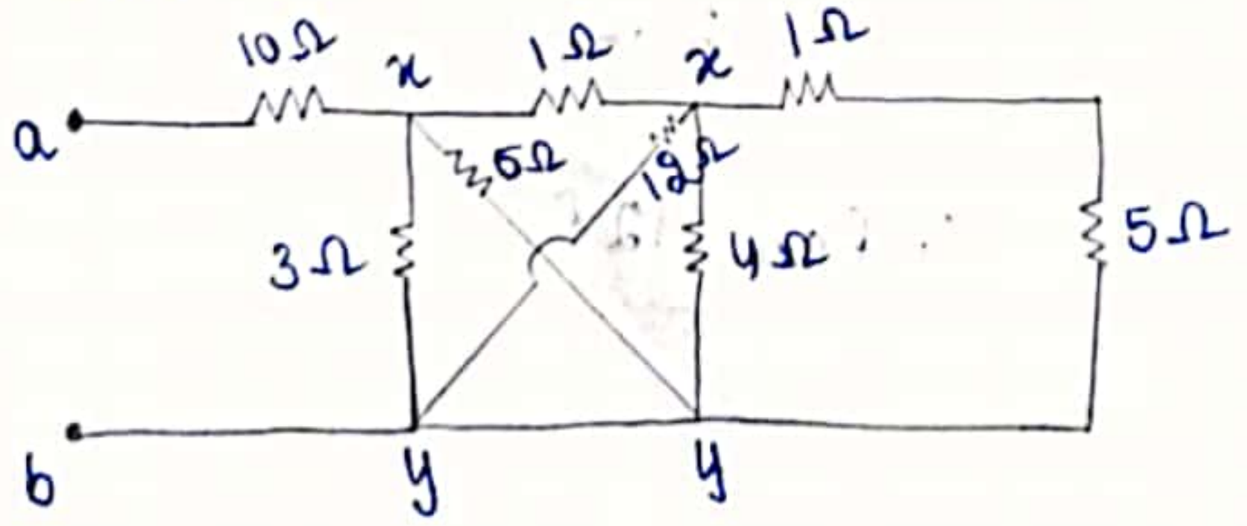
$R = \frac{5}{2}\Omega$

$\frac{5}{2}\Omega$, 7Ω are in series

$R_{ab} = \frac{5}{2} + 7 = \frac{19}{2} = 9.5$

$\therefore R_{ab} = 9.5\Omega$

Q) $R_{ab} = ?$



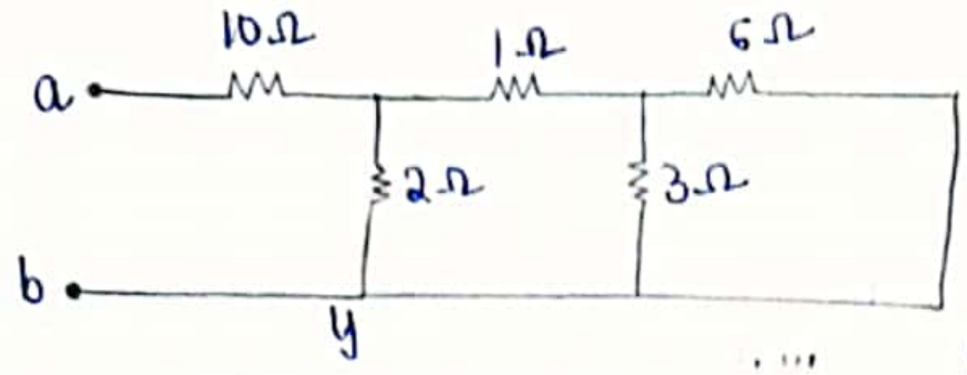
parallel

$= 2.5\Omega$

rallel

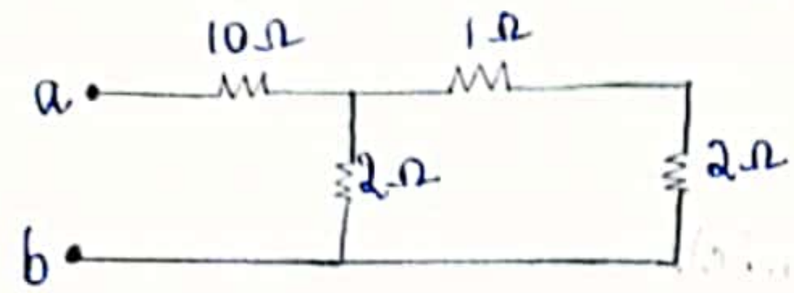
3Ω

series



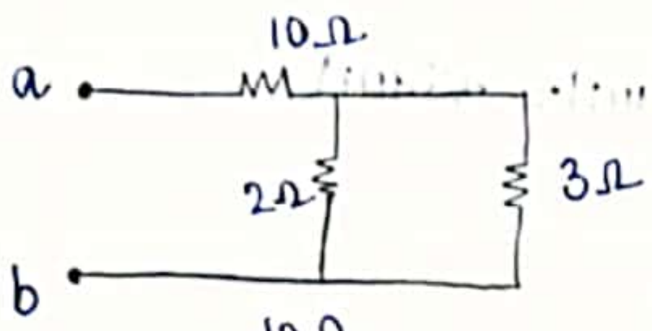
$3\Omega, 6\Omega$ are in parallel

$$R_1 = \frac{3\times 6}{9} = 2\Omega$$



$12\Omega, 4\Omega$ are in parallel

$$R_2 = \frac{12\times 4}{16} = 3\Omega$$



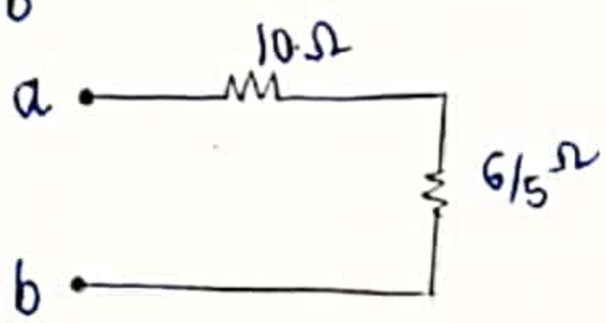
$6\Omega, 3\Omega$ are in parallel

$$R_3 = \frac{6\times 3}{6+3} = 2\Omega$$

$1\Omega, 2\Omega$ are in series $\Rightarrow R = 3\Omega$

$2\Omega, 3\Omega$ are in parallel

$$R = \frac{2\times 3}{2+3} = 1.2\Omega$$



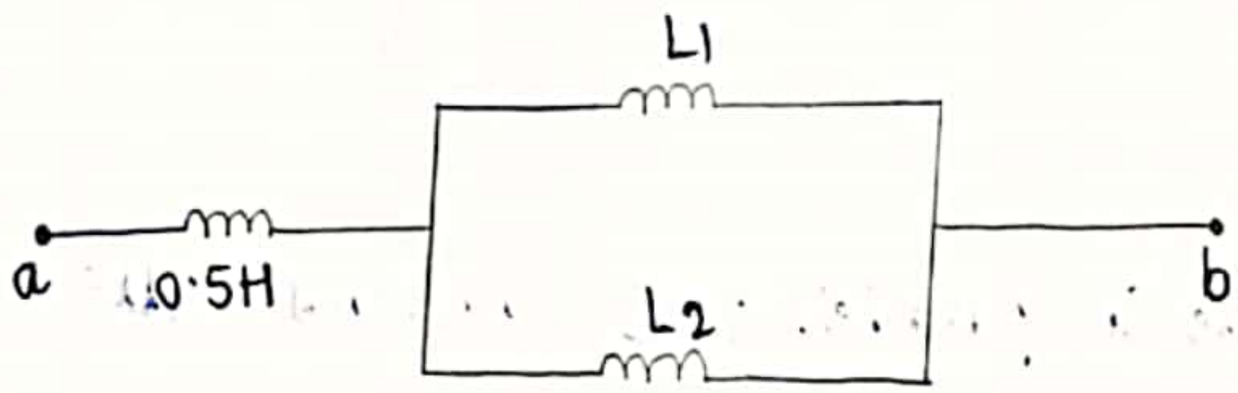
$1.2\Omega, 10\Omega$ are in series

$R_{ab} = 1.2 + 10 = 11.2\Omega$

$\therefore R_{ab} = 11.2\Omega$

* Problems on Inductors :—

Q)



If $L_1 = 2L_2$; $L_{ab} = 0.7H$ then find L_1 & L_2 = ?

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} \Rightarrow L = \frac{2L_2}{3}$$

$$\Rightarrow 0.5 + \frac{2L_2}{3} = 0.7$$

$$L_2 = 0.3H$$

$$\Rightarrow L_1 = 0.6H$$

$\therefore L_1 = 0.6H, \; L_2 = 0.3H$

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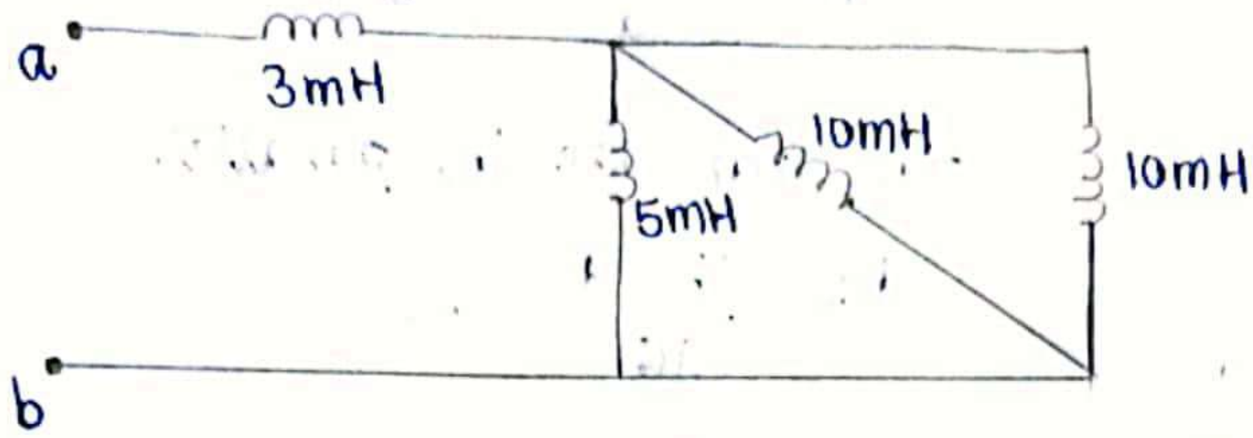
Q) $L_{ab} = ?$



5mH, 10mH, 10mH are in parallel

$$\frac{1}{L} = \frac{1}{5} + \frac{1}{10} + \frac{1}{10} \Rightarrow L = \frac{5}{2}\,mH = 2.5\,mH$$

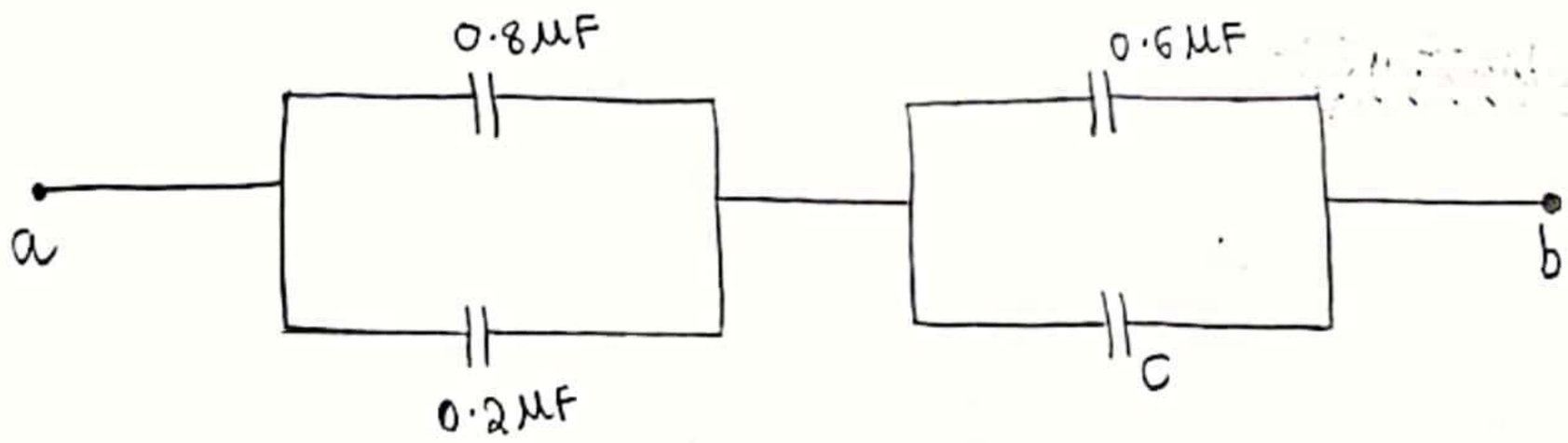
3mH, 2.5 mH are in series

$$L_{eq} = L_{ab} = 3mH + 2.5mH$$
$$= 5.5\,mH$$
$$\therefore L_{ab} = 5.5\,mH$$

17/04/23

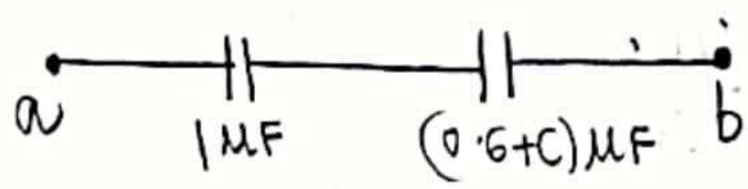
* Problems on Capacitors :—

Q) $C_{ab} = 0.5\,\mu F$ then find C.



0.8μF, 0.2μF are in parallel ; $C = 0.8 + 0.2 = 1\,\mu F$

0.6μF, CF are in parallel ; $C = 0.6 + C\,\mu F$

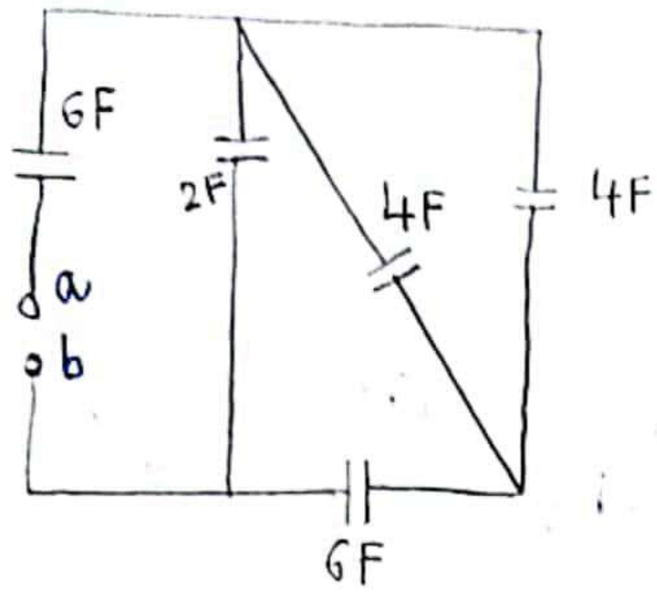


1μF, (0.6+C) μF are in series,

$$\frac{1}{0.5} = \frac{1}{1} + \frac{1}{0.6+C}$$

$$\Rightarrow C = 0.4\,\mu F$$

P) $C_{ab} = ?$

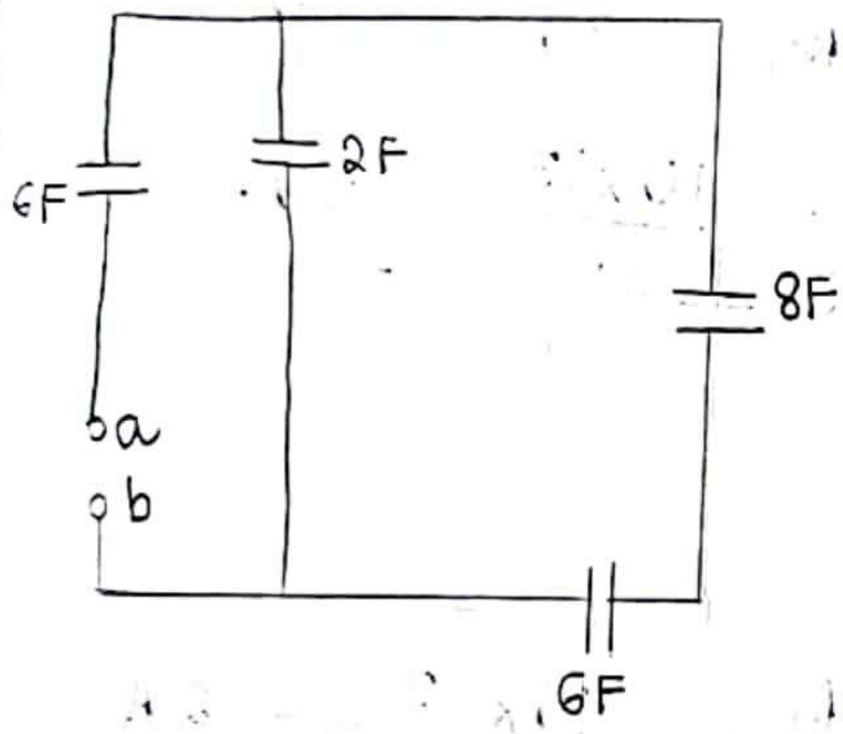


4F and 4F are in parallel

$C = 8F$

8F, 6F are in series

$C = \frac{48}{14} = \frac{24}{7} F$



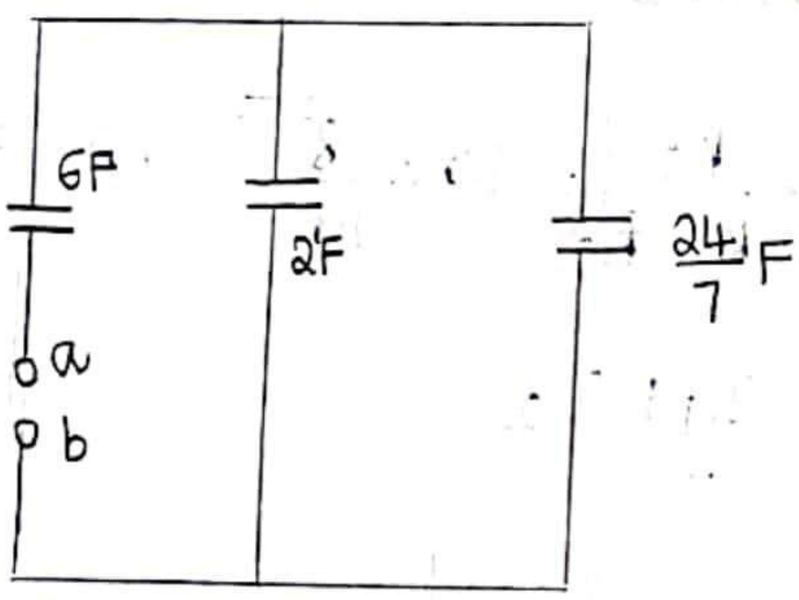
$\frac{24}{7}$ F, 2F are in parallel

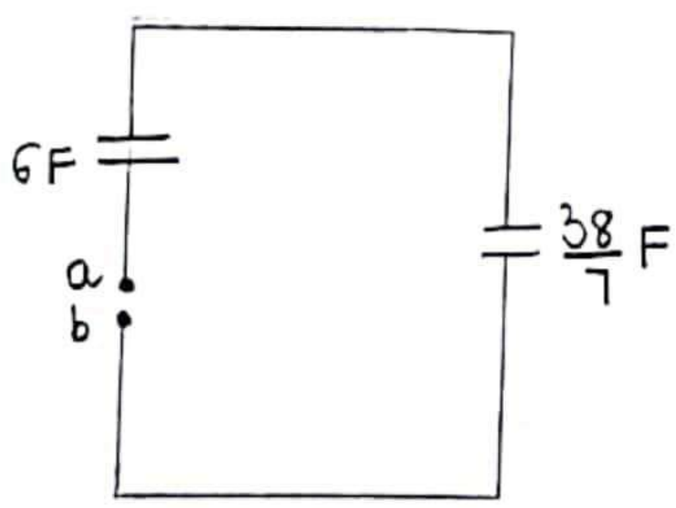
$C = \frac{24}{7} + 2 = \frac{38}{7} F$

6F, $\frac{38}{7}$ F are in series

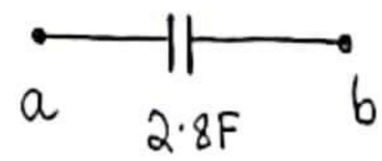
$$C = \frac{6 \times \frac{38}{7}}{6 + \frac{38}{7}} = 2.8F$$

$\therefore C_{ab} = 2.8 F$

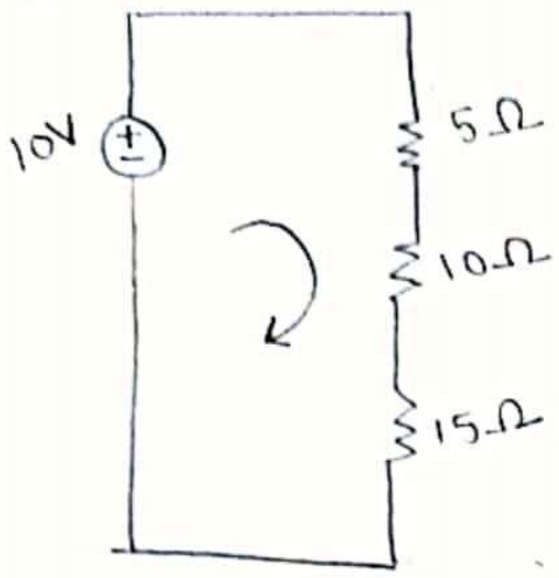




$\Rightarrow$



Q) Find I, Voltage drop across three resistors.



$R_{eq} = 30\Omega$

$V = 10V$

$I = \frac{10}{30} = \frac{1}{3} A$

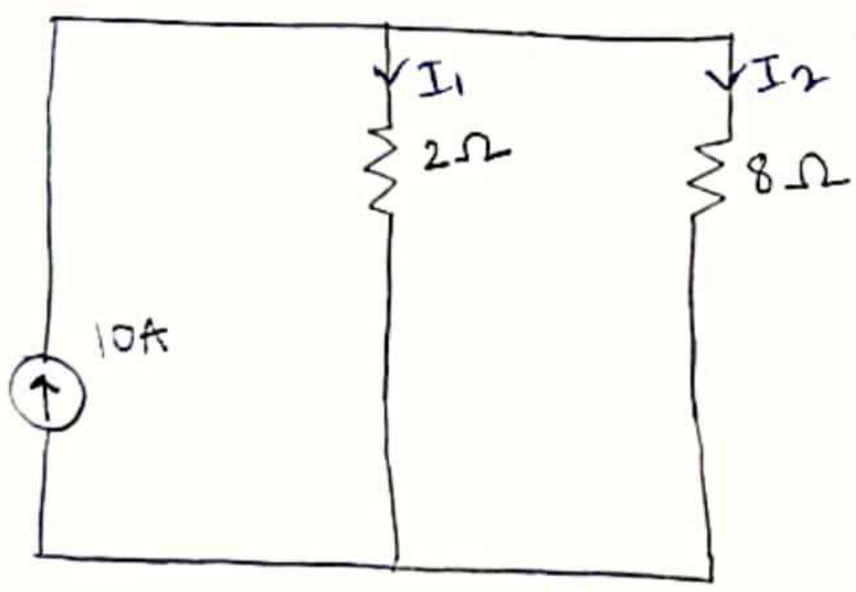
$V_{R_1} = IR_1 = \frac{V \times R_1}{R_1+R_2+R_3} = \frac{10 \times 5}{30} = \frac{5}{3} V$

$V_{R_2} = IR_2 = \frac{V \times R_2}{R_1+R_2+R_3} = \frac{10 \times 10}{30} = \frac{10}{3} V$

$V_{R_3} = IR_3 = \frac{V \times R_3}{R_1+R_2+R_3} = \frac{10 \times 15}{30} = 5V.$

$V_{R_1} + V_{R_2} + V_{R_3} = 10V = V$

Q) Find I_1, I_2.

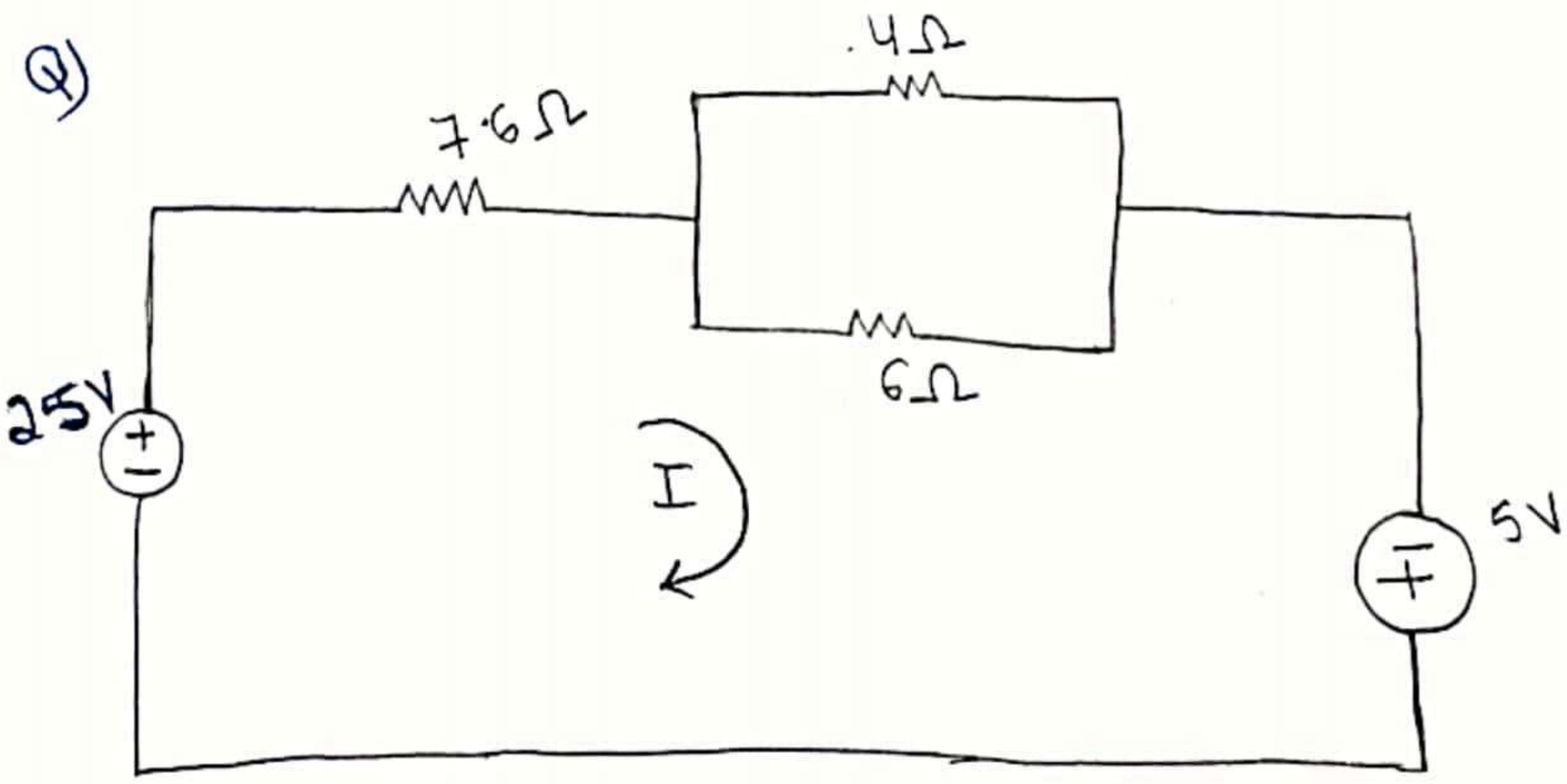


$I_1 = I \times \frac{R_1}{R_1+R_2} = 10 \times \frac{2}{10} = 2A$

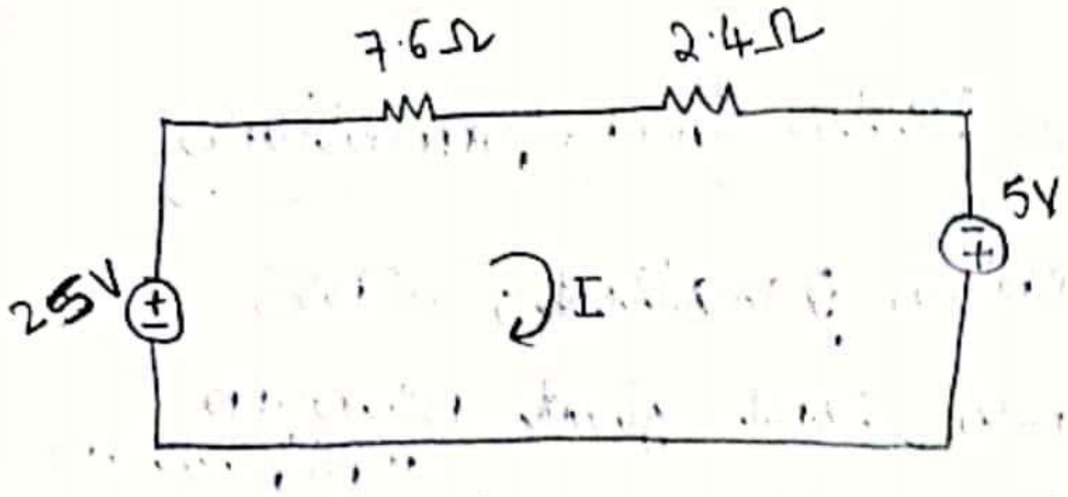
$I_2 = I_2 \times \frac{R_2}{R_1+R_2} = 10 \times \frac{8}{10} = 8A$

$I = 10A = I_1 + I_2$

Q)



Find I, power supplied by each source.

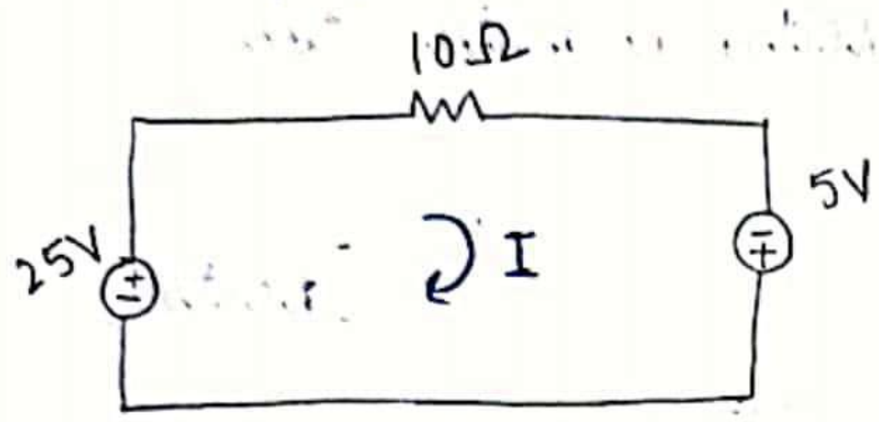


4Ω, 6Ω are in parallel

$$R = \frac{6 \times 4}{6+4} = 2.4\,\Omega$$

2.4Ω, 7.6Ω are in parallel

$$R = 2.4 + 7.6 = 10\,\Omega$$



$$-25 + 10I - 5 = 0$$

$$I = 3$$

Power supplied by 25V = $VI = 25 \times 3 = \underline{75W}$

by 5V = $VI = 5 \times 3 = \underline{15W}$

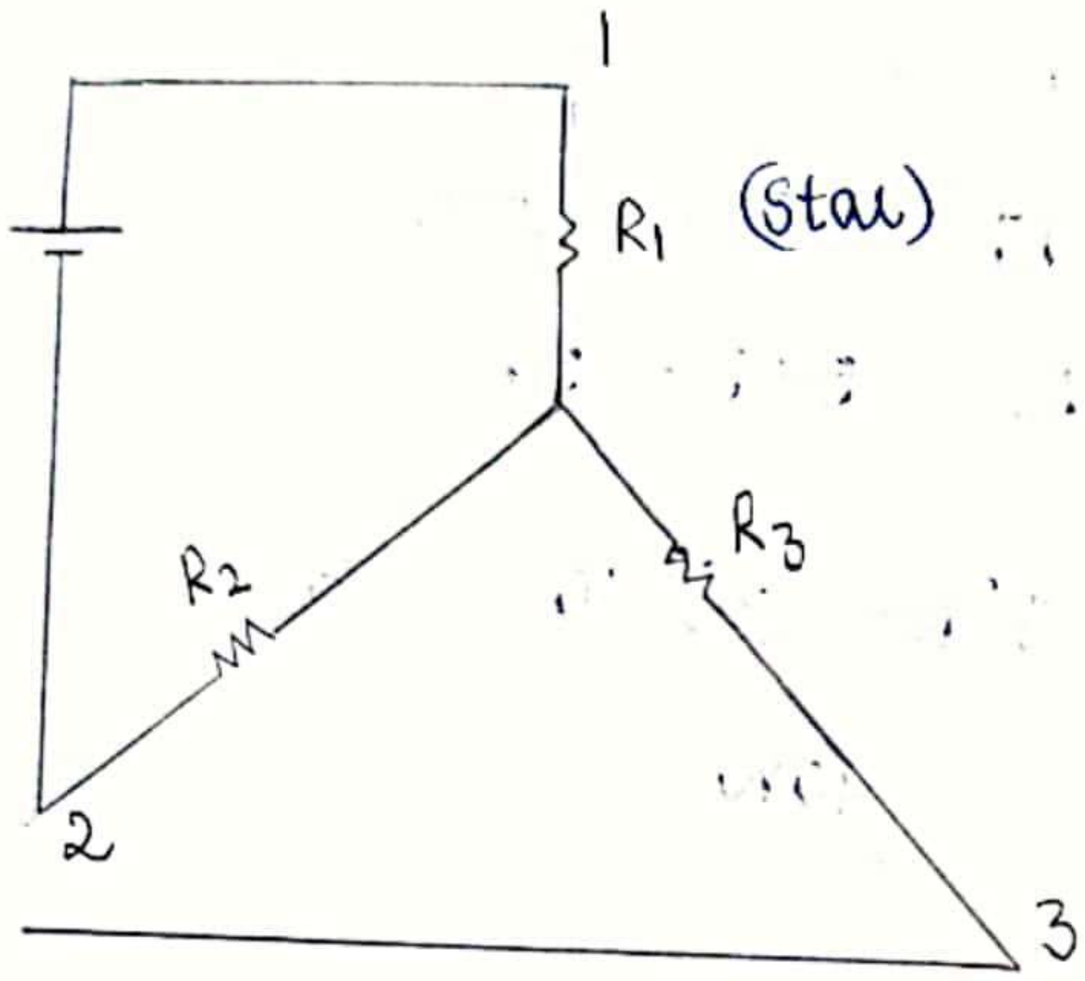
Power consumed by 10Ω = $I^2R = (3)^2\,10$

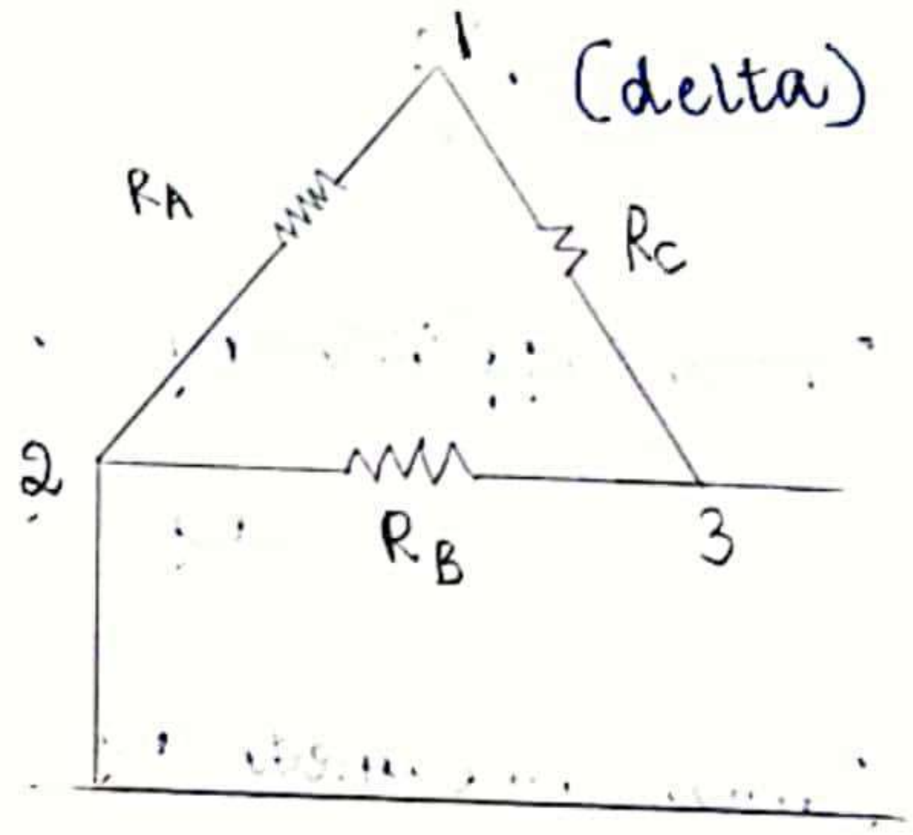
$= \underline{90W}$

Power supplied = power consumed

** Delta-Star (or) Star-Delta transformations

In some complex networks, series, parallel, series-parallel combination of elements can't yield network simplification. Such networks are handed by Star-delta or delta-star transformations.





R_1, R_2, R_3 are said to be connected in T, Y or star manner
R_A, R_B, R_C are said to be connected in delta or π manner.
The above networks are equal if their respective resistances from the terminals 1-2, 2-3 & 1-3 are equal.

At 1-2 Junction:

$$R_{12}(\star) = R_1 + R_2$$

$$R_{12}(\Delta) = R_A \parallel \text{lel to } (R_B + R_C) = \frac{R_A R_B + R_A R_C}{R_A + R_B + R_C}$$

$$R_{12}(\star) = R_{12}(\Delta)$$

$$\Rightarrow R_1 + R_2 = \frac{R_A R_B + R_A R_C}{R_A + R_B + R_C} \quad \text{--- (1)}$$

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At 2-3 Junction:

$R_{23}(\star) = R_2 + R_3$

$R_{23}(\Delta) = R_B \parallel el$ to $(R_A + R_C)$

$$= \frac{R_A R_B + R_B * R_C}{R_A + R_B + R_C}$$

$R_{23}(\star) = R_{23}(\Delta)$

$$\Rightarrow R_2 + R_3 = \frac{R_A R_B + R_B R_C}{R_A + R_B + R_C} \quad \text{--- (2)}$$

At 1-3 Junction:

$R_{13}(\star) = R_1 + R_3$

$R_{13}(\Delta) = R_C \parallel el$ to $(R_A + R_B)$

$$= \frac{R_C R_A + R_C R_B}{R_A + R_B + R_C}$$

$R_{13}(\star) = R_{13}(\Delta)$

$$\Rightarrow R_1 + R_3 = \frac{R_C R_A + R_C R_B}{R_A + R_B + R_C} \quad \text{--- (3)}$$

Solving eq^s (1), (2) & (3):

$$R_1 = \frac{R_A R_C}{R_A + R_B + R_C} \quad \text{--- (4)}$$

$$R_2 = \frac{R_A R_B}{R_A + R_B + R_C} \quad \text{--- (5)}$$

$$R_3 = \frac{R_B R_C}{R_A + R_B + R_C} \quad \text{--- (6)}$$

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$$R_1 R_2 = \frac{R_A^2 R_B R_C}{(R_A + R_B + R_C)^2} \quad \text{—— (7)}$$

$$R_2 R_3 = \frac{R_A R_B^2 R_C}{(R_A + R_B + R_C)^2} \quad \text{—— (8)}$$

$$R_1 R_3 = \frac{R_A R_B R_C^2}{(R_A + R_B + R_C)^2} \quad \text{—— (9)}$$

$$\Rightarrow R_1 R_2 + R_2 R_3 + R_1 R_3 = \frac{R_A R_B R_C (R_A + R_B + R_C)}{(R_A + R_B + R_C)^2}$$

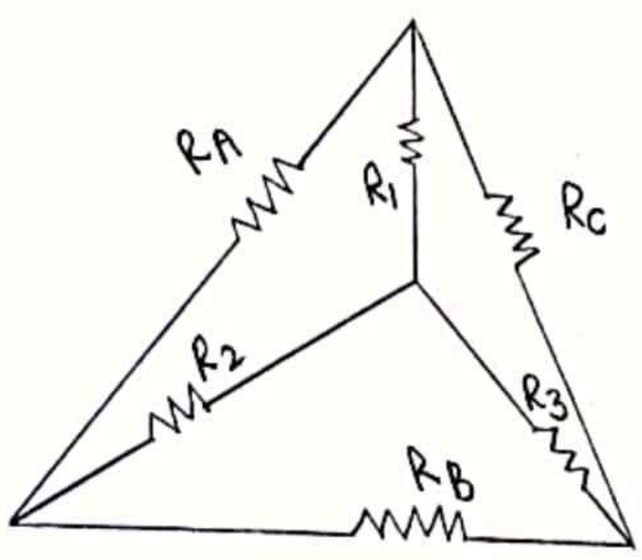
$$R_1 R_2 + R_2 R_3 + R_1 R_3 = \frac{R_A R_B R_C}{R_A + R_B + R_C} \quad \text{—— (10)}$$

eq $\frac{(10)}{(6)} \Rightarrow \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_3} = R_A$

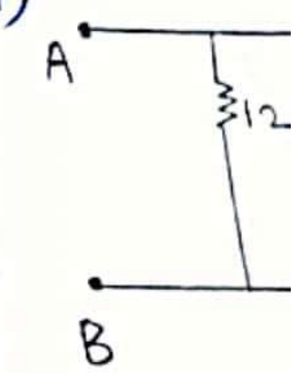
同理; $R_A = \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_3}$ —— (11)

$$R_B = \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_1} \quad \text{—— (12)}$$

$$R_C = \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_2} \quad \text{—— (13)}$$



Q)



Applyin
delta

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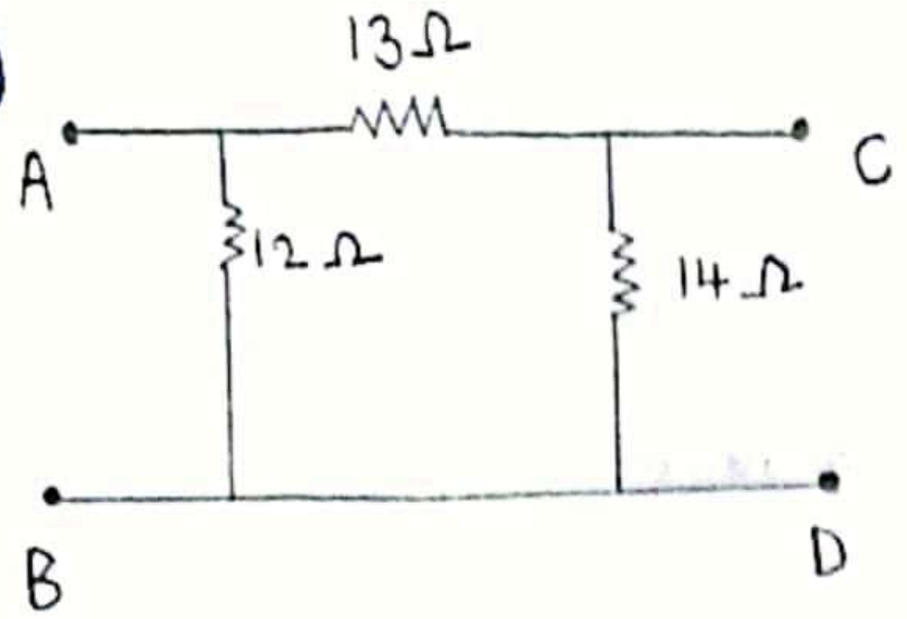
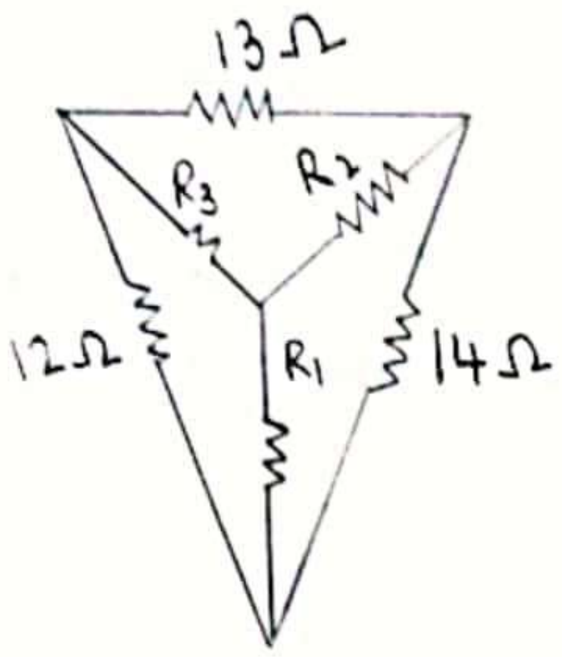
Q)

Q)



Applying the star connected equivalent circuit for the delta connected network.



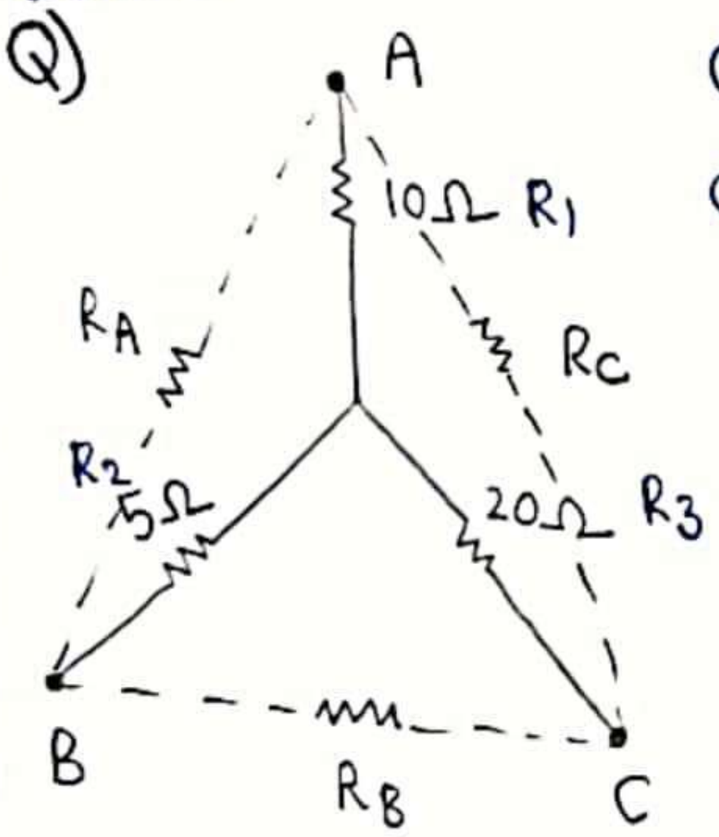
$$R_1 = \frac{12 \times 14}{12+14+13} = 4.3\,\Omega$$

$$R_2 = \frac{14 \times 13}{14+13+12} = \cancel{6.14\,\Omega}\ 4.66\,\Omega$$

$$R_3 = \frac{13 \times 12}{13+12+14} = \cancel{6.24\,\Omega}\ 4\,\Omega$$

18/04/23

Q)



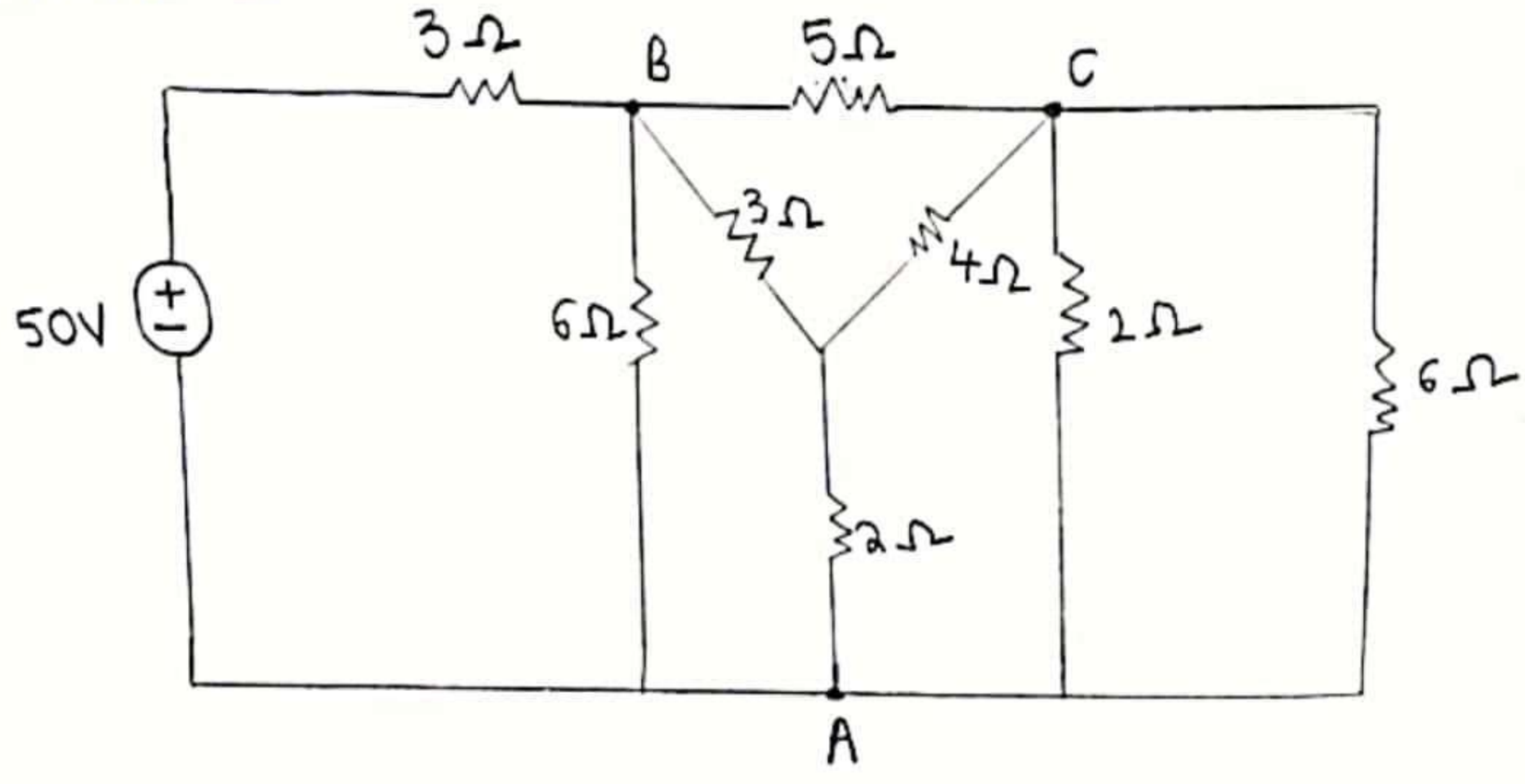
Obtain the delta connected equivalent circuit for the given star connected circuit.

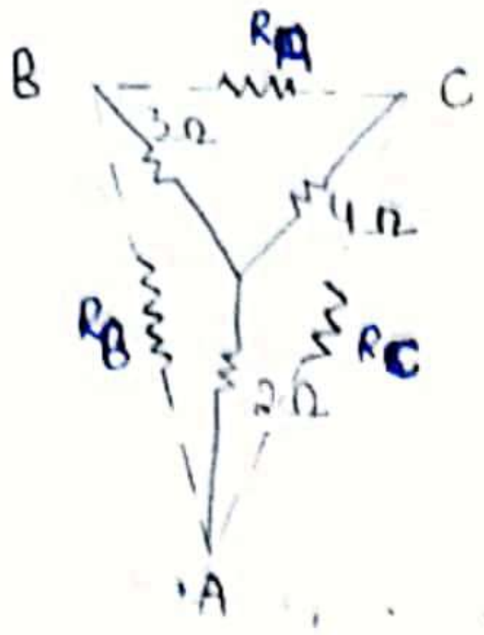
$$R_A = \frac{350}{20} = 17.5\,\Omega$$

$$R_B = \frac{350}{10} = 35\,\Omega$$

$$R_C = \frac{350}{5} = 70\,\Omega$$

Q) Find I drawn?

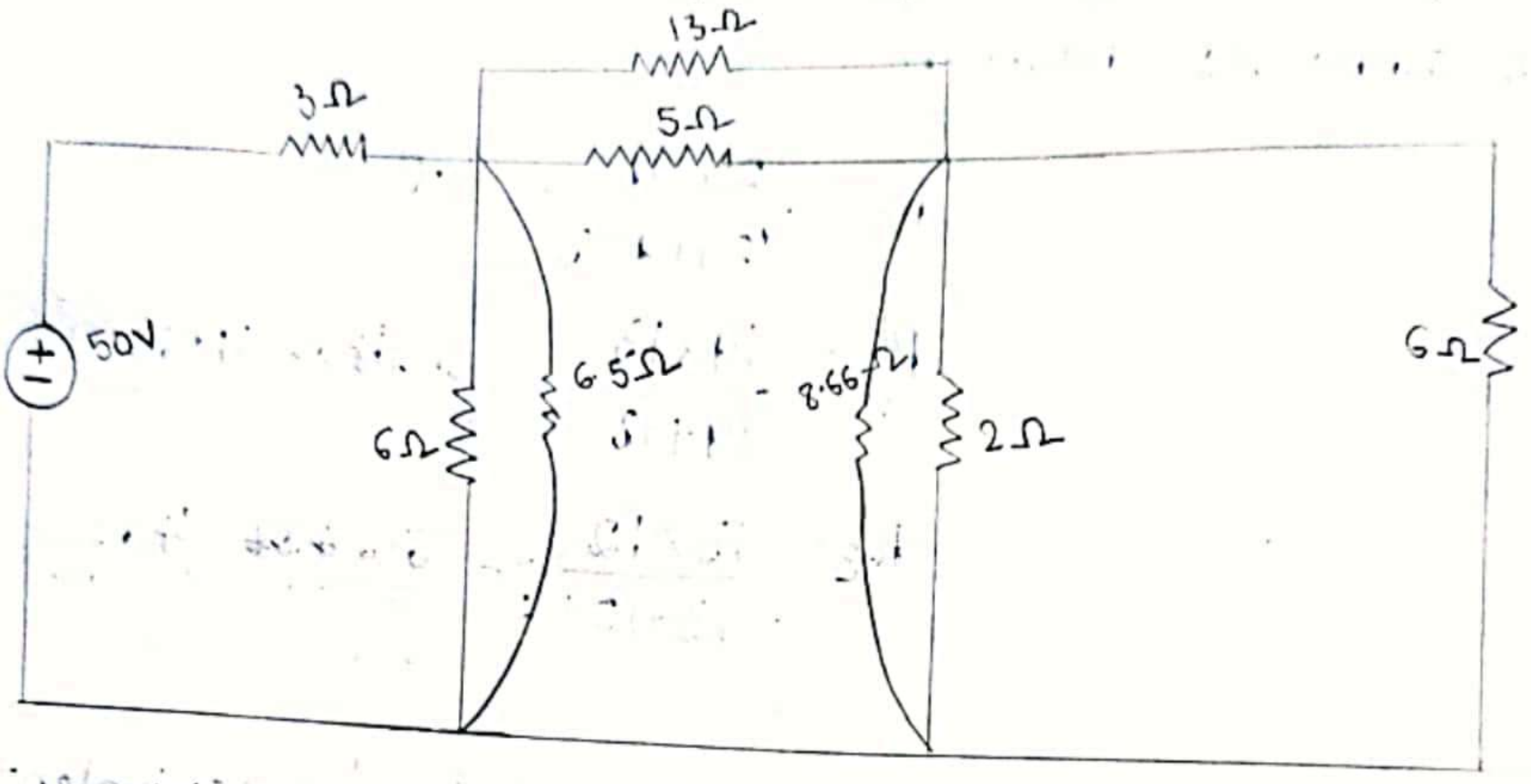




$$R_A = \frac{26}{2} = 13\Omega$$

$$R_C = \frac{26}{3}\Omega = 8.66\Omega$$

$$R_B = \frac{26}{4} = \frac{13}{2} = 6.5\Omega$$



13Ω, 5Ω are in parallel

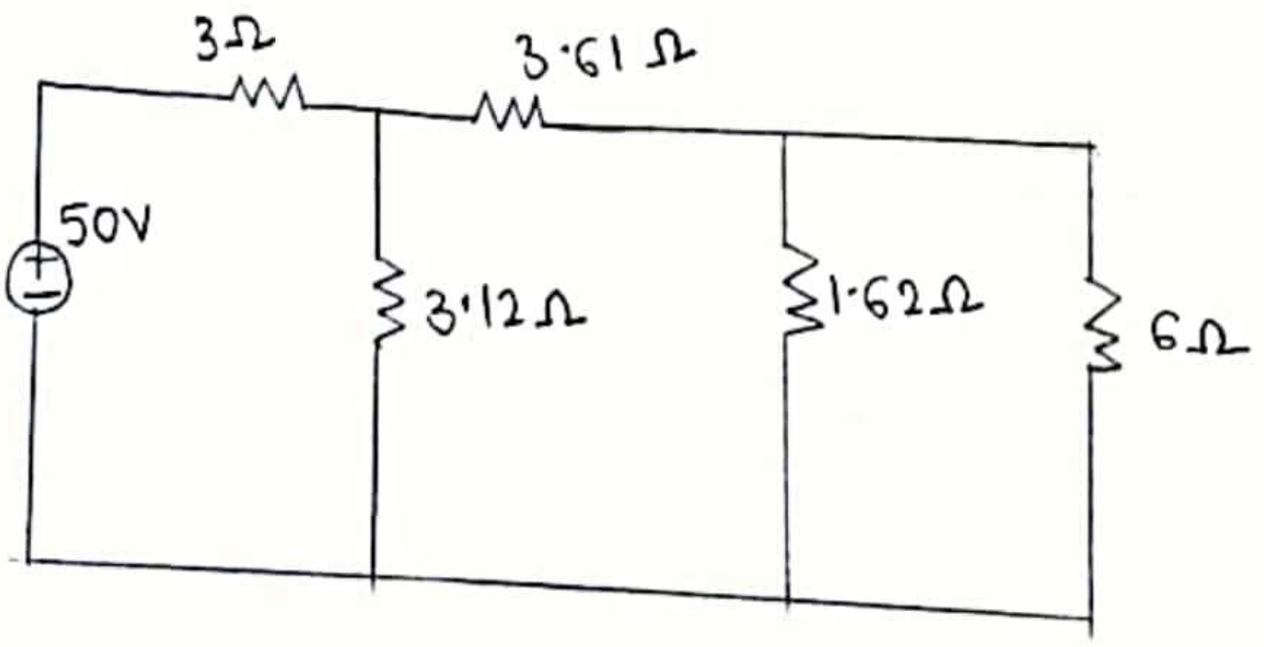
$$R = \frac{13 \times 5}{18} = 3.61\Omega$$

6.5Ω, 6Ω are in parallel

$$R = \frac{6.5 \times 6}{12.5} = 3.12\Omega$$

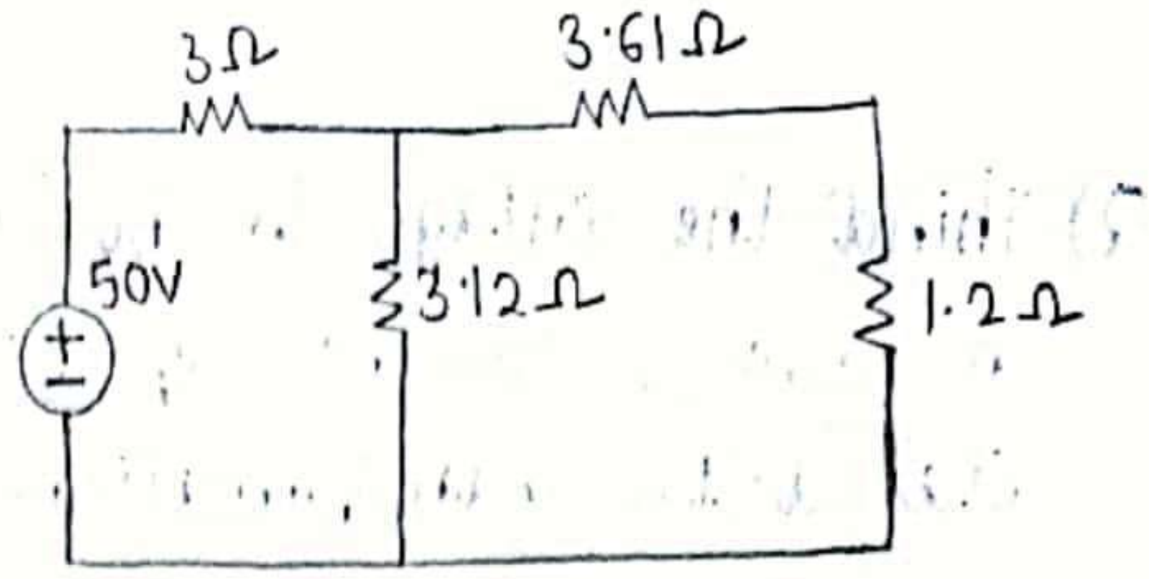
8.66Ω, 2Ω are in parallel

$$R = \frac{8.66 \times 2}{10.66} = 1.62\Omega$$



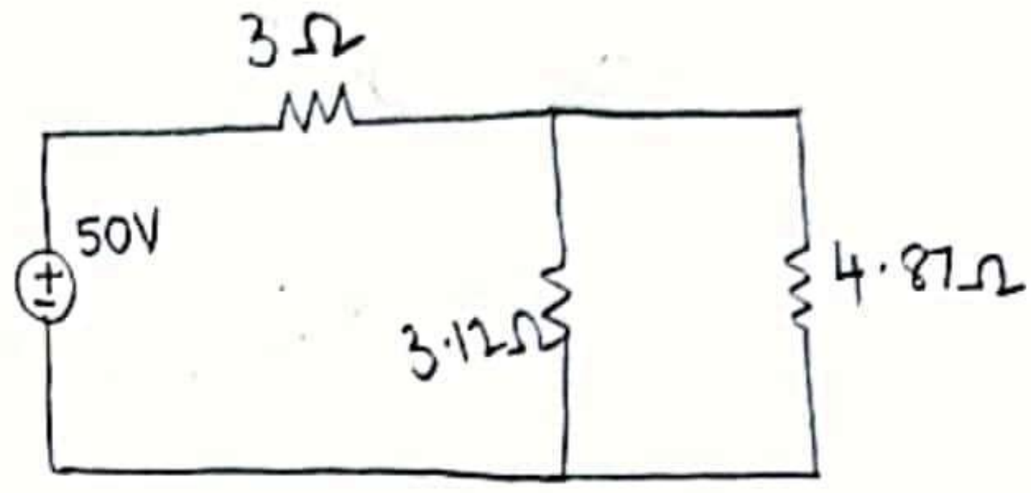
1.62Ω, 6Ω are in parallel,

$$R = \frac{6 * 1.62}{6 + 1.62} = 1.2\Omega$$



3.61Ω, 1.2Ω are in series,

$$R = 3.61 + 1.2 = 4.87\Omega$$

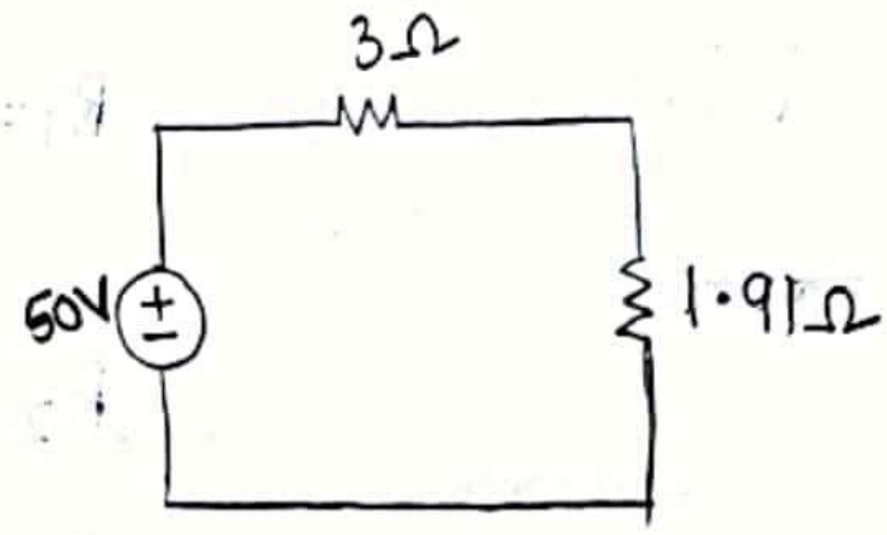


4.87Ω, 3.12Ω are in parallel,

$$R = \frac{4.87 \times 3.12}{4.87 + 3.12} = 1.91\Omega$$

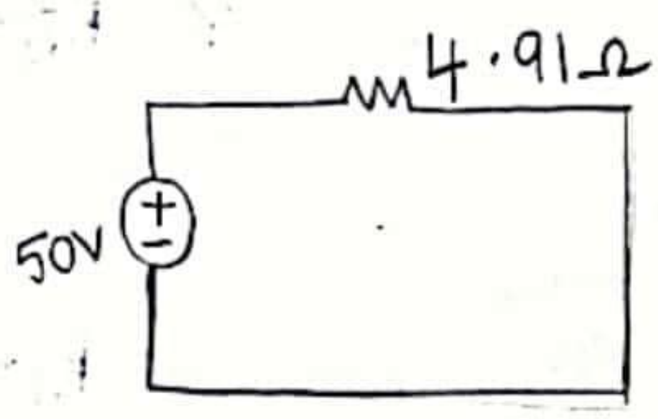
3Ω, 1.91Ω are in series

$$\Rightarrow R_{eq} = 3 + 1.91 = 4.91\Omega$$



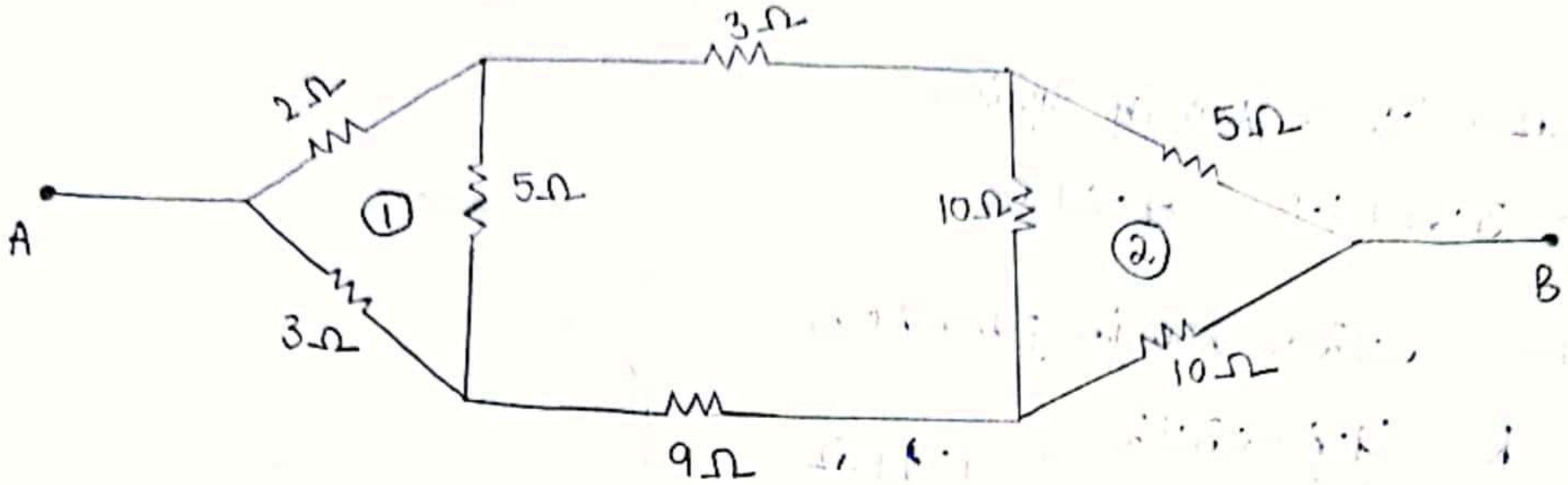
$$V = IR$$

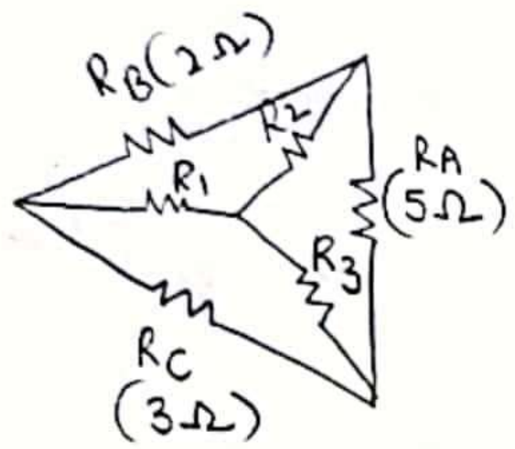
$$I = \frac{V}{R} = \frac{50}{4.91} = 10.1A$$



$\therefore$ Current drawn $= 10.1A$

Q) Find the voltage to be applied across A & B in order to drive a current of 5A into the circuit using star-delta transformations.

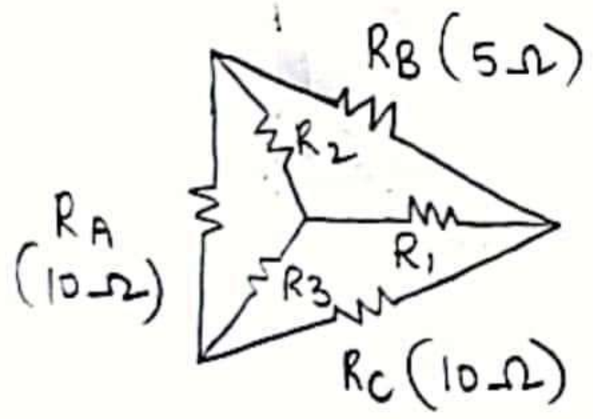




$$R_1 = \frac{R_B R_C}{R_A + R_B + R_C} = \frac{6}{10} = 0.6\,\Omega$$

$$R_2 = \frac{10}{10} = 1\,\Omega$$

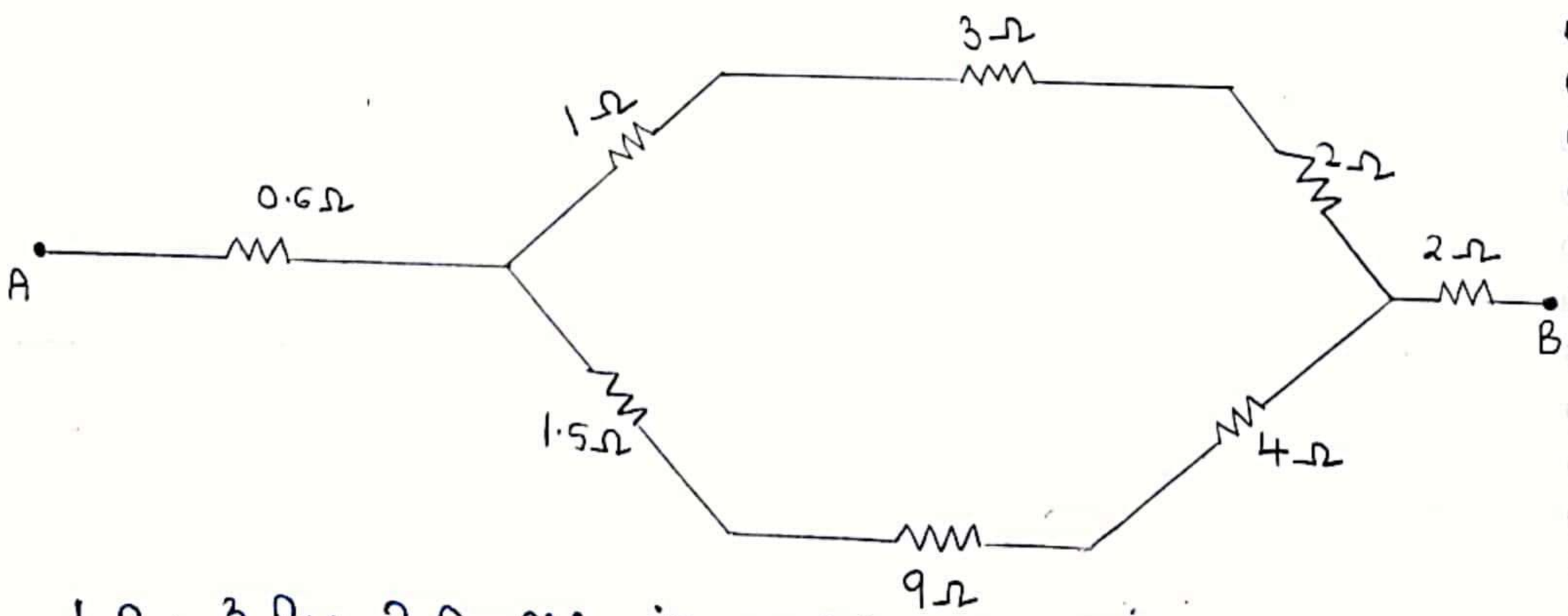
$$R_3 = \frac{15}{10} = 1.5\,\Omega$$



$$R_1 = \frac{50}{25} = 2\,\Omega$$

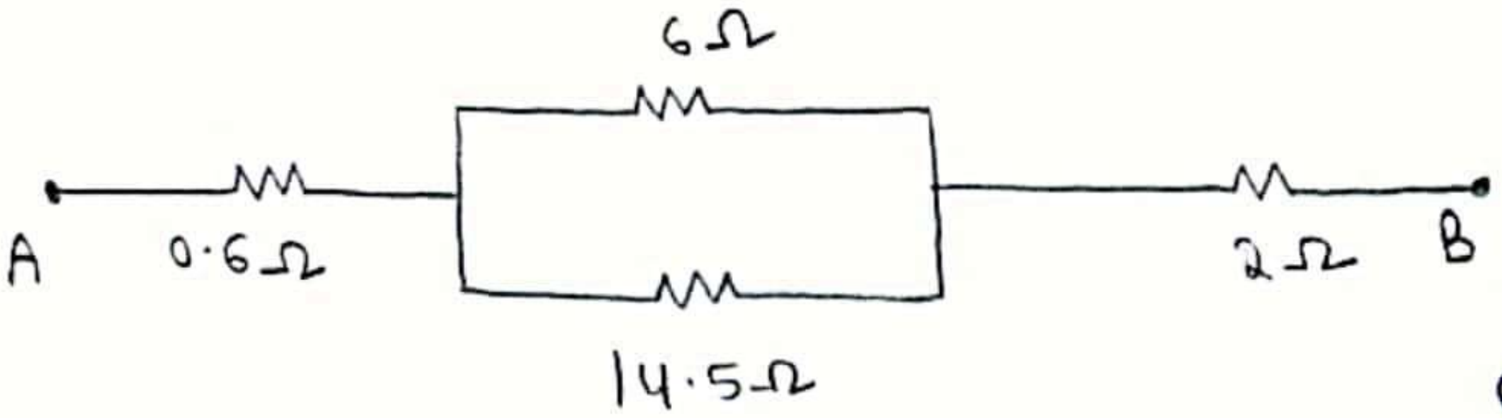
$$R_2 = \frac{50}{25} = 2\,\Omega$$

$$R_3 = \frac{100}{25} = 4\,\Omega$$



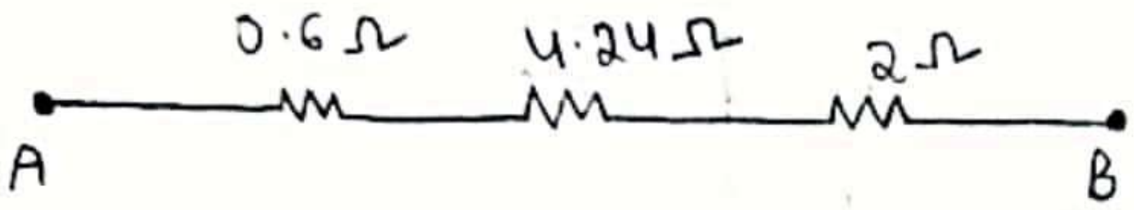
1Ω, 3Ω, 2Ω are in series $R = 6\,\Omega$

1.5Ω, 9Ω, 4Ω are in series $R = 14.5$.

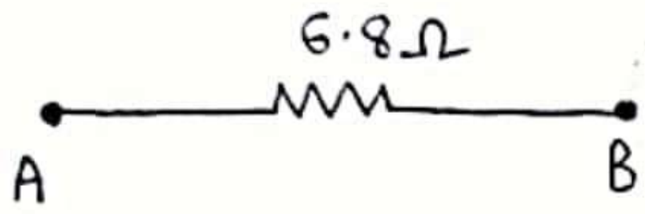


6Ω, 14.5 are in parallel

$$R = \frac{6 \times 14.5}{20.5} = 4.24\,\Omega$$



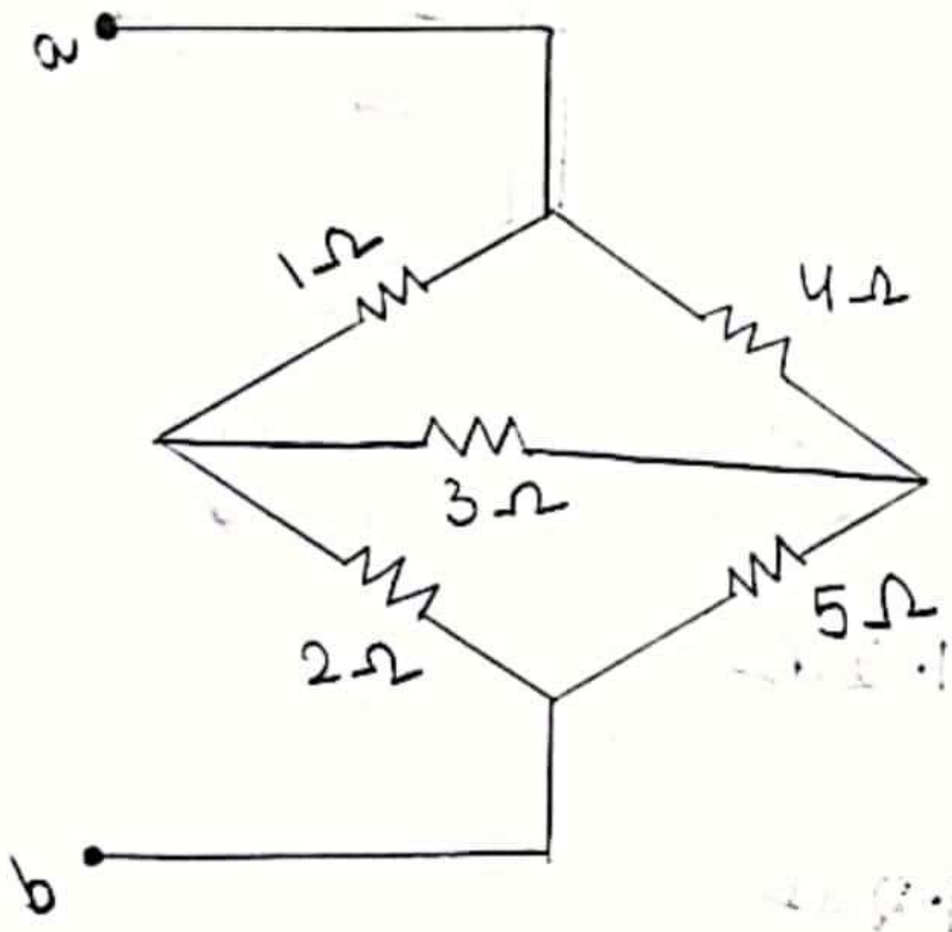
0.6Ω, 4.24Ω, 2Ω are in series

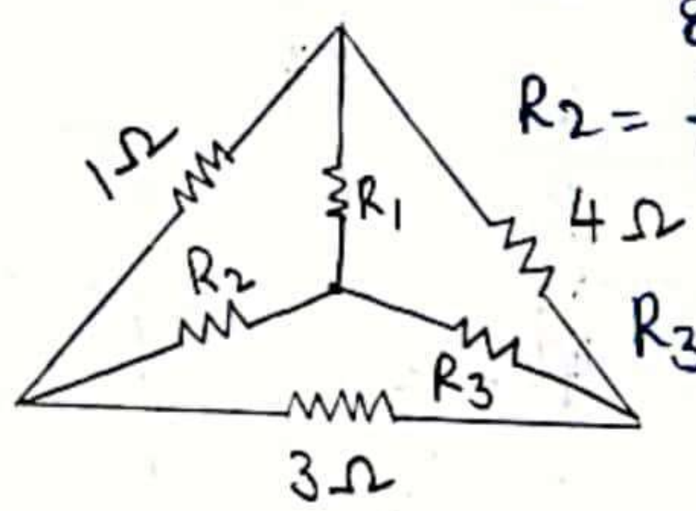


$$R_{AB} = 0.6 + 4.24 + 2\,\Omega$$
$$= 6.84\,\Omega$$

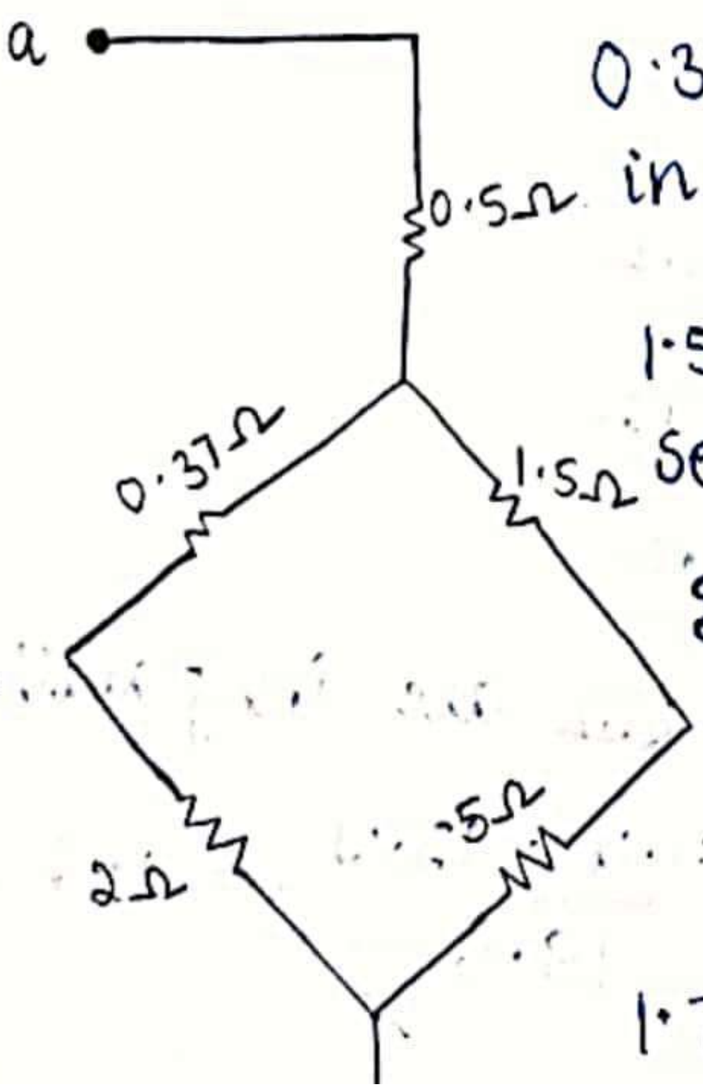
$$V_{AB} = I_{AB} \times R_{AB} = 5 \times 6.84$$
$$\therefore V_{AB} = 34.2\,V$$

Q)





$$R_1 = \frac{4}{8} = 0.5\,\Omega$$
$$R_2 = \frac{3}{8} = 0.37\,\Omega$$
$$R_3 = \frac{12}{8} = 1.5\,\Omega$$

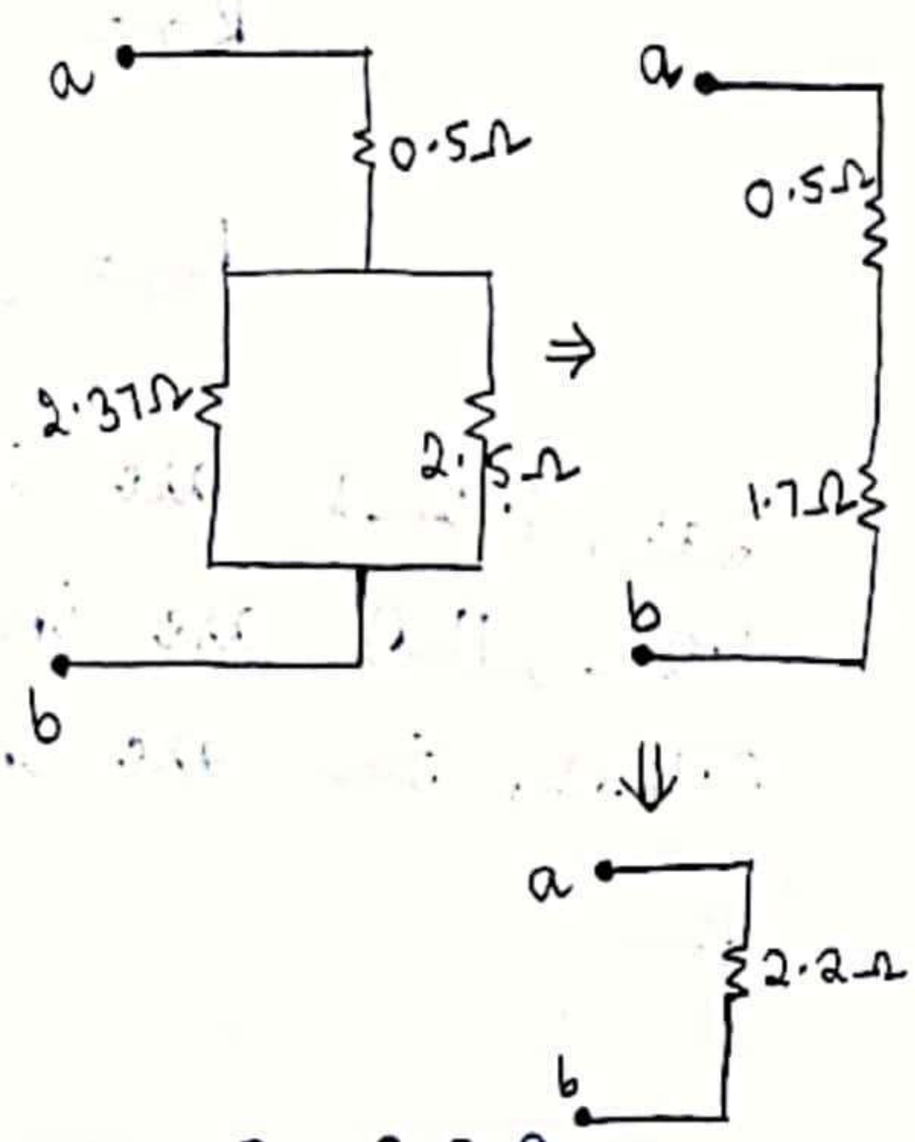


0.37Ω, 2Ω are in series, R = 2.37Ω

1.5Ω, 5Ω are in series, R = 6.5Ω

2.37Ω, 6.5Ω are in parallel

R = 1.7Ω



1.7Ω, 0.5Ω are in series, R = 2.2Ω

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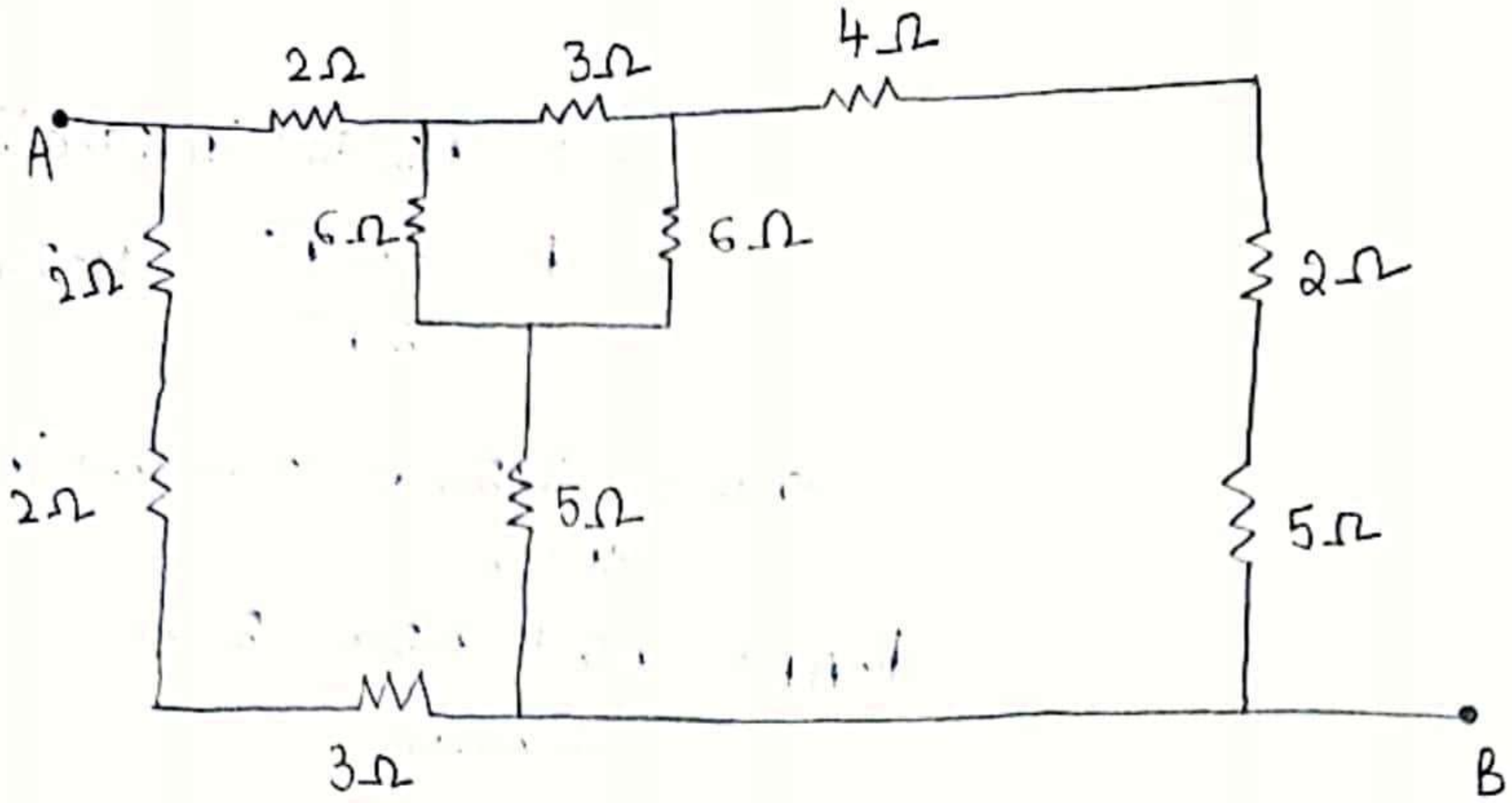
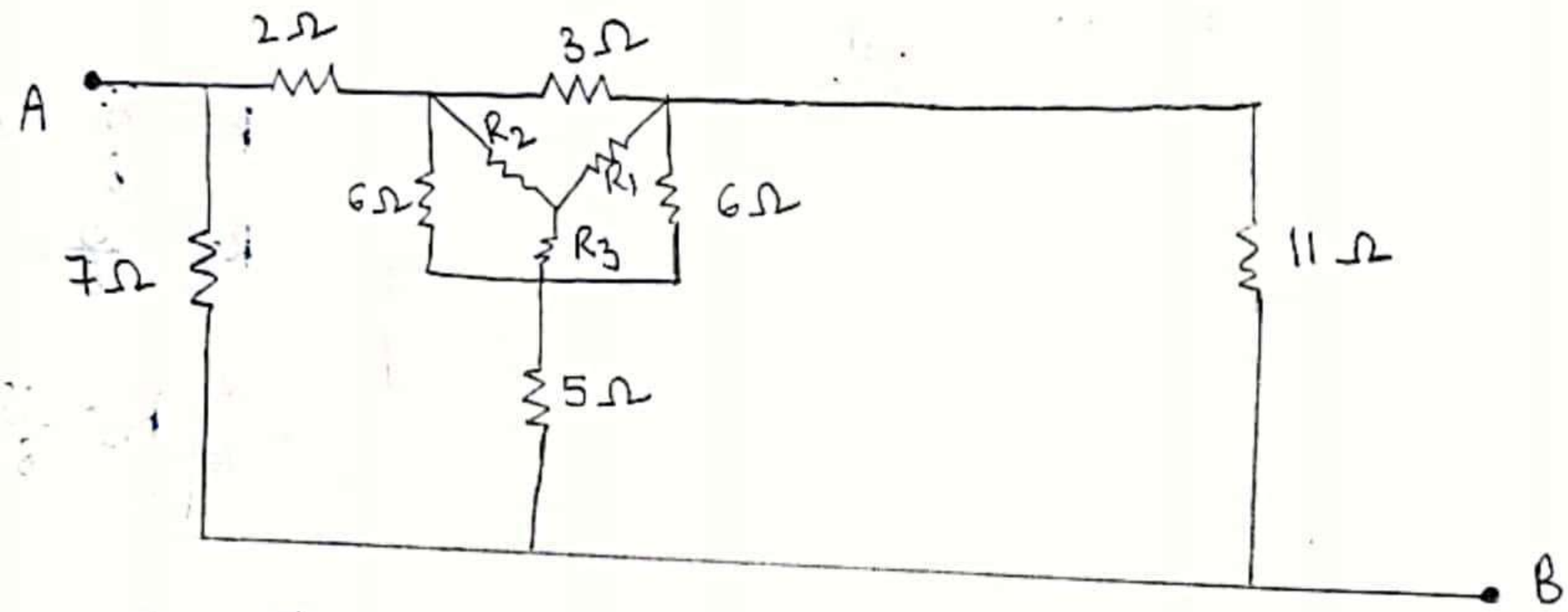
Q) Find Rab ?



2Ω, 2Ω, 3Ω are in series, R = 7Ω

4Ω, 2Ω, 5Ω are in series, R = 11Ω



equivalent star, $R_1 = \frac{3 \times 6}{3+6+6} = 1.2\,\Omega$

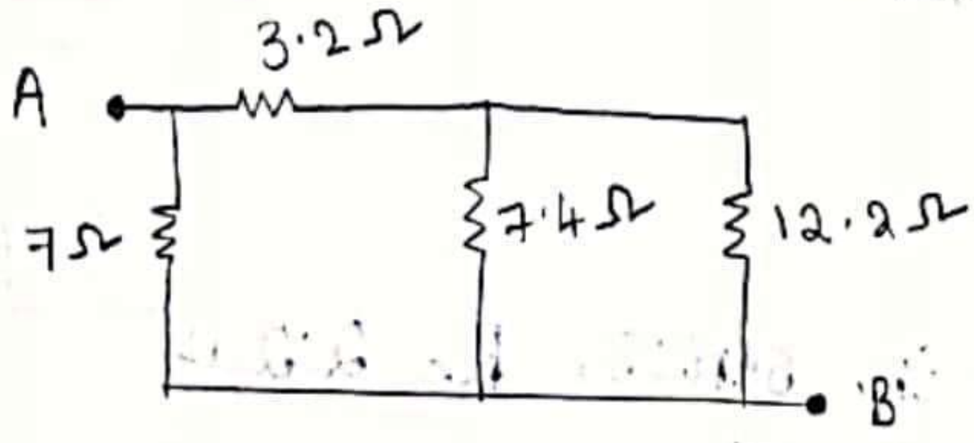
$R_2 = \frac{3 \times 6}{15} = 1.2\,\Omega$

$R_3 = \frac{6 \times 6}{15} = 2.4\,\Omega$

2Ω, 1.2Ω are in series, R = 3.2Ω

1.2Ω, 11Ω are in series, R = 12.2Ω

2.4Ω, 5Ω are in series, R = 7.4Ω



7.4Ω, 12.2Ω are in parallel,

$R = \frac{7.4 \times 12.2}{19.6} = 4.6\,\Omega$

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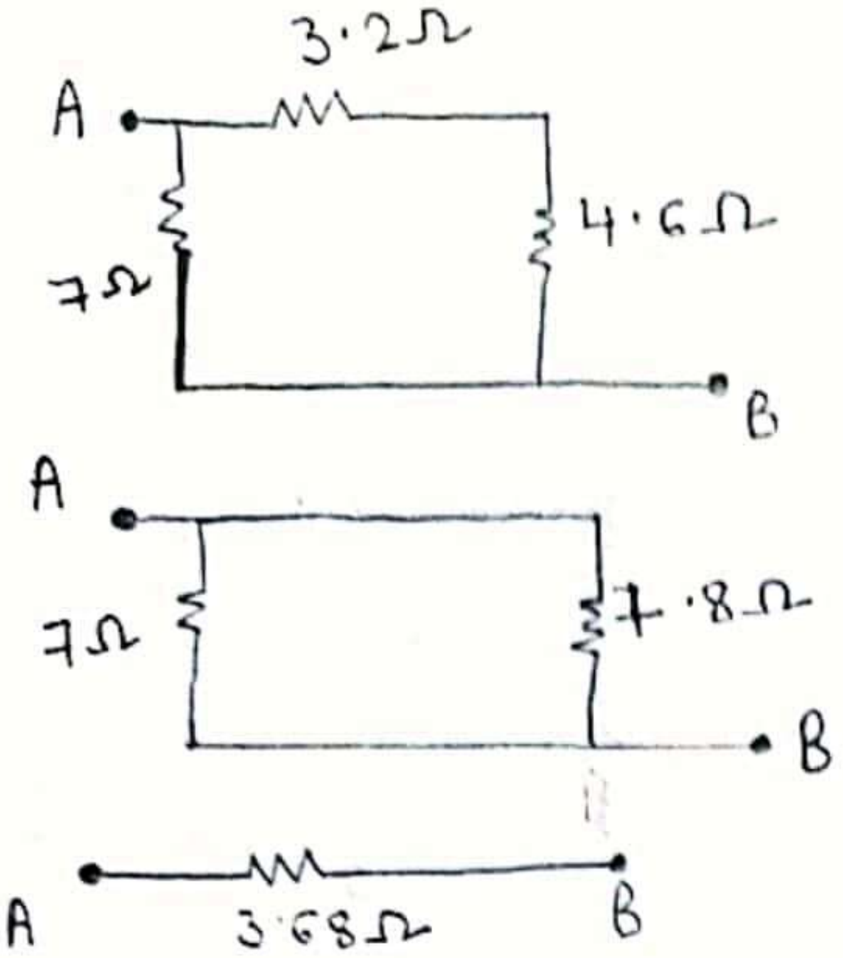


3.2Ω, 4.6Ω are in series,

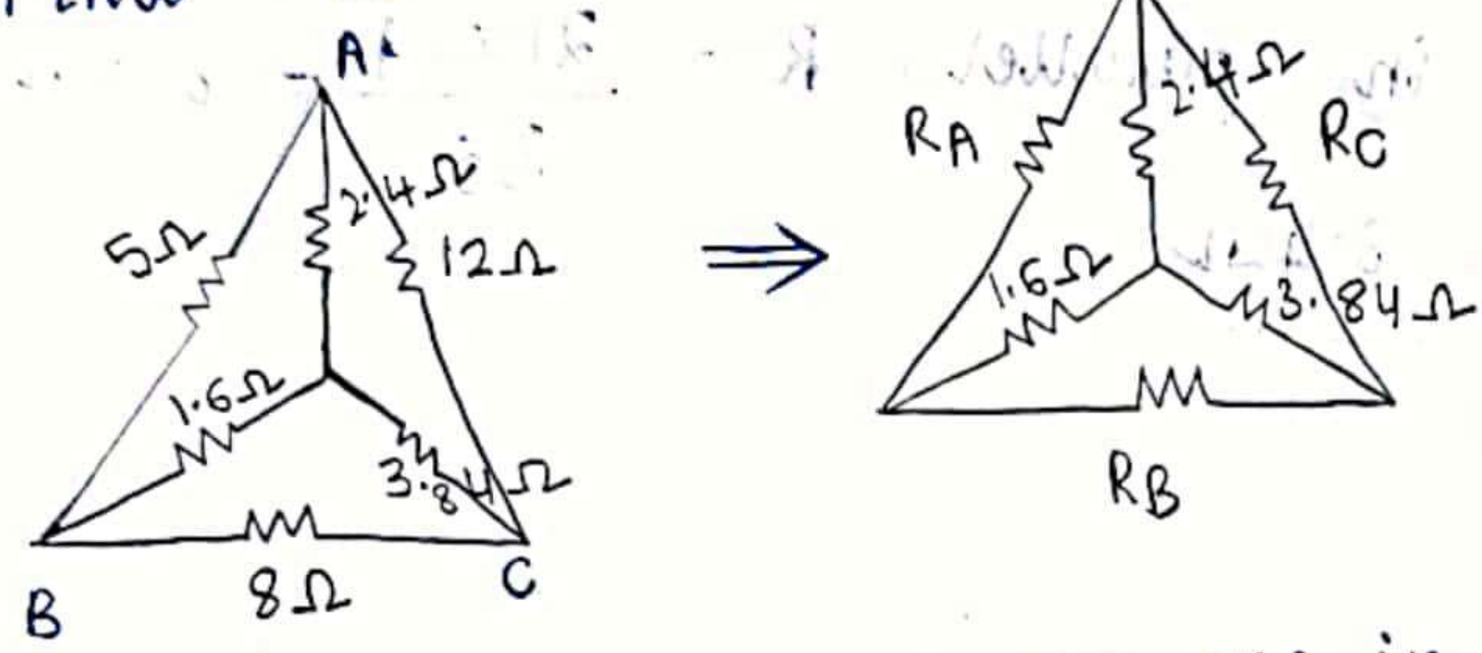
$$R = 3.2 + 4.6 = 7.8\Omega$$

7Ω, 7.8Ω are in parallel,

$$R = \frac{7 \times 7.8}{14.8} = 3.68\Omega$$

$$\therefore R_{ab} = \underline{\underline{3.68\Omega}}$$

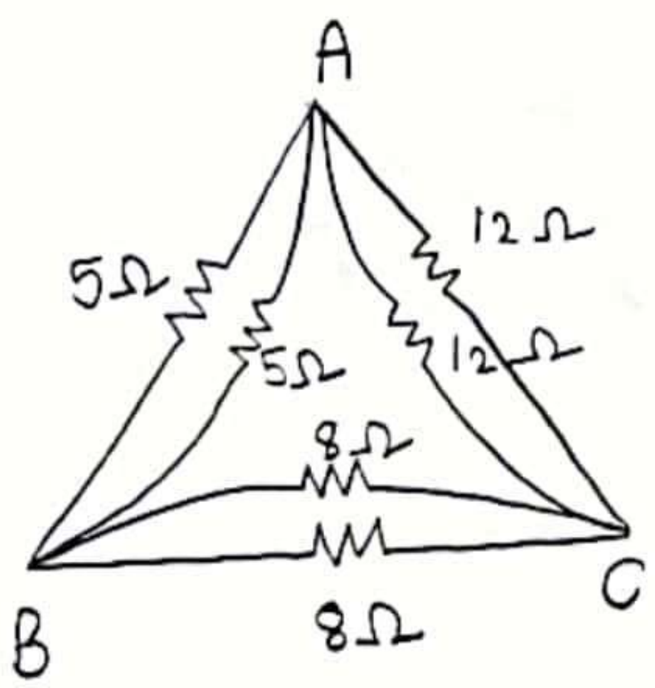
Q) Find R_{BC} ?



$R_A = 4.99\Omega \sim 5\Omega$

$R_B = 8\Omega$

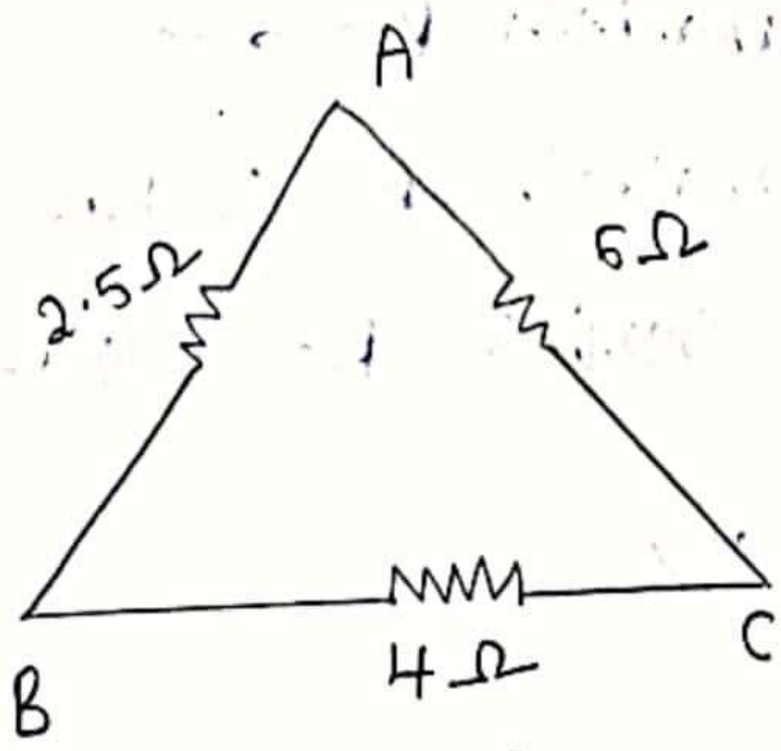
$R_C = 12\Omega$



5Ω, 5Ω are in parallel, $R = 2.5\Omega$

12Ω, 12Ω " " " , $R = 6\Omega$

8Ω, 8Ω " " " , $R = 4\Omega$



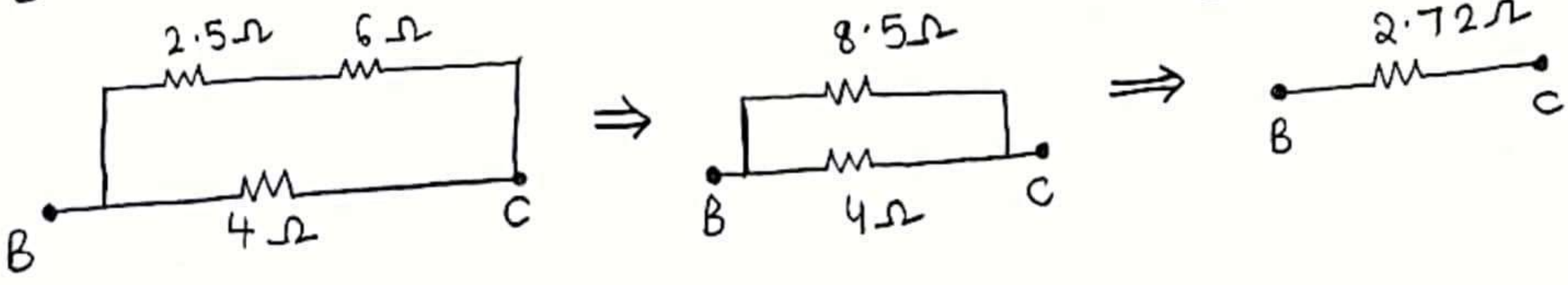
2.5Ω, 6Ω are in series,

$$R = 8.5\Omega$$

8.5Ω, 4Ω are in parallel,

$$R = \frac{8.5 \times 4}{12.5} = \frac{34}{12.5} = 2.72\Omega$$

$$\therefore R_{BC} = \underline{\underline{2.72\Omega}}$$



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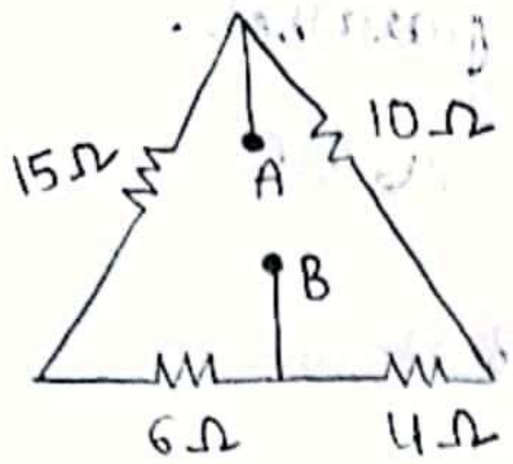
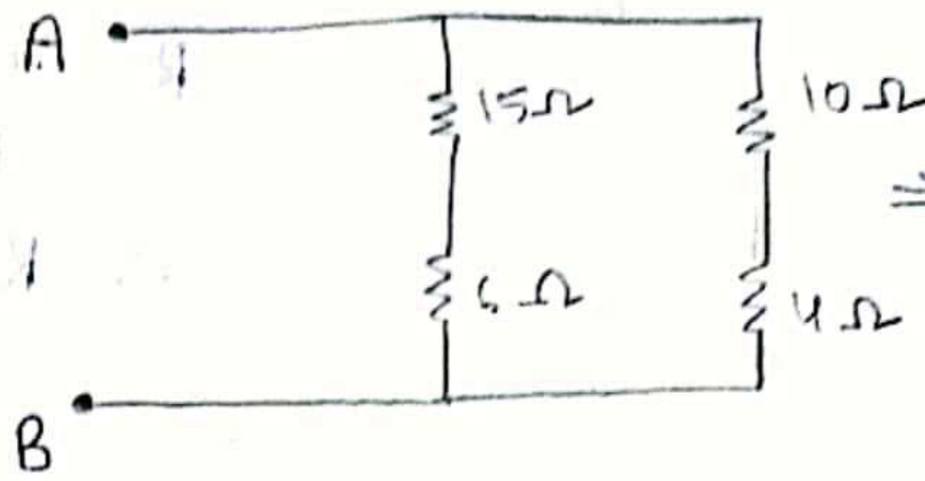
Q) Find R_{AB} ?



⇒



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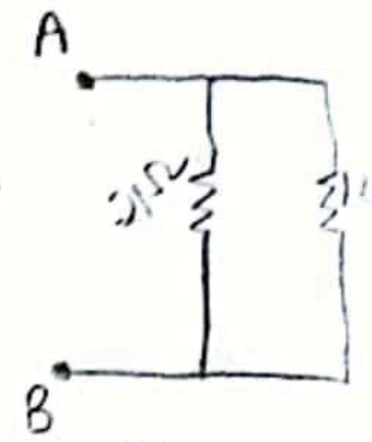

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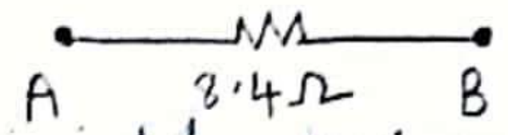


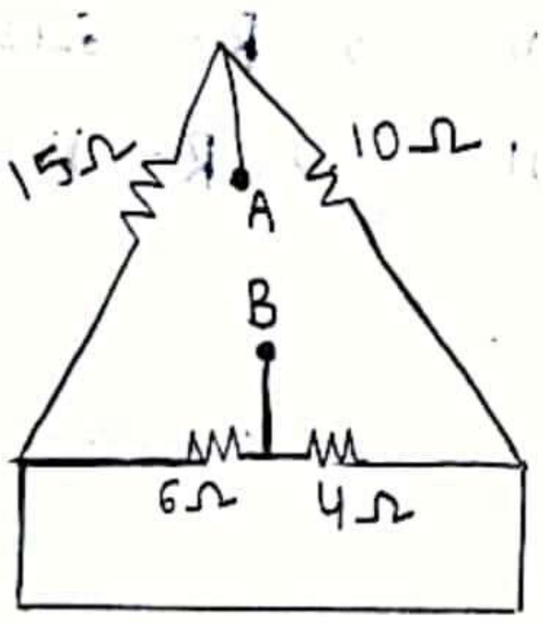
15Ω, 6Ω are in series, R = 21Ω

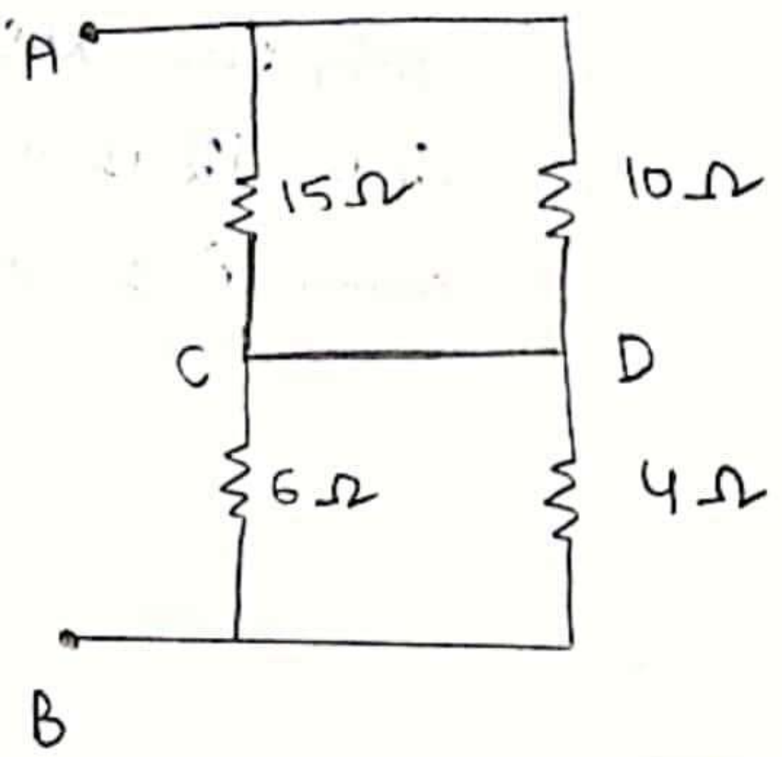
10Ω, 4Ω " " " , R = 14Ω

21Ω, 14Ω are in parallel, $R = \frac{21 \times 14}{35} = 8{\cdot}4\Omega$

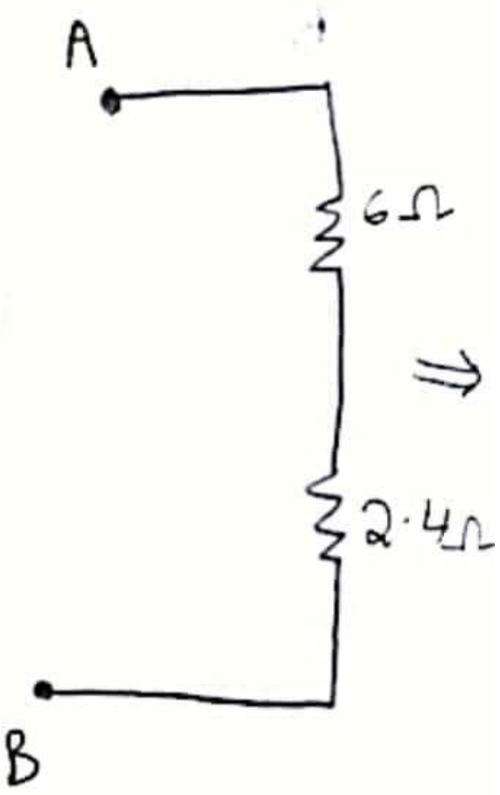
∴ $R_{AB} = \underline{\underline{8{\cdot}4\Omega}}$

Q) Find R_{AB} = ?

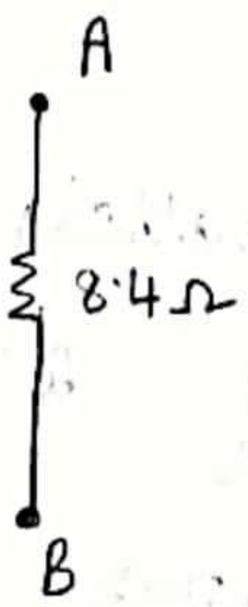




⇒



⇒



15Ω, 10Ω are in parallel, R = 6Ω

6Ω, 4Ω are in parallel, R = 2·4Ω

6Ω, 2·4Ω are in series, R = 8·4Ω

∴ $R_{AB} = \underline{\underline{8{\cdot}4\Omega}}$

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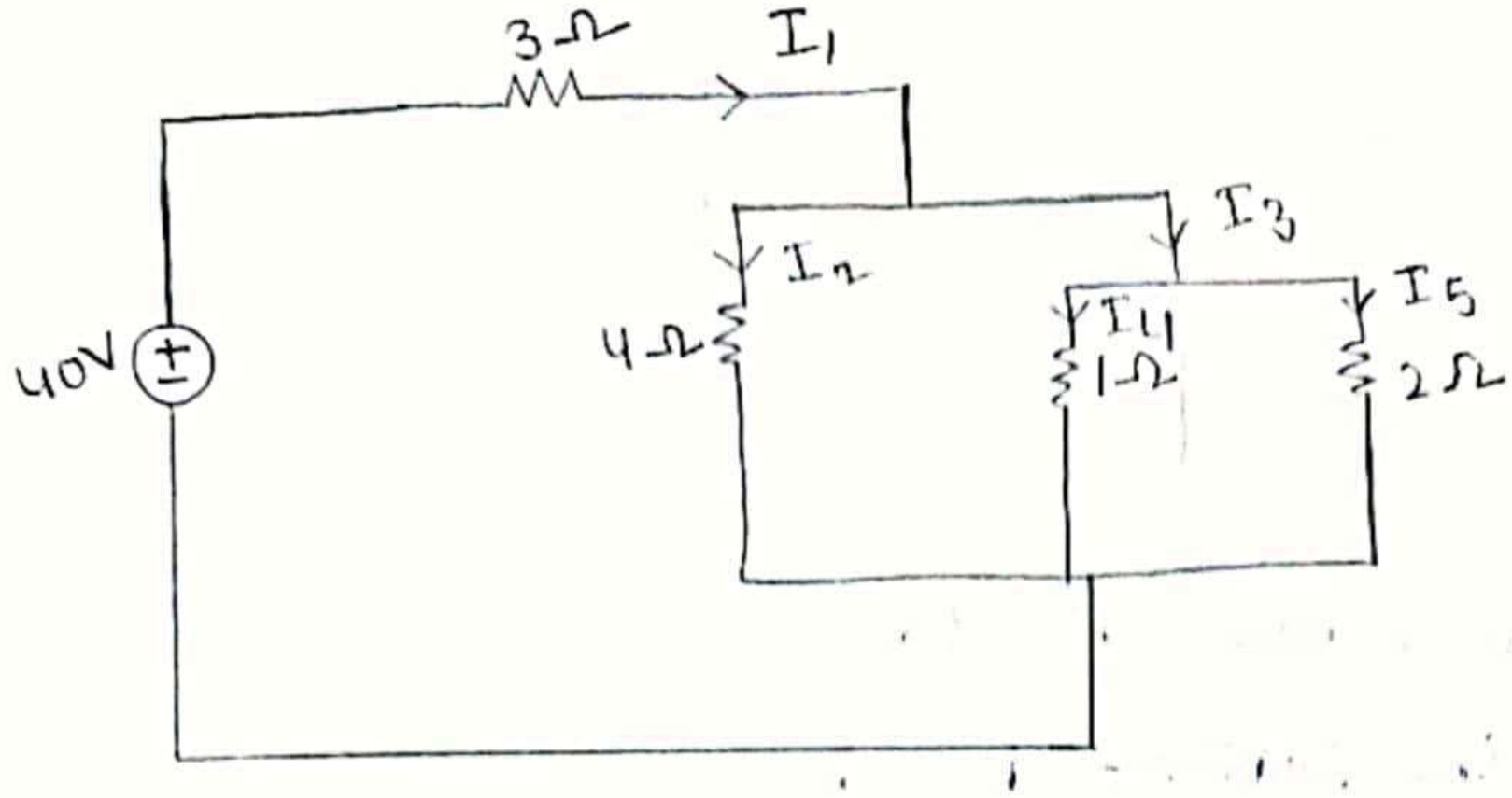
Q) Find I_1, I_2, I_3, I_4, I_5?



$$R_{eff} = \frac{25}{7}\,\Omega$$

$$I_1 = \frac{V}{R_{eff}} = \frac{40}{25/7} = \frac{280}{25} = 11.2A.$$

$$I_2 = I_1 \times \frac{2/3}{2/3 + 4} = 11.2 \times \frac{2}{14} = \frac{11.2}{7} = 1.6\Omega$$

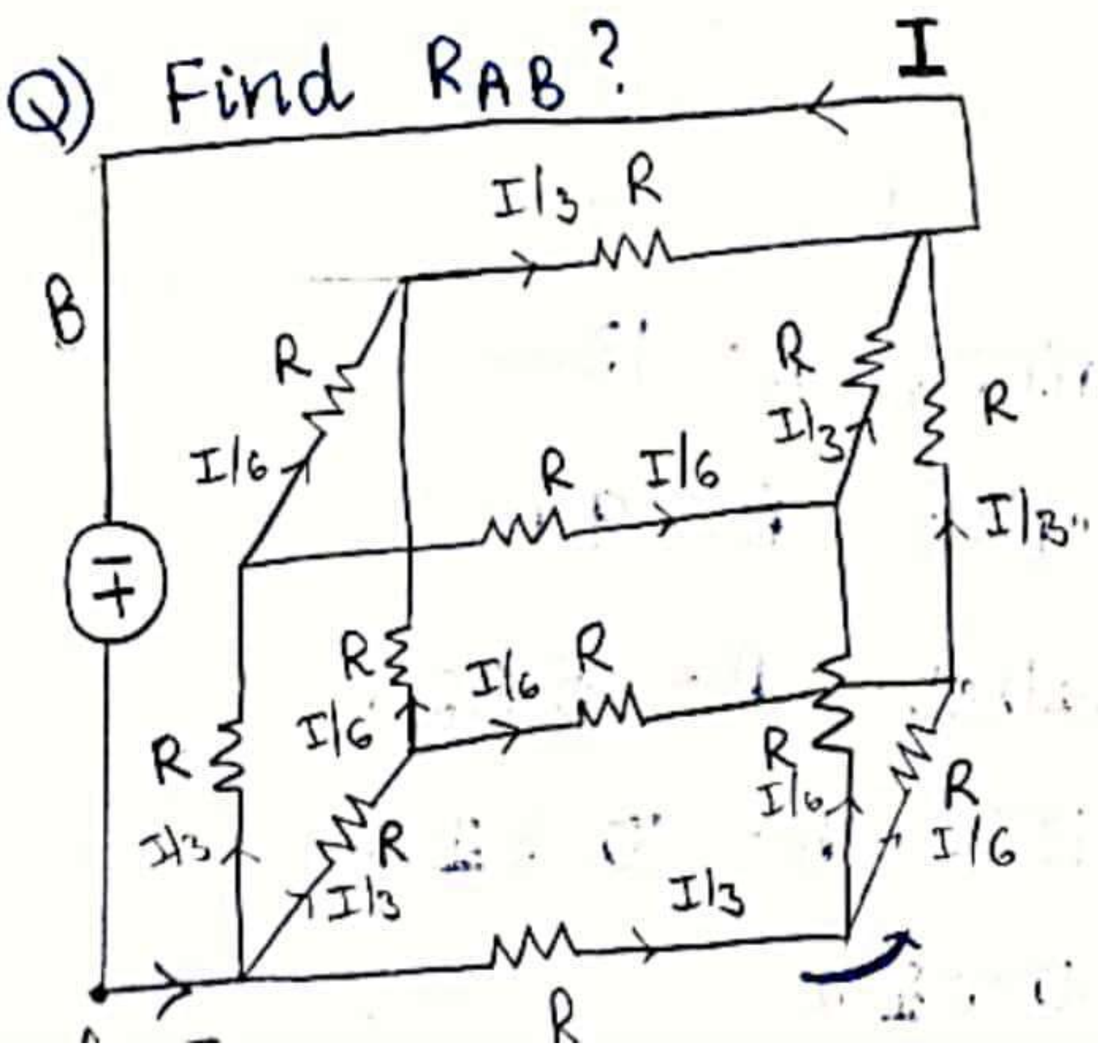
$$I_3 = I_1 \times \frac{4}{2/3 + 4} = 11.2 \times \frac{4 \times 3}{14} = \frac{11.2 \times 6}{7} = 9.6\Omega$$

$$I_5 = I_3 \times \frac{1}{3} = \frac{9.6}{3} = 3.2\Omega.$$

$$I_4 = I_3 \times \frac{2}{3} = \frac{9.6 \times 2}{3} = 6.4\Omega.$$

$\therefore I_1 = 11.2\Omega,\ I_2 = 1.6\Omega,\ I_3 = 9.6\Omega,\ I_4 = 6.4\Omega,\ I_5 = 3.2\Omega$

Q) Find R_{AB}?



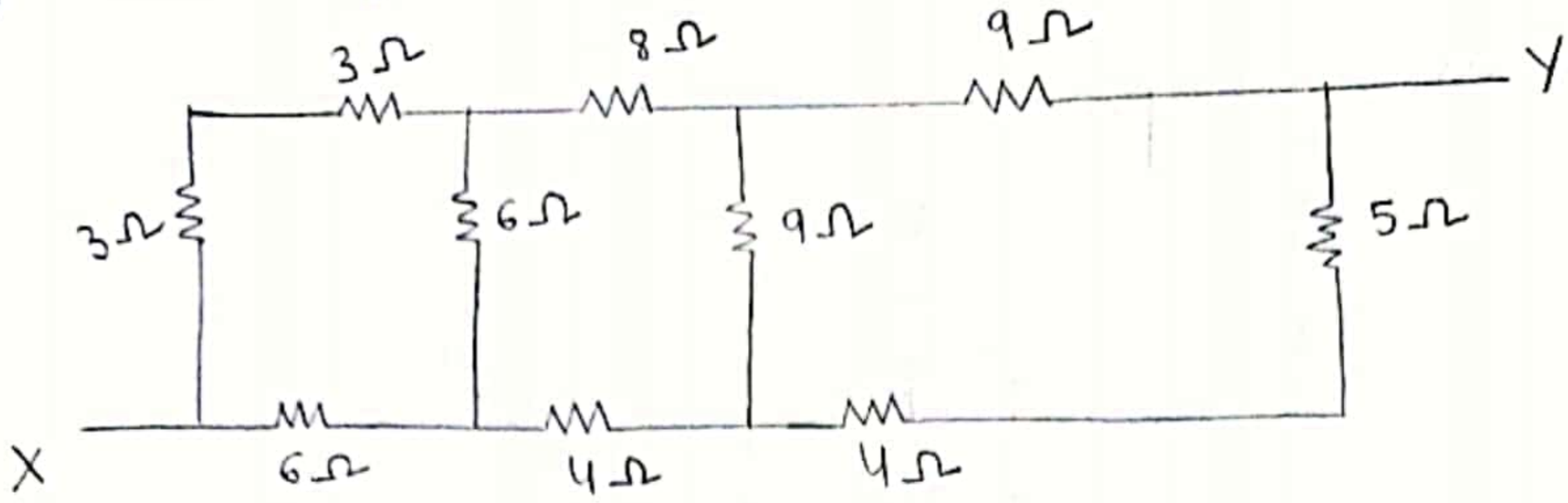
$$\frac{I}{3} \times R + \frac{I}{6} \times R + \frac{I}{3} R - V = 0$$

$$V = \frac{5}{6} IR$$

$$V/I = \frac{5}{6} R$$

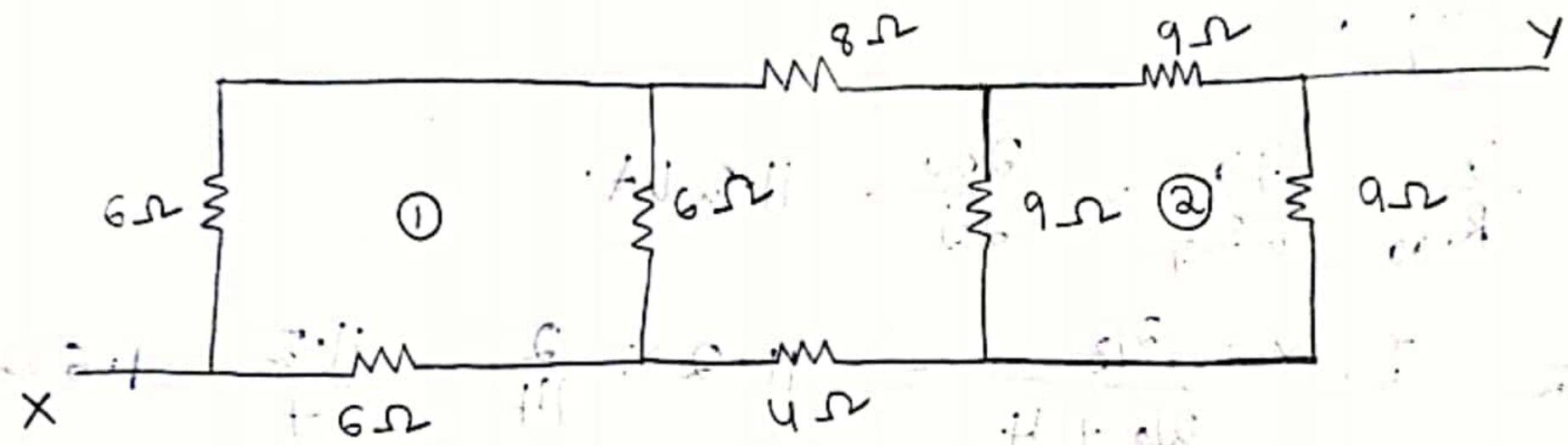
$$\therefore R_{AB} = 5/6\, R$$

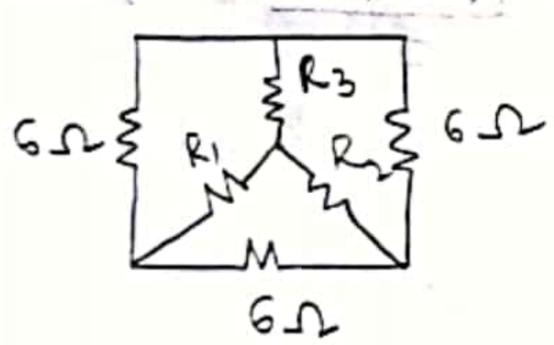
Q) Find R_{xy}?

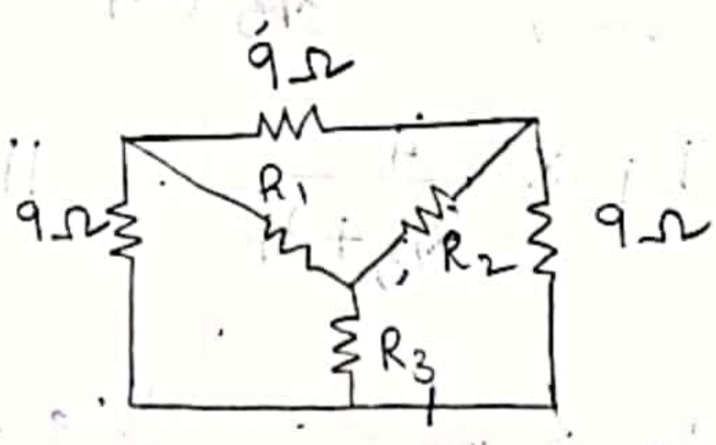


4Ω, 5Ω are in series, R = 9Ω

3Ω, 3Ω are in series, R = 6Ω

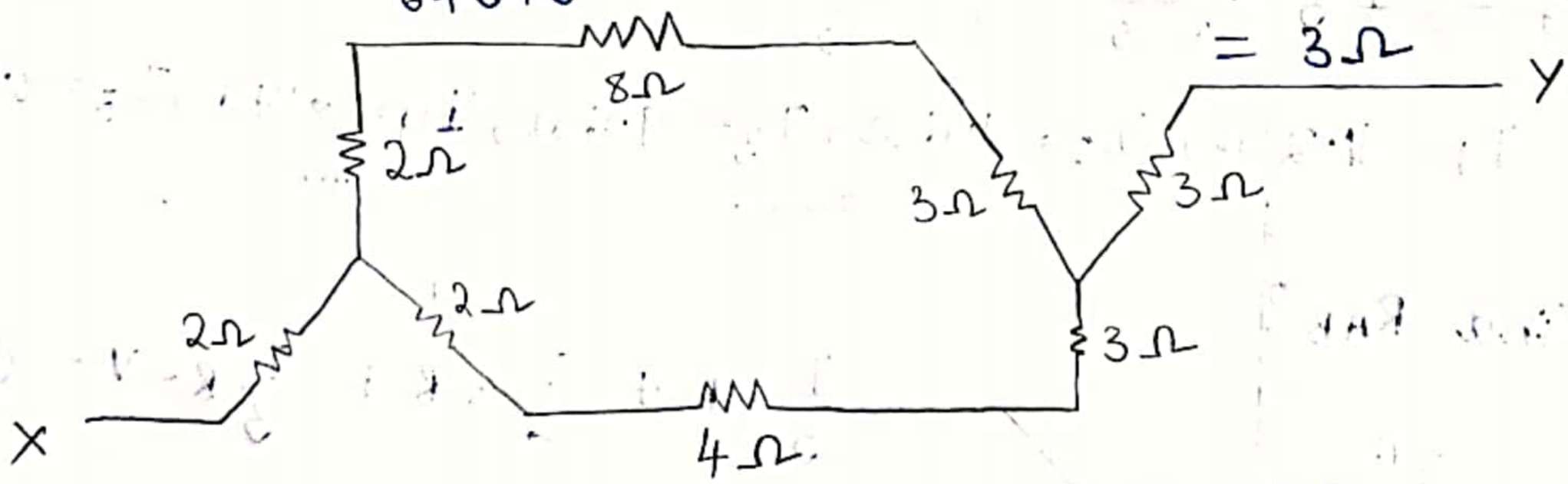






$R_1 = R_2 = R_3 = \frac{6 \times 6}{6+6+6} = 2\Omega$. $R_1 = R_2 = R_3 = \frac{9 \times 9}{9+9+9}$

$= 3\Omega$



2Ω, 8Ω, 3Ω are in series, R = 13Ω

4Ω, 3Ω, 2Ω are in series, R = 9Ω

13Ω, 9Ω are in parallel, R = 5.32Ω

5.32Ω, 2Ω, 3Ω are in series, R = 10.32Ω

∴ R_{xy} = 10.32Ω

*)

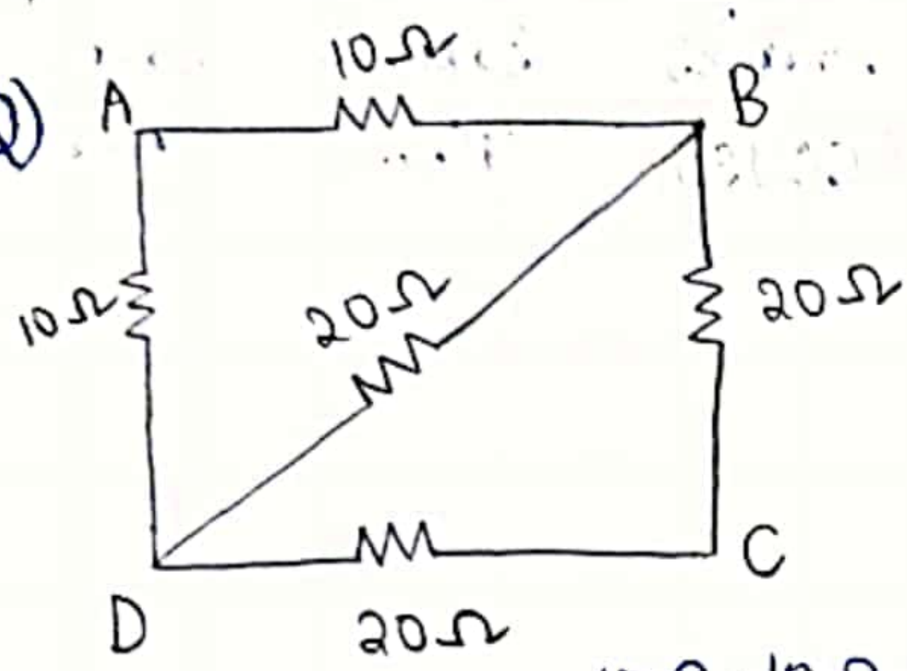
delta → star $= \frac{1}{3} \times R$

star → delta $= 3R$.

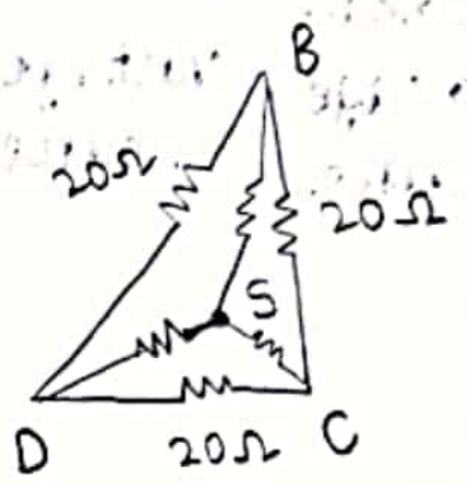
① 3 resistors are connected in delta each value of resistance is $R\,\Omega \Rightarrow R_{eq} = \frac{R}{3}\,\Omega$

② 3 resistors are connected in delta each value of resistance is $R\,\Omega \Rightarrow R_{eq} = 3R\,\Omega$

Q)



Find R_{BC}, R_{AC} = ??

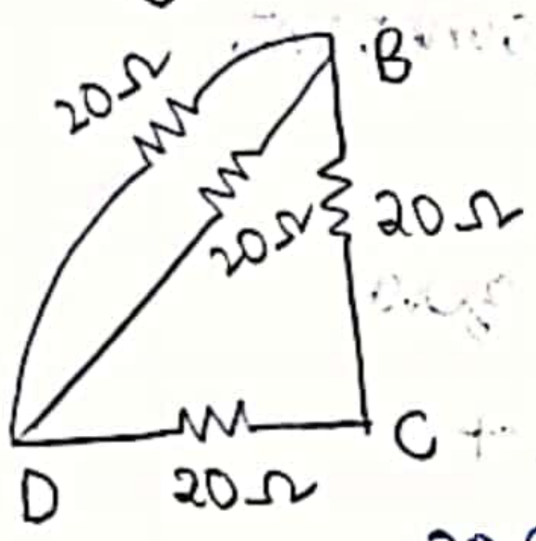


$R_1 = R_2 = R_3 = 6.66\,\Omega$.

10Ω, 10Ω are in series,

$R = 20\,\Omega$

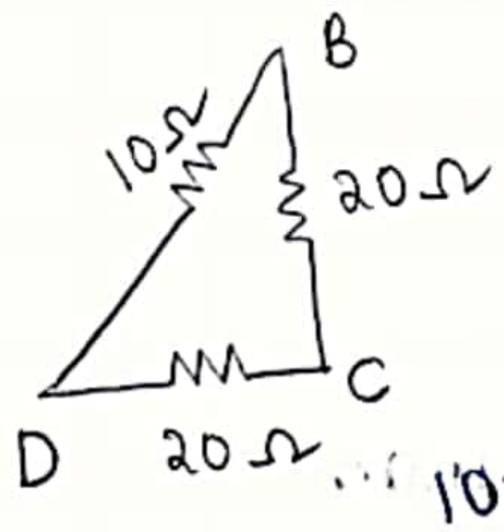
⇓



20Ω, 20Ω are in parallel,

$R = 10\,\Omega$

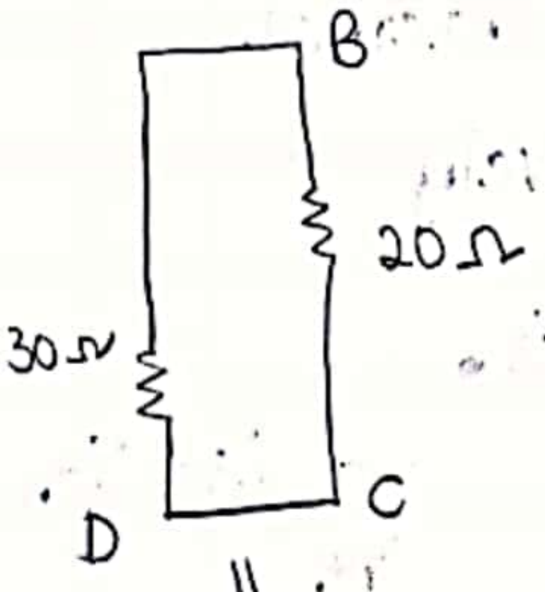
⇓



10Ω, 20Ω are in series,

$R = 30\,\Omega$

⇓

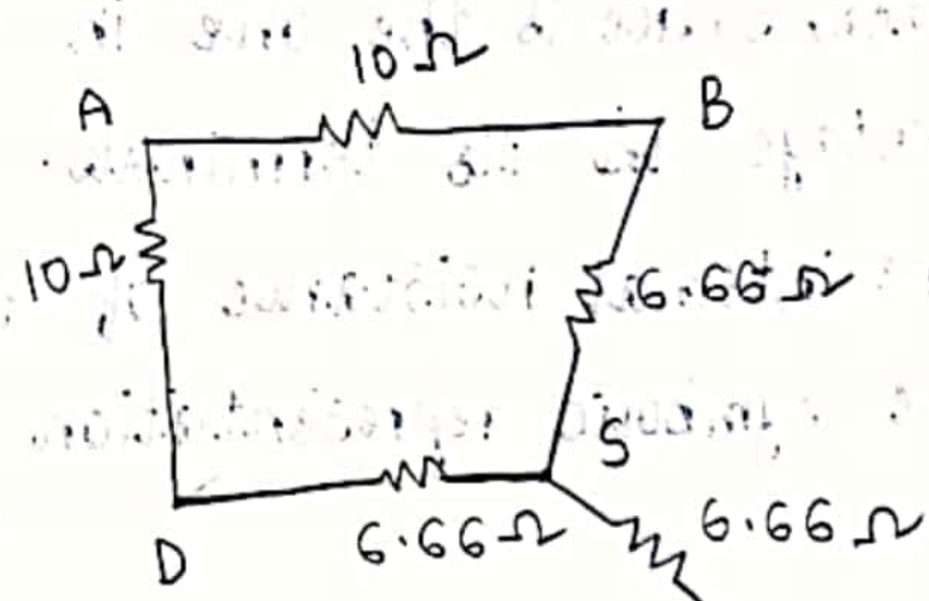


30Ω, 20Ω are in parallel,

$R = 12\,\Omega$.

⇓

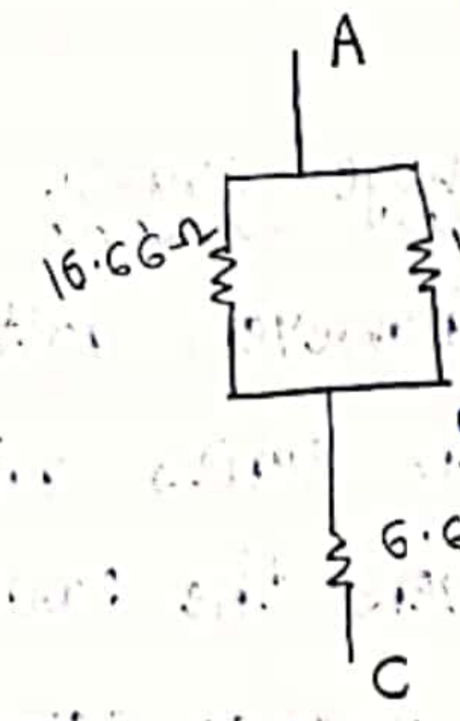
$R_{BC} = 12\,\Omega$



10Ω, 6.66Ω are in series,

$R = 16.66\,\Omega$

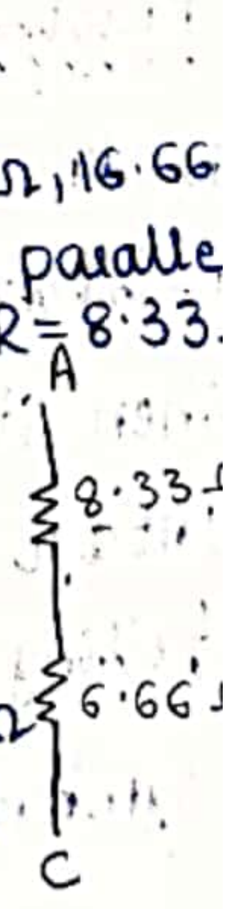
⇓



16.66Ω, 16.66 are in paralle

$R = 8.33$

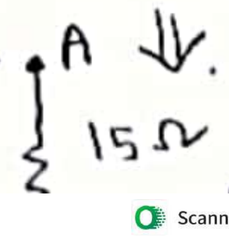
⇒



8.33Ω, 6.66Ω are in series

$R = 15\,\Omega$

⇓



25/04/23

* Types of Sources :—

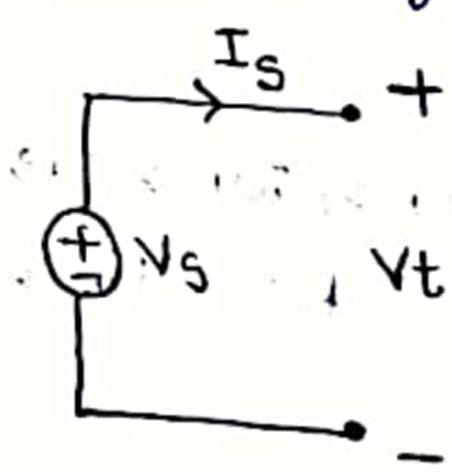
- Independent sources
  - Ideal Sources
    - Ideal Current Sources
    - Ideal voltage Sources
  - Practical Sources
    - Practical voltage Sources
    - Practical Current sources
- Dependent Sources (Controlled Sources)
  - Current controlled current Sources (CCCS)
  - Current controlled voltage Sources (CCVS)
  - voltage controlled current Sources (VCCS)
  - Voltage controlled Voltage Sources (VCVS)

* Ideal voltage Source :—

Ideal voltage Source is the one in which maintains the constant voltage at its terminals.

* The internal resistance of Ideal voltage source is zero.

The symbolic representation of IVS is



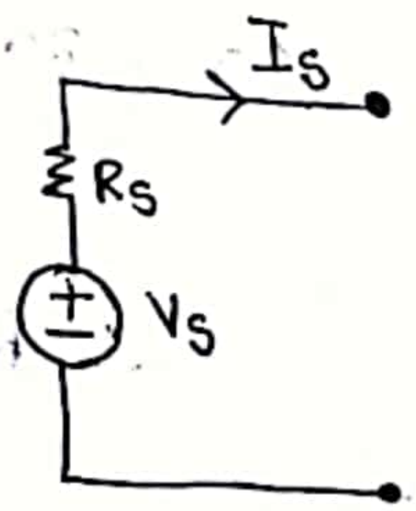
$\Rightarrow V_s = V_t$

* Practical voltage Source :—

In Practice, however, voltage Source has some internal resistance in series with the source.

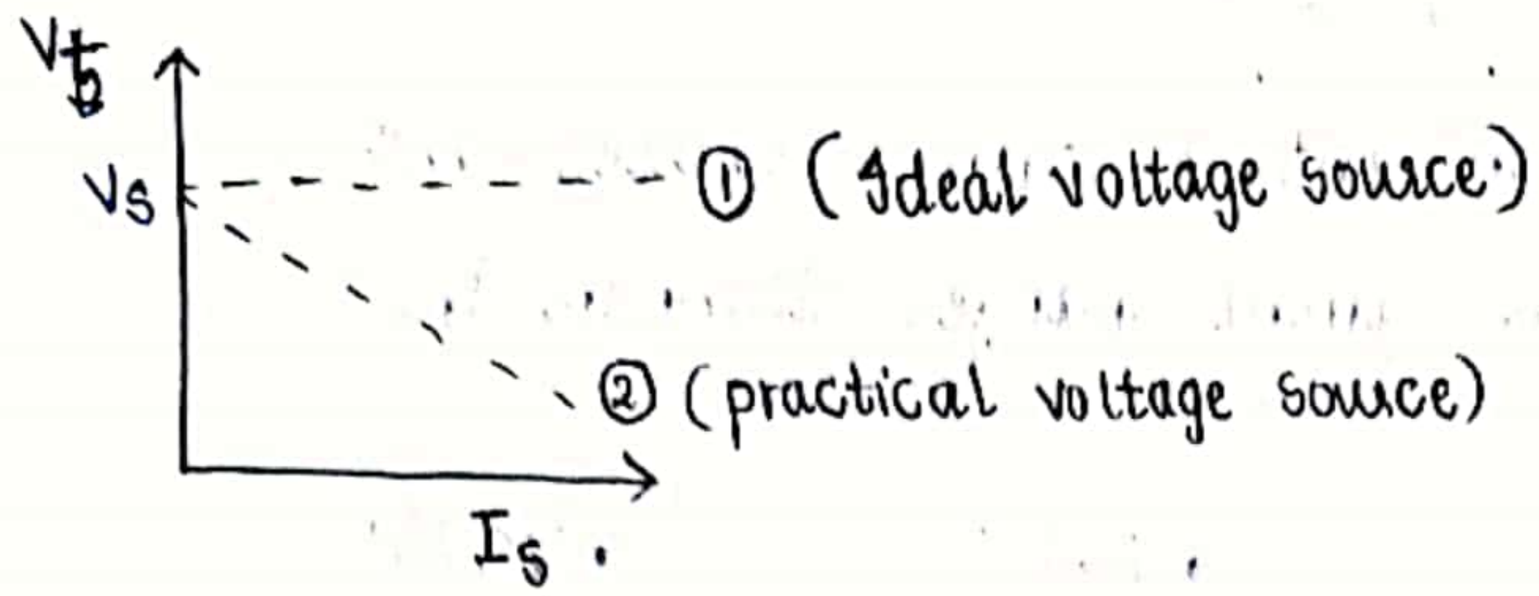
* When it delivers the power, there is always an internal voltage drop so that terminal voltage is progressively falling / decreasing.

Symbolic representation of PVS is :



$V_s = V_t$

V_t

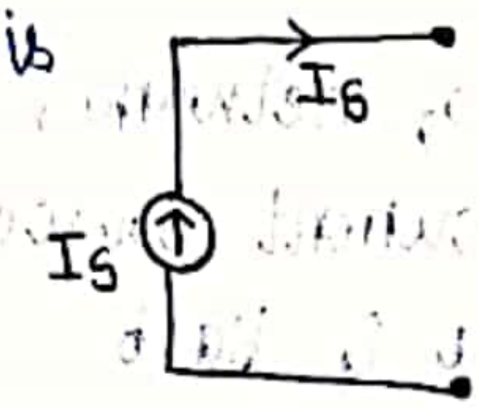


* **Ideal Current Source :—**

ICS is one which delivers constant current magnitude independent of the external current circuit.

* → The internal resistance of ICS is infinity.

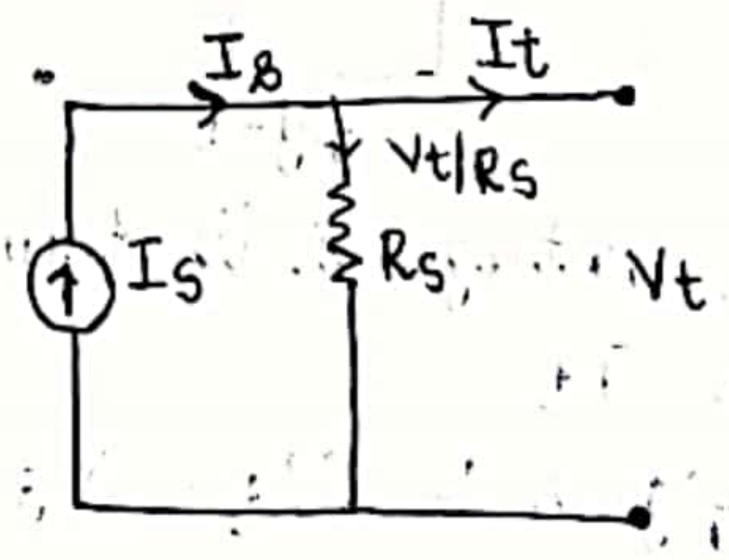
Symbolic representation is



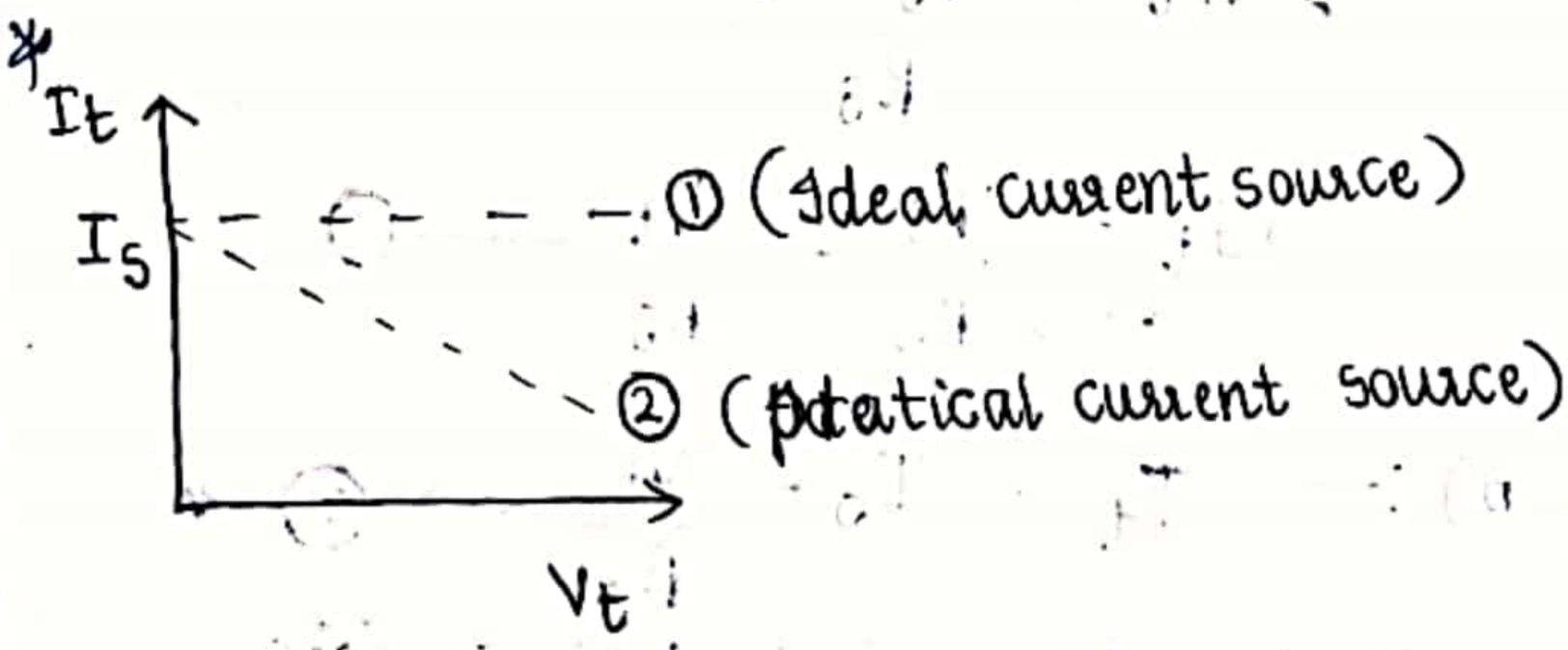
* **Practical Current Source :—**

In practice, no current source is ideal.

Symbolic representation,



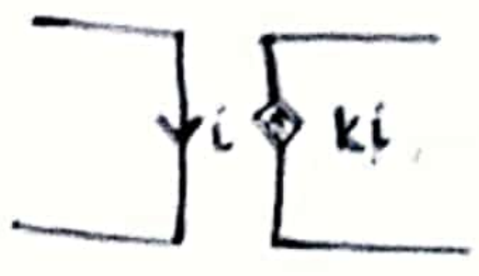
* → Resistance is in parallel with the current source.



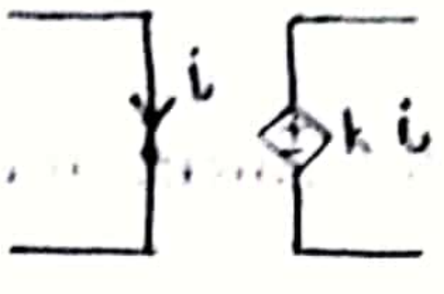
4 Dependent / Controlled Sources :—

Some networks in which voltage / current sources are controlled by voltage or current changes elsewhere in the circuit

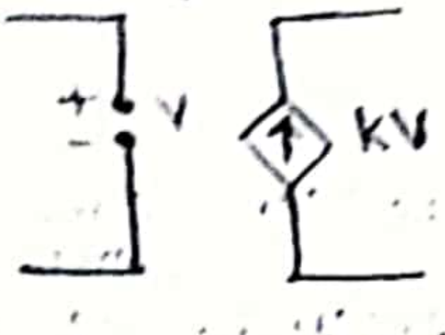
• CCCS :



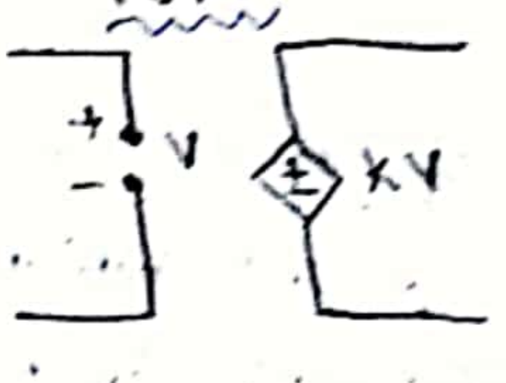
• CCVS :



• VCCS :



• VCVS :



where k = constant

* Source Transformation :—

For reducing the complexity of network, it is necessary to replace voltage source by current source and viceversa.

Consider a PVS & PCS, fig a & fig b

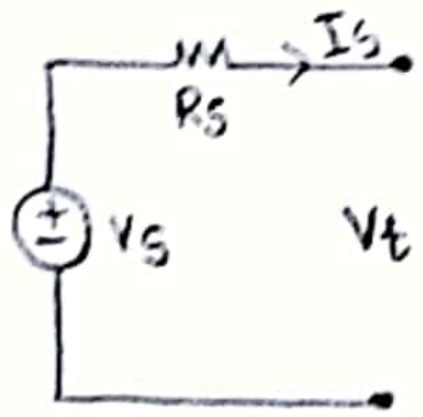


fig-a

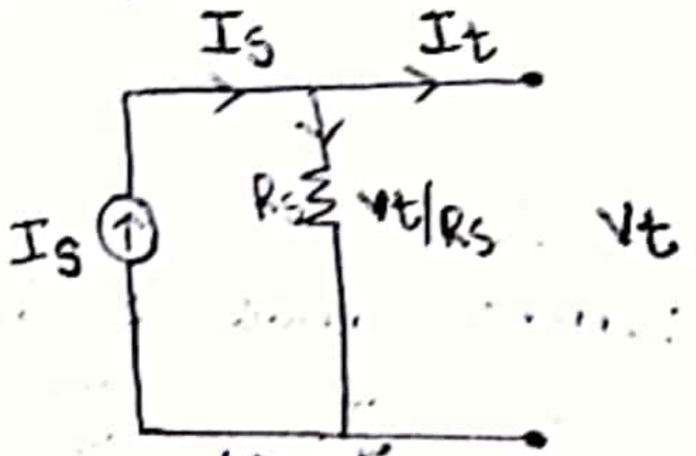


fig-b

For both the sources, voltage at its terminals is V_t and current supplied is I_t.

From the P.V.S (fig-a) :— $V_t = V_s - I_s R_s$

$$= V_s - I_t R_s$$

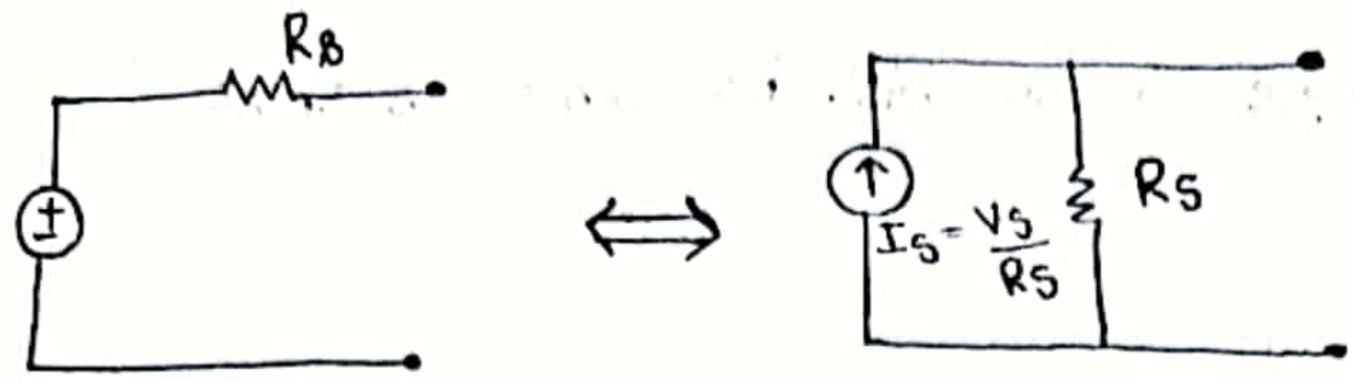
$$\Rightarrow I_t = \frac{V_s - V_t}{R_s}$$

$$\Rightarrow I_t = \frac{V_s}{R_s} - \frac{V_t}{R_s} \quad \text{—— (1)}$$

From the PCS (fig-b) :— $I_t = I_s - \frac{V_t}{R_s}$ —— (2)

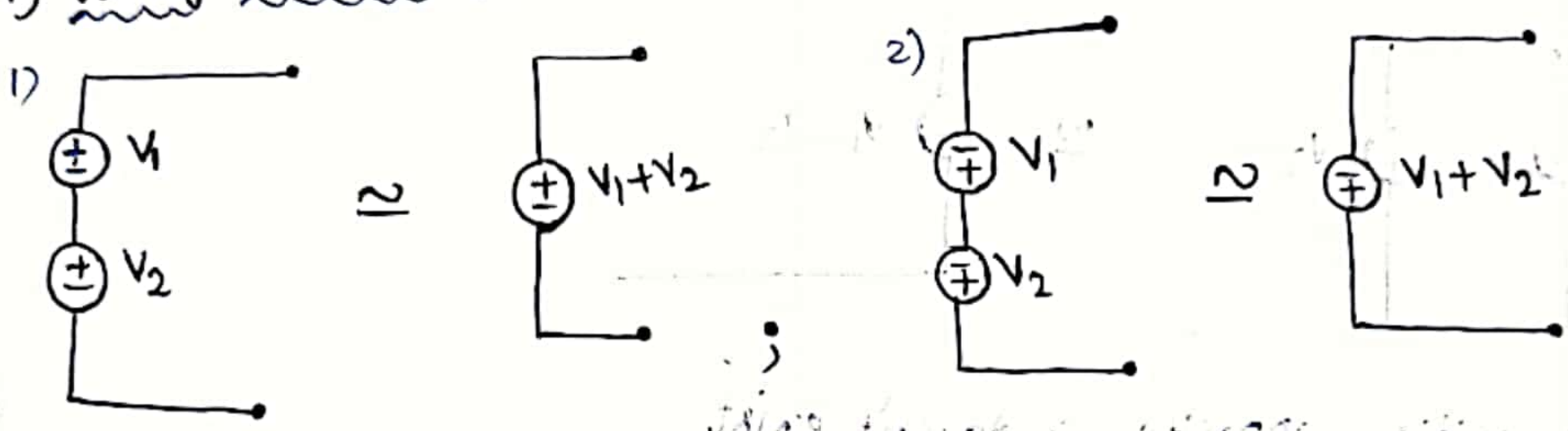
from (1) & (2) ; it is evident that both sources would deliver the same amount of current 'I_t' at voltage 'V_t' provided $I_s = \frac{V_s}{R_s}$

The voltage source in series with the R_s, its equivalent current source I_s in parallel with the R_s.



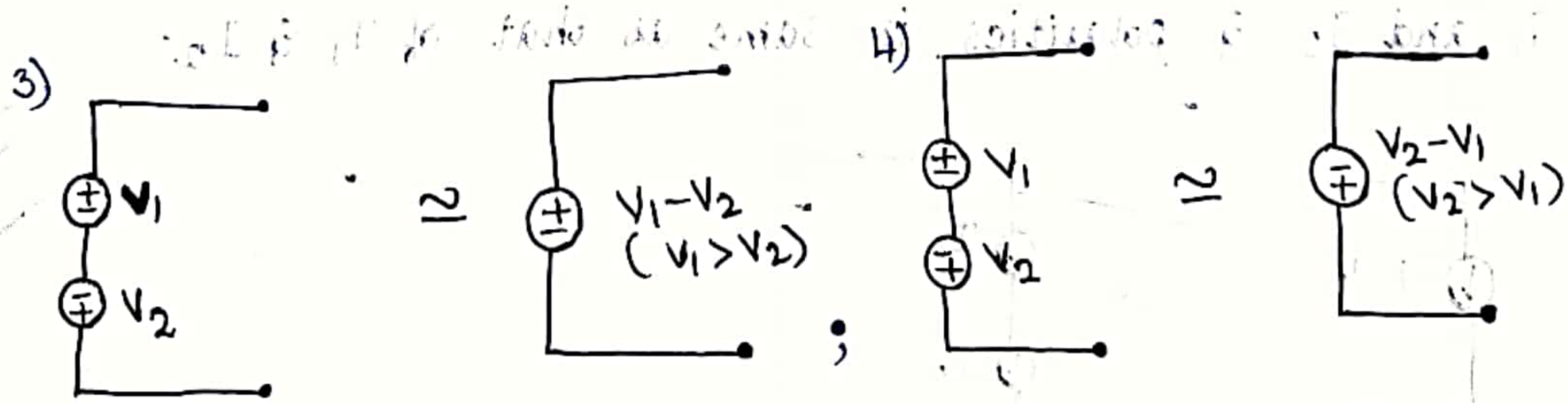
Combination of Sources :—

1) Voltage Sources in Series :—



Consider two voltage sources, V_1 & V_2 connected in series, then its equivalent single source is dependent on the polarity of the sources.

Note: The polarities of two sources are same then its equivalent single source is addition of two sources & polarity of such source is same as of the two sources.



Note: The polarities of two sources are different, the its eq single source is difference b/w 2 sources and polarity is same as that of greater of two sources.

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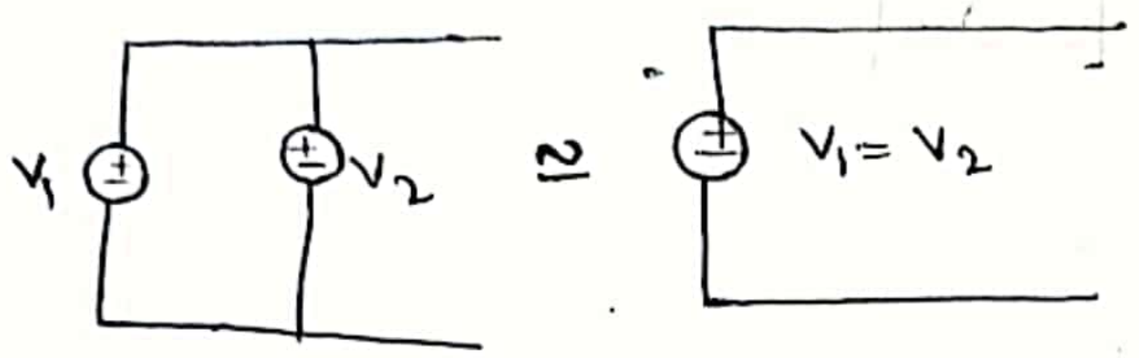
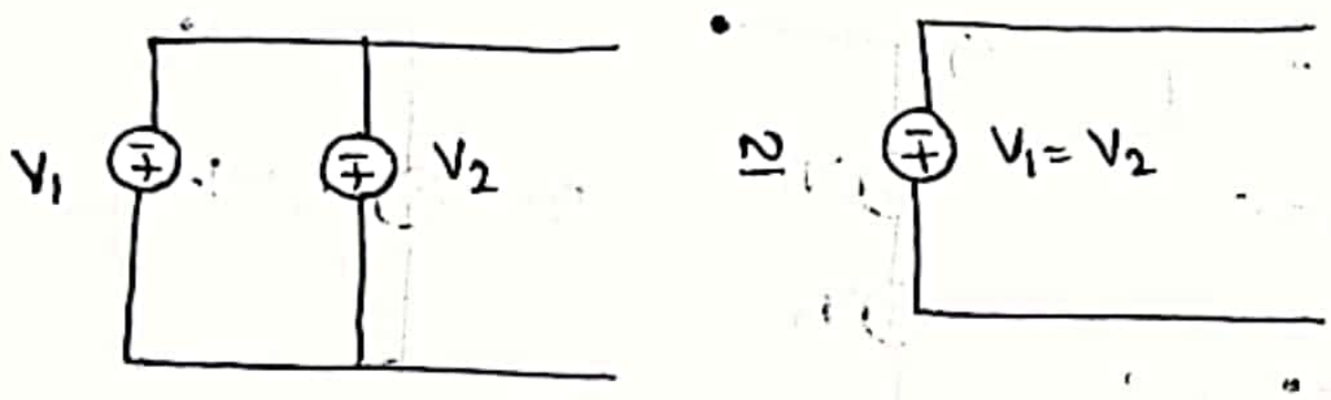
2) Voltage Sources in Parallel :—

Consider two voltage sources (V_1, V_2) are connected in parallel.

Then its equivalent single source will be same as that of V_1 and V_2.

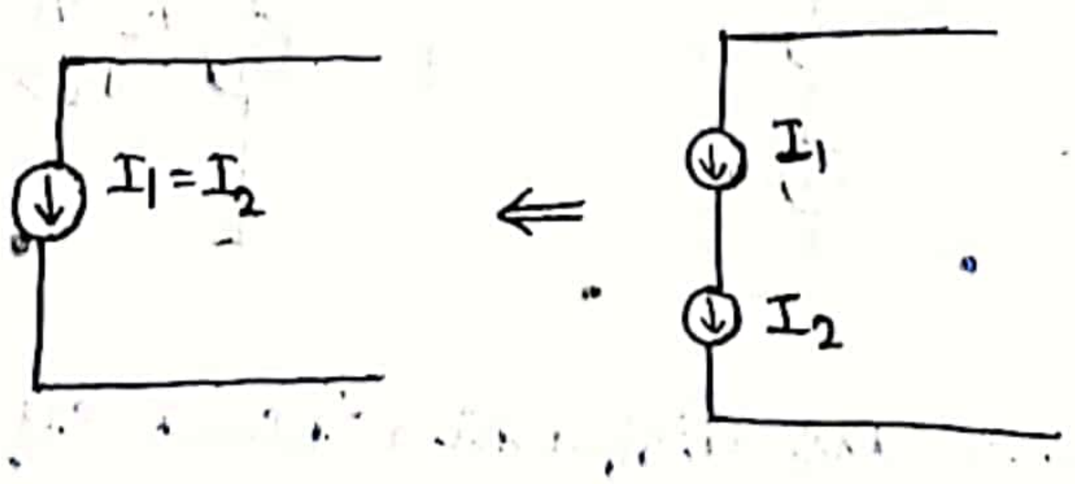


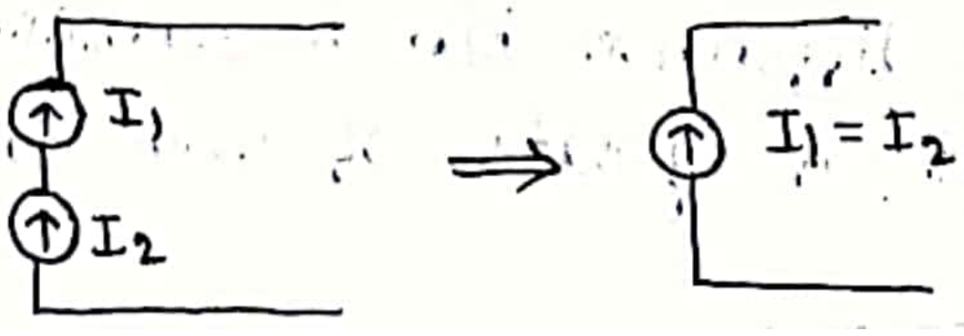


* If polarities opposite → doesn't exist
* If $V_1 \neq V_2$ → doesn't exist

3) Current Sources in Series :—

Consider two current sources connected in series, then its equivalent single source will be same as that of I_1 and I_2 & polarities is same as that of I_1 & I_2.





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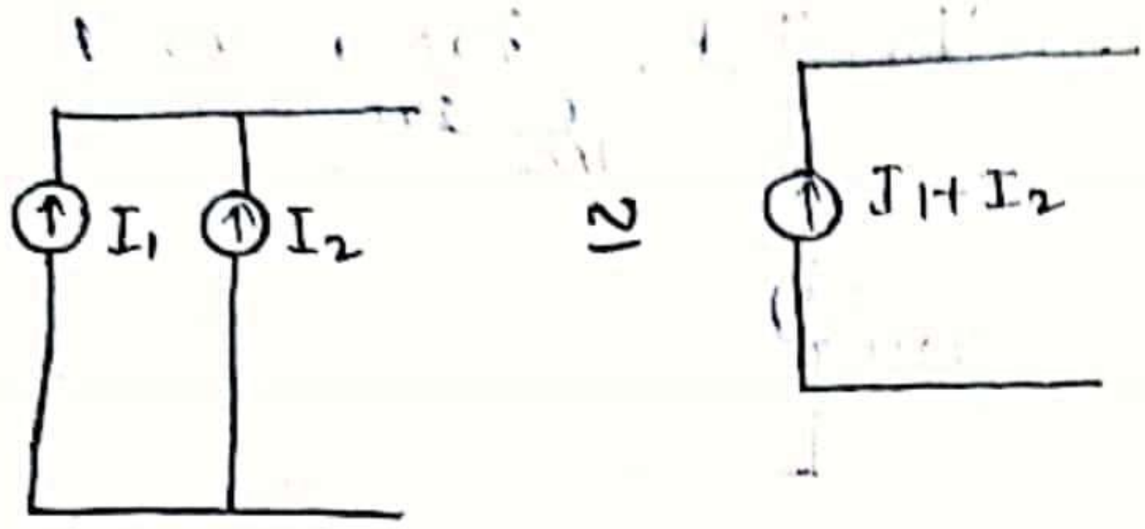
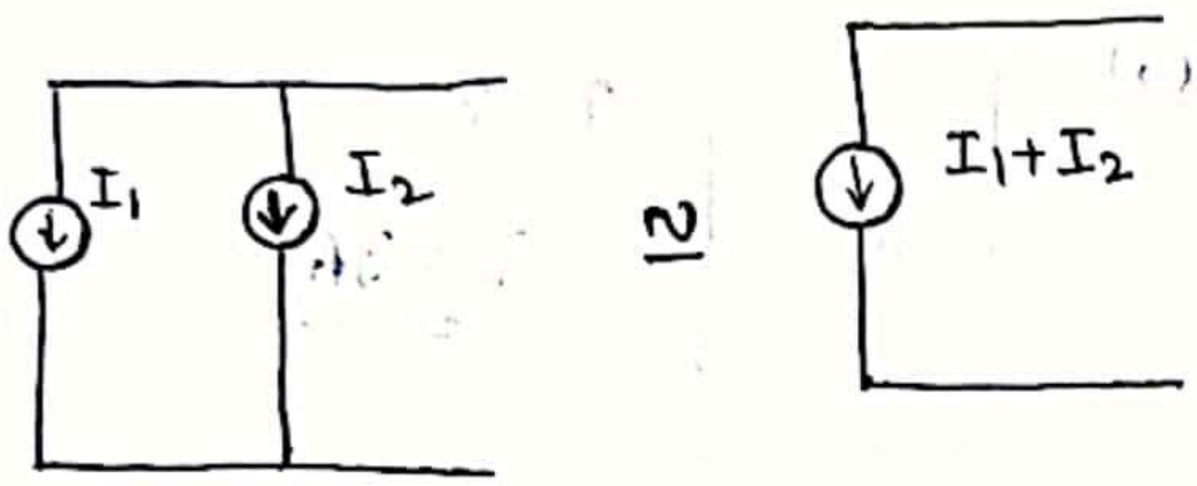
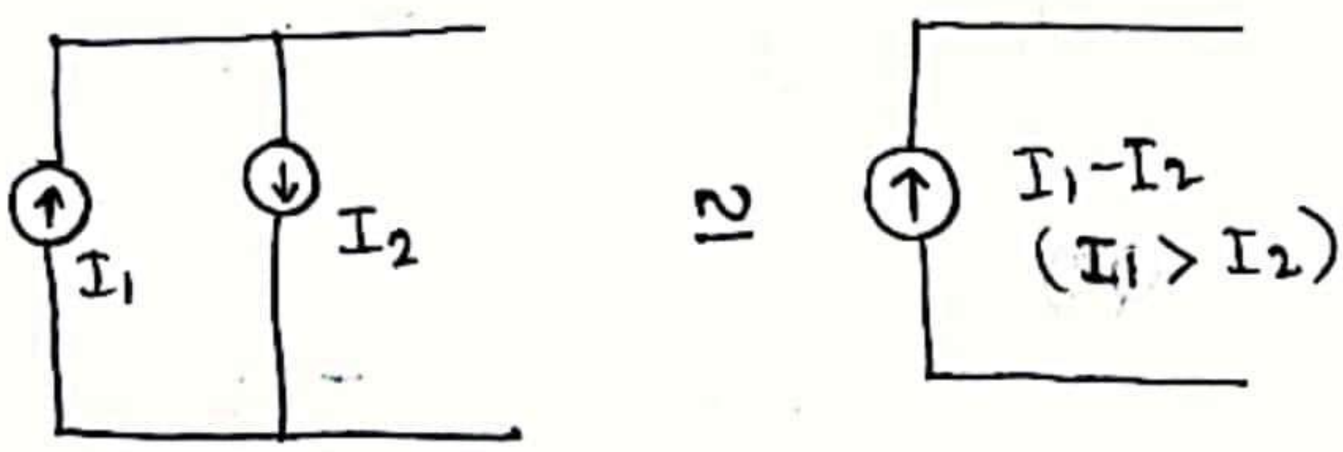
4) Current Sources in Parallel :-

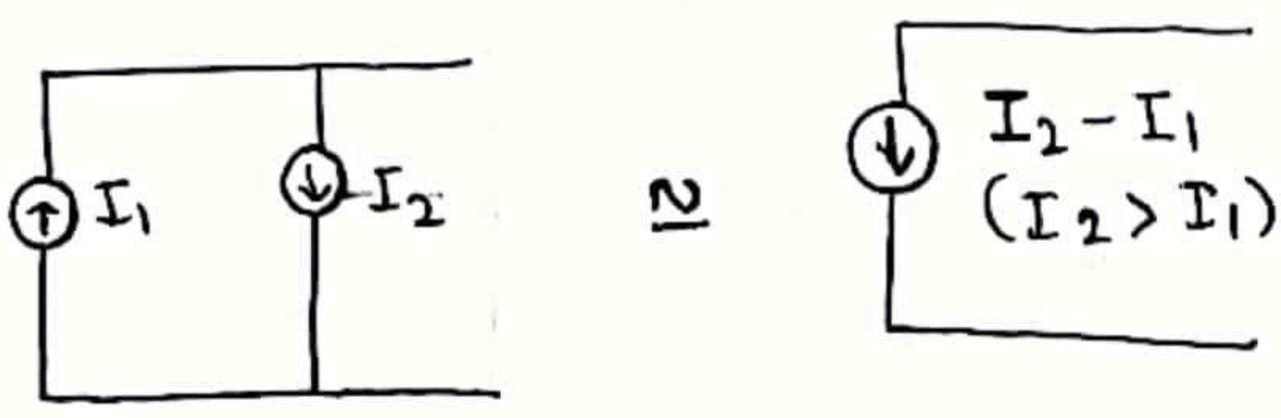
Consider two current sources connected in parallel. If the directions of currents are same, then its equivalent single source will be addition of two current sources & direction of such source is same that of I_1 & I_2.





Two current sources in parallel & directions different then its equivalent source is the difference of both sources and direction is same of that of the largest of two sources (I_1 or I_2).





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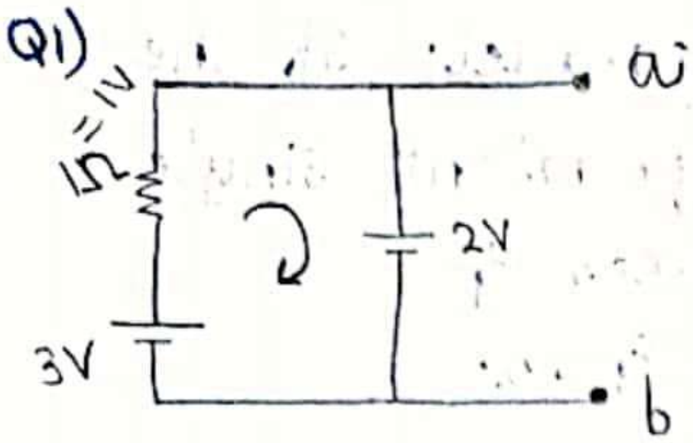
Q1)



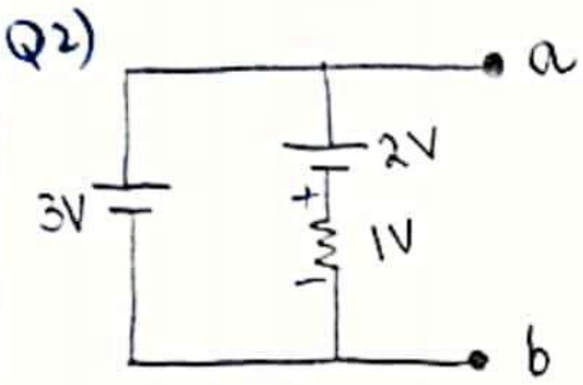
$V_{ab} = ?$

$\Sigma V = -3+1+2$

$\Sigma V = 0$

$\Rightarrow V_{ab} = 2V$

Q2)



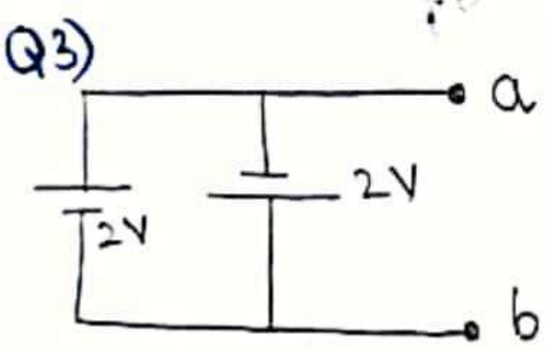
$V_{ab} = ?$

$\Sigma V = -3+2+1 = 0$

$\Sigma V = 0$

$\Rightarrow V_{ab} = 3V$

Q3)

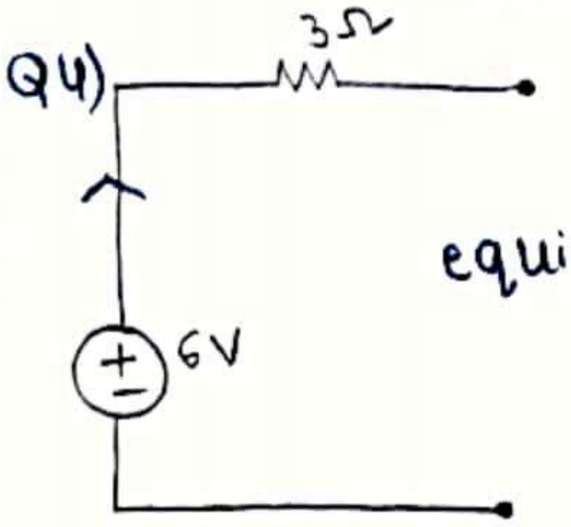


$V_{ab} = ?$

$\Sigma V = -2-2 = -4 \neq 0$

$\Rightarrow$ doesnot exists

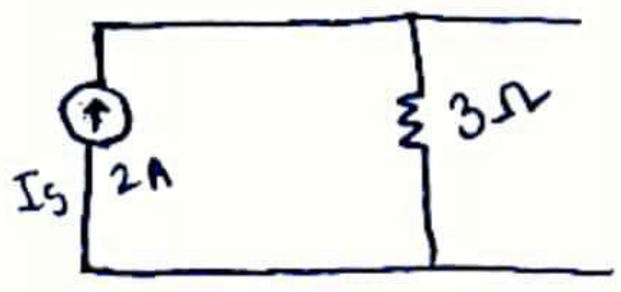
Q4)



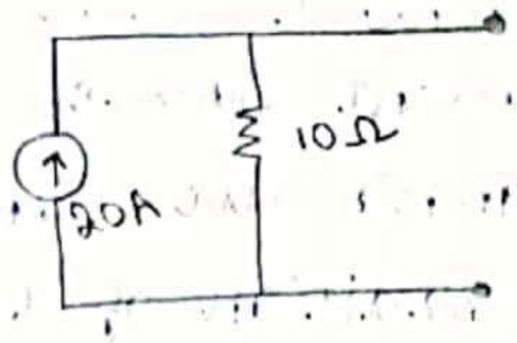
equivalent current source = ?

$I_S = \frac{V_S}{R_S} = \frac{6}{3} = 2A$

$\sim$



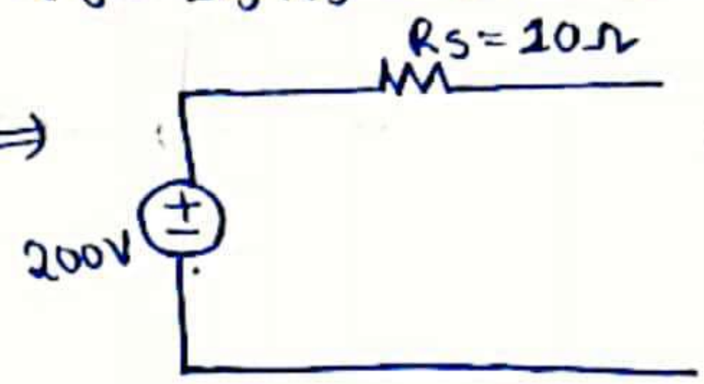
Q5)



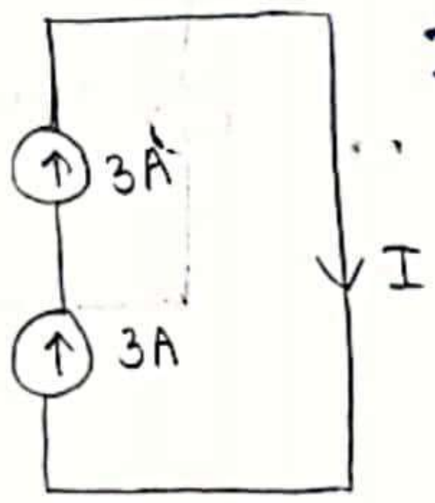
Equivalent voltage source = ?

$V_S = I_S R_S = 20 \times 10 = 200V$

$\Rightarrow$



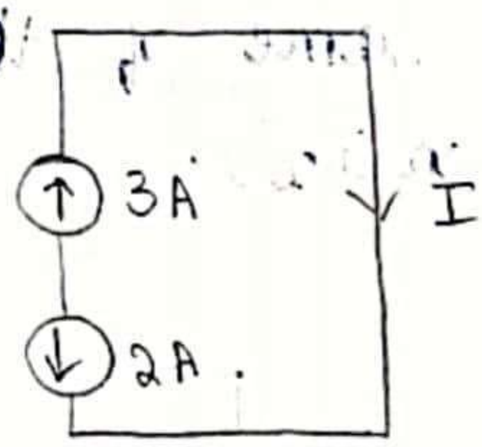
Q6)



$I = ?$

$I = 3A$

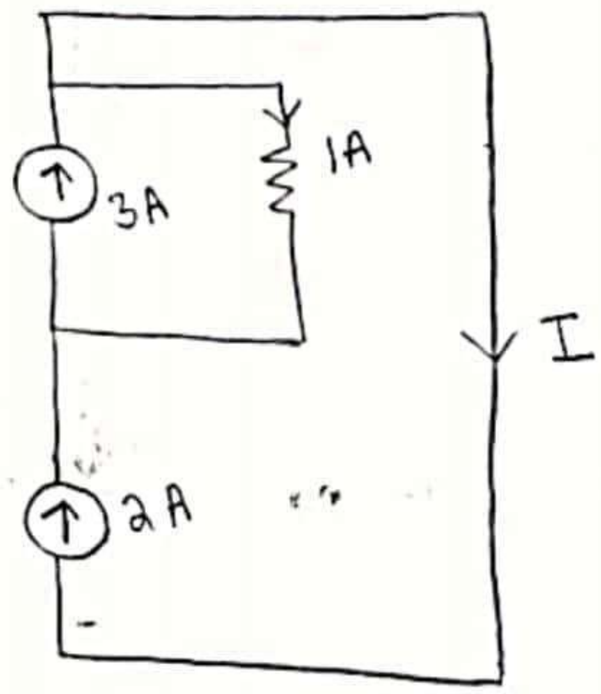
Q7)



$I = ?$

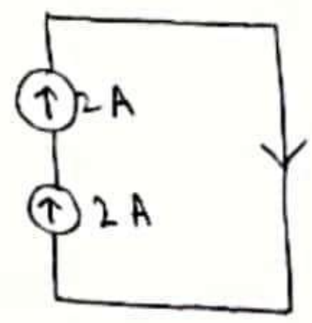
I doesn't exist

Q8)



$I = ?$

$\sim$



$I = 2A$

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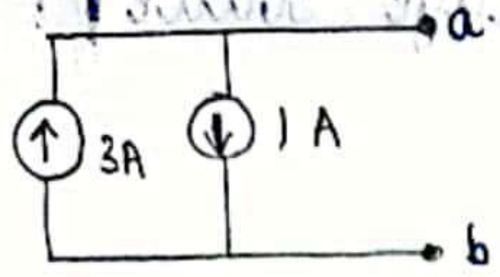
Q9)

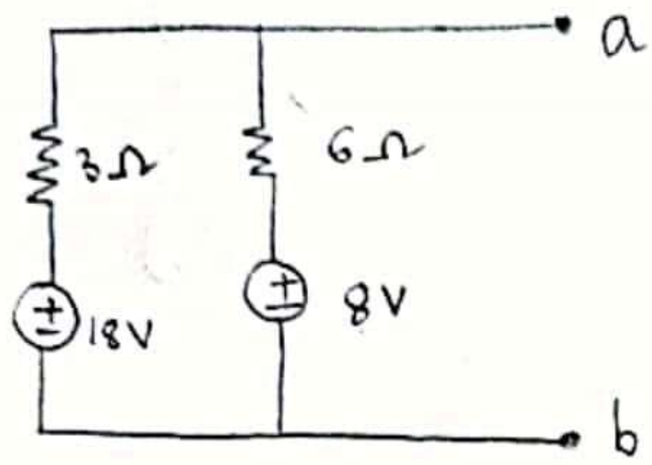


$I_{ab} = ?$

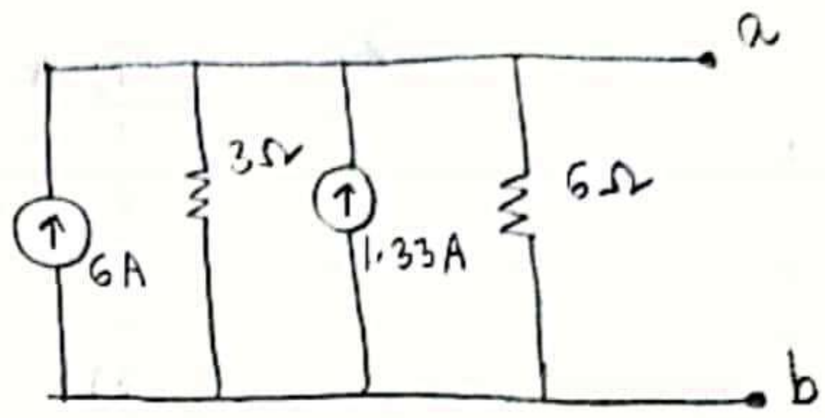
$I = 3 - 1 = 2A$

$\Rightarrow I = 2A$

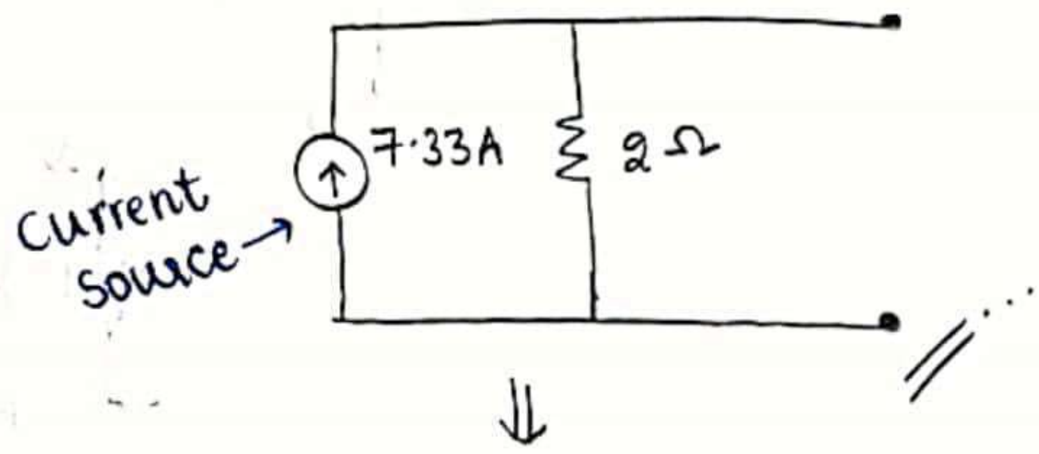
Q10) Find equivalent voltage & current source.



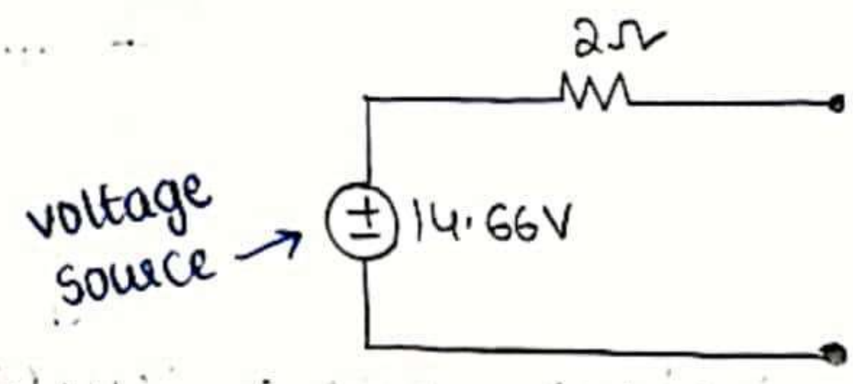
$\simeq$



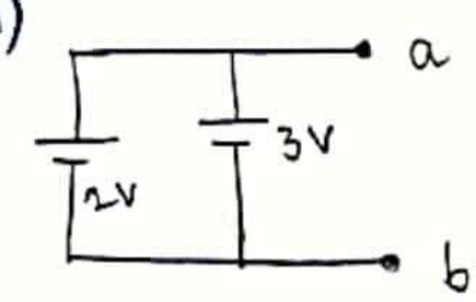
$\Downarrow$



$\Downarrow$



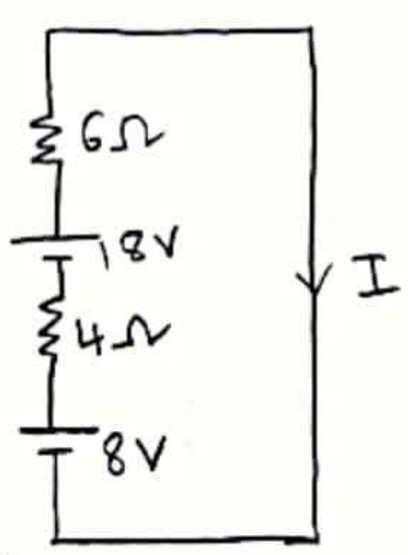
Q11)



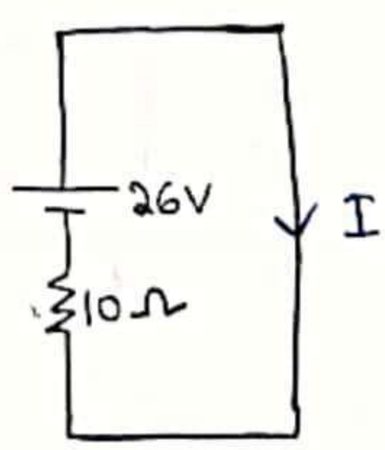
$V_{ab} = ?$

doesnot exist.

Q12) Find the current through the circuit.



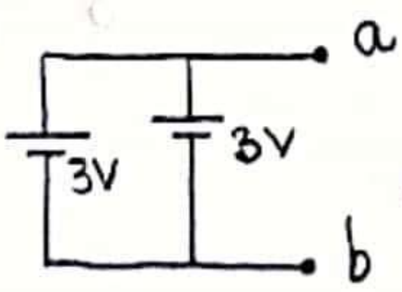
$\Rightarrow$



$I = \frac{V}{R} = \frac{26}{10} = 2.6A$

$\Rightarrow I = 2.6A$

Q13)



$V_{ab} = ?$

$\Rightarrow V_{ab} = 3V$

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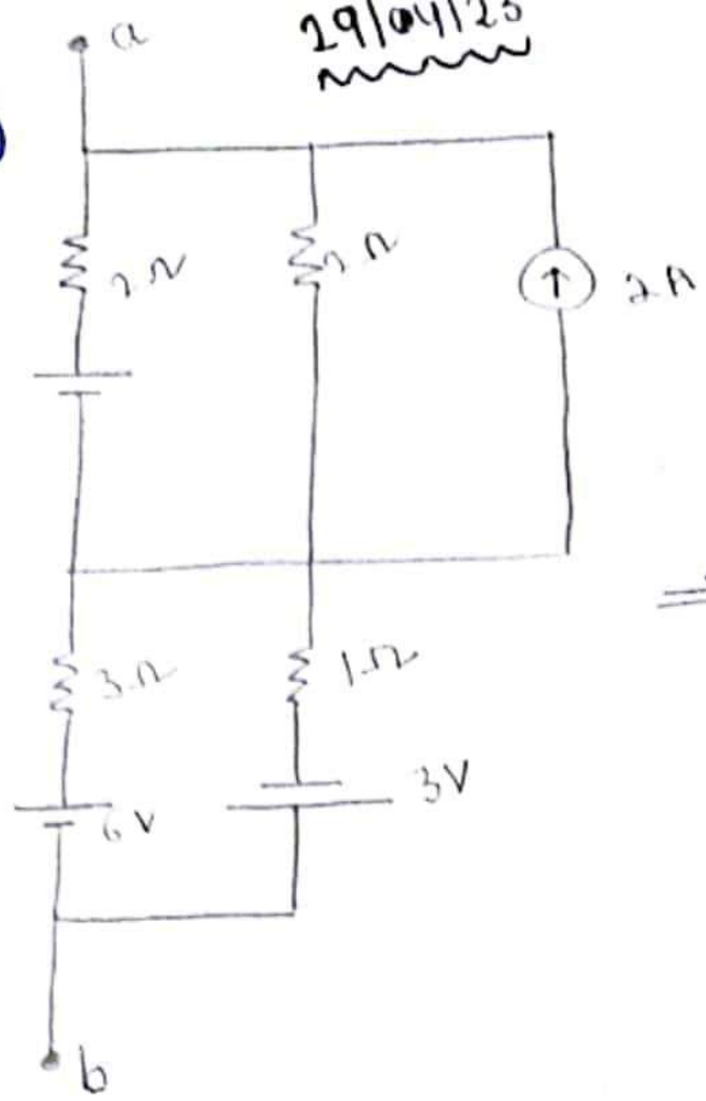
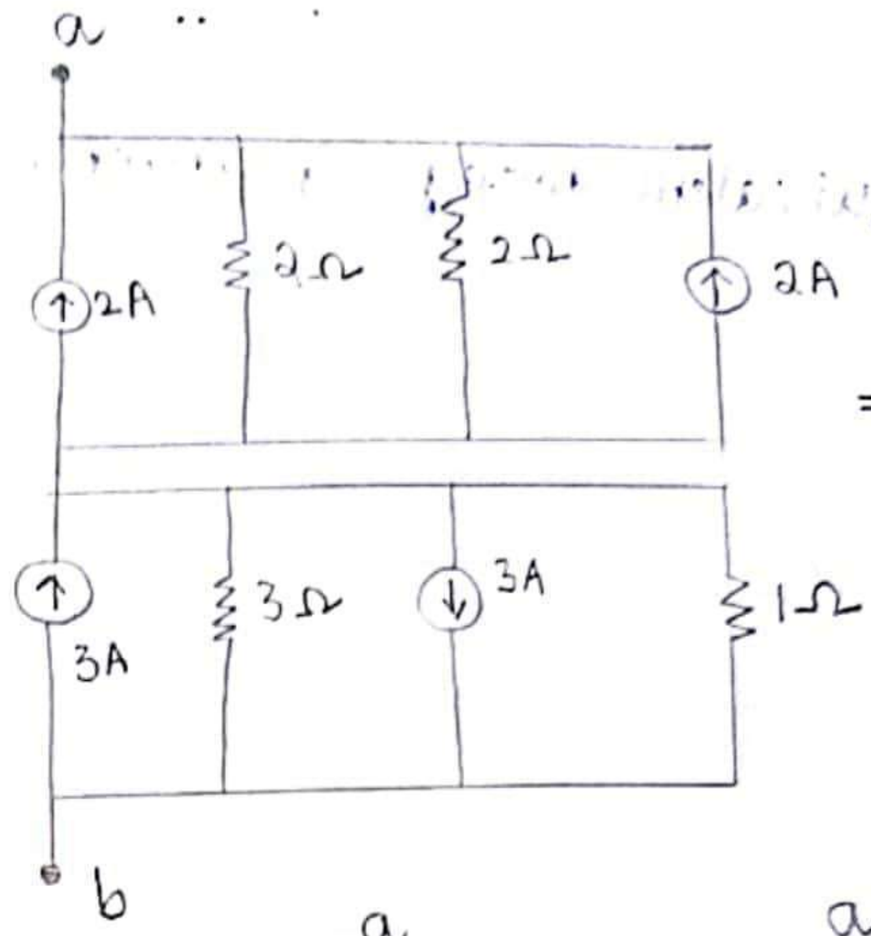
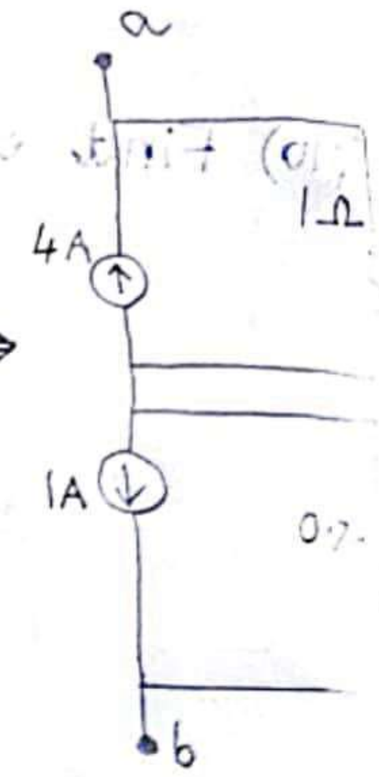
Q14) Convert into single voltage source ?



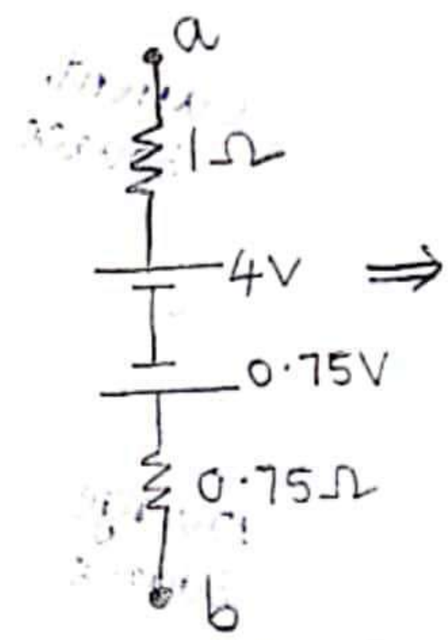
⇒



⇒



⇒



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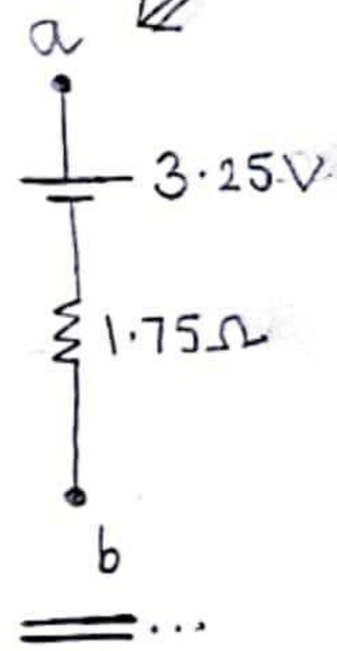
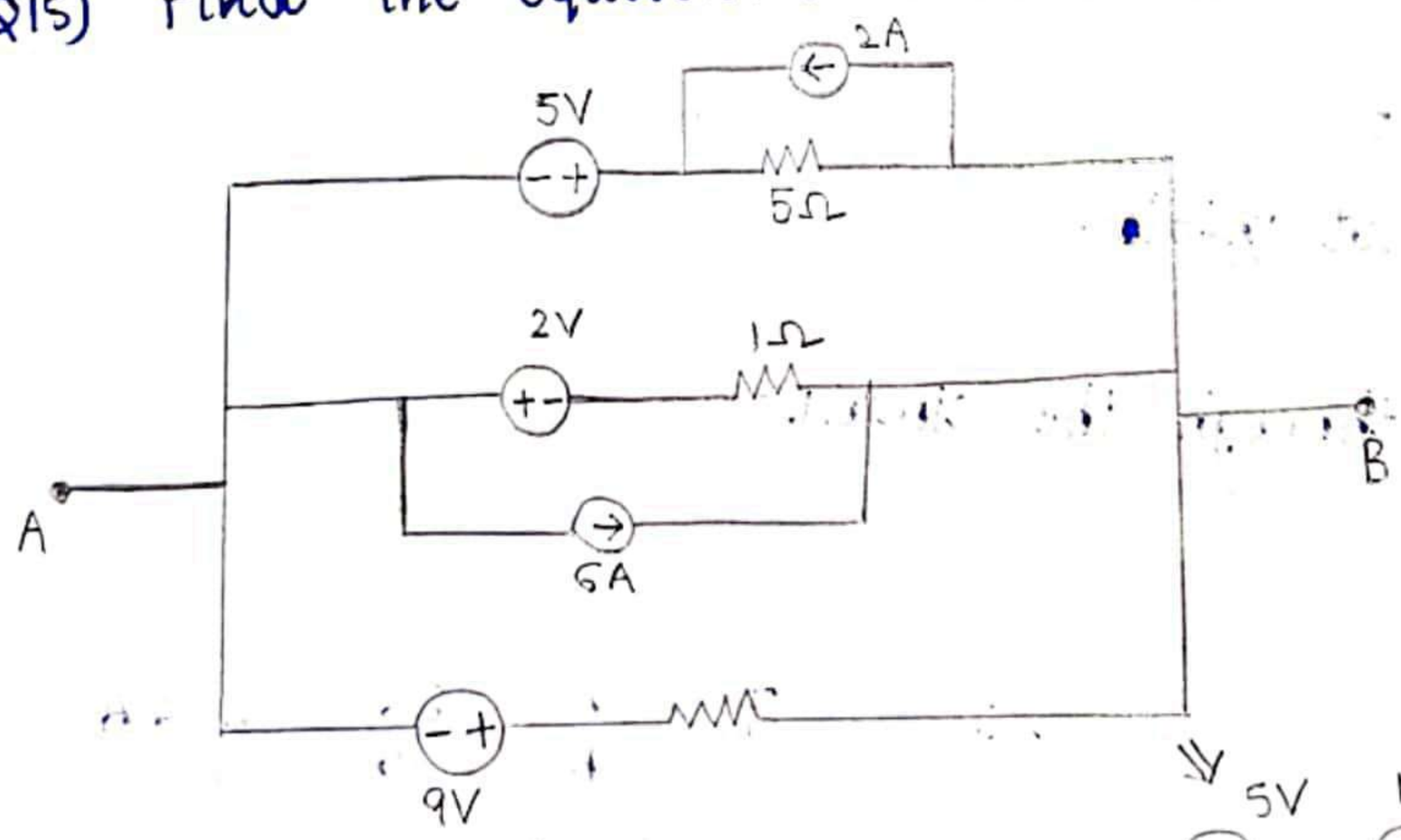
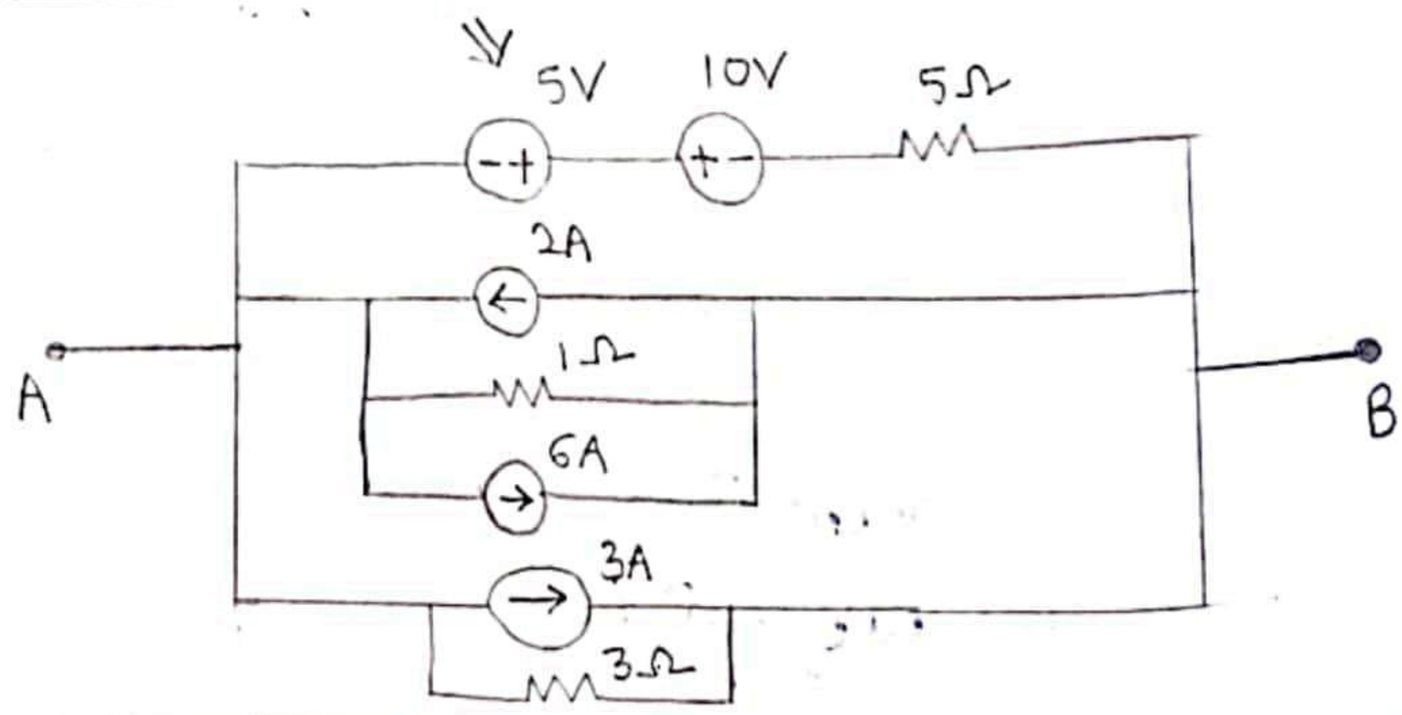
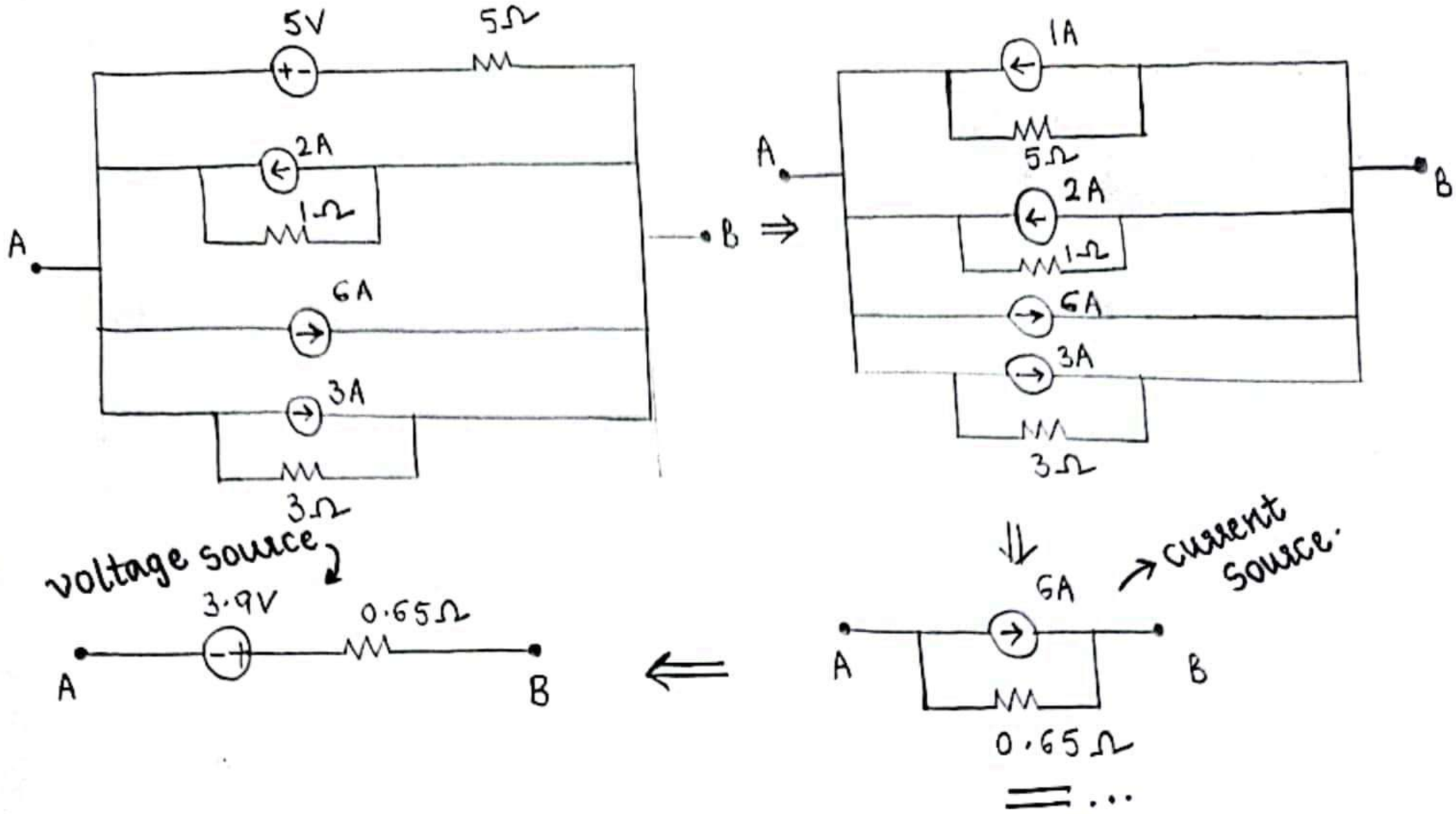


Q15) Find the equivalent current source ?

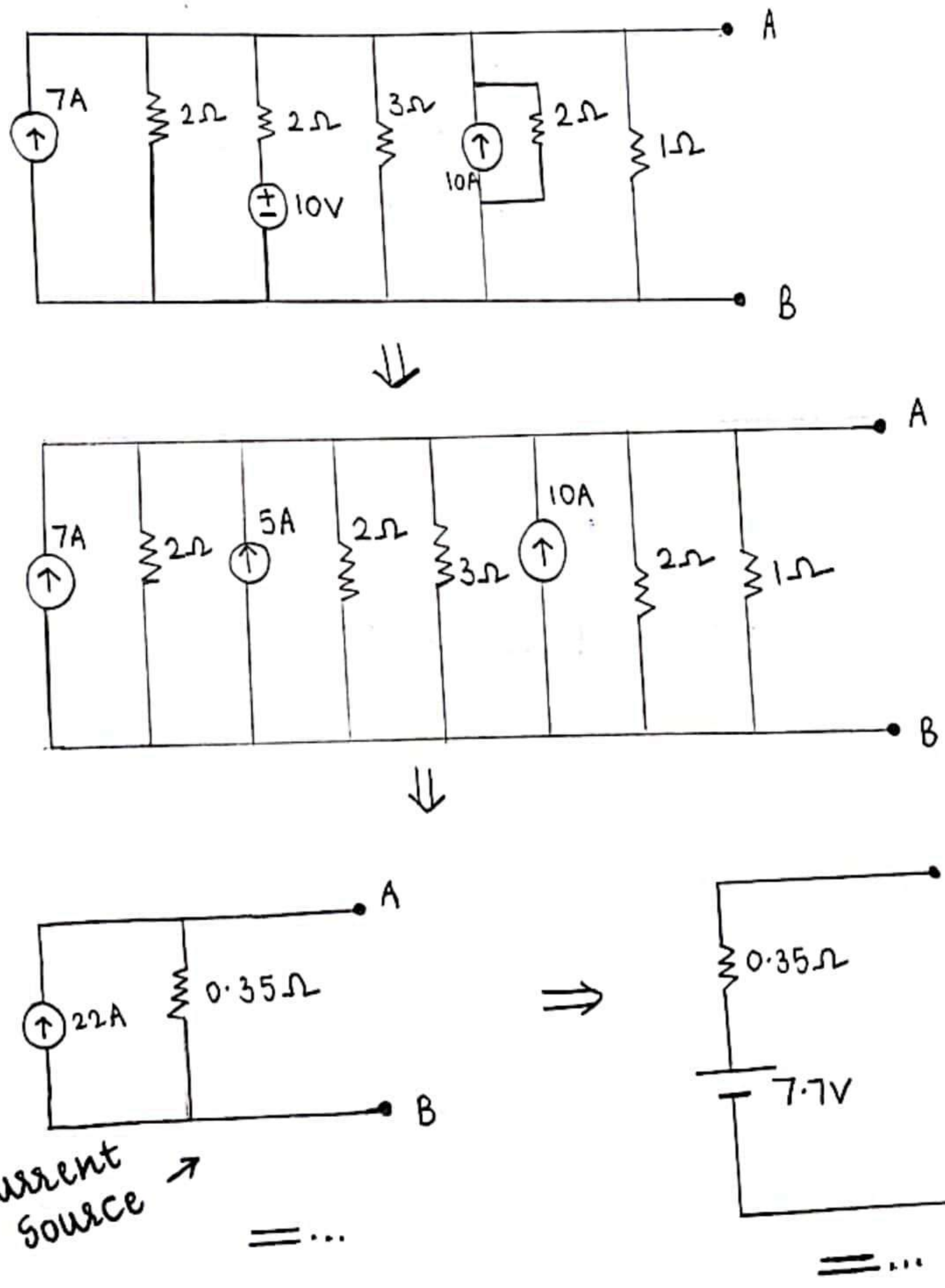


⇒





Q16) Find equivalent current & voltage sources.



15/05/23

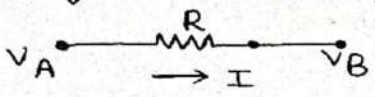
NETWORK ANALYSIS

Network Analysis :—

Nodal Analysis :— It is based upon KCL & Ohm's Law.

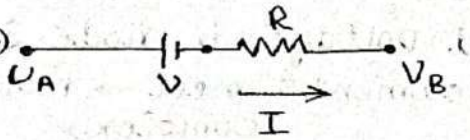
Important formulas :—

(i) If current is passing from A to B.



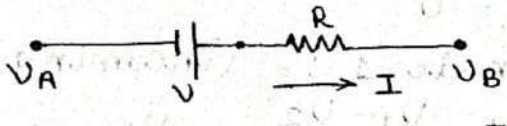
$$I = \frac{V_A - V_B}{R}$$

(ii) a)



$$I = \frac{(-V + V_A) - V_B}{R}$$

b)

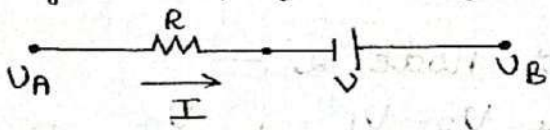


$$I = \frac{(-V + V_A) - V_B}{R}$$

Note :—

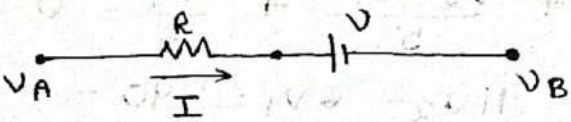
Wherever we want to calculate the voltage, start at the same point & go the ground following KVL sign convention

c)



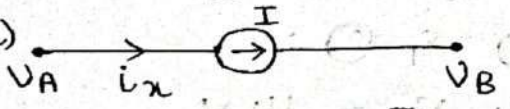
$$I = \frac{V_A - (-V + V_B)}{R}$$

d)



$$I = \frac{V_A - (V + V_B)}{R}$$

iii) a)

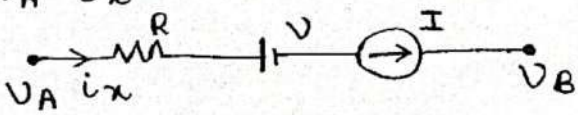


$i_x = I$

b)

$i_x = I$

c)



$i_x = I$

Procedure of Nodal Analysis :—

1) Identify all the nodes in the given circuit.
2) Select a node as reference (also called ground) and assign it a voltage of 0V

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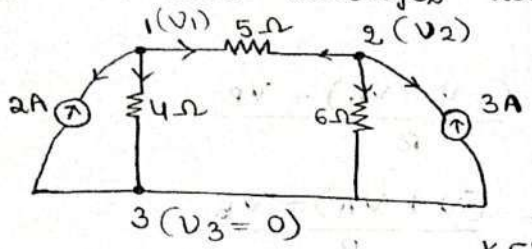
3) Label the voltage for all the remaining nodes.
4) Apply KCL at each node & express the branch currents in terms of node voltages.
5) Solve the resulting simultaneous eq's for node voltages.
6) Now node voltages are obtained, then node currents maybe acquired by Ohm's Law.

Q1) Find node voltages using nodal analysis.



* from node current always leaving (because node is at higher V and I goes from high V to low V & node voltage taken is higher V)

A:-

Ground voltage is node 3 (as 4 elements meet → more complex)

$V_3 = 0$

KCL at node 1 :- (incoming I is −ve)

$$-2 + \frac{V_1 - V_2}{5} + \frac{V_1}{4} = 0$$

$$9V_1 - 4V_2 = 40 \quad \text{—— (1)}$$

KCL at node 2 :-

$$-3 + \frac{V_2 - V_1}{5} + \frac{V_2}{6} = 0$$

$$11V_2 - 6V_1 = 90 \quad \text{—— (2)}$$

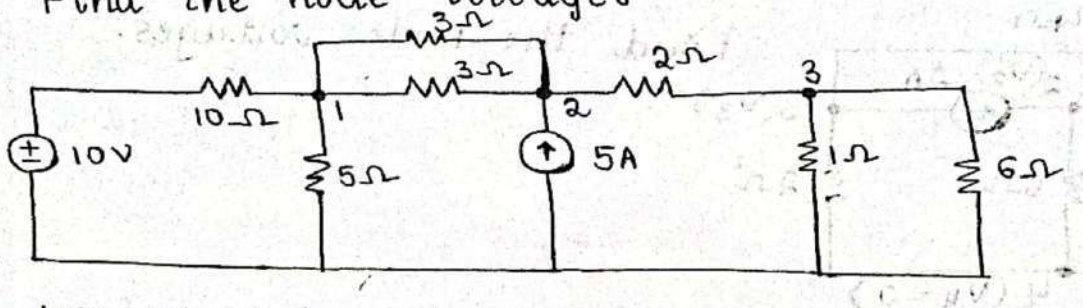
Solve eq (1) & (2);

$$\therefore V_1 = 10.67V; \quad V_2 = 14V$$

Q2)

A:

Q2) Find the node voltages.



A: KCL at node 1 :-

$$\frac{V_1 - V_2}{3} + \frac{V_1}{5} + \frac{(V_1 - (10+0))}{10} + \frac{V_1 - V_2}{3} = 0$$

$$V_1\left(\frac{2}{3} + \frac{1}{5} + \frac{1}{10}\right) + V_2\left(-\frac{1}{3} - \frac{1}{3}\right) = 1$$

$$\frac{29}{30}V_1 - \frac{2V_2}{3} = 1$$

$$29V_1 - 20V_2 = 30 \quad \text{—— (1)}$$

KCL at node 2 :-

$$\frac{V_2 - V_1}{3} + \frac{V_2 - V_1}{3} + \frac{V_2 - V_3}{2} = 5$$

$$-\frac{2V_1}{3} + \frac{7V_2}{6} - \frac{V_3}{2} = 5$$

$$-4V_1 + 7V_2 - 3V_3 = 30 \quad \text{—— (2)}$$

KCL at node 3 :-

$$\frac{V_3}{6} + \frac{V_3}{1} + \frac{V_3 - V_2}{2} = 0$$

$$\frac{5V_3}{6} - \frac{V_2}{2} = 0$$

$$10V_3 - 3V_2 = 0 \quad \text{(1)}$$

$\therefore V_1 = 8.07V$

$\therefore V_2 = 10.23V$

$\therefore V_3 = 3.08V$

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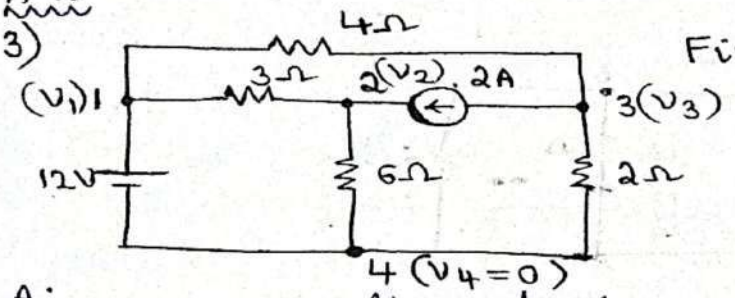
H.W

Q 3)



Find the node voltages.

A:

At node 1 :-

$$V_1 = 12V$$

At node 2 :-

$$-2 + \frac{V_2}{6} + \frac{V_2 - V_1}{3} = 0$$

$$V_2 = 12V$$

At node 3 :-

$$2 + \frac{V_3}{2} + \frac{V_3 - V_1}{4} = 0$$

$$\frac{3V_3}{4} - 1 = 0$$

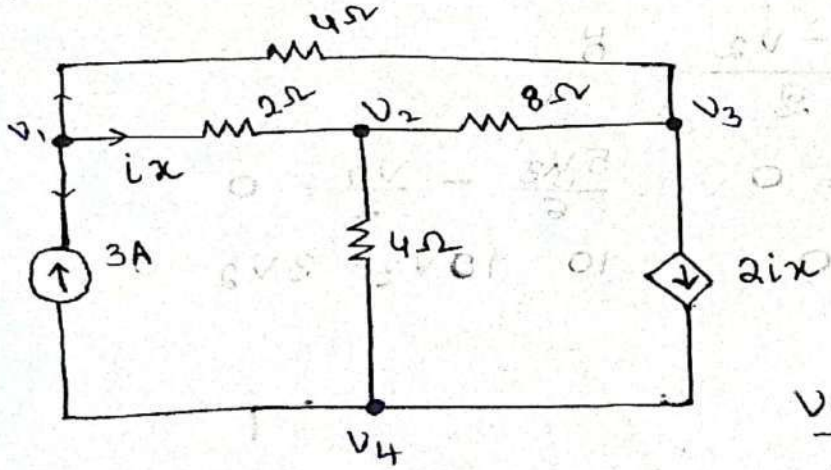
$$V_3 = 1.33V$$

$$V_4 = 0V$$

$\therefore V_1 = 12V,\ V_2 = 12V,\ V_3 = 1.33V,\ V_4 = 0V$

16/09/23

Q4)



Find the node voltages

KCL at node 1:

$$\frac{V_1 - V_2}{2} - 3 + \frac{V_1 - V_3}{4} = 0$$

KCL at node 2:

$$\frac{V_2 - V_3}{8} + \frac{V_2 - V_1}{2} + \frac{V_2}{4} = 0$$

KCL at node 3:

$$\frac{V_3 - V_2}{8} + \frac{V_3 - V_1}{4} + 2i_x = 0$$

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$$\frac{3v_1}{4} - \frac{v_2}{2} - \frac{v_3}{4} = 3$$

$$3v_1 - 2v_2 - v_3 = 12 \quad \text{—— (1)}$$

$$\frac{7v_2}{8} - \frac{4v_1}{8} - \frac{v_3}{8} = 0$$

$$-4v_1 + 7v_2 - v_3 = 0 \quad \text{—— (2)}$$

$$i_x = \frac{v_1 - v_2}{2}$$

$$\frac{3v_1}{4} - \frac{9v_2}{8} + \frac{3v_3}{8} = 0$$

$$6v_1 - 9v_2 + 3v_3 = 0$$

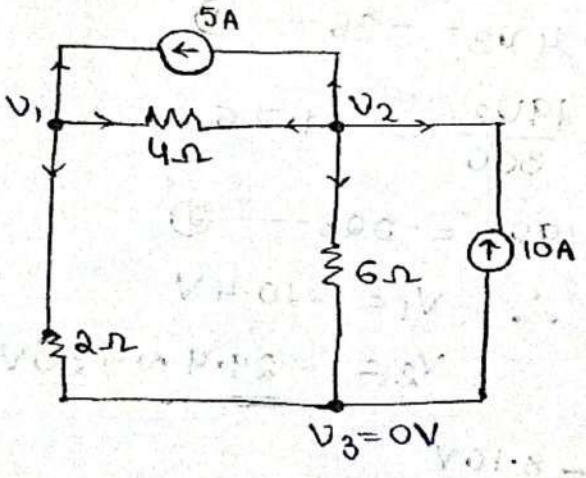
$$\Rightarrow 2v_1 - 3v_2 + v_3 = 0 \quad \text{—— (3)}$$

$v_1 = 4.8V$

$v_2 = 2.4V$

$v_3 = -2.4V$

Q5) Find node voltages.



At node 1:

$$\frac{v_1}{2} + \frac{v_1 - v_2}{4} - 5 = 0$$

$$\frac{3v_1}{4} - \frac{v_2}{4} = 5$$

$$\Rightarrow 3v_1 - v_2 = 20 \quad \text{—— (1)}$$

At node 2:

$$\frac{v_2}{6} + \frac{v_2 - v_1}{4} + 5 - 10 = 0$$

$$\frac{-v_1}{4} + \frac{5v_2}{12} = 5$$

$$-3v_1 + 5v_2 = 60 \quad \text{—— (2)}$$

$$\Rightarrow v_1 = 19.33V$$

$$v_2 = 20V$$

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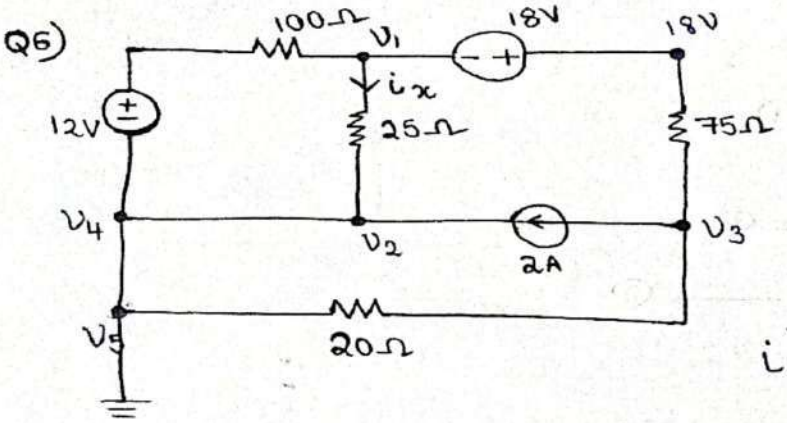
Q6)



Find the node voltages, i_x.

$v_2, v_4, v_5 \rightarrow$ common nodes

$\Rightarrow v_2, v_4, v_5 = 0\,V$

At node 1

$$i_x = \frac{v_1 - 0}{25} = \frac{v_1}{25}$$

$$\frac{v_1 - 0}{25} + \frac{v_1 - 12}{100} + \frac{(v_1 + 18) - v_3}{75} = 0$$

At node 3

$$\frac{(v_3 - 18) - v_1}{75} + \frac{v_3}{20} + 2 = 0$$

$$\Rightarrow \frac{v_1}{20} - \frac{v_3}{75} + \frac{v_1}{75} = \frac{-3}{25}$$

$$\frac{v_1}{3} + \frac{5v_1}{4} - \frac{v_3}{3} = -3$$

$$19v_1 - 4v_3 = -36 \quad \text{—— (1)}$$

$$\Rightarrow \frac{-v_1}{75} + \frac{19v_3}{300} = -1.76$$

$$-4v_1 + 19v_3 = -528 \quad \text{—— (2)}$$

~~$\therefore v_1 = 5.31\,V$~~ ~~$\therefore v_1 = -10.4\,V$~~

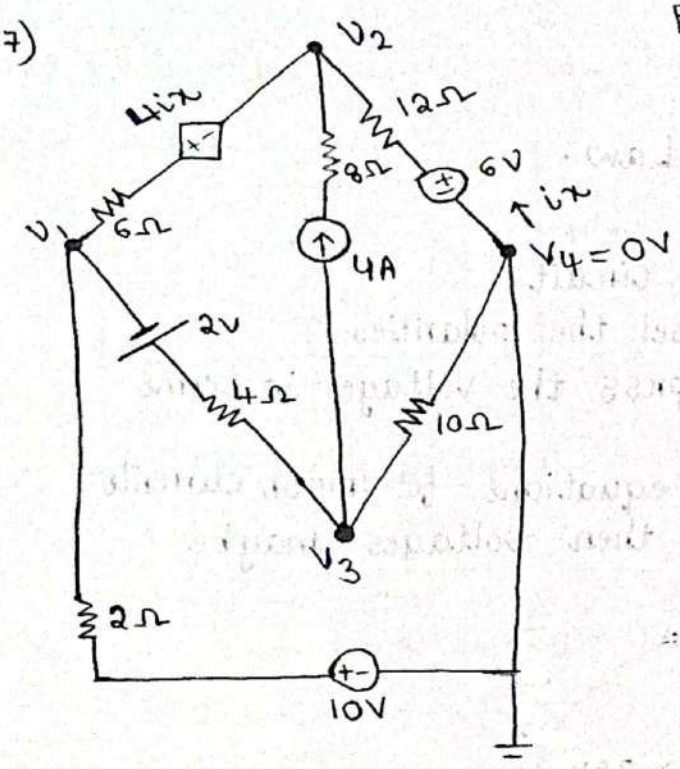
~~$v_2 = 29\,V$~~ ~~$v_2 = -29.9 \sim -30\,V$~~

$\therefore v_1 = -8.10\,V$

$v_2 = -29.5\,V$

$$i_x = \frac{-8.10}{25} = 0.324\,A$$

Q7)



Find node voltages.

At node 1,

$$\frac{V_1-10}{2} + \frac{V_1-V_2}{6} - \frac{4i_x}{6} + \frac{(V_1+2)-V_3}{4} = 0$$

At node 2,

$$\frac{\cancel{V_2-V_3}}{\cancel{8}} - 4 + \frac{V_2-6}{12} + \frac{V_2-V_1}{6} + \frac{4i_x}{6} = 0$$

At node 3,

$$\frac{V_3}{10} + \frac{V_3-V_1-2}{4} + \frac{\cancel{V_3-V_2}}{\cancel{8}} + 4 = 0$$

$$i_x = \frac{(0+6)-V_2}{12} = \frac{6-V_2}{18}$$

$$\frac{11V_1}{12} - \frac{7}{54}V_2 - \frac{V_3}{4} = \frac{+85}{18}$$

$$99V_1 - 14V_2 - 27V_3 = -30 \quad \text{—— (1)}$$

$$-\frac{V_1}{6} + \frac{23V_2}{108} = \frac{77}{18}$$

$$-18V_1 + 23V_2 = 154 \quad \text{—— (2)}$$

$$-\frac{V_1}{4} + \frac{7V_3}{20} = -\frac{7}{2}$$

$$-5V_1 + 7V_3 = -70 \quad \text{—— (3)}$$

Solving eq's, $V_1 = 3.96V$

$V_2 = 5.4V$

$V_3 = -7.17V$

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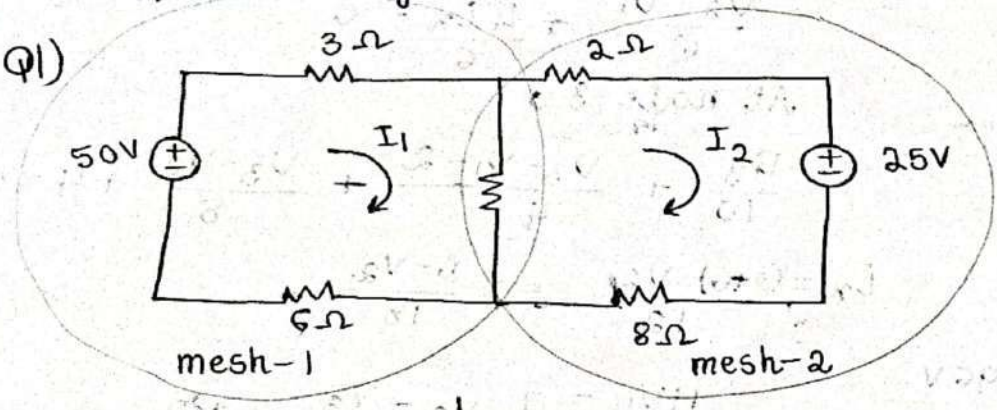
* Mesh Analysis :—

It is based upon KVL & Ohm's Law.

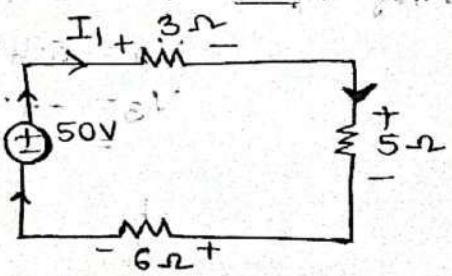
* Procedure :—

① Identify the meshes in the given circuit.
② Assign the mesh currents & label the polarities.
③ Apply KVL at each mesh & express the voltages in terms of mesh currents.
④ Solve the resulting simultaneous equations for mesh currents.
⑤ Now mesh currents are obtained then voltages maybe applied using ohm's Law.

Q1)



Mesh-1 :—



Apply KVL at mesh 1 :

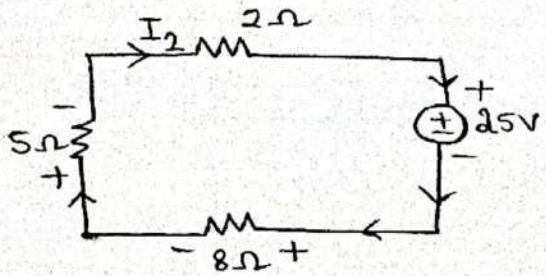
$$-50 + 3I_1 + 5(I_1 - I_2) + 6I_1 = 0$$

↳ Because 5Ω resistor is common for I_1 & I_2

$$\Rightarrow 14I_1 - 5I_2 = 50 \quad \text{—— (1)}$$

Apply KVL at mesh 2 :—

Mesh-2 :—



$$2I_2 + 25 + 8I_2 + 5(I_2 - I_1) = 0$$

$$\Rightarrow -5I_1 + 15I_2 = -25 \quad \text{—— (2)}$$

$$\therefore I_1 = 3.37A \; ; \; I_2 = -0.54A$$

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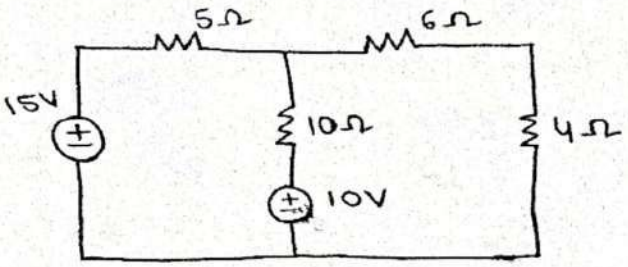
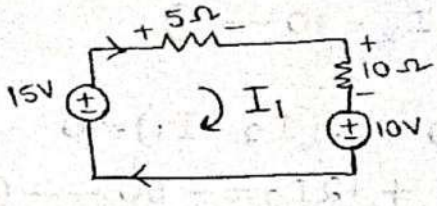
Q2) Find mesh currents using mesh analysis.

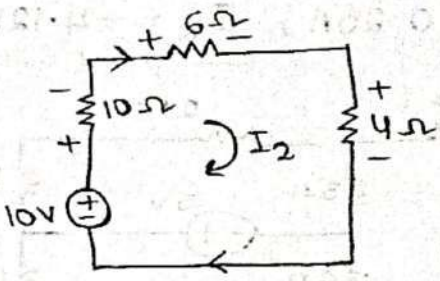




Mesh-1:-

$I_1 5 + 10(I_1 - I_2) + 10 - 15 = 0$

$\Rightarrow 15I_1 - 10I_2 = 5$ —— (1)



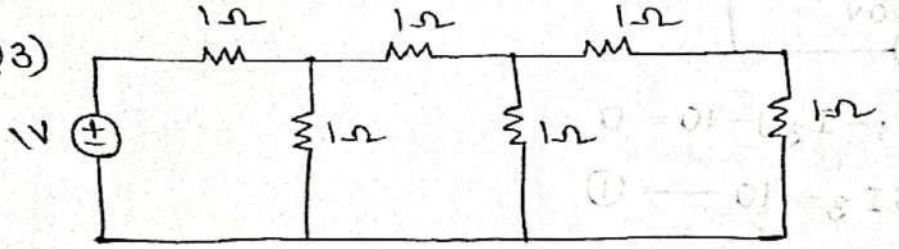
Mesh-2:-

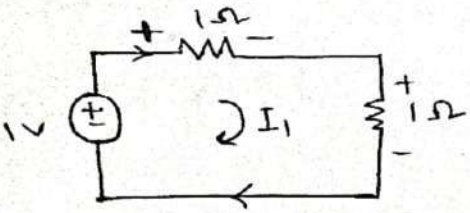
$6I_2 + 4I_2 - 10 + 10(I_2 - I_1) = 0$

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

$\therefore I_1 = 1A$ & $I_2 = 1A$

Q3)

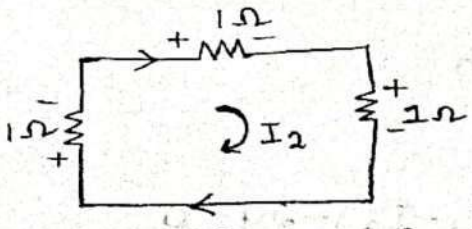




mesh-1:-

$I_1 + (I_1 - I_2) - 1 = 0$

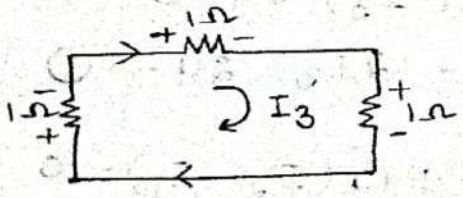
$\Rightarrow 2I_1 - I_2 = 1$ —— (1)



mesh-2:-

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

$\Rightarrow -I_1 + 3I_2 - I_3 = 0$ —— (2)



mesh-3:-

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

$\Rightarrow -I_2 + 3I_3 = 0$ —— (3)

$\therefore I_1 = 0.61A,\ I_2 = 0.23A,\ I_3 = 0.23A$

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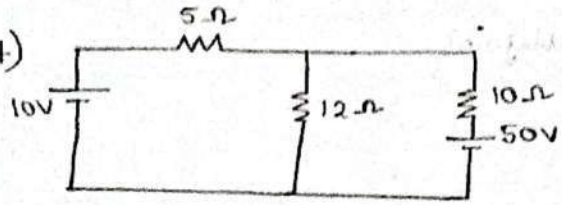
Q4)



mesh-1:—

$5I_1 + 2(I_1 - I_2) - 10 = 0$

$\Rightarrow 7I_1 - 2I_2 = 10$ —— ①

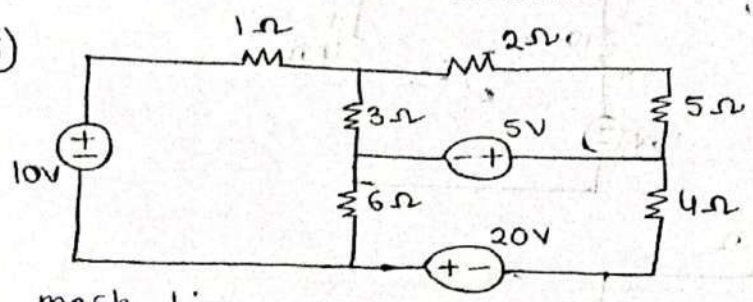
mesh-2:—

$10I_2 + 50 + 2(I_2 - I_1) = 0$

$\Rightarrow -2I_1 + 12I_2 = -50$ —— ②

$\therefore I_1 = 0.25A, \; I_2 = -4.125A$

Q5)



mesh-1:—

$I_1 + 2(I_1 - I_2) + 6(I_1 - I_3) - 10 = 0$

$\Rightarrow 9I_1 - 3I_2 - 6I_3 = 10$ —— ①

mesh-2:—

$2I_2 + 5I_2 + 5 + 3(I_2 - I_1) = 0$

$\Rightarrow -3I_1 + 10I_2 = -5$ —— ②

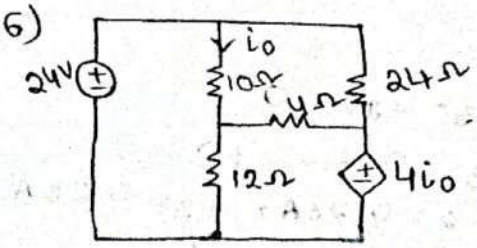
mesh-3:—

$4I_3 - 20 + 6(I_3 - I_1) - 5 = 0$

$\Rightarrow -6I_1 + 10I_3 = 25$ —— ③

$\therefore I_1 = 4.27A; \; I_2 = 0.78A, \; I_3 = 5.06A$

Q6)



mesh-1:—

$10(I_1 - I_2) + 12(I_1 - I_3) - 24 = 0$

$\Rightarrow 22I_1 - 10I_2 - 12I_3 = 24$ —— ①

mesh-2:—

$\Rightarrow 24I_2 + 4(I_2 - I_3) + 10(I_2 - I_1) = 0$

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$\Rightarrow -10I_1 + 38I_2 - 4I_3 = 0$ —— ②

mesh-3:—

$\Rightarrow 4(I_3 - I_2) + 4i_o + 12(I_3 - I_1) = 0$

$i_o = I_1 - I_2$

$4(I_3 - I_2) + 4(I_1 - I_2) + 12(I_3 - I_1) = 0$

$\Rightarrow -I_1 - I_2 + 2I_3 = 0$ —— ③

$\therefore I_1 = 2.25A;\ I_2 = 0.75A,\ I_3 = 1.5A \quad \therefore i_o = 1.5A$

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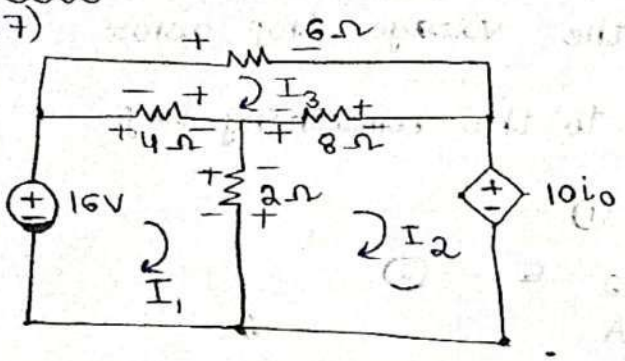
Q7)



Find mesh currents.

mesh-1:—

$-16 + 4(I_1 - I_3) + 2(I_1 - I_2) = 0$

$6I_1 - 2I_2 - 4I_3 = 16$

$\Rightarrow -3I_1 - I_2 - 2I_3 = 8$ —— ①

mesh-2:—

$8(I_2 - I_3) + 10i_o + 2(I_2 - I_1) = 0$

$\Rightarrow -2I_1 + 10I_2 - 8I_3 + 10i_o = 0$ —— ②

mesh-3:—

$6I_3 + 8(I_3 - I_2) + 4(I_3 - I_1) = 0$

$\Rightarrow -4I_1 - 8I_2 + 18I_3 = 0$ —— ③

$i_o = I_3$

$\Rightarrow -2I_1 + 10I_2 + 2I_3 = 0$

$\Rightarrow -I_1 + 5I_2 + I_3 = 0$ —— ②

$\therefore I_1 = 3.5A;\ I_2 = 0.5A,\ I_3 = 1A$

$\therefore i_o = 1A$

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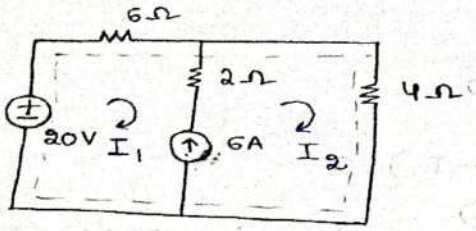
Q8) Find mesh currents.



* Note :- Super Mesh Problems → has current source
Mesh-1 & Mesh 2 have independent current source in common, so it is not possible to find out the voltage drop across the current source.

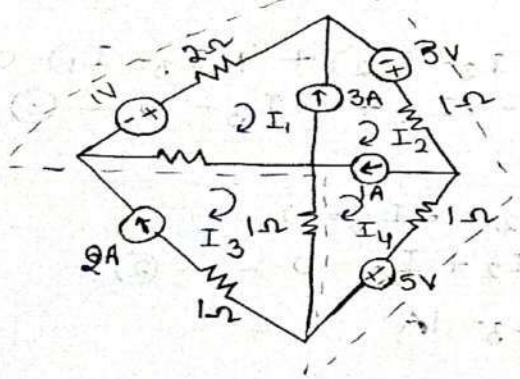
- Avoid current source and apply eq to the remaining loop (& its branch)

loop → $6I_1 + 4I_2 - 20 = 0$ — ①

Current source branch → $-I_1 + I_2 = 6$ — ②

$\therefore I_1 = -0.4A, \; I_2 = 5.6A$

Q9) Find mesh currents.



loop →

$-1 + I_1 - 3 + I_2 + I_4 - 5 + (I_4 - I_3) + (I_1 - I_3) = 0$

$\Rightarrow 2I_1 + I_2 - 2I_3 + 2I_4 = 9$ — ①

$I_2 - I_1 = 3$ — ②

$I_2 - I_4 = 1$ — ③

$I_3 = 2$ — ④

$\Rightarrow 2I_1 + I_2 + 2I_4 = 13$ — ①

$\therefore I_1 = 1.2A, \; I_2 = 4.2A, \; I_3 = 2A,$

$I_4 = 3.2A$

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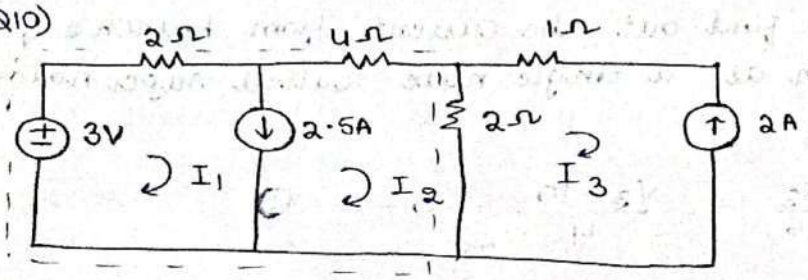
Q10)



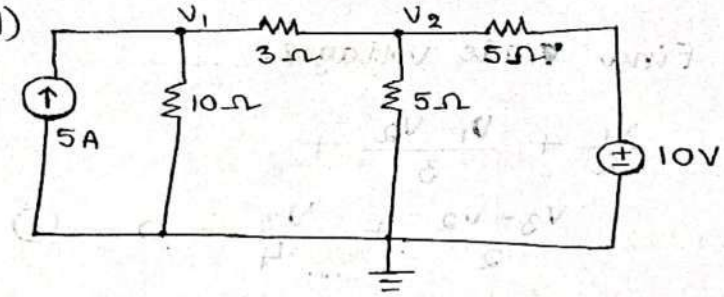
loop → $-3 + 2I_1 + 4I_2 + 2(I_2 - I_3) = 0$ — ①

$I_3 = -2A$ $\Rightarrow 2I_1 + 6I_2 = -1$

$I_2 - I_2 = 2.5A$

$\therefore I_1 = 1.75A$, $I_2 = -0.75A$

Q11)



Find node voltages.

Node 1 :—

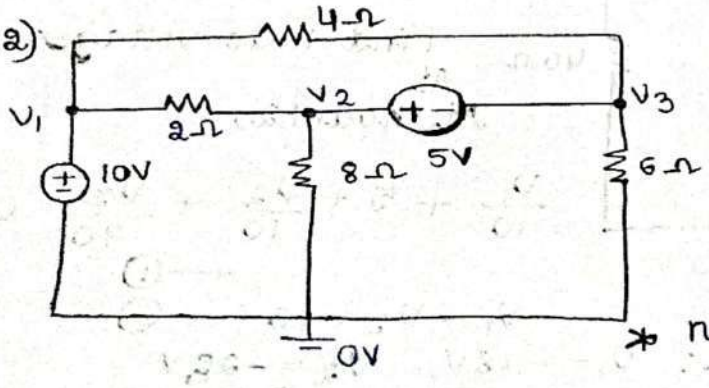
$$\frac{V_1 - V_2}{3} + \frac{V_1}{10} - 5 = 0 \quad \text{— ①}$$

Node - 2 :—

$$\frac{V_2}{5} + \frac{V_2 - V_1}{3} + \frac{V_2 - 10}{5} = 0 \quad \text{— ②}$$

$\therefore V_1 = 20.96V$, $V_2 = 12.25V$

Q12)



Find node voltages.

$V_1 = 10V$

At node 2,

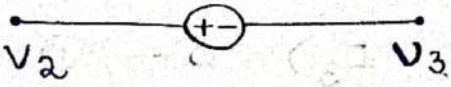
$(V_2 - 5) - V_3$

* node 2 & 3 have voltage source without series resistance;

So it is not possible to find out the current from branch 2 & 3
Such nodes can be taken as a single node called super node.

At node 2, 3 :-

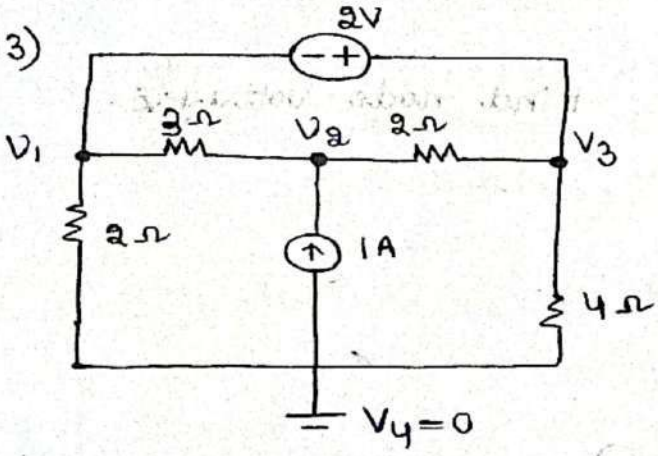
$$\frac{V_2}{8} + \frac{V_2 - 10}{2} + \frac{V_3}{6} + \frac{V_3 - 10}{4} = 0 \quad \text{--- (1)}$$



$$V_2 - V_3 = 5 \quad \text{--- (2)}$$

$\therefore V_1 = 10V, \; V_2 = 9.2V, \; V_3 = 4.2V, \; V_4 = 0V$

Q13)



Find node voltages.

$$\frac{V_1}{2} + \frac{V_1 - V_2}{3} + \frac{V_3 - V_2}{2} + \frac{V_3}{4} = 0 \quad \text{--- (1)}$$

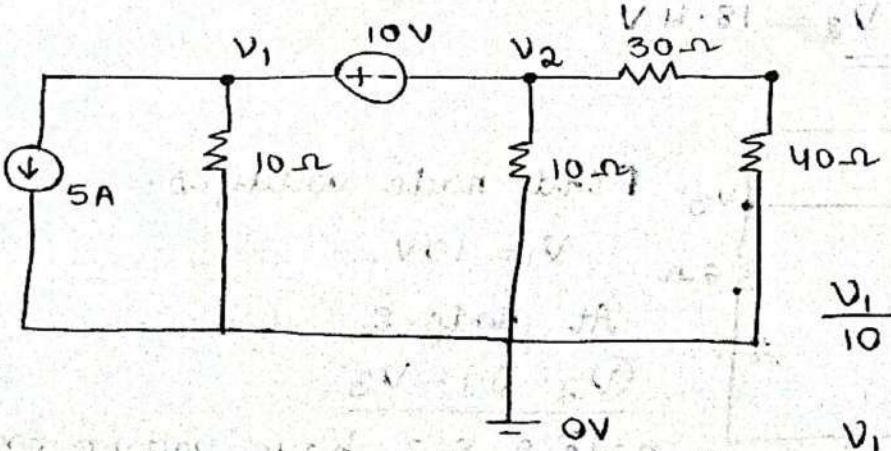
$$V_3 - V_1 = 2 \quad \text{--- (2)}$$

at node 2,

$$-1 + \frac{V_2 - V_3}{2} + \frac{V_2 - V_1}{3} = 0 \quad \text{--- (3)}$$

$\therefore V_1 = 0.66V, \; V_2 = 3.06V, \; V_3 = 2.66V$

Q14)



Find node voltages.

At node 1, 2,

$$\frac{V_1}{10} + 5 + \frac{V_2}{10} + \frac{V_2}{70} = 0 \quad \text{--- (1)}$$

$$V_1 - V_2 = 10 \quad \text{--- (2)}$$

$\therefore V_1 = -18V, \; V_2 = -28V$

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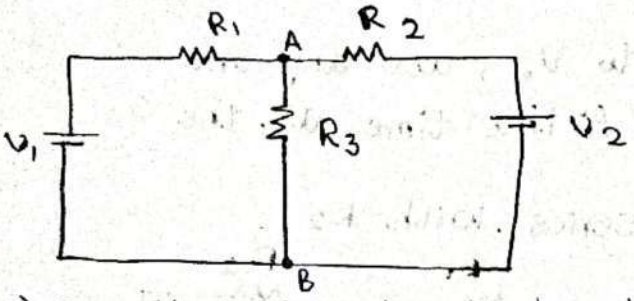
23/05/23

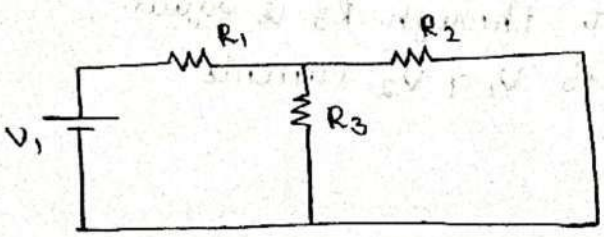
* Superposition Theorem :—

S.P Theorem states that any linear, bilateral network consisting of 2 or more sources, the response in any element is while all the sources acting is equal to algebraic sum of responses while individual sources acting alone, Provided all other sources are inactive by making them short-circuited with internal resistances.

* Explanation & Procedure :—



1) Consider the above network
2) calculate the current flowing through resistance R_3 using S.P theorem.
3) Acc to S.P.T sources must be acting independently.
4) Consider a voltage source V_1 is acting alone to obtain the current flowing through R_3, using any one of the network reduction techniques. At this time, remaining sources are inoperative. (voltage srcs — short circuited, current srcs — open circuited)



R_2, R_3 are in parallel

$$R_{eq_1} = \frac{R_2 R_3}{R_1 + R_2}$$

R_{eq_1} & R_1 are in series

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

$$I_T = \frac{V_1}{R_1 + \frac{R_2 R_3}{R_2 + R_3}}$$

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I_{R_3} (using current division rule) $= I_T \times \dfrac{R_2}{R_2 + R_3}$

$$= \frac{V_1}{R_1 + \left(\dfrac{R_2 R_3}{R_2 + R_3}\right)} \times \frac{R_2}{R_2 + R_3}$$

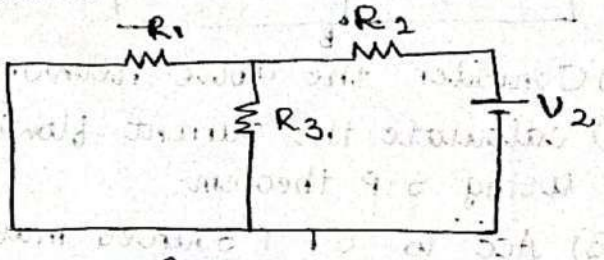
$$= \frac{V_1 R_2}{R_1 R_2 + R_2 R_3 + R_1 R_3}$$

5) to obtain current through R_3 due to V_2, use any one of the network reduction technique. At this time all the others srcs are inoperative.

R_1 & R_3 ||el and resultant in series with R_2

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

$$I_T = \frac{V_2}{R_2 + \dfrac{R_1 R_3}{R_1 + R_3}}$$



I_{R_3} (using current division rule) $= I_T \times \dfrac{R_1}{R_1 + R_3}$

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

6) According to S.P.T; total current through R_3 is equal to algebraic sum of voltage sources V_1 & V_2 currents acting individually.

$$\Rightarrow \text{total } I_{R_3} = \frac{V_1 R_2 + V_2 R_1}{R_1 R_2 + R_2 R_3 + R_1 R_3}$$

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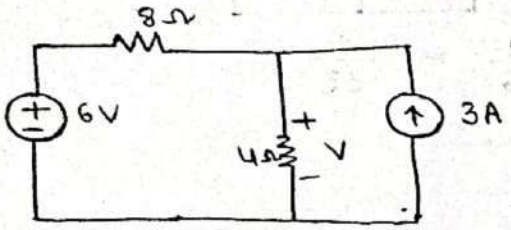
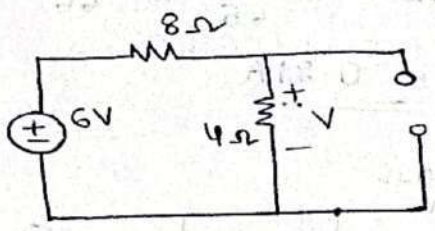
* Steps to apply S.P.T :-

1) Select an independent sources
   voltage srcs — short-circuited
   current srcs — open-circuited
2) To get current flowing or voltage across the req element, use any one of the network reduction techniques.
3) Repeat step 1, 2 for all the sources...
4) Acc to S.P.T ; the total current / voltage = algebraic sum of effects produced by individual srcs.

Q1) Using S.P.T, Find V.



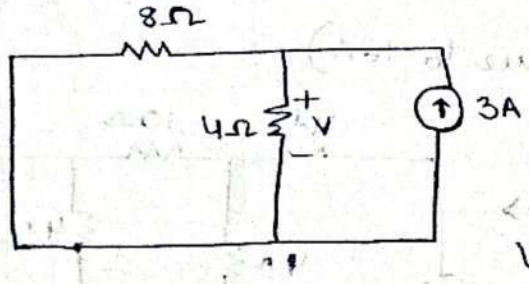
3A → open circuited & using 6V.



voltage drop across 4Ω
(using voltage division rule) $= 6 \times \frac{4}{4+8}$

$V_1 = 2V$

6V → short - circuited, using 3A



current through 4Ω $= 3 \times \frac{8}{4+8}$

$= 2A$

voltage drop $= IR$

$V_2 = 2 \times 4 = 8V$

$\therefore V = V_1 + V_2$

$= 2 + 8$

$\therefore V = 10V$

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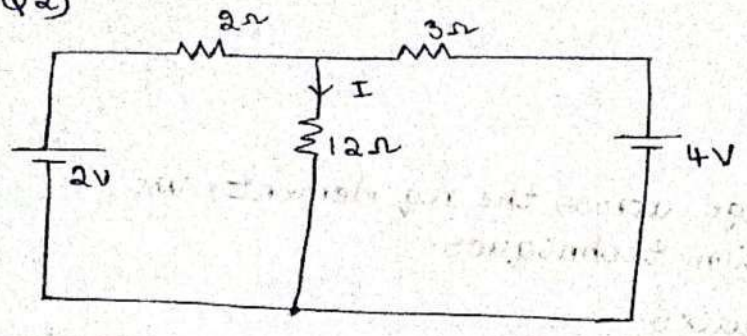
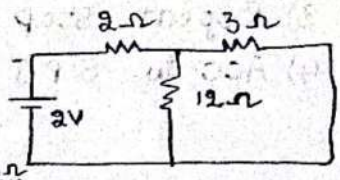
Q2)

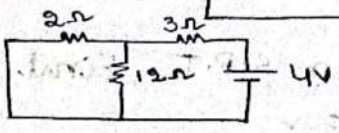


Determine current through 12Ω using S.P.T.

I_1 (due to 2V) $= \dfrac{2\times 3}{6+24+36} = \dfrac{6}{66} = \dfrac{1}{11}$ A



I_2 (due to 4V) $= \dfrac{4\times 2}{6+24+36} = \dfrac{8}{66}$ A

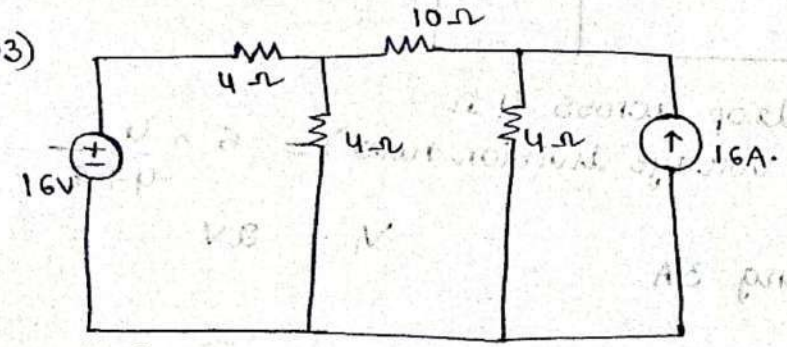


According to S.P.T,

I through 12Ω $= \dfrac{6}{66} + \dfrac{8}{66} = \dfrac{14}{66} = \dfrac{7}{33}$

$\therefore$ I $= 0.21$ A

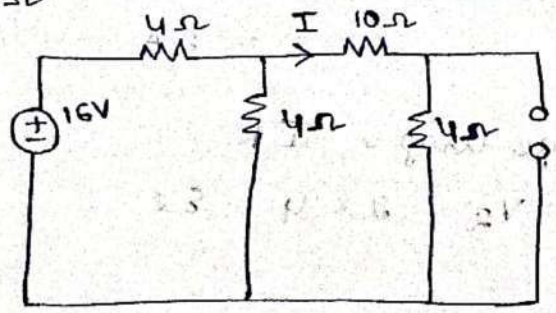
Q3)



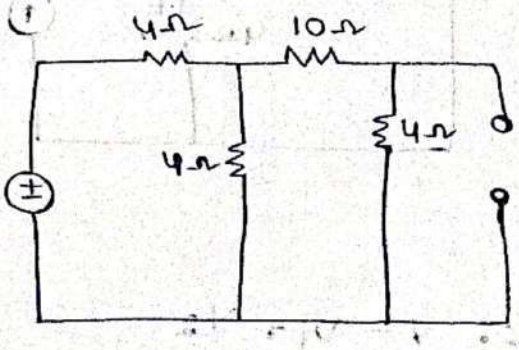
Find $I_{10\Omega}$ using S.P.T

$I_{10\Omega} = I_1$ (due to 16V) $+ I_2$ (due to 16A)

$I_1 \Rightarrow$



$\Rightarrow$



$$\frac{V-16}{4} + \frac{V}{4} + \frac{V}{14} = 0$$

$$V = 7\text{ V}$$

$$I_1 = \frac{7}{14} = \frac{1}{2} = 0.5\text{A}$$

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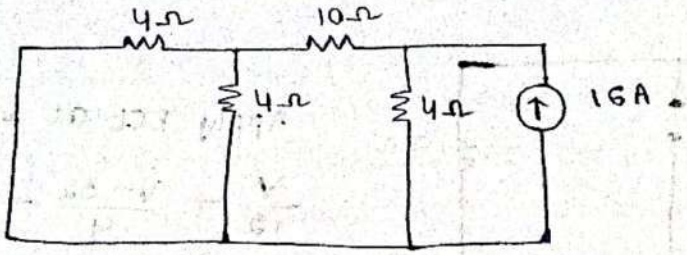
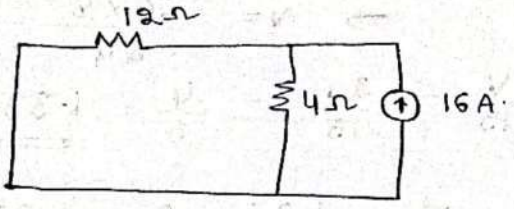
$I_2 \Rightarrow$



4Ω, 4Ω are in parallel ⇒ R = 2Ω

2Ω, 10Ω are in series ⇒ R = 12Ω

$\Rightarrow$



$$I_2 = 16 \times \frac{4}{12+4} = 4A$$

According to S.P.T, $I_{10\Omega} = 0.5 - 4$ (different current polarities)

$= -3.5A$

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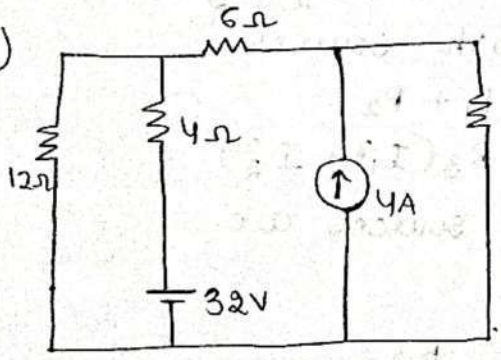
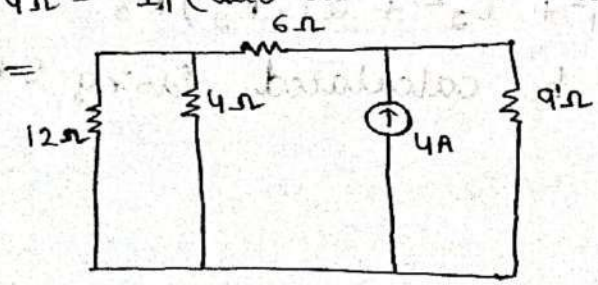
1)



Find $I_{9\Omega}$ using S.P.T.

$I_{9\Omega} = I_1$ (due to 32V) + I_2 (due to 4A)

$I_2 =$



12Ω, 4Ω are in parallel

R = 3Ω

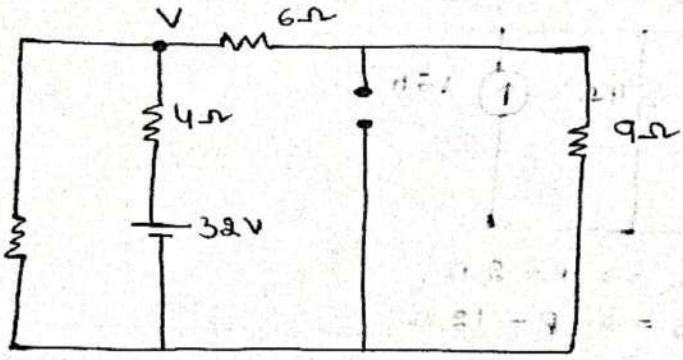
6Ω, 3Ω are in series

R = 9Ω

$$\Rightarrow I_2 = 4 \times \frac{9}{18} = 2 \text{ A}$$

$I_2 = 2A$

$I_1 =$



Apply KCL at V :—

$$\frac{V}{12} + \frac{V-32}{4} + \frac{V}{15} = 0$$

$$\frac{5V + 15V + 4V}{60} = 8$$

$$\Rightarrow V = \frac{60 \times 8}{24} = 20V$$

$$I_1 = \frac{V}{15} = \frac{20}{15} = \frac{4}{3} = 1.33A$$

$$I_{9\Omega} = I_1 + I_2 = 1.33 + 2 = 3.33A$$

* Limitations of S.P.T :—

1) not suitable for power response finding. (from fig in S.P.T. theory ex)

Power dissipated in R_3 due to $V_1 = P_1 = I_1^2 R_3$

in R_3 due to $V_2 = P_2 = I_2^2 R_3$

→ Total power dissipated when both sources are acting independently $= P_{T_1} = P_1 + P_2$

$$= R_3(I_1^2 + I_2^2)$$

→ Total power dissipated in R_3 when two sources are acting at a time $(P_{T_2}) = I^2 R_3$

$$= (I_1 + I_2)^2 R_3$$

$$= (I_1^2 + I_2^2 + 2I_1 I_2) R_3$$

$\Rightarrow P_{T_1} \neq P_{T_2}$, so power can't be calculated using S.P.T.

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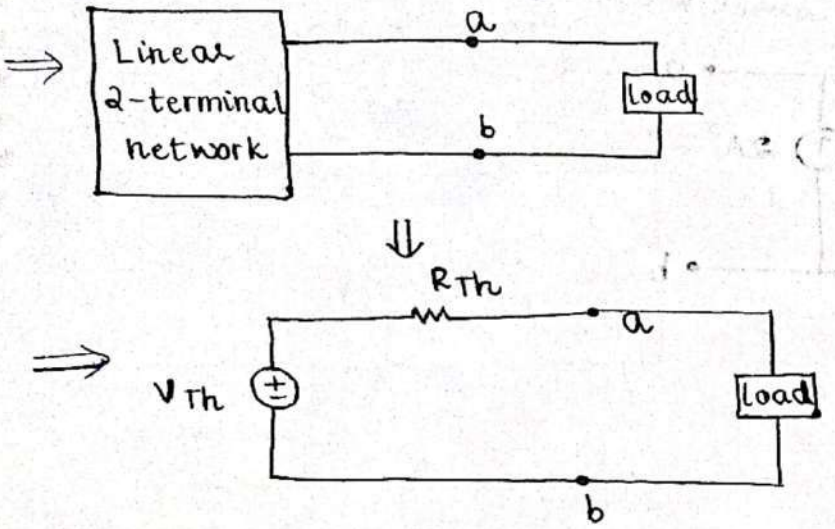
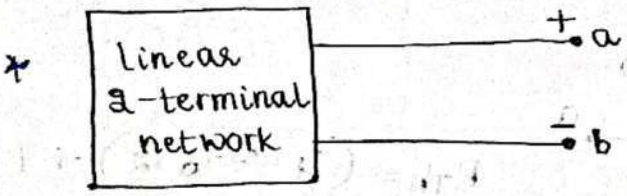
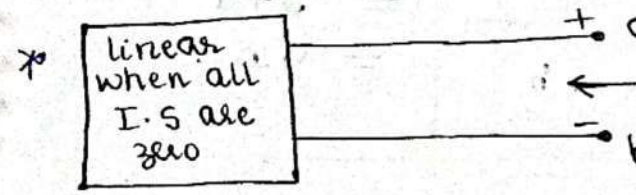
* Thevenin's Theorem :—

It states that any linear two terminal network can be replaced by equivalent circuit that consists voltage source (V_{Th}) in series with the resistance (R_{Th}) where V_{Th} is the open circuit voltage at the terminals & R_{Th} is the equivalent resistance at the terminals when all independent sources are set equal to zero '0'.





$V_{Th} = V_{oc}$



$R_{Th} = R_{eq}$

* Procedure :—

1) Find the V_{Th} at the terminals.
2) Find R_{Th} at the given terminals when I.S are zero.
3) Replacing voltage src with short circuit.
4) Replacing current src with open circuit.
5) Reconnect R_L to the Thevenin's equivalent network.

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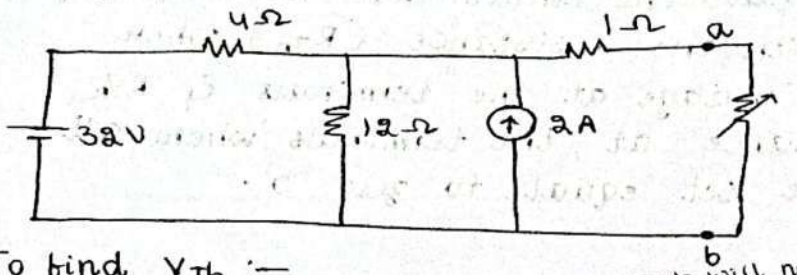
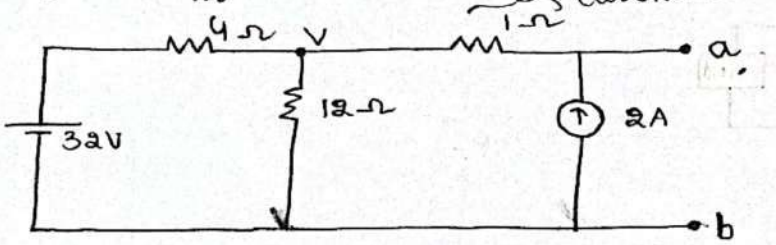
Q1) Find the thevenin's eq circuit. Calculate the current through the load resistance (R_L).



R_L (6, 16, 32) ohms

To find V_{Th} :—

current will not flow coz its open.



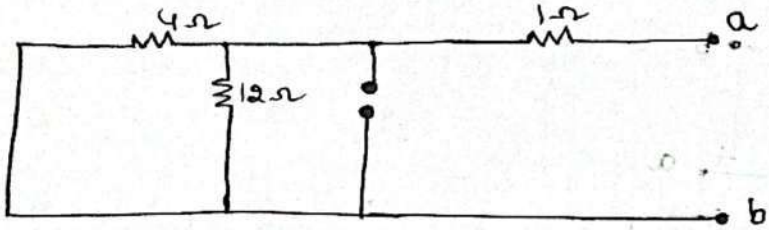
KCL at node V :—

$$\frac{V-32}{4} + \frac{V}{12} - 2 = 0$$

$$\Rightarrow V_{Th} = 30V$$

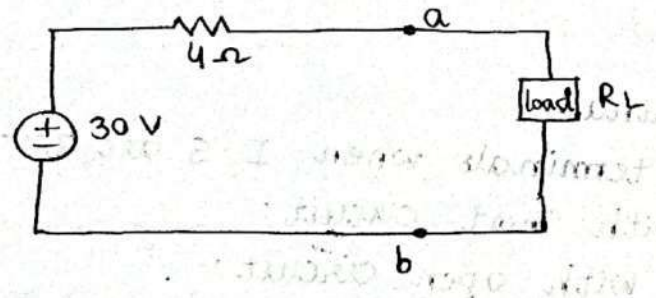
$$V_{Th} = V_{ab} = 30V$$

find R_{Th} :— all I.S set to zero.



$$R_{Th} = (4 \parallel \text{el to } 12) + 1$$
$$= 3 + 1$$
$$= 4\Omega$$

equivalent circuit :—



when $(R_L)_1 = 6\Omega$

$$I_1 = \frac{30}{10} = 3A$$

$(R_L)_2 = 16\Omega$

$$I_2 = \frac{30}{16+4} = 1.5A$$

$(R_L)_3 = 32\Omega$

$$I_3 = \frac{30}{16+32} = 0.83A$$

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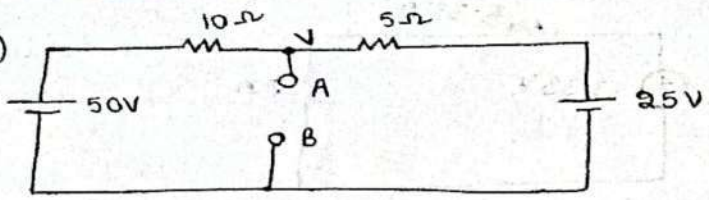
Q2)



Determine thevenin's eq circuit at terminals A & B.

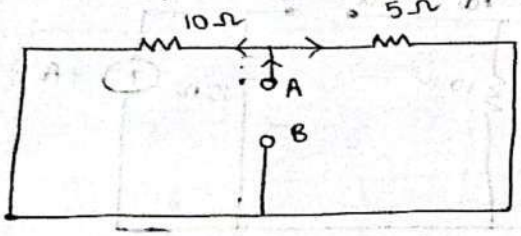
to Find V_{Th} :—

$$\frac{V-25}{5} + \frac{V-50}{10} = 0$$

$$\frac{3V}{10} = 10$$

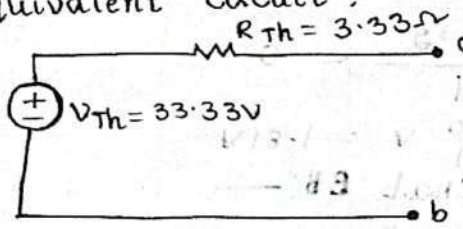
$$V = 33.33V$$

to find R_{Th} :—

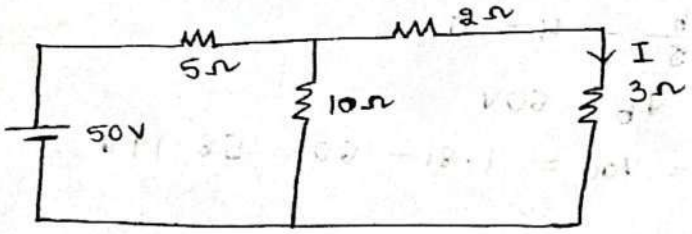


$$\therefore R_{Th} = \frac{10 \times 5}{15} = 3.33\Omega$$

equivalent circuit :—

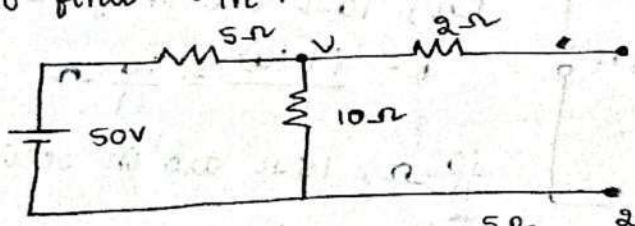


Q3)



$I_{3\Omega} = ?$

to find V_{Th} :—

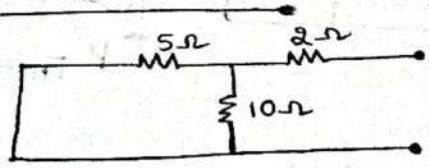


KCL at node V :—

$$\frac{V-50}{5} + \frac{V}{10} = 0$$

$$V_{Th} = 33.33V$$

to find R_{Th} =



$$R_{Th} = \frac{5 \times 10}{15} + 2 = 5.33\Omega$$

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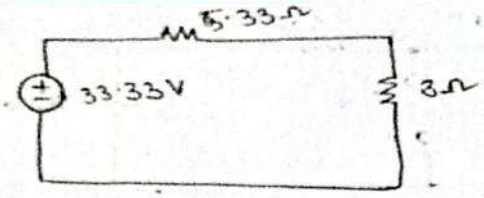
equivalent circuit :—



$$I_{3\Omega} = \frac{33.33}{8.33}$$

$$\therefore I_{3\Omega} = 4A$$

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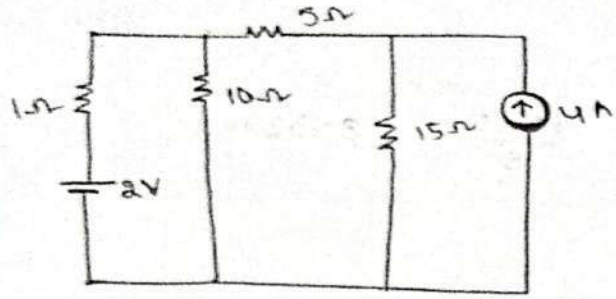
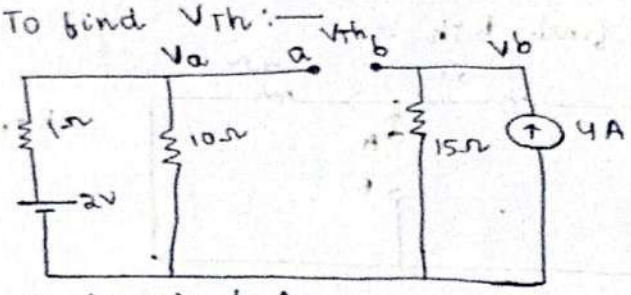
Q4) Find $I_{5\Omega}$.



To find V_{Th} :—



KCL at terminal A :—

$$\frac{V_a}{10} + \frac{V_a - 2}{1} = 0$$

$$V_a = \frac{20}{11} V = 1.81V$$

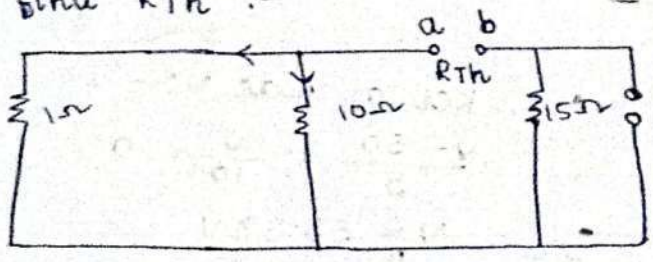
KCL at terminal B :—

$$\frac{V_b}{15} + 4 = 0$$

$$= V_b = 60V$$

$$V_{ab} = V_{Th} = V_{oc} = 1.81 - 60 = 58.19V$$

To find R_{Th} :—



1Ω, 10Ω are in parallel

$$R = \frac{1(10)}{11} = \frac{10}{11}\Omega$$

$\frac{10}{11}\Omega$, 15Ω are in series

$$R_{Th} = 15.9\Omega$$

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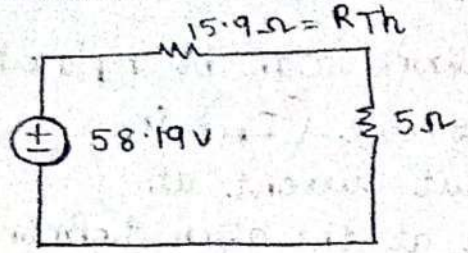
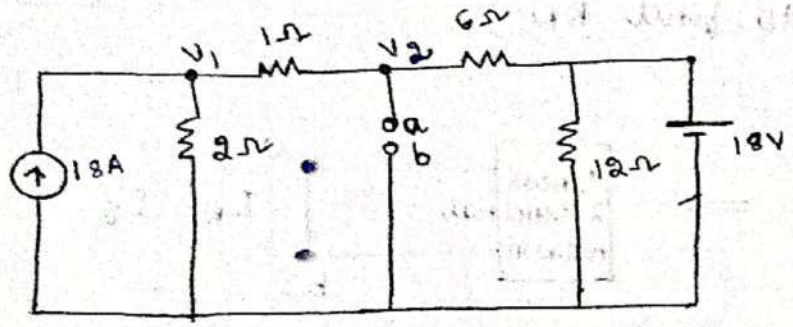
equivalent circuit :—



$$I_{5\Omega} = \frac{58.19}{15.9+5} = 2.78 \text{ A}$$

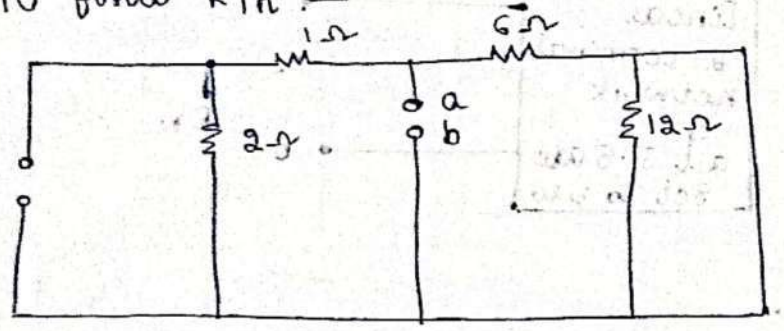
$$I_{5\Omega} = 2.78\text{A}$$

Q5)



Find eq circuit across terminals a & b.

To find R_{Th} :—



2Ω, 1Ω are in series

$R = 3\Omega$ ①

3Ω, 6Ω are in parallel

$R_{Th} = 2\Omega$

doesn't go through 12Ω branch, goes through other plain branch.

To find V_{Th} :—

KCL at node 1 :—

$$\frac{V_1}{2} + \frac{V_1 - V_2}{1} = 18$$

$$\Rightarrow 3V_1 - 2V_2 = 36 \quad \text{—— ①}$$

KCL at node 2 :—

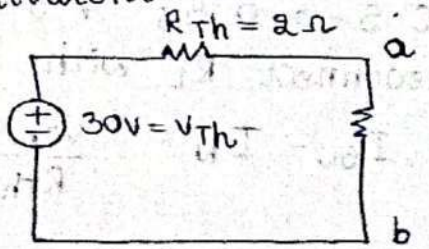
$$\frac{V_2 - V_1}{1} + \frac{V_2 - 18}{6} = 0$$

$$7V_2 - 6V_1 = 18 \quad \text{—— ②}$$

$V_1 = 32$ V

$V_2 = V_{Th} = 30$ V

equivalent circuit :—



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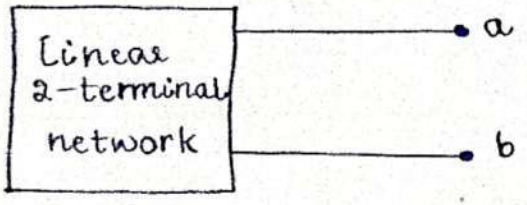
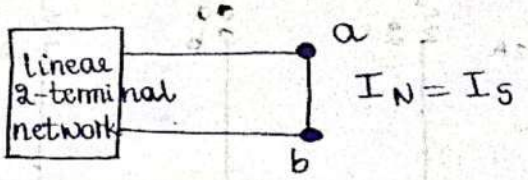
* Norton's Theorem :—

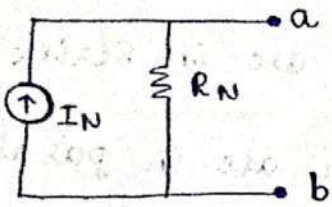
It states that any linear 2-terminal network can be replaced by equivalent circuit consisting of current source (I_N) in parallel with R_N where $I_N \rightarrow$ short circuit current at the given terminals & $R_N \rightarrow$ eq resistance at the given terminals. (when all I.S set to zero to find R_N.).

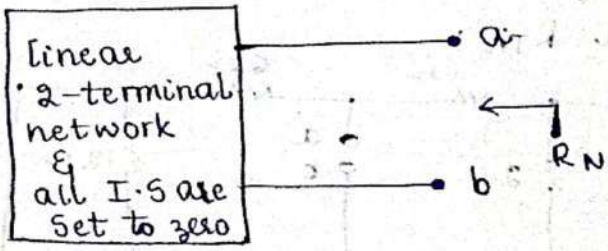


$\Longrightarrow$



$\Downarrow$





* Procedure :—

1) Find $I_N = I_{SC}$
2) Find R_L (all I.S are equal to zero)
3) C.S $\rightarrow$ O.S ; V.S $\rightarrow$ S.S
4) Reconnect R_L with norton's eq circuit.

$$I_{SC} = I_N = \frac{V_{Th}}{R_{Th}}$$

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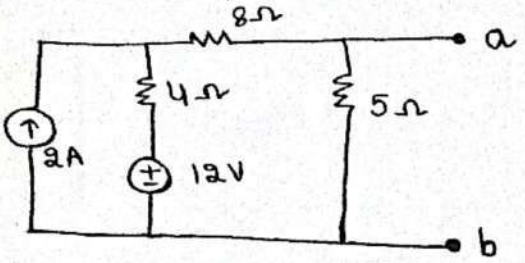
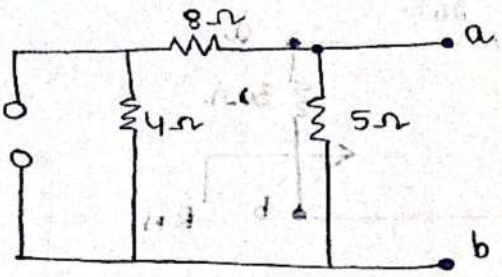
Q1) Find eq circuit.



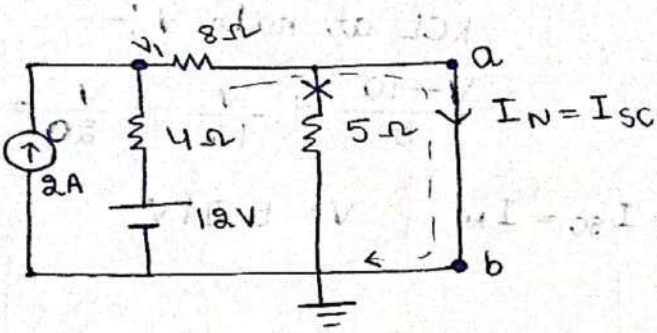
$\Rightarrow$



To find R_N :—

$$R_N = (4+8) \| 5$$
$$= 3.5\Omega$$

To find I_N :—

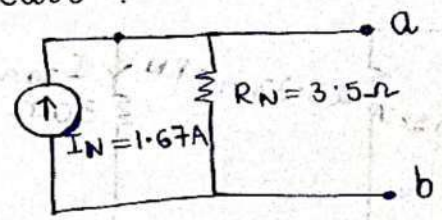


KCL at V_1 :—

$$\frac{V_1 - 12}{4} + (-2) + \frac{V_1}{8} = 0$$
$$V_1 = 13.33\,V = V_{th}$$

$$I_N = \frac{V_1}{R} = \frac{13.33}{8} = 1.67\,A$$

eq circuit :—



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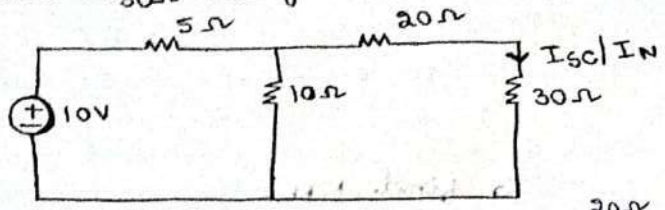
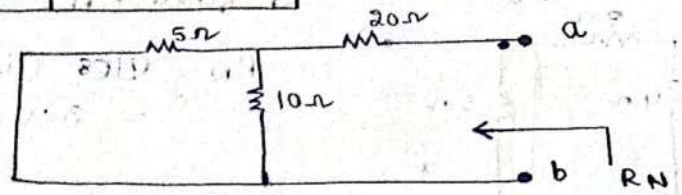
Q2) Find $I_{30\Omega}$ using N.T.

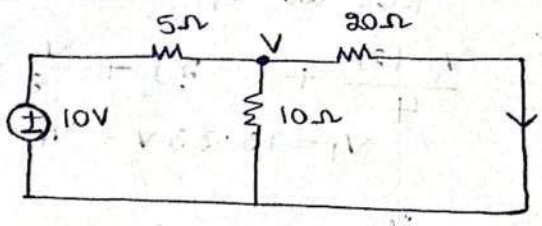


find R_N :—



$$R_N = (5 \| 10) + 20$$
$$= 23.33\Omega$$

find I_N :—

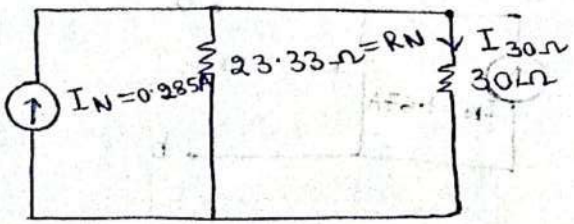


KCL at node V :—

$$\frac{V-10}{5} + \frac{V}{10} + \frac{V}{20} = 0$$

$$V = 5.71V$$

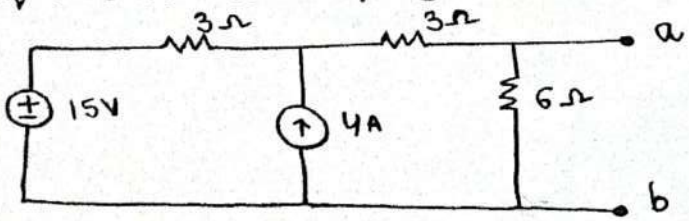
$$I_N = \frac{V}{20} = \frac{57}{20} = 0.285\,A$$



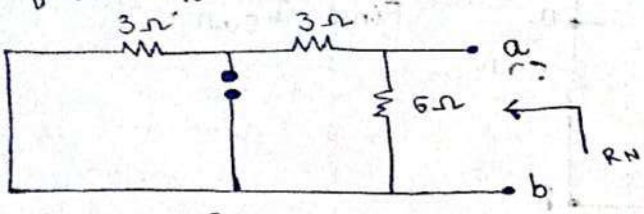
$$I_{30\Omega} = 0.285 \times \frac{23.33}{53.33}$$

$$\Longrightarrow I_{30\Omega} = \underline{\underline{0.12A}}$$

Q3) eq circuit at A & B.

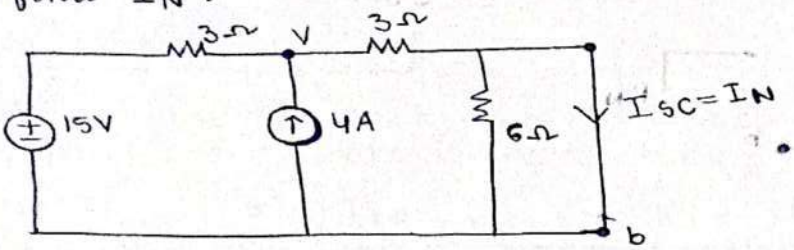


To find R_N :—



$$R_N = (3+3) \parallel 6$$
$$= 3\Omega$$

find I_N :—



KCL at V :—

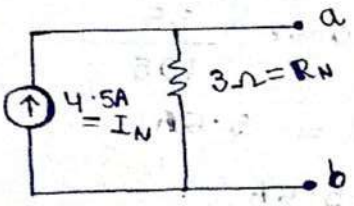
$$\frac{V-15}{3} - 4 + \frac{V}{3} = 0$$

$$\frac{2V}{3} = 9$$

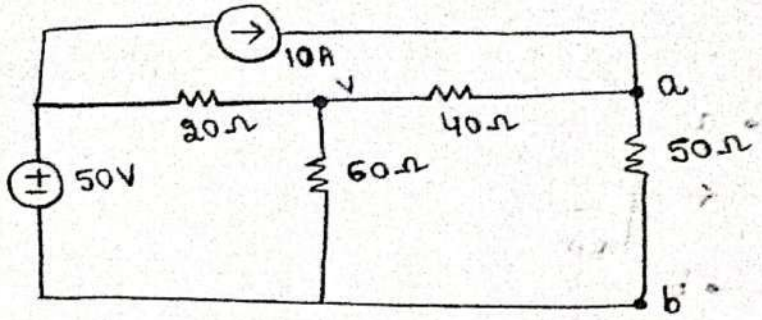
$$V = 13.5V$$

$$I_N = \frac{V}{3} = \frac{13.5}{3} = 4.5A$$

eq circuit :—

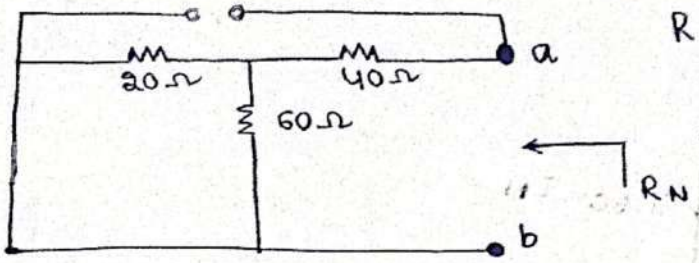


Q4)



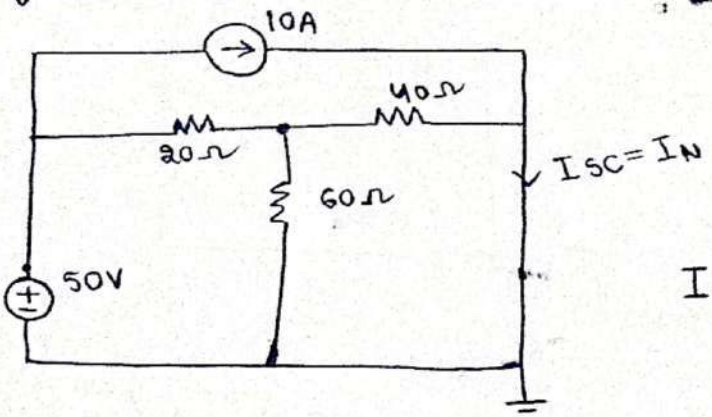
Find $I_{50\Omega}$.

find R_N :—



$$R_N = (20 \| 60) + 40$$
$$= 55\Omega$$

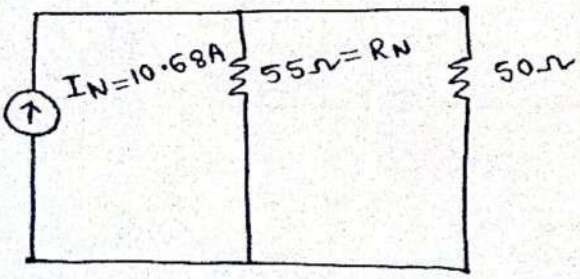
find I_N :—



KCL at node V :—

$$\frac{V}{40} + \frac{V}{60} + \frac{V-50}{20} = 0$$
$$\Rightarrow V = 27.27V$$
$$I_{SC} = I_N = \frac{V}{40} + 10$$
$$= \frac{27.27}{40} + 10$$
$$= 10.68A$$

eq circuit :—



$$I_{50\Omega} = 10.68 \times \frac{55}{105}$$
$$= 5.6A$$

$$\therefore I_{50\Omega} = 5.6A$$

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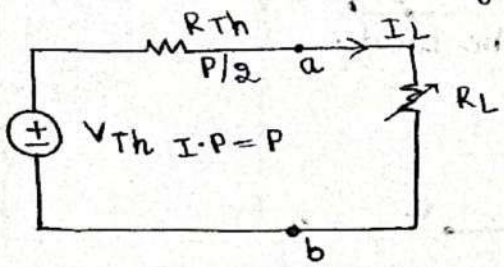
* Maximum Power Transfer Theorem :—

→ Thevenin's eq circuit is used to find the maximum power delivered to the load in a linear circuit.

→ we assume that we can adjust the load resistance R_L.

→ If the entire network is replaced by thevenins eq circuit except R_L as shown in below figure.



Power delivered to the load $(P_L) = I_L^2 R_L$

$$P_L = \frac{(V_{Th})^2}{(R_{Th}+R_L)^2} \times R_L$$

→ To prove the maximum power transfer theorem, differentiate P_L w.r.t R_L and make it equal to 0

$$\Rightarrow V_{Th}^2 \left(\frac{(R_{Th}+R_L)^2 - 2(R_L)(R_{Th}+R_L)}{(R_{Th}+R_L)^4} \right) = 0$$

$$\Rightarrow R_{Th}^2 = R_L^2$$

$$\Rightarrow R_{Th} = R_L$$

→ The maximum power is delivered to load when $R_L = R_{Th}$.

→ $$P_{max} = \frac{(V_{Th})^2}{(R_{Th}+R_{Th})^2} \times R_{Th} = \frac{V_{Th}^2}{4R_{Th}}$$

$$P_{max} = \frac{V_{Th}^2}{4R_{Th}}$$

→ The efficient at max power delivered to the load = 50%

$$\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{P/2}{P} \times 100 = 50\%$$

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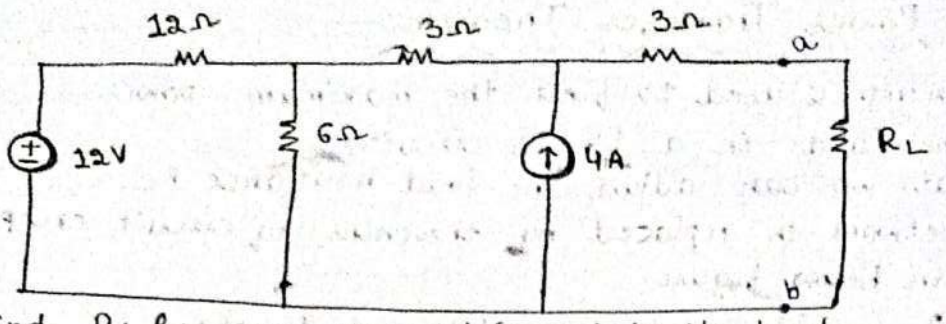
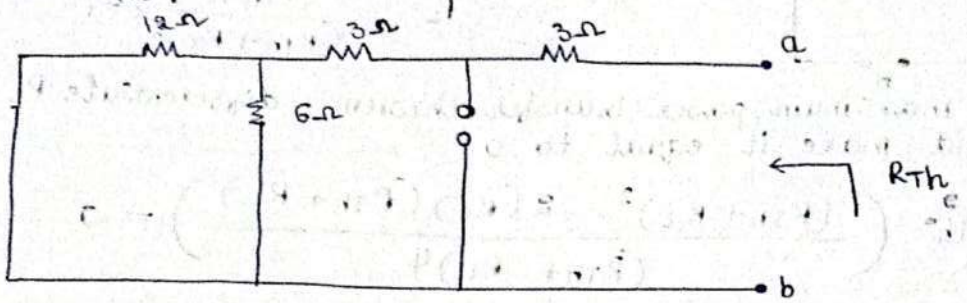
Q1)



Find R_L for max power delivered to the load.
Find P_{max}.

find R_{Th} :—



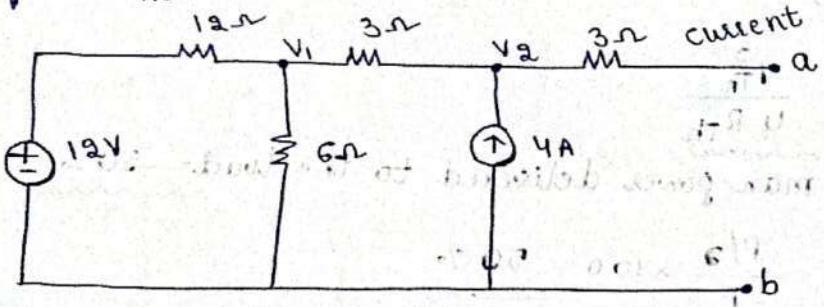
$R_{Th} = ?$

$$= (3+3) + \left(\frac{6 \times 12}{6+12}\right)$$

$$= 6 + 4$$

$$= 10\Omega = R_L \text{ (as power max).}$$

find V_{Th} :—



current doesn't flow coz open circuit.

KCL at V_1 :— $\frac{V_1 - 12}{12} + \frac{V_1}{6} + \frac{V_1 - V_2}{3} = 0$

$$\frac{7V_1}{12} - \frac{V_2}{3} = 1 \implies 7V_1 - 4V_2 = 12 \quad \text{—— (1)}$$

KCL at V_2 :— $\frac{V_2 - V_1}{3} + (-4) = 0 \implies$

$$V_2 - V_1 = 12 \quad \text{—— (2)}$$

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$V_1 = 20V$

$V_2 = 32V = V_{Th}$

$\therefore P_{max} = \dfrac{(V_{Th})^2}{4 \times R_{Th}} = \dfrac{32 \times 32}{4 \times 10} = 25.6W$

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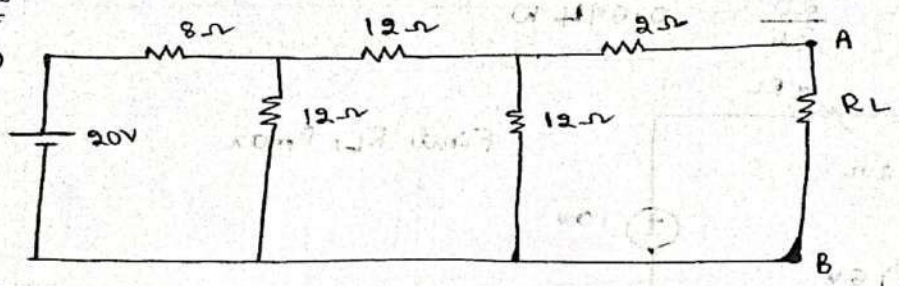
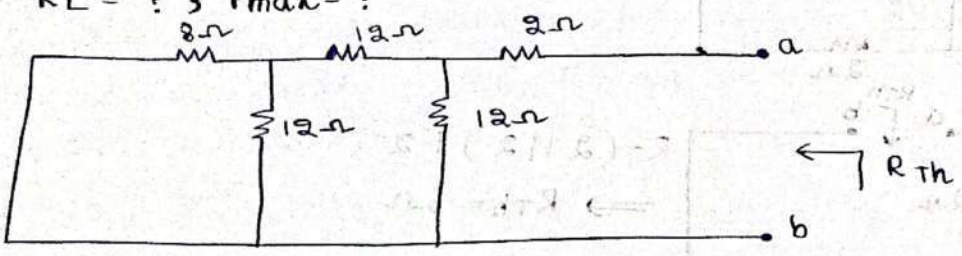
Q2)



$R_L = ?$, $P_{max} = ?$



8Ω, 12Ω are in parallel

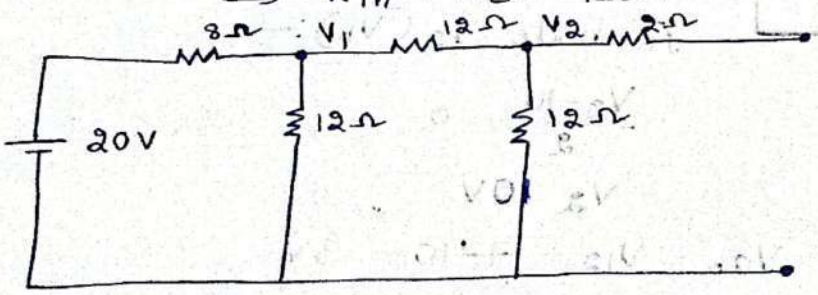
$R = \dfrac{8 \times 12}{8+12} = 4.8\Omega$

4.8Ω, 12Ω are in series, $R = 16.8\Omega$

16.8Ω, 12Ω are in parallel, $R = \dfrac{16.8 \times 12}{28.8} = 7\Omega$

7Ω, 2Ω are in series

$\Rightarrow R_{Th} = R_L = 9\Omega$.



At V_1,

$\dfrac{V_1 - V_2}{12} + \dfrac{V_1}{12} + \dfrac{V_1 - 20}{8} = 0$

$\Rightarrow 2V_1 - V_2 = 30$ —— (1)

At V_2,

$\dfrac{V_2}{12} + \dfrac{V_2 - V_1}{12} = 0$

$\Rightarrow V_1 - 2V_2 = 0$ —— (2)

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

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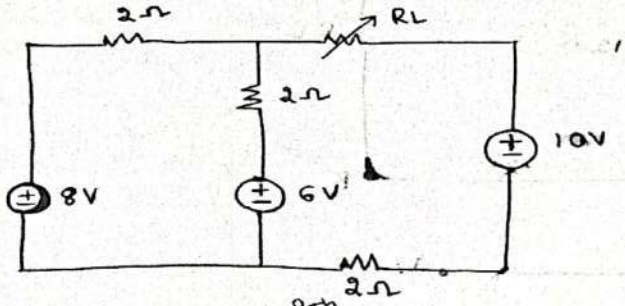
$V_1 = 10V$

$V_2 = V_{Th} = 5V$

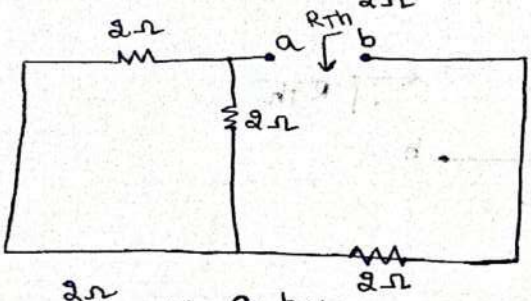
$$P_{max} = \frac{V_{Th}^2}{4 \times R_{Th}} = \frac{10 \times 10}{4(9) \times 4}$$

$$\therefore P_{max} = \frac{25}{36} = 0.694\ W$$

Q3)

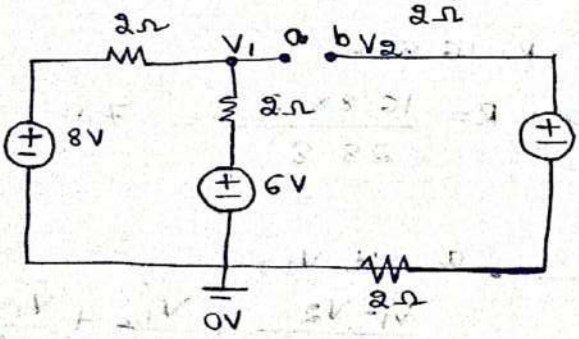


Find R_L, P_{max}



$R = (2 \| 2) + 2$

$\Longrightarrow R_{Th} = 3\Omega$



KCL At node V_1 (V_a):—

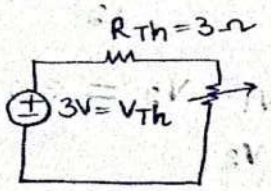
$$\frac{V_1 - 8}{2} + \frac{V_1 - 6}{2} = 0$$

$V_1 = 7V$

At node V_2 (V_b):—

$$\frac{V_2 - 10}{2} = 0$$

$V_2 = 10V$



$V_{ab} = V_{12} = 7 - 10 = 3V$

$V_{Th} = 3V$

$$\therefore P_{max} = \frac{3 \times 3}{4(3)} = 0.75W$$

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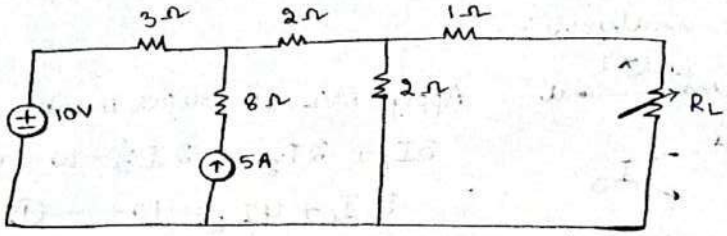
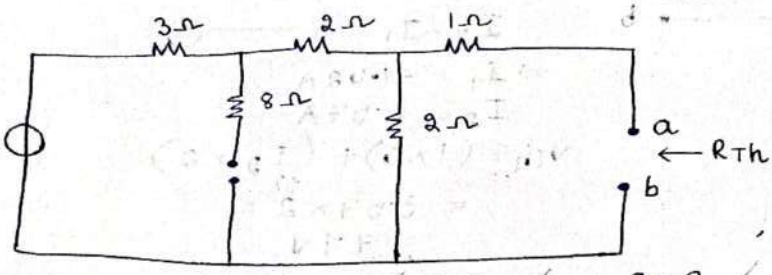
Q4)



Find R_L & P_{max}.



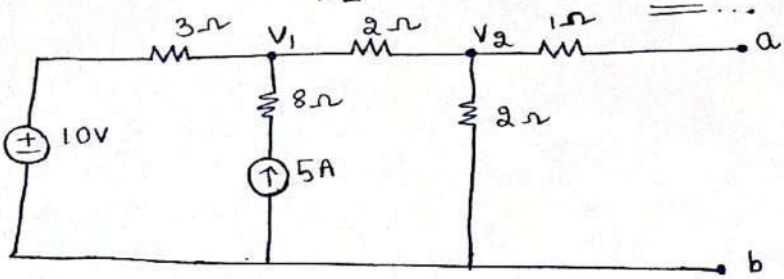
3Ω, 8Ω are in parallel, $R = \frac{3\times 8}{11} = \frac{24}{11}\Omega$

3Ω, 2Ω are in series, $R = 3+2 = 5\Omega$

5Ω, 2Ω are in series, $R = \frac{10}{7}\Omega$

$\frac{10}{7}\Omega$, 1Ω are in series, $R = \frac{10}{7}+1 = \frac{17}{7}$

$$R_L = R_{Th} = 2.43\Omega$$



V_1 :-

$$\frac{V_1 - V_2}{2} + \frac{V_1 - 10}{3} - 5 = 0$$

V_2 :-

$$\frac{V_2}{2} + \frac{V_2 - V_1}{2} = 0$$

$V_1 = 14.2V$, $V_2 = 7.1V$

$$V_2 = V_{Th} = 7.1V$$

$$\therefore P_{max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{(7.1)^2}{4\times 2.4} = 5.2W$$

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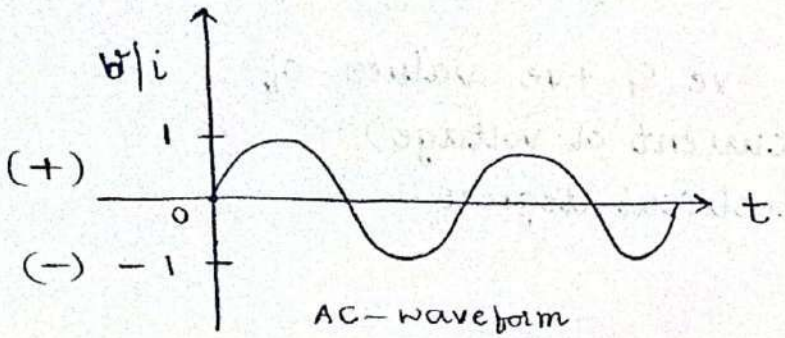
UNIT-3
AC CIRCUITS



AC-waveform

1) AC current is the current which constantly changes its magnitude (amplitude) & reverses polarities regular intervals of time.

2) Because the changes are so regular, the alternating current or voltage have a no. of properties associated with such a waveform.

Basic Properties (AC Terminology):-

1). Alternating voltage :-

It is the voltage which varies magnitude as well as polarity at regular intervals of time.

represented with

$$V = V_m \sin(\omega t).$$

2) Alternating current :-

It is the current which varies magnitude as well as polarity at regular intervals of time.

$$i = i_m \sin(\omega t).$$

3) Frequency (f) :- 50 Hz

no. of cycles that occur in one second.

$$= \frac{\text{no. of cycles}}{\text{sec}} \ (Hz)$$

= reciprocal of time period = $\frac{1}{T}$

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4) Time Period (T):-

Time required (in secs), to complete one cycle.

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

5) Cycle :-

It is the combination of -ve & +ve values of alternating quantity (current or voltage)

one cycle span = 360 electrical degrees.

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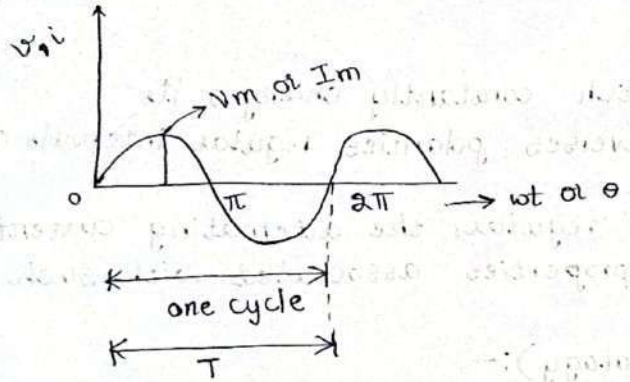
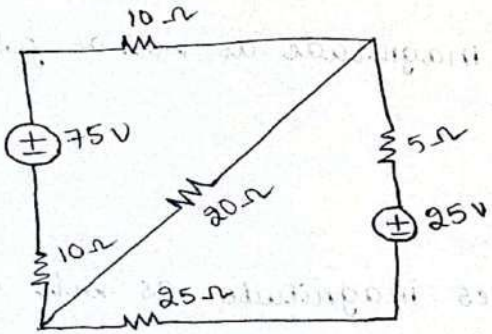


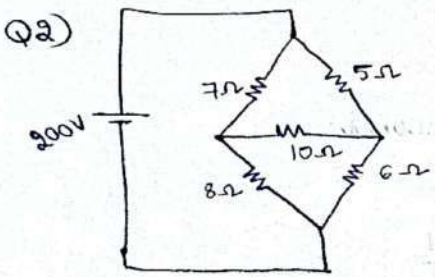
Q1)



Find $I_{20\Omega}$ using S.P.T, T.T, N.T

$I = 1.71A$

Q2)



Find $I_{10\Omega}$ using T.T & N.T.

Ans :- 0.147 A

Q1) 25Ω, 5Ω are in parallel

$R = 30\Omega$

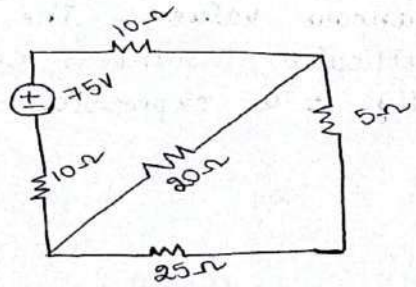
$$R = \left(\frac{30 \times 20}{30 + 20}\right) + 10$$

$$= 12 + 10 = 22\Omega$$

$$I_T = \frac{V}{R} = \frac{75}{22} =$$

$$I_1 = \frac{75}{22} \times \frac{30}{50}$$

$$= \frac{45}{22} =$$



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Instantaneous value :— The value of voltage or current at particular instant is called instantaneous value. Generally it is expressed in same alphabet.

Wave Form :— The shape of wave is obtained by plotting the instantaneous values of either voltage & current as ordinate aganist to time is called wave form.

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Amplitude / max value / peak value :—

The max value obtained by voltage or current

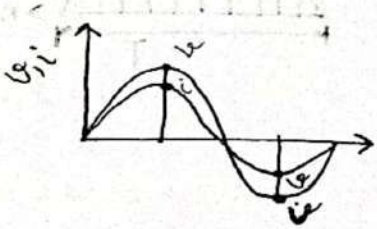
peak to peak value :— (V_{PP} / I_{PP})

The max variation b/w the max +ve & max -ve instantaneous value is called peak to peak value.

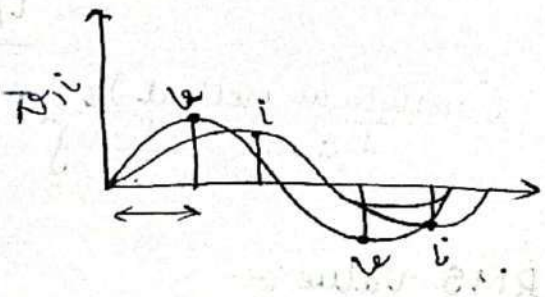
For pure sinusoidal wave form, peak to peak value is $2V_m$ or $2I_m$.

Phase :— The angular measure of alternating quantity is called phase.

i) In-phase :— When 2 alternating quantities reaching their max & min values simultaneously. These quantities are said to be in-phase.



ii) Out-of-phase :— When 2 alternating quantities do not reach max & min values simultaneously. They are said to be out of phase.



Angular displacement b/w 2 alternating quantities is called phase difference.

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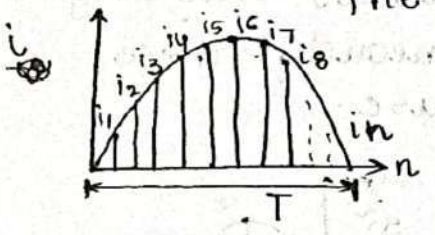
Angular frequency :- (ω)

The no. of radians ~~occu~~ occurred in one sec.
measured in radians/sec.

$\because$ 2π radians covered in one cycle, there are 'f' cycles ~~to~~ occuring in one sec $\Longrightarrow$ $\omega = 2\pi f$

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

Average value :-



The Arithmetic average of all instantaneous values of voltage or current over a cycle is called average value. It can be calculated using graphical or analytical method.

$$I_{avg} = \frac{\text{Area under one alteration}}{\text{base length}}$$

Let $i_1, i_2, i_3, \ldots i_n$ be mid ordinates

$$I_{avg} = \text{mean of mid ordinates}$$

$$= \frac{i_1 + i_2 + \cdots + i_n}{n}$$

(analytical method) :

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

Note:- 1) For symmetrical wave form avg value is calculated only for positive half cycle.

2) for unsymmetrical wave form, for full cycle.

RMS Value :-

RMS value of alternating quantity is defined as the steady current (DC) which when flowing through the given resistance per given time produces same amount of heat as that of AC current production, when flowing through a same resistance for same time.

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Heat produced by AC current = Heat produced by DC current.

$H_{DC} = H_{AC}$.

It is defined as the square root of mean of ~~RMS~~ square of instantaneous values.

$$RMS = \sqrt{\text{Mean of square of inst. values}}$$

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

analytical method

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt}$$

(*) Form Factor :— (F.F)

It is the ratio of RMS value to average value.

(*) Peak Factor :— (P.F)

It is the ratio of maximum value to RMS value.

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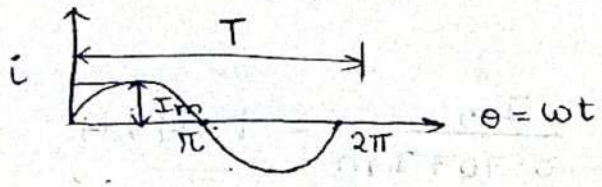
(*) Derive Average, RMS, F.F & P.F for a Sinusoidal wave form :—



Let us consider maximum value of current for a given sinusoidal wave form, is $I_m = I_{max}$

Average value :—

average value → half cycle

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

$\Rightarrow T = \pi$

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} I_m \sin(\omega t)\,d\omega t = -\frac{I_m}{\pi}\left[\cos(\omega t)\right]_0^{\pi}$$

$$= \frac{2I_m}{\pi}$$

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$$= 0.636\, I_m$$

RMS value :—

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T i^2\, dt}$$

$$I_{RMS}^2 = \frac{1}{T}\int_0^T i^2\, dt$$

$$T = 2\pi$$

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

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

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

$$= \frac{I_m^2}{2}$$

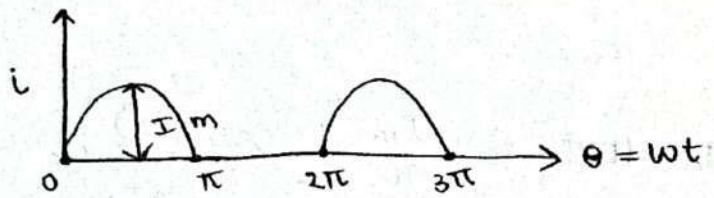
$$I_{RMS} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m$$

$$\text{Form factor} = \frac{\text{R.M.S value}}{\text{Average value}} = \frac{0.707\, I_m}{0.636\, I_m}$$

$$= 1.11$$

$$\text{peak factor} = \frac{\text{Max value}}{\text{RMS value}} = \frac{I_m}{0.707\, I_m} = 1.414$$

* Derive average, RMS, F.F, P.F of a half-wave rectifier output.



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$(I_m = I_{max})$

Average value :—

$$I_{avg} = \frac{1}{T}\int_0^T i \cdot dt$$

$T = 2\pi$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\omega t \, d\omega t + \int_{\pi}^{2\pi} 0 \cdot d\omega t\right]$$

$$= \frac{I_m}{2\pi}\left[-\cos\omega t\right]_0^{\pi}$$

$$= \frac{2I_m}{2\pi} = \frac{I_m}{\pi} = \underline{\underline{0.318\, I_m}}$$

R.M.S value :—

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T i^2 \cdot dt}$$

$T = 2\pi$

$$I_{RMS}^2 = \frac{1}{2\pi}\left[\int_0^{\pi} (I_m \sin(\omega t))^2 + \int_{\pi}^{2\pi} 0^2 \, d\omega t\right]$$

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

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

$$I_{RMS}^2 = \frac{I_m^2}{4}$$

$$\Rightarrow I_{RMS} = \underline{\underline{\frac{I_m}{2}}}$$

$$F.F = \frac{R.M.S}{avg} = \frac{\frac{I_m}{2}}{\frac{I_m}{\pi}} = \frac{\pi}{2} = \underline{\underline{1.57}}$$

$$P.F = \frac{max}{R.M.S} = \frac{I_m}{\frac{I_m}{2}} = \underline{\underline{2}}$$

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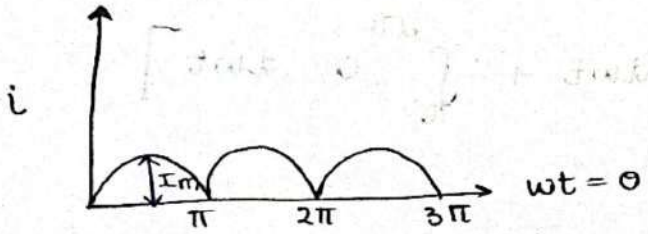
* Derive RMS, average, F.F & P.F for a full wave rectifier output.



Unsymmetric wave form.

Average value:—

$$I_{avg} = \frac{1}{T}\int_0^T i\,dt$$

$$T = \pi$$

$$= \frac{1}{\pi}\int_0^{\pi} I_m \sin wt \, dwt$$

$$= \frac{2I_m}{\pi} = 0.636 I_m$$

RMS value:—

$$I_{RMS}^2 = \frac{1}{T}\int_0^T i^2\,dt$$

$$T = \pi$$

$$= \frac{1}{\pi}\int_0^{\pi} (I_m \sin wt)^2\, dwt$$

$$= \frac{I_m^2}{\pi}\left[\left(\frac{1-\cos 2wt}{2}\right)\right]_0^{\pi}$$

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

$$= \frac{I_m^2}{2}$$

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

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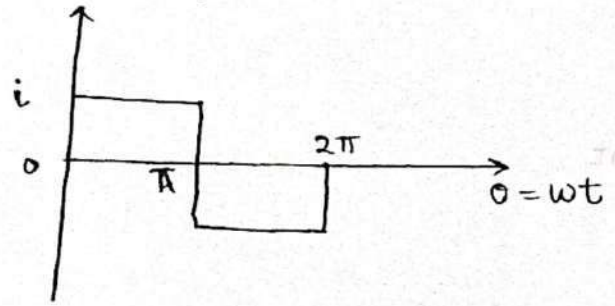
$$F \cdot F = \frac{R \cdot M \cdot S}{avg} = \frac{I_m/\sqrt{2}}{\frac{2 I_m}{\pi}} = \underline{\underline{1.11}}$$

$$P \cdot F = \frac{I_m}{R \cdot M \cdot S} = \frac{I_m}{0.707 I_m} = \underline{\underline{1.414}}$$

* Derive average, R·M·S, F·F, P·F :—



Let us consider $I_{max} = I_m$

average value:-

$$I_{avg} = \frac{1}{T} \int_0^T i \cdot dt$$

$T = \pi$

$$= \frac{1}{\pi} \int_0^{\pi} I_m \cdot d\theta$$

$$= \frac{I_m}{\pi} [\theta]_0^{\pi}$$

$$= \underline{\underline{I_m}}$$

R·M·S value :—

$$I_{RMS}^2 = \frac{1}{T} \int_0^T i^2 \cdot dt$$

$$= \frac{1}{\pi} \int_0^{\pi} I_m^2 \, d\theta$$

$$= \frac{I_m^2}{\pi} [\theta]_0^{\pi} = I_m^2$$

$$I_{RMS} = \underline{\underline{I_m}}$$

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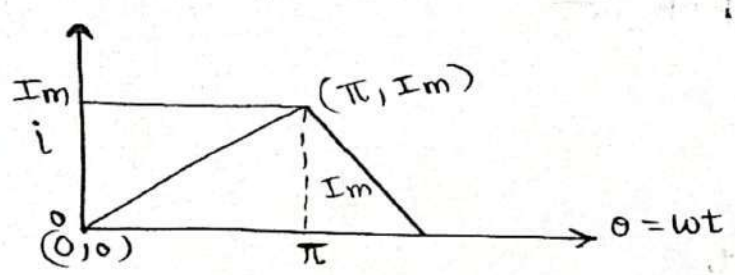
$$F \cdot F = \frac{R.M.S}{avg} = \frac{I_m}{I_m} = 1$$

$$P \cdot F = \frac{max}{R.M.S} = \frac{I_m}{I_m} = 1$$

* Derive average, R.M.S, F.F & P.F :—



$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_1 - x_2}$$

$$y = i, \quad x = \theta \implies \frac{i - 0}{\theta - 0} = \frac{0 - I_m}{0 - \pi}$$

$$i = \frac{I_m}{\pi}(\theta).$$

Average value :—

$$I_{avg} = \frac{1}{T}\int_0^T i \cdot dt$$

$$= \frac{1}{\pi}\int_0^{\pi} \left(\frac{I_m}{\pi} \cdot \theta\right) dt \qquad T = \pi$$

$$= \frac{I_m}{\pi^2}\left[\frac{\theta^2}{2}\right]_0^{\pi} = \frac{I_m}{\pi^2} \times \frac{\pi^2}{2} = \frac{I_m}{2}$$

R.M.S value :—

$$I_{RMS}^2 = \frac{1}{T}\int_0^T i^2\, dt$$

$$= \frac{1}{\pi}\int_0^{\pi} \left(\frac{I_m}{\pi}\theta\right)^2 dt \qquad T = \pi$$

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$$= \frac{I_m^2}{\pi^3} \left[\frac{\theta^3}{3} \right]_0^{\pi}$$

$$= \frac{I_m^2}{3}$$

$$I_{RMS} = \frac{I_m}{\sqrt{3}}$$

$$F \cdot F = \frac{R \cdot M \cdot S}{avg} = \frac{\frac{I_m}{\sqrt{3}}}{\frac{I_m}{2}} = \frac{2}{\sqrt{3}} = \underline{\underline{1.154}} \ldots$$

$$P \cdot F = \frac{max}{R \cdot M \cdot S} = \frac{I_m}{\frac{I_m}{\sqrt{3}}} = \sqrt{3} = \underline{\underline{1.732}} \ldots$$

Q1)

An alternating current is given by $i = 141.4 \sin(314t)$ then find max value, Time period, frequency, instantaneous value at 3 milliseconds (time).

Sol:- ② $\omega = 314$

$$T = \frac{2\pi}{\omega} = \frac{2(3.14)}{314}$$

$$= \underline{\underline{0.02}} \text{ secs.}$$

① $I = I_m \sin \omega t$

$$\Rightarrow I_m = \underline{\underline{141.4}} \text{ A}$$

③ $\text{frequency} = \frac{1}{T} = \frac{1}{0.02} = \underline{\underline{50}} \text{ Hz}$

④ $i = I_m \sin \omega t$

$$= 141.4 \times \sin(314) \times 3 \times 10^{-3}$$

$$= 141.4 \times 0.0164$$

$$= \underline{\underline{2.324}} \text{ A}$$

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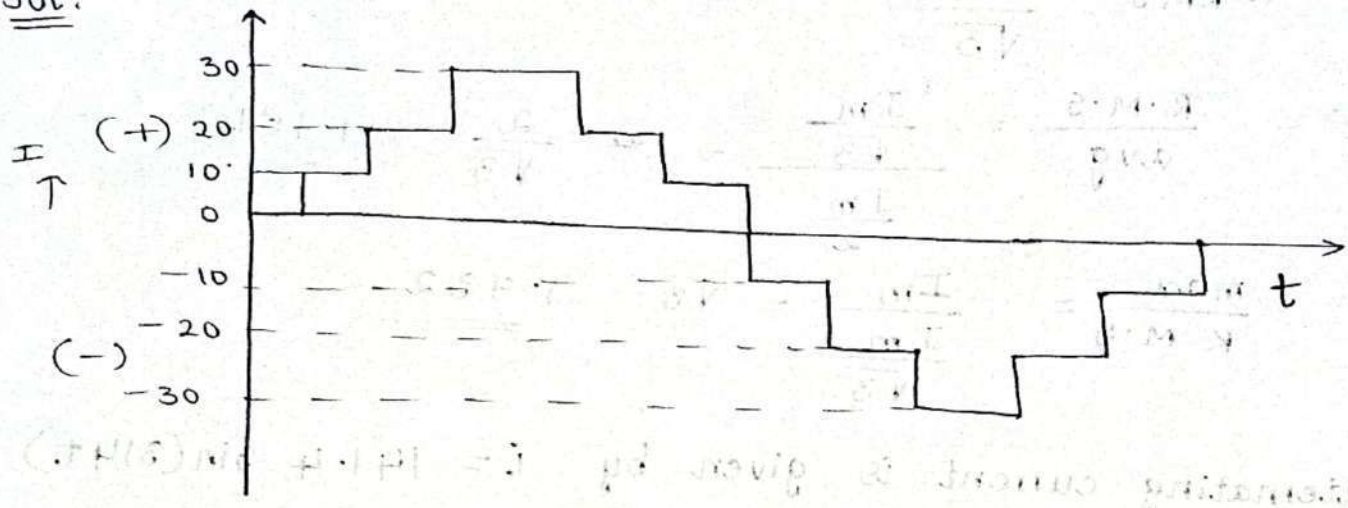
Q2) A current has the following steady values in Amperes in equal interval of time changing instantaneously from one value to the next, 0, 10, 20, 30, 20, 10, 0, −10, −20, −30, −20, −10, 0, etc. Calculate avg value, R·M·S value, F·F, P·F.

* Sol:-



$$I_{avg} = \frac{0+10+20+30+20+10}{6}$$

$$= \frac{90}{6} = \underline{\underline{15\,A}}$$

$$I_{RMS} = \sqrt{\frac{i_2^2 + i_2^2 + i_3^2 + i_4^2 + i_5^2 + i_6^2}{n}}$$

$$= \sqrt{\frac{0^2+10^2+20^2+30^2+20^2+10^2}{6}}$$

$$= \underline{\underline{17.7\,A}}$$

$$F \cdot F = \frac{I_{R \cdot M \cdot S}}{I_{avg}} = \frac{17.7}{15} = \underline{\underline{1.18}}$$

$$P \cdot F = \frac{I_{max}}{I_{R \cdot M \cdot S}} = \frac{30}{17.7} = \underline{\underline{1.69}}$$

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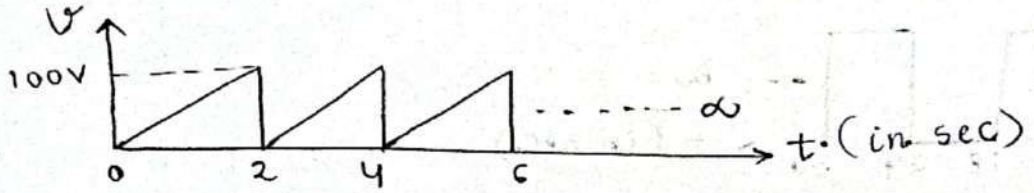
Q3) Calculate avg, R.M.S, F.F & P.F.



Sol:- slope ⇒ $\frac{y-y_1}{x-x_1} = \frac{y_2-y_1}{x_1-x_2} \Rightarrow \frac{V}{t} = \frac{100}{2} \Rightarrow V = 50t$

$$V_{avg} = \frac{1}{T}\int_0^T v \cdot dt$$

$$V = 50t \quad \text{for} \quad 0 < t < 2$$

$$V_{avg} = \frac{1}{2}\int_0^2 50t\, dt$$

$$= \frac{1}{2}\left[25t^2\right]_0^2$$

$$= \frac{100}{2} = \underline{\underline{50V}}$$

$$V^2_{R.M.S} = \frac{1}{T}\int_0^T v^2 \cdot dt$$

$$= \frac{1}{2}\int_0^2 (50t)^2\, dt$$

$$= \frac{1}{2}\int_0^2 2500t^2\, dt$$

$$= \frac{2500}{2}\left[\frac{t^3}{3}\right]_0^2$$

$$= \underline{\underline{57.73V}}$$

$$F.F = \frac{V_{RMS}}{V_{avg}} = \frac{57.73}{50} = \underline{\underline{1.15}}$$

$$P.F = \frac{V_{max}}{V_{R.M.S}} = \frac{100}{57.73} = \underline{\underline{1.73}}$$

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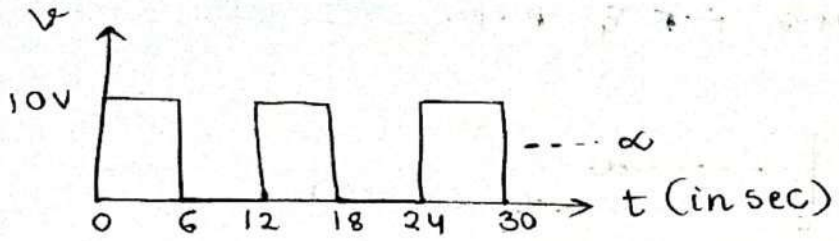
Q4)



Calculate. Vavg, V_{RMS}, F.F, P.F.

$$V(t) = \begin{cases} 10\,V & 0 < t < 6 \\ 0\,V & 6 < t < 12 \end{cases}$$

~~$0 < t < 6$~~ $\cancel{\frac{V}{t} = \frac{10}{6} = \frac{5}{3} \Rightarrow V = \frac{5}{3}t}$

~~$6 < t < 12$~~ $\cancel{\frac{V}{t} = \frac{0}{t} = 0 \Rightarrow V = 0}$

$$V_{avg} = \frac{1}{T}\int_0^T v \cdot dt$$

$$= \frac{1}{12}\int_0^{12} v \cdot dt = \frac{1}{12}\left[\int_0^6 10 \cdot dt + \int_6^{12} 0 \cdot dt\right]$$

$$= \frac{1}{12}\left[10\,t\right]_0^6$$

$$= \frac{1}{12} \times 10 \times 6$$

$$V_{avg} = 5 = \underline{\underline{5\,V}}$$

$$V_{RMS}^2 = \frac{1}{T}\int_0^T v^2\,dt = \frac{1}{12}\int_0^{12} v^2 \cdot dt = \frac{1}{12}\left[\int_0^6 (10)^2 dt + \int_6^{12} (0)^2 dt\right]$$

$$= \frac{1}{12}\left[100\,t\right]_0^6 = \frac{1}{12} \times 100 \times 6$$

$$V_{RMS}^2 = 50V$$

$$V_{RMS} = 7.07V$$

$$F \cdot F = \frac{V_{RMS}}{V_{avg}} = \cancel{\frac{16.67}{2.5} = 6.668} = \frac{7.07}{5} = 1.414$$

$$P \cdot F = \frac{V_{max}}{V_{RMS}} = \frac{10}{7.07} = \underline{\underline{1.414}}$$

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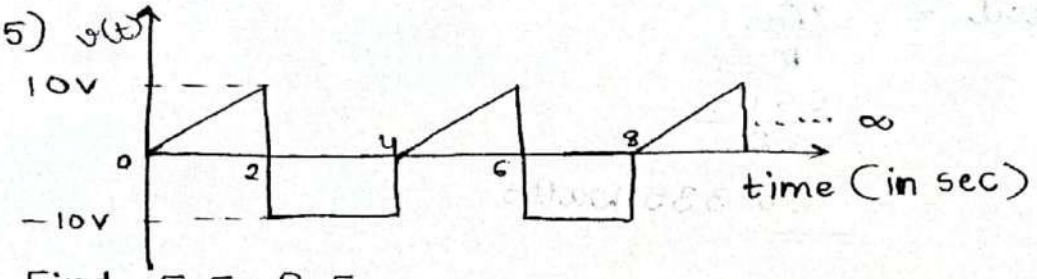
Q5)



Find F.F, P.F.
If the current is passing through a 2-Ω resistor. Find power dissipated by the resistor.

$$v(t) = \begin{cases} 5t & 0<t<2 \\ -10 & 2<t<4 \end{cases}$$

$$V_{avg} = \frac{1}{T}\int_0^T v \cdot dt$$

$$= \frac{1}{4}\left[\int_0^2 5t \cdot dt + \int_2^4 -10\, dt\right]$$

$$= \frac{1}{4}\left[\left[\frac{5t^2}{2}\right]_0^2 + \left[-10t\right]_2^4\right]$$

$$= \frac{1}{4}\left[10 + (-40+20)\right]$$

$$V_{avg} = \cancel{\frac{30}{4} = 7.5V} \; \underline{\underline{2.5\,V}}$$

$$V_{RMS}^2 = \frac{1}{T}\int_0^T v^2\, dt$$

$$= \frac{1}{4}\left[\int_0^2 (5t)^2 dt + \int_2^4 (-10)^2 dt\right]$$

$$= \frac{1}{4}\left[\left[\frac{25t^3}{3}\right]_0^2 + \left[400-200\right]\right]$$

$$= \frac{1}{4}\left[66.67 + 200\right] = \frac{266.67}{4} = 66.67$$

$$V_{RMS} = \underline{\underline{8.165\,V}}$$

$$F.F = \frac{V_{RMS}}{V_{avg}} = \underline{\underline{3.266}} \; ; \quad P.F = \frac{V_{max}}{V_{RMS}} = \frac{10}{8.165} = \underline{\underline{1.224}}$$

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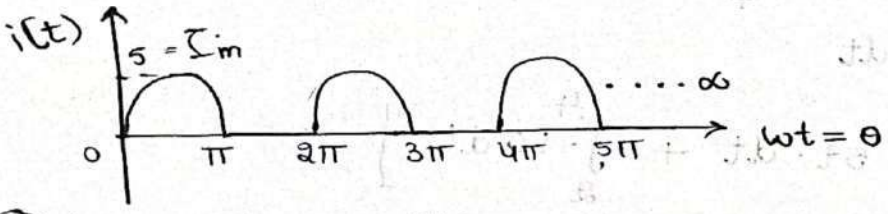
power dissipated $= \frac{V_{RMS}^2}{R}$

$= \frac{66.67}{2}$

$\therefore P = 33.335$ watts

$i = \frac{V_{RMS}}{R} = \frac{8.165}{2} = 4.08A$

Q6) Determine P.F, F.F.



(*) half-wave rectifier.

$I_m = 5A$

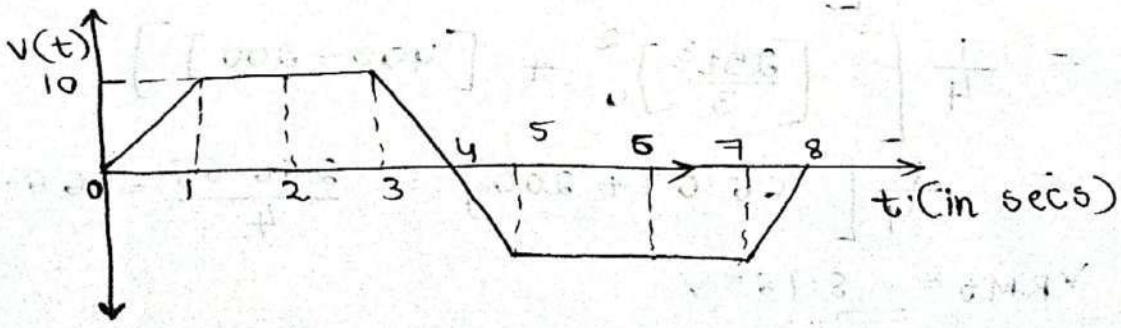
$I_{avg} = \frac{5}{\pi} = 1.59 A$

$I_{RMS} = \frac{I_m}{2} = \frac{5}{2} = 2.5 A$

P.F = 2 (I_M / I_{RMS})

F.F = 1.57 (I_{RMS} / I_{avg})

Q7) Find V_{RMS}, P.F, F.F.



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$$V(t) = \begin{cases} 10t & \text{for } 0 < t < 1 \\ 10 & \text{for } 1 < t < 2 \end{cases} \qquad \frac{V}{t} = \frac{0 - 10}{0 - 1}$$

$$\Rightarrow V = 10t$$

$$V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{2}\left[\int_0^1 10t \cdot dt + \int_1^2 10\,dt\right]$$

$$= \frac{1}{2}\left[\left[5t^2\right]_0^1 + \left[10t\right]_1^2\right]$$

$$= \frac{1}{2}\left[5 + 10\right]$$

$$= \underline{\underline{7.5V}}$$

$$V_{RMS}^2 = \frac{1}{T}\int_0^T v^2(t)\,dt$$

$$= \frac{1}{2}\left[\int_0^1 (10t)^2\,dt + \int_1^2 100\,dt\right]$$

$$= \frac{1}{2} \times 100\left[\left[\frac{t^3}{3}\right]_0^1 + \left[t\right]_1^2\right]$$

$$= \frac{100 \times 4}{6} = 33.33 \times 2 = 66.66$$

$$\Rightarrow V_{RMS} = \underline{\underline{8.16}}\,V$$

$$P \cdot F = \frac{V_{max}}{V_{RMS}} = \frac{10}{8.16} = \underline{\underline{1.225}}$$

$$F \cdot F = \frac{V_{RMS}}{V_{avg}} = \frac{8.16}{7.5} = \underline{\underline{1.088}}$$

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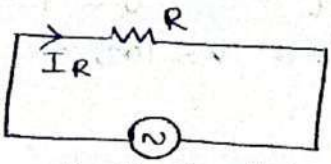
Pure resistor excitation with AC voltage:—



$V = V_m \sin\omega t = V_m \angle 0^\circ$

Let us consider sinusoidal AC voltage is applied across the resistor is $V_m \sin\omega t$, that can be written as $V_m \angle 0^\circ$.

The current flowing through the resistor $i = \frac{V}{R}$

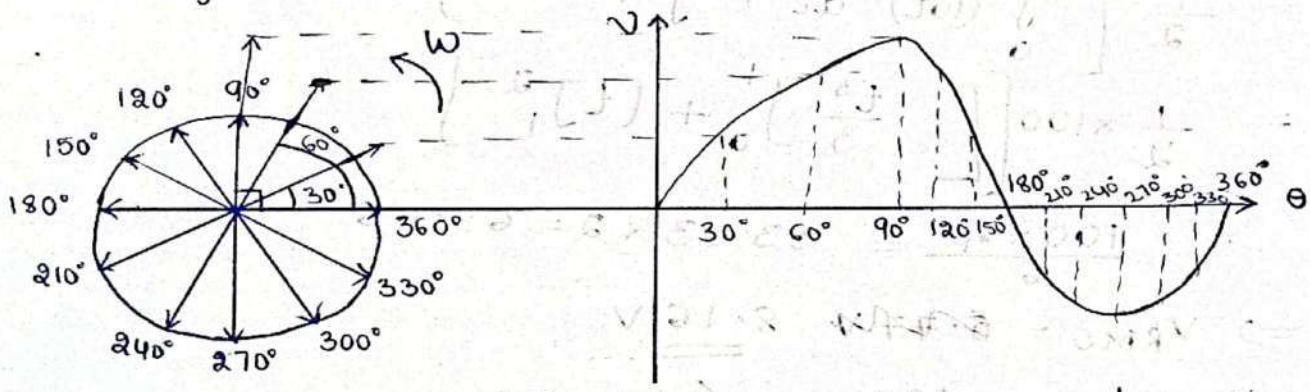
$$i = \frac{V_m \sin\omega t}{R} = I_m \sin\omega t = I_m \angle 0^\circ \quad \left[\because \frac{V_m}{R} = I_m\right]$$

Note:— In pure resistor, the current flowing through resistor is inphase with the voltage.

$\xrightarrow{I_R}$ V (ref)

Phasor Representation:—

Phasor is a mathematical quantity which has both magnitude & direction.



Phasor always rotates in anti clockwise direction

ω is angular frequency & measured in radians/sec.

Instantaneous Power:—

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

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Average Power:— It can be obtained by integrating the instantaneous power over one cycle.

$$P_{avg} = \frac{1}{T}\int_0^T P\,dt$$

$$= \frac{1}{2\pi}\int_0^{2\pi} -\frac{V_m I_m}{2}\cos 2\omega t \; d\omega t \qquad T = 2\pi$$

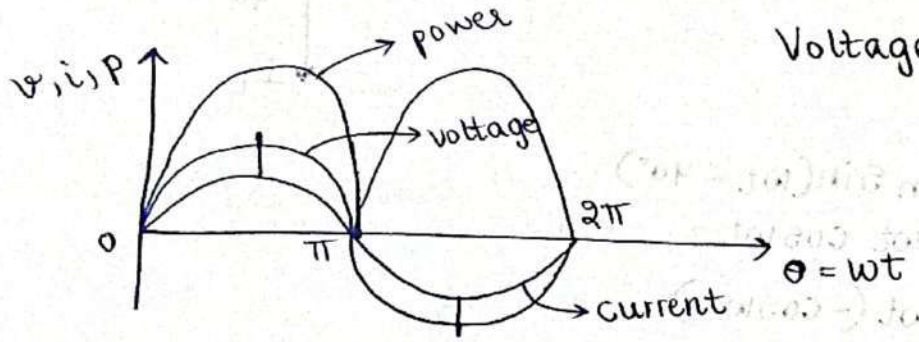
$$= -\frac{V_m I_m}{4\pi}\left[\frac{\sin 2\omega t}{2}\right]_0^{2\pi}$$

$$= -\frac{V_m I_m}{2\pi}[0]$$

$$= 0$$

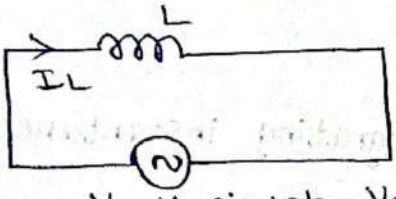
$$P_{avg} = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}$$

$$\therefore P_{avg} = V_{RMS} \times I_{RMS}$$



Voltage Wave.

Pure Inductor Excitation with AC voltage.



$V = V_m \sin\omega t = V_m \angle 0^\circ$

Let us consider sinusoidal AC voltage is applied across the resistor is $V_m \sin\omega t$ that can be written as $V_m \angle 0^\circ$

When AC current is flowing through the inductor then voltage will be induced across the voltage.

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

$$V\,dt = L\,di$$

Integrating on both sides,

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$$\int v\,dt = \int L\,di$$

$$\int V_m \sin\omega t\,dt = Li$$

$$i = \frac{V_m}{L}\left(-\frac{\cos\omega t}{\omega}\right)$$

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

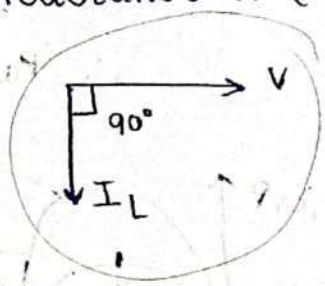
$$= \frac{V_m}{\omega L}\left(\sin(\omega t - 90^\circ)\right)$$

$$i = I_m \sin(\omega t - 90^\circ) \quad \left[\because \frac{V_m}{\omega L} = I_m\right]$$

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

where X_L is the inductive reactance in (Ω)

Note:—
In pure inductor, current lacks voltage by 90°



Instantaneous Power:—

$$P = vi$$

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

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

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

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

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

Average Power:— It can be obtained by integrating instantaneous power over one cycle.

$$P_{avg} = \frac{1}{T}\int_0^T P\,dt$$

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

$$= -\frac{V_m I_m}{4\pi}\left[-\frac{\cos 2\omega t}{2}\right]_0^{2\pi} = -\frac{V_m I_m}{8\pi}\left[-\cos 4\pi - (-\cos 0)\right]$$

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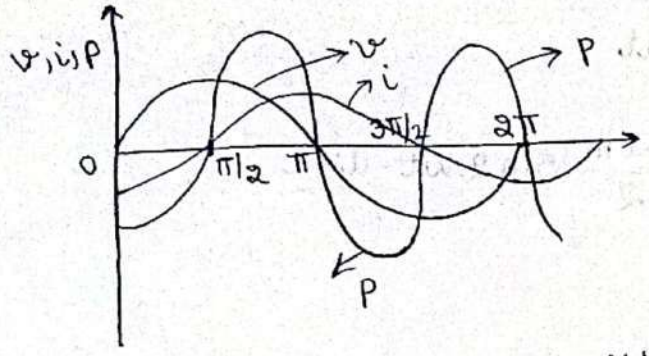
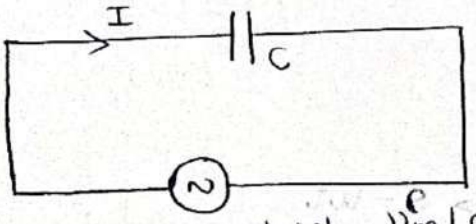
$$= -\frac{V_m I_m}{8\pi}(0)$$

$$\Rightarrow P_{avg} = 0.$$

Note:- The power dissipated in pure inductive circuit is zero.



Pure Capacitor excitation with AC voltage:—



Let us consider sinusoidal AC voltage is applied across the capacitor is $V_m \sin\omega t$ i.e, V_m at an angle $0°$; $V_m\angle 0°$

$$v = V_m \sin\omega t = V_m\angle 0°$$

The charge stored in a capacitor is,

$$q = Cv$$

$$\frac{dq}{dt} = C\frac{dv}{dt}$$

$$i = C\frac{dv}{dt}$$

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

$$= C V_m \omega \cos\omega t$$

$$= V_m \omega C \cdot \sin(\omega t + 90°)$$

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

$\left[\because I_m = V_m \omega C\right.$

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

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

$\left.X_C = \text{capacitive reactance}\right]$

Instantaneous Power:—

$$P = vi$$

$$= V_m \sin\omega t \cdot I_m \sin(\omega t + 90°)$$

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

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

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

Average Power :—

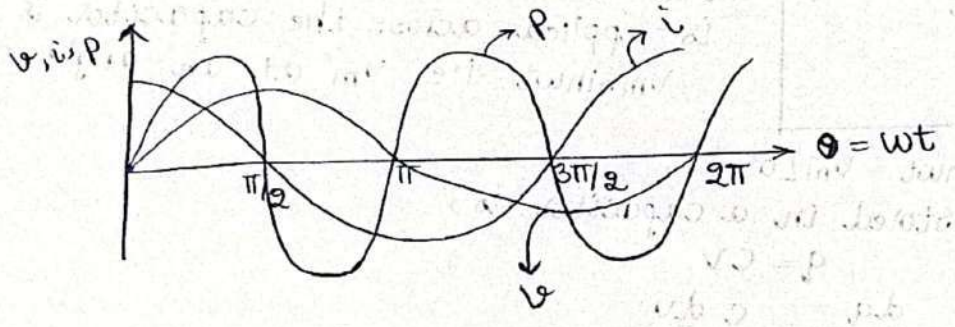
$$P_{avg} = \frac{1}{T} \int_0^T P\,dt$$

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

By solving,

$$P_{avg} = 0$$

Note :— The power dissipated in pure capacitor is zero.



Impedance (Z) :—

→ It is defined as opposition of circuit to flow of AC is called Impedance.

Denoted by Z.

measured in ohms.

→ It is also defined as ratio of voltage & current

→ It is also defined as combination of resistance & reactance.

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

$$Z = (R + jX)\,\Omega$$

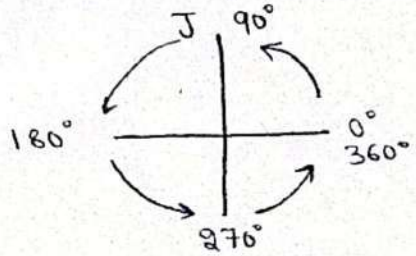
R — Real term

X — Imaginary term

'J' operator :— 'J' term is the most important term used in engineering.

When any time varying signal is multiplied by 'J', that signal advances or leads by 90°.

It is always placed infront of imaginary term



$90° \longrightarrow J = +J = \sqrt{-1}$

$180° \longrightarrow J^2 = (\sqrt{-1})^2 = -1$

$270° \longrightarrow J^3 = J^2 \cdot J = -J$

$360° \longrightarrow J^4 = J^2 \cdot J^2 = 1$

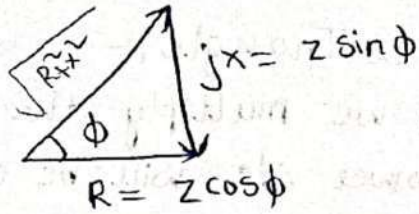
$Z = R + jX$

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

$R = Z\cos\phi$

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

$X = Z\sin\phi$



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

$\phi = \tan^{-1}\left(\frac{X}{R}\right)$

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

Impedance can be represented in 4 ways.

1) $Z = R + jX \rightarrow$ Rectangular/complex form

2) $V\angle\phi \rightarrow$ polar form

3) $Z = r\cos\phi = j\, r\sin\phi \longrightarrow$ trignometric form

4) $Z = re^{jP} \rightarrow$ exponential form.

Q) $Z_1 = x_1 + jy_1 = r_1\angle\phi_1$

$Z_2 = x_2 + iy_2 = r_2\angle\phi_2$

Find $Z_1 + Z_2$, $Z_1 - Z_2$, $Z_1 \cdot Z_2$, $\frac{Z_1}{Z_2}$

$Z_1 + Z_2 = (x_1 + x_2) + j(y_1 + y_2)$

$Z_1 - Z_2 = (x_1 - x_2) + j(y_1 - y_2)$

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$$Z_1 \cdot Z_2 = x_1x_2 + x_1 j y_2 + x_2 j y_1 - y_1 y_2$$
$$= x_1x_2 + j(x_1y_2 - x_2y_1) - y_1y_2$$
$$Z_1Z_2 = r_1\angle\phi_1 \cdot r_2\angle\phi_2$$
$$= r_1r_2(\angle\phi_1 + \phi_2)$$
$$\frac{Z_1}{Z_2} = \frac{x_1 + j y_1}{x_2 + j y_2}$$
$$= \frac{r_1\angle\phi_1}{r_2\angle\phi_2} = \frac{r_1}{r_2}\angle\phi_1 - \phi_2$$

addition, subtraction – Rectangular form.

multiplication, division – trigno & expo form.

Power Triangle :–

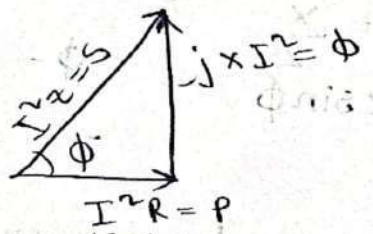
If we multiply the 3 sides of impedance Δle by i^2 then power Δle will be obtained.

Active power :–

$P = I^2R \rightarrow$ Actual power

$Q = I^2 JX \rightarrow$ Imag power

$S = I^2 Z \rightarrow$ Total power



i) Real / True / Average Power (P) :–

It is defined as product of applied voltage & ~~quat~~ real component of current.

$$P = I^2R$$
$$= I(IR) = I(IZ\cos\phi)$$
$$= IZ(I\cos\phi) \qquad \left[\because Z = \frac{V}{I} \Rightarrow V = IZ\right]$$
$$= VI\cos\phi$$
$$P = VI\cos\phi \text{ watts / kwatts}$$

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ii) Reactive Power(Q) :—

It is defined as product of applied voltage & reactive component of current.

$$Q = I^2 X$$
$$= I^2 (Z \sin\phi)$$
$$= IZ (I \sin\phi)$$
$$= VI \sin\phi \quad (\because V = IZ)$$
$$\Rightarrow Q = VI \sin\phi \text{ var / kvar}$$

[var: voltage ampere reactive]

iii) Apparent Power(S):—

It is defined as product of applied voltage & current.

$$S = I^2 Z$$
$$= I(IZ) \quad (\because V = IZ)$$
$$= VI$$
$$\Rightarrow S = VI \text{ VA / KVA}$$

[VA: volt ampere]

$$S = P + jQ$$
$$= \sqrt{P^2 + Q^2}$$
$$\phi = \tan^{-1}\left(\frac{Q}{P}\right)$$

Power Factor:— ($\cos\phi$):—

It is defined as cos of phase angle b/w voltage & current.

(or)

ratio of reactance to impedance

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

(or)

ratio of active power to reactive power

$$\cos\phi = \frac{P}{S} = \frac{KW}{KVA}$$

max power factor is 0 to 1

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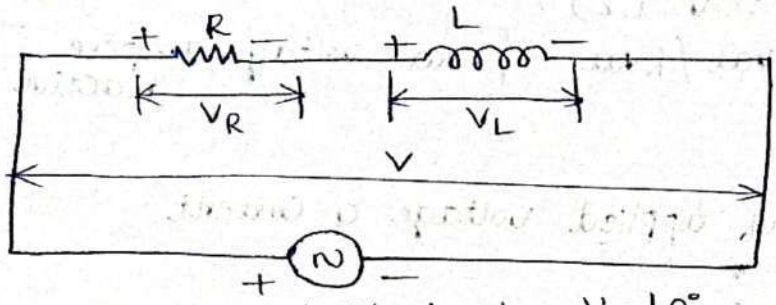
Analysis of Series RL Circuit :—

Let us consider a sinusoidal AC voltage is applied across the series RL network, then current flowing through the circuit is



$V = V_m \sin \omega t = V_m \angle 0^\circ$

Apply KVL,

$$V = V_R + V_L$$
$$= IR + Ij X_L$$
$$= I(R + jX_L)$$
$$\frac{V}{I} = R + jX_L$$
$$Z = R + jX_L$$

$$I = \frac{V}{Z} = \frac{V_m \sin \omega t}{R + jX_L} = \frac{V_m \sin \omega t}{|Z| \angle \phi}$$

$$= \frac{V_m \angle 0^\circ}{|Z| \angle \phi} = I_m (0 - \phi)$$

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

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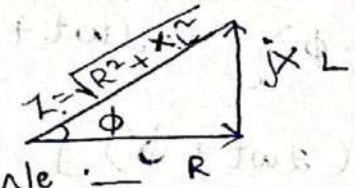
Instantaneous Power:—

$$\phi = vi$$
$$= V_m \sin\omega t \cdot I_m \sin(\omega t - \phi)$$
$$= V_m I_m \sin\omega t \cdot \sin(\omega t - \phi)$$
$$= \frac{2 V_m I_m}{2} \sin\omega t \, \sin(\omega t - \phi)$$
$$= \frac{V_m I_m}{2} \left[\cos(\omega t - \omega t + \phi) - \cos(\omega t + \omega t - \phi)\right]$$
$$= \frac{V_m I_m}{2} \left[\cos\phi - \cos(2\omega t - \phi)\right]$$
$$= \underbrace{\frac{V_m I_m}{2}\cos\phi}_{\text{Steady power}} - \underbrace{\frac{V_m I_m}{2}\cos(2\omega t - \phi)}_{\text{Fluctuating power}} = \frac{V_m I_m}{2}\left[\cos\phi - \cos(2\omega t - \phi)\right]$$

$$P_{avg} = \frac{V_m I_m}{2}\cos\phi$$
$$= \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \cos\phi$$
$$P_{avg} = V_{RMS} \cdot I_{RMS} \cos\phi$$
$$P = VI\cos\phi$$

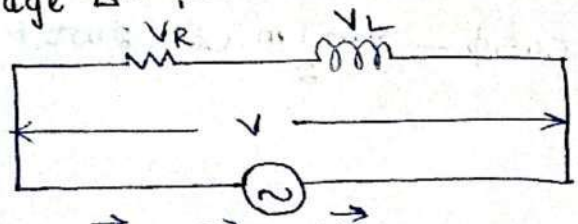
Impedance Δle:—

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

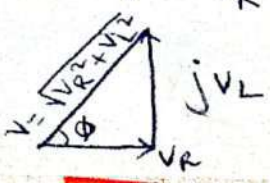


$$\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$$
$$\cos\phi = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{Z}$$

Voltage Δle:—



$$\vec{V} = \vec{V_R} + \vec{V_L}$$



$$\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right)$$
$$\cos\phi = \frac{V_R}{V} = \frac{IR}{IZ} = \frac{R}{Z}$$
$$P = VI\cos\phi$$
$$= IZ \times I \times \frac{R}{Z}$$
$$= I^2 R.$$

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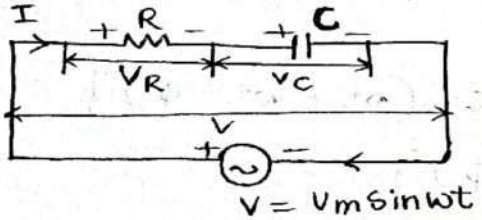
Analysis of series RC circuit :—

Consider a sinusoidal AC voltage is applied across series RC circuit where $V = V_m \sin \omega t = V_m \angle 0°$

The current flowing through the circuit is



Apply KVL,

$$V_R + V_C - V = 0$$

$$V = V_R + V_C$$

$$= IR + I(-jX_C)$$

$$= I(R - jX_C)$$

$$\frac{V}{I} = Z = (R - jX_C)$$

$$I = \frac{V}{Z} = \frac{V_m \sin \omega t}{R - jX_C} = \frac{V_m \angle 0°}{|Z| \angle \phi} = \frac{V_m}{|Z|} \angle (0° - (-\phi))$$

$$= I_m \angle 0 + \phi$$

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

Instantaneous power :—

$$P = VI$$

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

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

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

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

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

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

$$P_{avg} = \frac{V_m I_m}{2} \cos \phi$$

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

$$= V_{RMS} I_{RMS} \cos \phi$$

$$= VI \cos \phi$$

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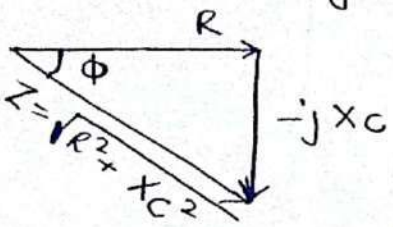
Impedance Triangle:—

$$Z = R - jX_C$$

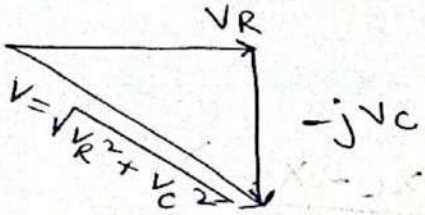


$$\cos\phi = \frac{R}{Z}$$

$$\phi = \tan^{-1}\left(-\frac{X_C}{R}\right)$$

Voltage Triangle:—

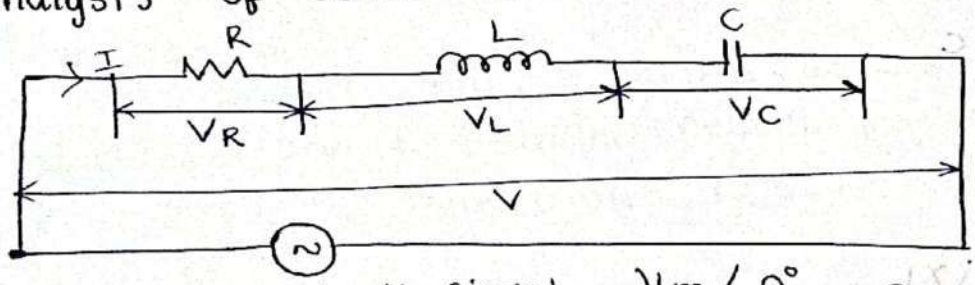
$$\overline{V} = \overline{V_R} + \overline{V_L}$$



$$\cos\phi = \frac{V_R}{V} = \frac{IR}{IZ} = \frac{R}{Z}$$

$$\phi = \tan^{-1}\left(-\frac{V_C}{V_R}\right)$$

Analysis of series RLC circuit:—



$$V = V_m \sin\omega t = V_m \angle 0^\circ$$

$$V = V_R + V_L - V_C$$

$$= IR + jIX_L - jX_C I$$

$$= I(R + jX_L - jX_C)$$

$$\frac{V}{I} = R + jX_L - jX_C$$

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

$$I = \frac{V}{Z} = \frac{V_m \sin\omega t}{R + j(X_L - X_C)} = \frac{V_m \angle 0^\circ}{|Z| \angle \pm\phi}$$

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

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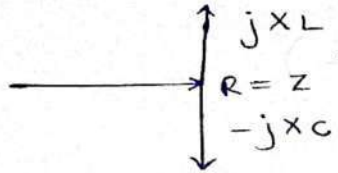
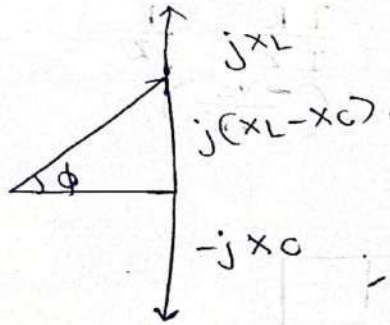
$$Z = R + j(X_L - X_C)$$

(i) $X_L = X_C$



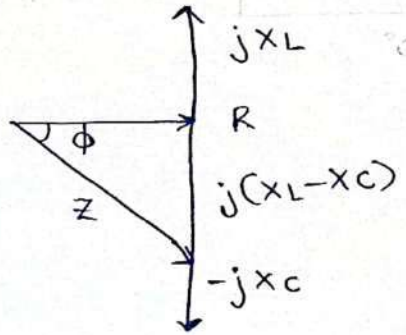
(ii) $X_L > X_C$



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

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

(iii) $X_L < X_C$



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

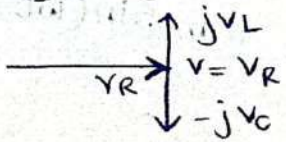
$$\cos\phi = \frac{R}{Z}$$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

voltage triangle :-

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

(i) $V_L = V_C$



Q1)

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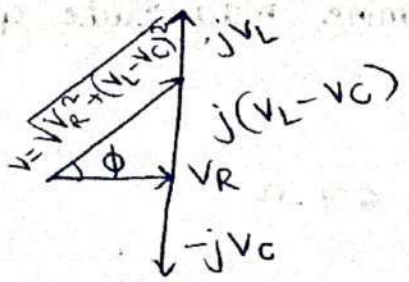
(ii) $V_L > V_C$

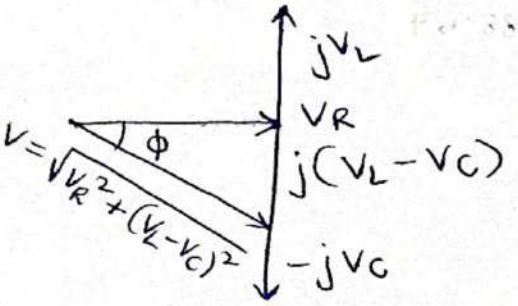


$$\cos\phi = \frac{V_R}{V} = \frac{IR}{IZ} = \frac{R}{Z}$$

$$\phi = \tan^{-1}\left(\frac{V_L - V_C}{V_R}\right)$$

ϕ is +ve.

(iii) $V_L < V_C$



$$\cos\phi = \frac{V_R}{V} = \frac{IR}{IZ} = \frac{R}{Z}$$

$$\phi = \tan^{-1}\left(\frac{V_L - V_C}{V_R}\right)$$

ϕ is −ve.

Q1) If a voltage of $v(t) = 20\sin(314t + 35)$ is applied to a inductor of inductance 0.04H. Determine current flowing through circuit.

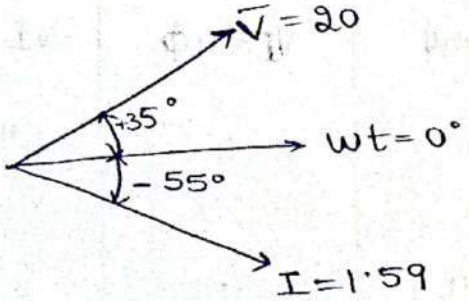
$$X_L = \underbrace{2\pi f}_{\omega L} L = 314 \times 0.04 = 12.56\,\Omega$$

$$V_L = I \cdot jX_L$$

$$20 = jI(12.56)$$

$$I = \frac{20}{j \times 12.56} = \frac{20\angle +35}{1\angle 90 \times 12.56} = 1.59 \times \angle -55^\circ$$

$$= 1.59\sin(314t - 55^\circ)$$



$+j = 1\angle 90^\circ$

$-j = 1\angle -90^\circ$

$\boxed{P.F = 0}$ = phase angle b/w V & I.

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Q2) If voltage of $V(t) = 50\sin(212t - 25°)$ is applied to a capacitor of capacitance $25\mu F$. Determine magnitude & direction of current.

$$V_C = -j X_C \cdot I$$

$$X_C = \frac{1}{\omega C} = \frac{1}{212 \times 25 \times 10^{-6}} = 188.67\,\Omega$$

$$V_C = -j(188.67) \times I$$

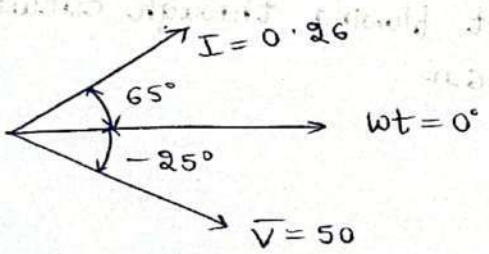
$$\Rightarrow I = \frac{50}{-j \times 188.67} = \frac{50\angle -25°}{1\angle -90° \times 188.67}$$

$$= \frac{50\angle 65°}{188.67}$$

$$= 0.26\angle 65°$$

$$= I_m \sin(212t + 65°)$$

$$I = 0.26 \sin(212t + 65°)$$



phase angle b/w V & I = 90°

$\cos\phi = 0$.

* OBSERVATION TABLE :—

N/W	Z	I	ϕ	P	Q	S
R_L	$R + jX_L$	$\frac{V}{Z}$	$\tan^{-1}\left(\frac{X_L}{R}\right)$	$VI\cos\phi$	$VI\sin\phi$	VI
R_C	$R - jX_C$	V/Z	$\tan^{-1}\left(\frac{-X_C}{R}\right)$	"	"	"
R_{LC}	$R + j(X_L - X_C)$	V/Z	$\tan^{-1}\left(\frac{X_L - X_C}{R}\right)$	"	"	"

Q3)

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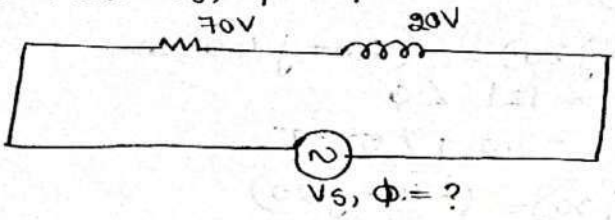
Q3) Find V_S, $\phi = ?$

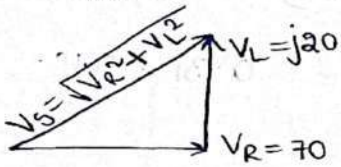


$V = V_m \sin \omega t$

$V_S = V_R + j V_L$

$= 70 + j\,20$

$|V_S| = \sqrt{70^2 + 20^2} = 72.8$



$\phi = \tan^{-1}\left(\frac{V_L}{R}\right)$

$= \tan^{-1}\left(\frac{20}{70}\right) = 15.9$

$\phi = 15.9°$

$\cos\phi = \cos(15.9°)$

$= 0.96$

R_L network lagging

R_C network leading

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Q4) $Z_1 = (5+j10)$, $Z_2 = (20+j30)$

(i) $Z_1 + Z_2 = (5+j10) + (20+j30) = (25+j40)\Omega$

$= |Z| \angle \phi$

$|Z| = \sqrt{25^2+40^2} = 47.1\Omega$

$= 47.1 \angle 57.9^\circ$

$\phi = \tan^{-1}\left(\frac{40}{25}\right) = 57.9^\circ$

(ii) $Z_1 - Z_2 = (5+j10) - (20+j30) = (-15-j20)$

$= |Z| \angle \phi$

$|Z| = \sqrt{15^2+20^2} = 25\Omega$

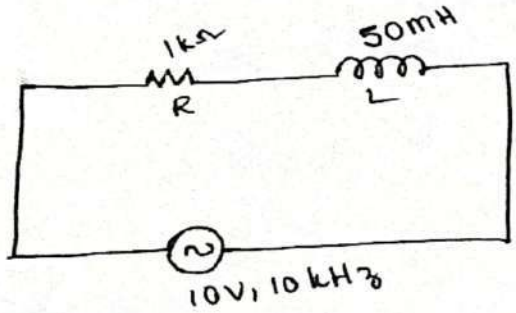
$\phi = \tan^{-1}\left(\frac{20}{15}\right) = 53.06^\circ$

$= 25 \angle -126.9^\circ$

(iii) $Z_1 \times Z_2 = (5+j10)(20+j30) = 403.1 \angle 119.74^\circ$

(iv) $Z_1 / Z_2 = \frac{(5+j10)}{(20+j30)} = 0.31 \angle 7.1^\circ$

Q5)



Find Impedance (Z), current (I), V_R, V_L, phase angle (ϕ).

$V = 10V$

$f = 10kHz$

$R = 1k\Omega$

$L = 50mH$

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

$= 2 \times 3.14 \times 10 \times 10^3 \times 50 \times 10^{-3}$

$= 1000 \times 3.14$

$= 3140\Omega$

(i) $Z = R + jX_L$

$= 1000 + jX_L$

$= 1000 + j(3140)$

$= 3295.39 \angle 72.33^\circ \Omega$

(ii) $I = \frac{V}{Z} = \frac{10}{3295.39 \angle 72.33} = 3.03 \times 10^{-3} \angle -72.33^\circ$ A

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(iii) phase angle $\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$

$= \tan^{-1}\left(\frac{3140}{1000}\right)$

$\phi = 72.33^\circ$

$\cos\phi = \cos(72.33^\circ) = 0.303$ lag

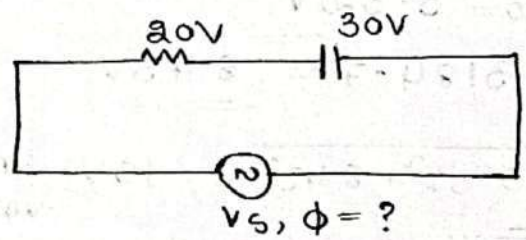
or $\cos\phi = \frac{R}{Z}$

(iv) $V_R = IR = 3.03 \times 1000 \times 10^{-3} = 3.03\,V$

(v) $V_L = I \times X_L = 3.03 \times 10^{-3} \times 3140 = 9.51\,V$

* $V = \sqrt{V_R^2 + V_L^2} = \sqrt{(3.03)^2 + (9.51)^2} = 10\,V$ = src voltage.

Q6)



$V_S = V_R - jV_C$

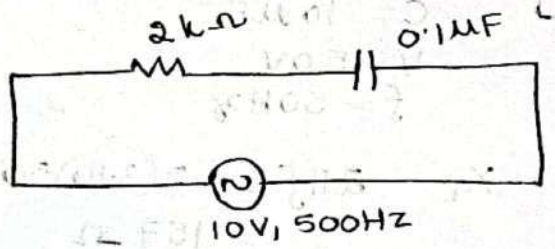
$V_S = \sqrt{V_R^2 + V_C^2}$

$= \sqrt{20^2 + 30^2} = 36.05\,V$

$\phi = \tan^{-1}\left(\frac{-V_C}{V_R}\right)$

$= \tan^{-1}\left(\frac{-30}{20}\right) = -56.3^\circ$

Q7)



Find Z, I, ϕ, V_R, V_C.

$R = 2000\,\Omega$

$C = 0.1\,\mu F$

$V = 10\,V$

$f = 500\,Hz$

$X_C = \frac{1}{2\pi f C} = \frac{1}{\omega C} = \frac{1}{2 \times 3.14 \times 500 \times 0.1 \times 10^{-6}} = \frac{1}{3.14 \times 10^{-4}}$

$= 3184.7$

$Z = R - jX_C = 2000 - j(3184.7)$

$|Z| = 3760.6$, $\phi = \tan^{-1}\left(\frac{-3184.7}{2000}\right) = -57.8^\circ$

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$Z = 3760.6 \angle -57.8^\circ \ \Omega$

(ii) $I = \frac{V}{Z} = \frac{10}{3760.6 \angle -57.8^\circ} = 2.66 \times 10^{-3} \angle 57.8^\circ$ A

(iii) phase angle $\phi = \tan^{-1}\left(\frac{-X_C}{R}\right)$

$= \tan^{-1}\left(-\frac{3184.7}{2000}\right)$

$= -57.8^\circ$

$\cos\phi = \cos(-57.8) = 0.53$ leading

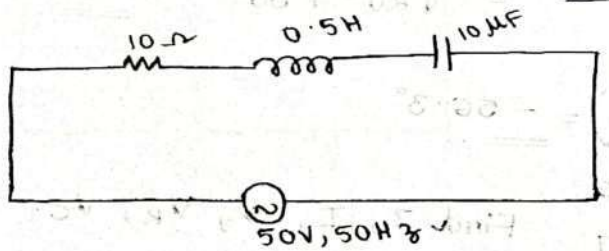
or $\cos\phi = \frac{R}{Z}$

(iv) $V_R = IR = 2.66 \times 10^{-3} \times 2000 = 5.32$ V

(v) $V_C = I \times X_C = 2.66 \times 10^{-3} \times 3184.7 = 8.43$ V

* $V_S = \sqrt{V_R^2 + V_C^2} = \sqrt{5.32^2 + 8.43^2} = 10$ V = Src voltage

Q8)



Find $Z, I, V_R, V_L, V_C, \phi$

$R = 10\Omega$
$L = 0.5$H
$C = 10\mu$F
$V = 50$V
$f = 50$Hz

$X_L = 2\pi f L = 2(3.14)50 \times 0.5$
$= 157\Omega$

$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.14 \times 50 \times 10\mu F}$
$= \frac{1000}{3.14} = 318.47\Omega$

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

$= 10 + j(-161.47)$

$|Z| = 161.77$

$\phi = \tan^{-1}\left(\frac{-161.4}{10}\right) = -86.45^\circ$

$Z = 161.77 \angle -86.45^\circ \ \Omega$

(ii) $I = \frac{50}{161.77 \angle -86.45^\circ} = 0.3095 \angle 86.45^\circ$ A

(iii) $V_R = IR = 0.3095 \times 10 = 3.095\,V$

(iv) $V_L = I \times X_L = 0.3095 \times 157 = 48.59\,V$

(v) $V_C = I \times X_C = 0.3095 \times 318.47 = 98.57\,V$

(vi) $V_S = \sqrt{V_R^2 + (V_L - V_C)^2}$

$= \sqrt{(3.095)^2 + (48.59 - 98.57)^2}$

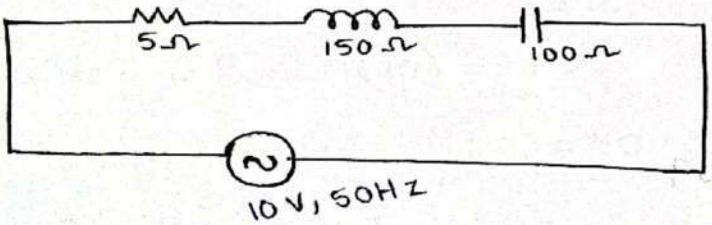
$V_S \simeq 50\,V$

(vii) $\phi = -86.45°$

Power factor $= \cos\phi = \cos(-86.45°) = 0.061$ leading.

3/7/23

Q9)



Find ϕ, Z, I, V_R, V_L, V_C, P, Q, S.

$X_L = 150\,\Omega$

$X_C = 100\,\Omega$

$R = 5\,\Omega$

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

$= 5 + j(150 - 100)$

$= 5 + j(50)$

$|Z| = \sqrt{2500 + 25} = \sqrt{2525} = 50.25$

$\phi = \tan^{-1}\left(\frac{50}{5}\right) = \tan^{-1}(10°) = 84.29°$

$Z = 50.25 \angle 84.29°\,\Omega$

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(ii) $I = \frac{V}{Z} = \frac{10}{50.25 \angle 84.29^\circ} = 0.199 \angle -84.29^\circ \, A$

(iii) $V_R = IR = 0.199 \times 5 = 0.995 \, V$

(iv) $V_L = I \times X_L = 0.199 \times 150 = 29.85 \, V$

(v) $V_C = I \times X_C = 0.199 \times 100 = 19.9 \, V$

(vi) $V_S = \sqrt{V_R^2 + (V_L - V_C)^2}$

$= \sqrt{(0.995)^2 + (29.85 - 19.9)^2}$

$= 9.99 V \sim 10 V$

(vii) $\cos\phi = \cos(84.29)$

$= 0.09$ lagging.

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

$= 10 \times 0.199 \times 0.09$

$= 0.1791 \, W$

(ix) $Q = VI\sin\phi$

$= 10 \times 0.199 \times \sin(84.29^\circ)$

$= 10 \times 0.199 \times 0.995$

$= 1.98$ vars

(x) $S = VI = 10 \times 0.199$

$= 1.99 \, VA$

$S = P + jQ = \sqrt{P^2 + Q^2} = \sqrt{(0.1791)^2 + (1.98)^2}$

$= 1.9 \, VA$

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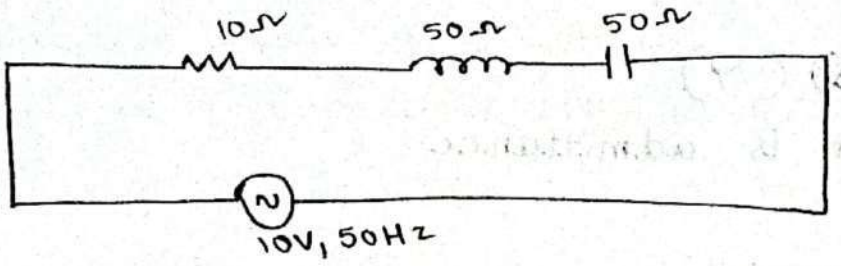
Q10)



Find Z, ϕ, I, V_R, V_L, V_C, P, Q, S, $\cos\phi$.

$X_L = 50\,\Omega$

$X_C = 50\,\Omega$

$R = 10\,\Omega$

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

$= 10 + j(50 - 50)$

$= 10 + j(0)$

$|Z| = 10$

$\phi = \tan^{-1}\left(\frac{0}{10}\right) = \underline{\underline{0^\circ}}$

$Z = \underline{\underline{10 \angle 0^\circ}}\ \Omega$

(ii) $I = \frac{V}{Z} = \frac{10}{10} = \underline{\underline{1\,A}}$

(iii) $V_R = IR = 1(10) = \underline{\underline{10\,V}}$

(iv) $V_L = I \times X_L = 1(50) = \underline{\underline{50V}}$

(v) $V_C = I \times X_C = 1(50) = \underline{\underline{50V}}$

(vi) $V_S = \sqrt{V_R^2 + (V_L - V_C)^2}$

$= V_R = \underline{\underline{10\,V}}$

(vii) $\cos\phi = \cos(0) = \underline{\underline{1}}$

(viii) $P = VI\cos\phi = 10 \times 1 = \underline{\underline{10\,W}}$

(ix) $Q = VI\sin\phi = \underline{\underline{0\ VA}}$

(x) $S = VI = 10 \times 1 = \underline{\underline{10\ VA}}$

$S = P + jQ = \sqrt{P^2 + Q^2} = \sqrt{10^2 + 0^2} = \underline{\underline{10\ VA}}$

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Admittance :— (Y)

Reciprocal of impedance is admittance.
denoted by Z.
Units — mho (or) siemens.

$$Y = \frac{1}{Z} \mho$$

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

Conductance :— (G)

Reciprocal of resistance, denoted by G.

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

units — mho.

$$V_R = IR = \frac{I}{G}$$

$$\Rightarrow I = V_R \times G$$

Susceptance (B) :—

Reciprocal of reactance, denoted by B.

$$B = \frac{1}{X} \mho$$

Inductive Susceptance (B_L) :—

Reciprocal of Inductive reactance, denoted by B_L

$$B_L = \frac{1}{X_L} \mho = \frac{1}{2\pi f L} \mho$$

$$V_L = I_L \times jX_L$$

$$\Rightarrow I_L = \frac{V_L}{jX_L} = V_L(-jB_L)$$

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Capacitive Susceptance (B_C) :—

Reciprocal of capacitive reactance, denoted by B_C

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

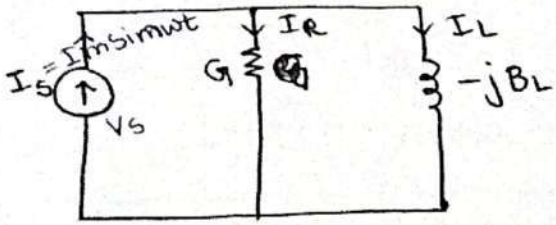
$$V_C = I_C \times (-jX_C)$$

$$\Rightarrow I_C = \frac{V_C}{-j \times X_C} = V_C(jB_C)$$

*) $Y = G + j(B_C - B_L)\mho$

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

Parallel RL Network :—



Let a current src of $I_m \sin\omega t$ is applied across the parallel combination of RL network. Then current flowing through the circuit is,

Apply KCL,

$$I_S = I_R + I_L$$

Let

$$\cancel{V_S = \frac{V}{R}}$$

$$I_S = \frac{V_S}{R} + \frac{V_S}{j \times X_L}$$

$$= V_S G + V_S(-jB_L)$$

$$= V_S(G - jB_L)$$

$$\frac{I_S}{V_S} = G - jB_L$$

$$\Rightarrow Y = G - jB_L \ \mho$$

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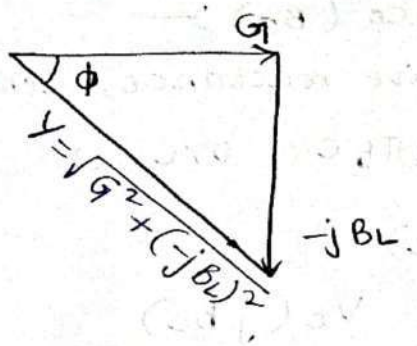
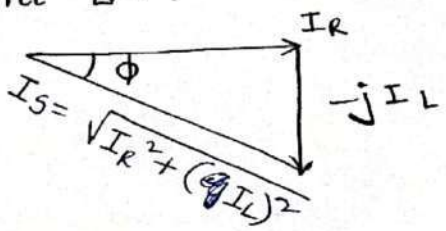
Admittance Δle :—



$$\phi = \tan^{-1}\left(\frac{-B_L}{G}\right)$$

↳ −ve

Current Δle :—



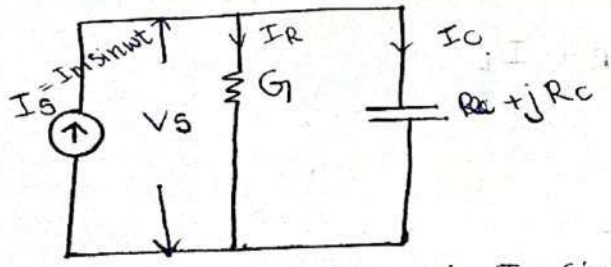
$$\phi = \tan^{-1}\left(\frac{-I_L}{I_R}\right)$$

↳ −ve

$$* \quad I_R = \frac{I_S \angle 0^\circ \times jX_L}{R + jX_L}$$

$$* \quad I_L = \frac{I_S \angle 0^\circ \times R}{R + jX_L}$$

Parallel RC network :—



Let a current src of $I_m \sin\omega t$ is applied across the ||lel RC network,

Apply KCL :

$$I_S = I_R + I_C$$

$$= \frac{V_S}{R} + \frac{V_S}{-jX_C}$$

$$= V_S G + V_S (jB_C)$$

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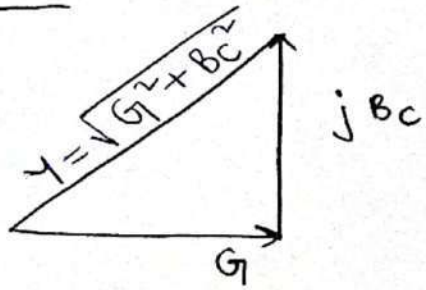
$$I_S = V_S(G + jB_C)$$

$$\frac{I_S}{V_S} = Y = G + jB_C \ \mho$$

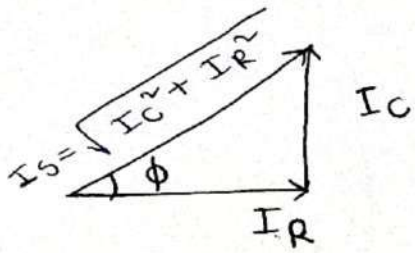
Y Δle :—



$$\phi = \tan^{-1}\left(\frac{B_C}{G}\right)$$

↳ +ve.

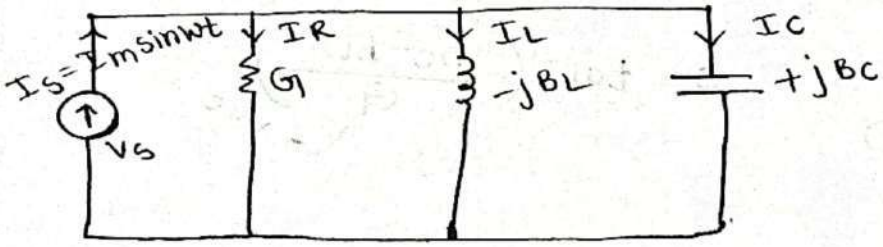
Current Δle :—



$$\phi = \tan^{-1}\left(\frac{I_C}{I_R}\right)$$

↳ +ve

Parallel RLC network :—



Let a current src of $I_m \sin\omega t$ is applied across ||lel RLC network,

Apply KCL :

$$I_S = I_L + I_R + I_C$$

$$= \frac{V_S}{jB_L} + \frac{V_S}{R} + \frac{V_S}{-jB_C}$$

$$= V_S G + V_S jB_C - V_S jB_L$$

$$I_S = V_S(G + jB_C - jB_L)$$

$$\frac{I_S}{V_S} = Y = G + jB_C - jB_L = G + j(B_C - B_L) \ \mho$$

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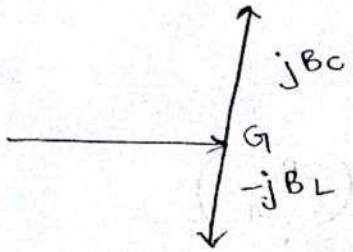
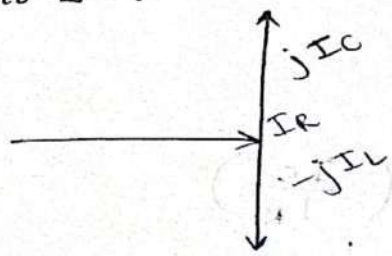
case-1 :— $B_L = B_C$



$Y = G$

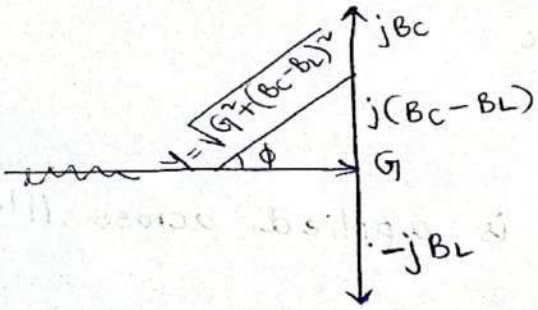
current Δle :—



$I_S = I_R$

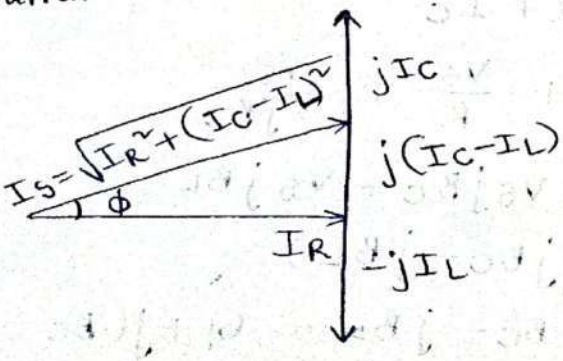
case-2 :— $B_C > B_L$

$Y = G + j(B_C - B_L)$



$\phi = \tan^{-1}\left(\frac{B_C - B_L}{G}\right)$ +ve

current Δle :—



$\phi = \tan^{-1}\left(\frac{I_C - I_L}{I_R}\right)$

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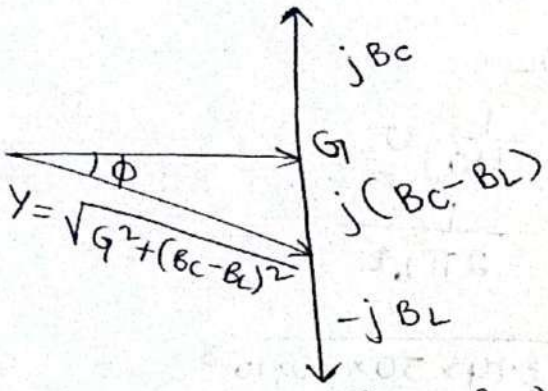
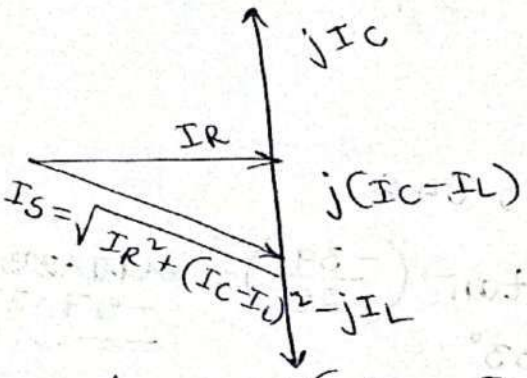
case-3 :— $B_L > B_C$.

$$Y = G + j(B_L - B_C)$$



$$\phi = \tan^{-1}\left(\frac{B_C - B_L}{G}\right) \rightarrow -ve.$$



$$\phi = \tan^{-1}\left(\frac{I_C - I_L}{I_R}\right) \rightarrow -ve.$$

N/W	Y	I	ϕ	P.F	P	Q	S
RL	$G - jB_L$	$V_S Y$	$\tan^{-1}\left(\frac{-B_L}{G}\right)$	$\cos\phi$	$VI\cos\phi$	$VI\sin\phi$	VI
RC	$G + jB_C$	$V_S Y$	$\tan^{-1}\left(\frac{B_C}{G}\right)$	$\cos\phi$	"	"	VI
RLC	$G + j(B_C - B_L)$	$V_S Y$	$\tan^{-1}\left(\frac{B_C - B_L}{G}\right)$	$\cos\phi$	"	"	VI

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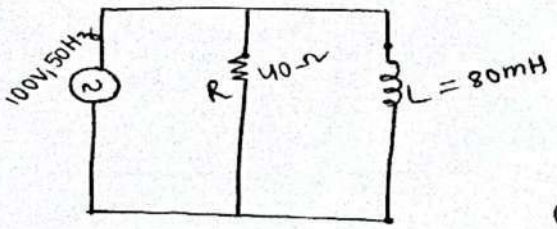
Q1)



Find Y, ϕ, I, I_R, I_L, $\cos\phi$, P, Q, S

$$Y = G - jB_L$$

$$G = \frac{1}{R} = \frac{1}{40}\ \mho$$

$$B_L = \frac{1}{X_L} = \frac{1}{2\pi f L}$$

$$= \frac{1}{2 \times 3.14 \times 50 \times 80 \times 10^{-3}}$$

$$= \frac{1}{25.12}\ \mho$$

$$Y = \frac{1}{40} - j\frac{1}{25.12}$$

$$= 0.025 - j(0.039)$$

$$|Y| = \sqrt{(0.025)^2 + (0.039)^2} = 0.046$$

$$\phi = \tan^{-1}\left(\frac{-0.039}{0.025}\right) = \tan^{-1}\left(\frac{-39}{25}\right) = -57.33^\circ$$

$$= 0.046 \angle -57.33^\circ$$

$$I_R = \frac{V_S}{R} = \frac{100}{40} = 2.5\,A$$

$$I_L = \frac{V_S}{jX_L} = \frac{100}{j(25.12)} = -j\,3.98\ A$$

$$I_S = \sqrt{I_R^2 + (-I_L)^2} = \sqrt{(2.5)^2 + (3.98)^2}$$

$$I_S = 4.7\,A$$

$$I_S = V_S Y = 100 \times 0.046$$

$$= 4.6\,A$$

$$\cos\phi = \cos(-57.33) = 0.539$$

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$P = VI\cos\phi$

$= 100 \times 4.6 \times 0.539$

$= \underline{\underline{247.9\ W}}$

$Q = VI\sin\phi$

$= 100 \times 4.6 \sin(-57.33^\circ)$

$= \underline{\underline{-387.22}}$ Vars.

$S = VI = 100 \times 4.6$

$= \underline{\underline{460\ VA}}$

$S = P + jQ$

$S = \sqrt{P^2 + Q^2} = \sqrt{(-387.22)^2 + (247.9)^2}$

$= \sqrt{149939.3 + 61454.41}$

$= \underline{\underline{459.7 \sim 460\ V}}$

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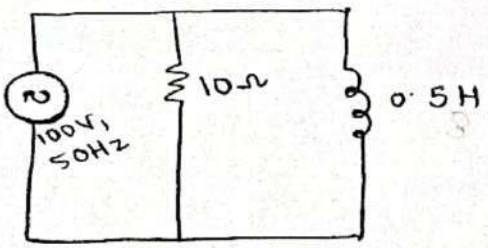
Q2)



Find $Z, I, \phi, \cos\phi, \overset{\text{Active}}{P}, \overset{\text{reactive}}{Q}, \overset{\text{apparent}}{S}$.

$Y = G - jB_L$

$G = \frac{1}{R} = \frac{1}{10} = 0.1\,℧$

$B_L = \frac{1}{X_L} = \frac{1}{2\pi f L} = \frac{1}{2 \times 3.14 \times 0.5 \times 50}$

$= \frac{1}{157}$

$= 6.36 \times 10^{-3}\,℧$

$Y = 0.1 - j(6.36 \times 10^{-3})$

$|Y| = \sqrt{0.01 + (40.4496 \times 10^{-6})}$

$= 0.1$

$\phi = \tan^{-1}\left(\frac{-6.36 \times 10^{-3}}{0.1}\right) = \cancel{-32.44^\circ}\ -3.64^\circ$

$Y = \underline{\underline{0.1 \angle -32.64^\circ}}$

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$$Z = \frac{R \times jX_L}{R + jX_L} = \frac{10 \times j\,157}{10 + j\,157} \quad (\text{or}) \quad Z = \frac{1}{Y}$$

$$Z = \frac{1}{Y} = \underline{\underline{10 \angle 3.64^\circ\ \Omega}}$$

$$I = \frac{V}{Z} = \frac{100}{10 \angle 3.64^\circ} = \underline{\underline{10 \angle -3.64^\circ}}$$

$$I = I_R + I_L$$

$$I_R = \frac{V}{R} = \frac{100}{10} = 10\ A$$

$$I_L = \frac{V}{j \times X_L} = \frac{100}{j \times 157} = -j\,0.636\ A$$

$$I = 10 - j\,0.636$$

$$|I| = \sqrt{10^2 + (0.636)^2} \cong \underline{\underline{10}} \angle -3.64^\circ\ A$$

$$P.F = \cos\phi = \cos(-3.64) = \underline{\underline{0.998}}$$

$$P = VI\cos\phi = 100 \times 10 \times 0.998$$

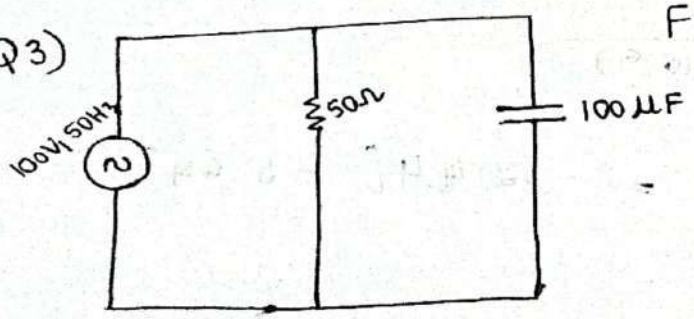
$$= \underline{\underline{998\ W}}$$

$$Q = VI\sin\phi = 100 \times 10 \times \sin(-3.64^\circ)$$

$$= \underline{\underline{+63.488\ \text{Vars}}}$$

$$S = VI = 100 \times 10 = \underline{\underline{1000\ VA}}$$

Q3)



Find $Y, Z, I, \phi, \cos\phi, P, Q, S$.

$$Y = G + jB_C\ \mho$$

$$G = \frac{1}{R} = \frac{1}{50} = 0.02\ \mho$$

$$B_C = 2\pi f C = 2 \times 3.14 \times 50 \times 100 \times 10^{-6}$$

$$= 0.0314\ \mho$$

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$Y = 0.02 + j(0.0314)$

$|Y| = \sqrt{(0.02)^2 + (0.0314)^2} = 0.37 \times 10^{-1} = 0.037$

$\phi = \tan^{-1}\left(\frac{0.0314}{0.02}\right) = \tan^{-1}(1.57) = 57.5^\circ$

$Y = 0.037 \angle 57.5^\circ$

$Z = \frac{1}{Y} = \frac{1}{0.037\angle 57.5^\circ} = 27.027 \angle -57.5^\circ$ (or) $Z = \frac{50 \times -j31.8}{50 - j31.8}$

$I = \frac{V}{Z} = \frac{100}{27.027 \angle -57.5^\circ} = 3.7 \angle 57.5^\circ$

$X_C = \frac{1}{2\pi f C} = \frac{1}{0.0314} = 31.8\,\Omega$

$P.F = \cos\phi = \cos(57.5) = 0.537$

$I_R = \frac{V}{R} = \frac{100}{50} = 2\,A$

$I_C = \frac{V}{-j \times X_C} = \frac{100}{-j\,31.8} = j\,3.14$

$I = 2 + j\,3.14$

$|I| = \sqrt{4 + (3.14)^2} = 3.72\,A$

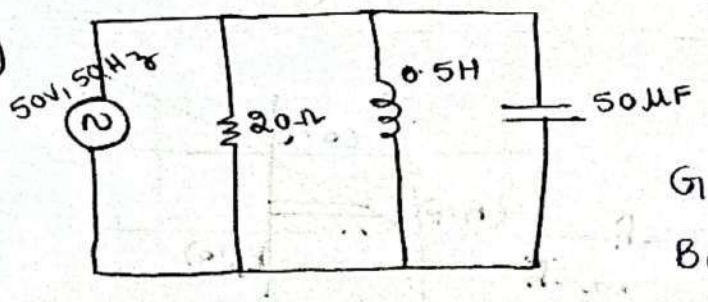
$I = 3.72 \angle 57.5^\circ$

$P = VI\cos\phi = 100 \times 3.7 \times 0.537 = 198.69\,W$

$Q = VI\sin\phi = 100 \times 3.7 \times \sin(57.5) = 312.05$ Vars

$S = VI = 100 \times 3.7 = 370\,VA$

Q4)



Find $Y, Z, \phi, I, I_R, I_L, I_C, P, Q, S$.

$Y = G + j(B_C - B_L)$

$G = \frac{1}{R} = \frac{1}{20} = 0.05\,℧$

$B_C = 2\pi f C = 2 \times 3.14 \times 50 \times 50 \times 10^{-6}$
$= 0.015\,℧$

$B_L = \frac{1}{2\pi f L} = \frac{1}{2\pi \times 50 \times 0.5} = 6.36 \times 10^{-3}\,℧$

$Y = 0.05 + j(0.015 - 6.36 \times 10^{-3})$

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UNIT-1

1) $\Delta - \lambda$, $\lambda - \Delta$ Derivation | transformation.
2) Explain KVL, KCL.
3) Derive power & energy inductor & capacitor
4) Explain the ~~classicifaction~~ classification of elements | components
5) Find Req (L, C, R)

UNIT-2

1) Nodal analysis
2) Mesh analysis
3) SPT
4) Thevinin's theorem
5) Norton's theorem.
6) Pmax transfer theory.
7) Reciprocity theorem.

$$Y = 0.05 + j(8.64 \times 10^{-3})$$

$$|Y| = \sqrt{(0.05)^2 + (8.64 \times 10^{-3})^2} = 0.050$$

$$Y = 0.050 \angle 9.84^\circ \, \mho \qquad Z = \frac{1}{Y} = \frac{1}{0.050 \angle 9.84^\circ}$$

$$= 20 \angle -9.84 \, \Omega$$

$$I = \frac{V}{Z} = \frac{50}{20 \angle -9.84} = 2.5 \angle 9.84^\circ \text{ A}$$

$$I_R = \frac{V}{R} = \frac{50}{20} = 2.5 \text{ A}$$

$$I_L = \frac{V}{jX_L} = \frac{50}{j\,157.2} = -j0.31 \text{ A}$$

$$I_C = \frac{V}{-jX_C} = \frac{50}{-j\,63.69} = j\,0.789 \text{ A}$$

$$I = I_R + I_L + I_C = 2.5 + j(0.789 - 0.31) = 2.5 \angle 10.84^\circ$$

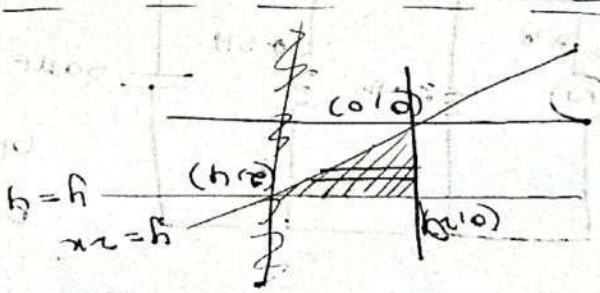
$$S = P + jQ$$

$$P = VI\cos\phi = 50 \times 2.5 \times \cos(9.84) = 123.16 \text{ W}$$

$$Q = VI\sin\phi = 50 \times 2.5 \times \sin(9.84) = 21.25 \text{ Vars}$$

$$S = VI = 50 \times 2.5 = 125 \text{ VA}$$

$$S = \sqrt{P^2 + Q^2} = \sqrt{(123.16)^2 + (21.25)^2} = 124.97 \sim 125 \text{ VA}$$



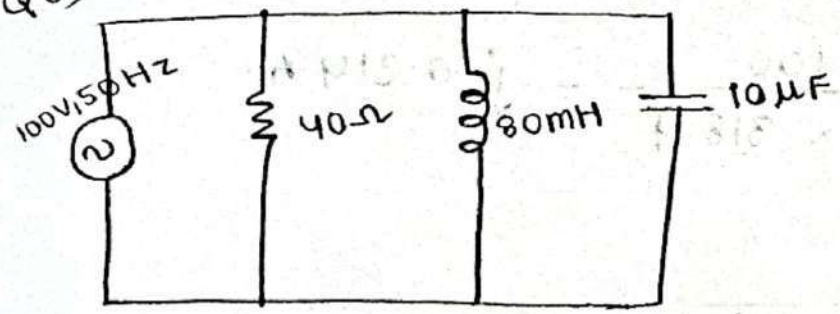
$$y' \sec^{-3} x + y \sec^{-2} x = \text{(sec 1}$$

$$y' + \frac{dy}{dx}$$

$$y'$$

6/7/20

Q5)



Find Y, Z, ϕ, I, I_R, I_L, I_C, P, Q, S.

$R = 40\Omega$
$L = 80\times10^{-3}$ H
$C = 10\times10^{-6}$ F

$X_L = 2\pi f L = 2\times3.14\times50\times80\times10^{-3}$
$= 25.12\Omega$

$B_L = \frac{1}{X_f} = \frac{1}{25.12} = 0.04\,℧\ (0.039\,℧)$

$X_C = \frac{1}{2\pi f C} = \frac{1}{2\times3.14\times50\times10^{-6}} = \frac{1000}{3.14} = 318.4\Omega$

$B_C = \frac{1}{X_C} = \frac{1}{318.4} = 0.0031\,℧$

$R = \frac{1}{G} \Rightarrow G = \frac{1}{40} = 0.025\,℧$

(i) $Y = G + j(B_C - B_L)$
$= 0.025 + j(0.0031 - 0.039)$
$= 0.025 + j(-0.008)\ j(-0.0359)$
$|Y| = \cancel{0.0262}\ 0.043$

$\phi = \cancel{\tan^{-1}\left(\frac{-0.008}{0.025}\right)}\ \tan^{-1}\left(\frac{-0.036}{0.025}\right)$
$= -55.1°$

$Y = 0.043\angle-55.1°\,℧$

$Z = \frac{1}{Y} = \frac{1}{0.043\angle-55.1°} = 23.25\angle55.1°\,\Omega$

$I = \frac{V}{Z} = \frac{100}{23.25} = 4.301\angle-55.1°$ A

$I_R = \frac{V}{R} = \frac{100}{40} = 2.5$ A.

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$$I_L = \frac{V}{jX_L} = \frac{100}{j \times 25.12} = -j\,3.9\ A.$$

$$I_C = \frac{V}{-jX_C} = \frac{100}{-j \times 318.4} = j\,0.314\ A.$$

$$I = \sqrt{I_R^2 + (I_C - I_L)^2}$$

$$= \sqrt{(2.5)^2 + (0.314 - 3.9)^2}$$

$$= 4.3$$

$$\phi = \tan^{-1}\left(\frac{I_C - I_L}{I_R}\right) = -55.1^\circ$$

$$I = 4.3\angle -55.1^\circ.$$

$$P = VI\cos\phi = 100 \times 4.3 \times \cos(-55.1)$$

$$= 246.02\ W$$

$$Q = VI\sin\phi = 100 \times 4.3 \times \sin(-55.1^\circ)$$

$$= -352.66\ Vars$$

$$S = VI = 100 \times 4.3 = \underline{\underline{430}}\ VA$$

$$S = \sqrt{P^2 + Q^2} = \sqrt{(246.02)^2 + (352.66)^2}$$

$$= \sqrt{60525.8 + 124369.0}$$

$$= \sqrt{184894.87}$$

$$= 429.99$$

$$\sim \underline{\underline{430}}\ VA$$

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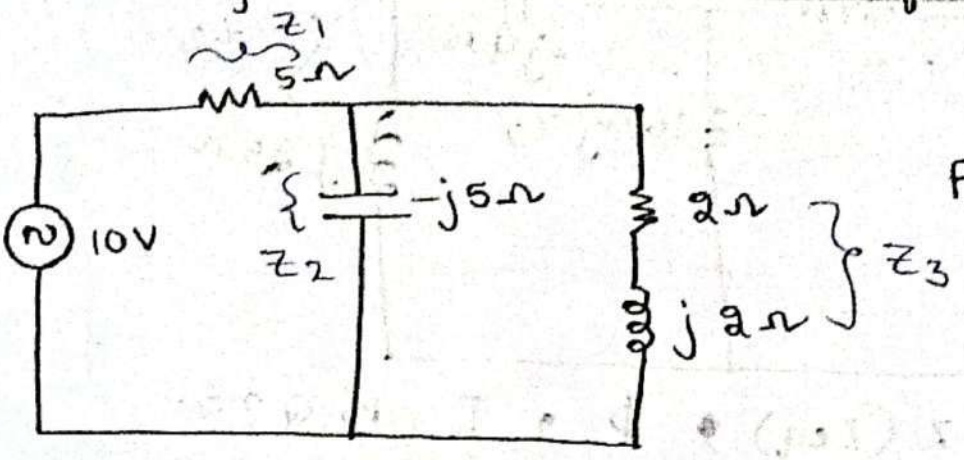
Series-parallel Combination of RLC Circuit.

Q1)



Find Z_{eq}, ϕ, I.

$Z_1 = 5\Omega$

$Z_2 = -5j\Omega$

$Z_3 = (2+j2)\Omega$

$$Z_{eq} = Z_1 + \frac{Z_2 Z_3}{Z_2 + Z_3}$$

$$= 5 + \left(\frac{-j5 \times (2+j2)}{-j5 + 2 + j2}\right)$$

$$= 5 + \left(\frac{10 - j10}{2 - j3}\right)$$

$$= 5 + 3.92 \angle 11.309$$

$$Z_{eq} = 8.87 \angle 4.96^\circ \Omega$$

$$\phi = 4.96^\circ$$

$$I = \frac{V}{Z_{eq}} = \frac{10}{8.87 \angle 4.96^\circ}$$

$$= 1.126 \angle -4.96^\circ \text{ A}$$

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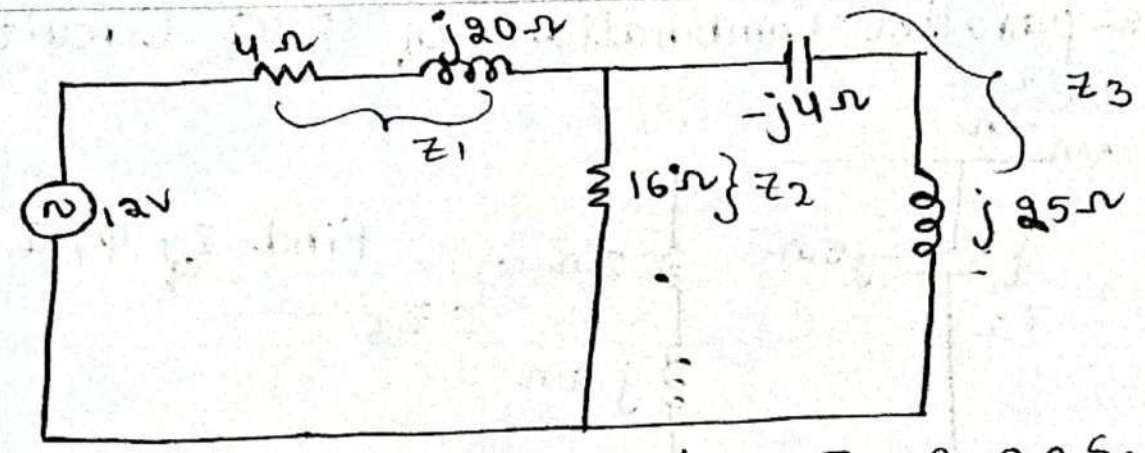
Q2)



Find Total Z (Zeq), ϕ, I, P, Q, S.

$Z_3 = -j4\Omega + j25\Omega$

$= j21\Omega$

$Z_1 = (4 + j20)\Omega$

$Z_2 = 16\Omega$

$$Z_{eq} = Z_1 + \frac{Z_2 Z_3}{Z_2 + Z_3}$$

$$= (4+j20) + \frac{16 \times (j21)}{16 + j21} = 4 + j20 + 10.123 + j7.71$$

$$= 14.123 + j27.71$$

$$Z_{eq} = 31.10 \angle 63^\circ \Omega$$

$$\phi = 63^\circ$$

$$I = \frac{V}{Z_{eq}} = \frac{12}{31.10 \angle 63^\circ}$$

$$= 0.38 \angle -63^\circ \text{ A}$$

$P = VI\cos\phi = 12 \times 0.38 \times \cos(63^\circ) = 2.052$ W

$Q = VI\sin\phi = 12 \times 0.38 \times \sin 63^\circ = 4.0584$ varg

$S = VI = 12 \times 0.38 = 4.56$ VA

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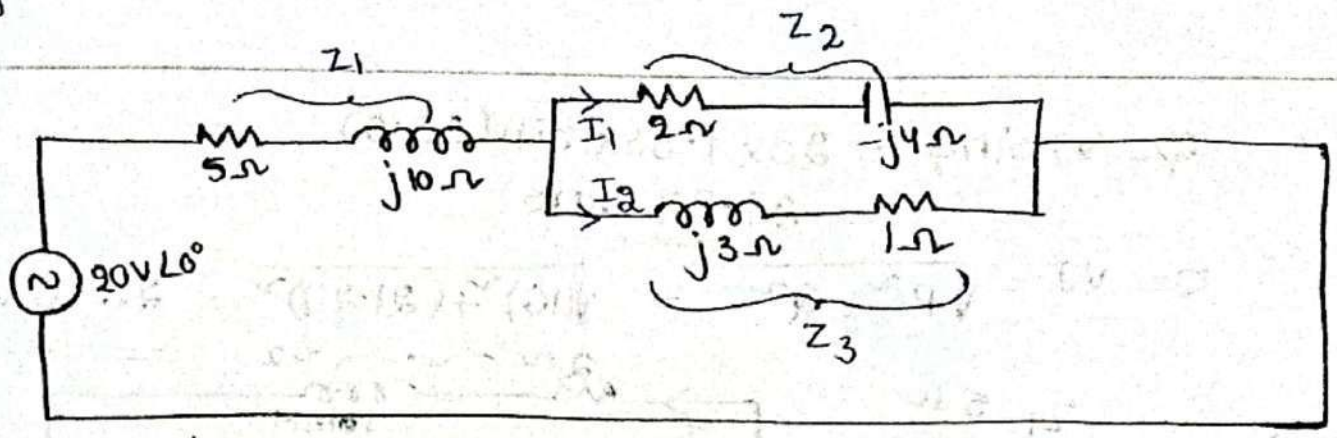
Q3)



Find $Z, \phi, I, I_1, I_2, P, Q, S$.

$$Z = Z_1 + Z_2 \| Z_3$$

$$= Z_1 + \frac{Z_2 Z_3}{Z_2 + Z_3}$$

$$Z_1 = (5 + j10)\,\Omega$$

$$Z_2 = (2 - j4)\,\Omega$$

$$Z_3 = (1 + j3)\,\Omega$$

$$Z = (5 + j10)\left(\frac{(2-j4)\times(1+j3)}{2-j4+1+j3}\right)$$

$$= 5 + j10 + 4 + j2$$

$$= 9 + j12 \qquad \phi = \tan^{-1}\left(\frac{12}{9}\right) = 53.13^\circ$$

$$Z = |Z|\angle i$$

$$= 15\angle 53.13^\circ$$

$$I = \frac{V}{Z} = \frac{20\angle 0^\circ}{15\angle 53.13^\circ} = 1.33\angle -53.13^\circ$$

$$I_1 = I \times \frac{Z_3}{Z_2 + Z_3} = 1.33\angle -53.13 \times \frac{(1+j3)}{(1+j3)+(2-j4)}$$

$$= 1.33\angle 36.82^\circ$$

$$I_2 = I \times \frac{Z_2}{Z_2 + Z_3} = 1.33\angle -53.13 \times \frac{(2-j4)}{(1+j3)+(2-j4)}$$

$$= 1.88\angle -98.13^\circ$$

$$I = I_1 + I_2 = 1.33\angle 36.82^\circ + 1.88\angle -98.13^\circ$$

$$= 1.33\angle -53^\circ$$

$$P = VI\cos\phi = 20 \times 1.33\cos(53.13) = 15.96\,W$$

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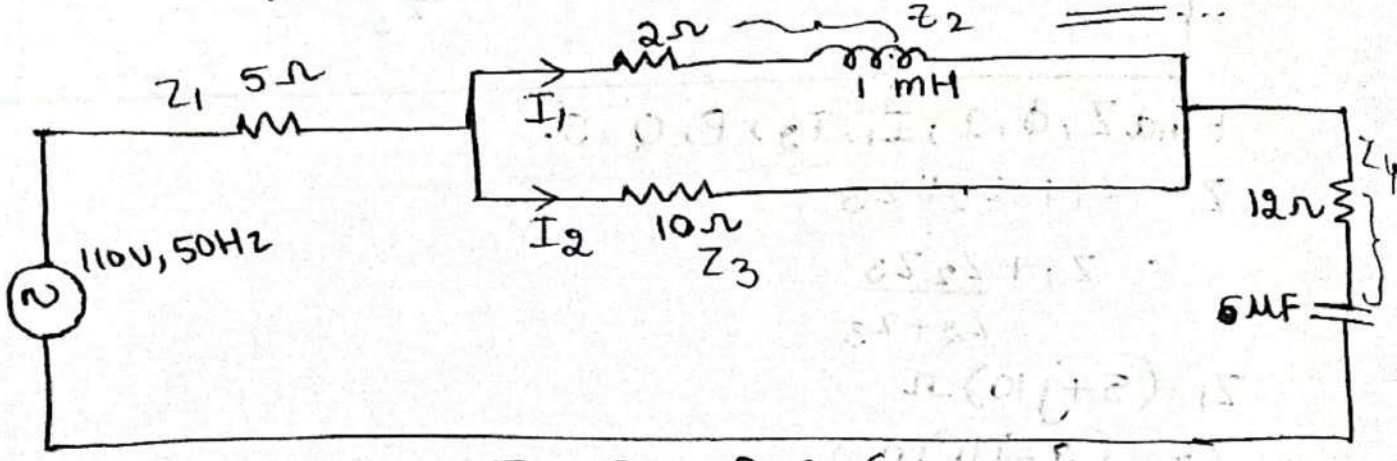
$Q = VI\sin\phi = 20 \times 1.33 \times \sin(53.0)$

$= 21.27$ Vars

$S = VI = \sqrt{P^2 + Q^2} = \sqrt{(16)^2 + (21.27)^2} = 26.6$ VA

Q4)



Find $Z, \phi, I, I_1, I_2, P, Q, S$.

$Z_1 = 5\Omega$

$Z_2 = 2 + j(2\pi f L) = 2 + j(2\pi \times 50 \times 1 \times 10^{-3})$

$= 2 + j0.31\ \Omega$

$Z_3 = 10\Omega$

$Z_4 = R - jX_C$

$= 12 - j\dfrac{1}{2\pi f C}$

$= 12 - j\dfrac{1}{2\pi \times 50 \times 6 \times 10^{-6}}$

$= (12 - j530.78)\ \Omega$

$Z = Z_1 + \dfrac{Z_2 Z_3}{Z_2 + Z_3} + Z_4$

$= 5 + \dfrac{(2 + j0.31)(10)}{2 + j0.31 + 10} + (12 - j530.78)$

$= 530.89 \angle -87.98^\circ\ \Omega$

$\phi = -87.98^\circ$

$Y = \dfrac{1}{Z} = \dfrac{1}{530.89 \angle -87.98^\circ} = 0.00189 \angle 87.98^\circ$

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$$I = \frac{V}{Z} = \frac{110\angle 0^\circ}{530.89\angle -87.98^\circ} = 0.207\angle 87.98^\circ \text{ A}$$

$$I_1 = I \times \frac{Z_3}{Z_2+Z_3} = 0.207\angle 88^\circ \times \frac{10}{10+2+j0.31}$$

$$I_1 = 0.17\angle 86.48^\circ \text{ A}$$

$$I_2 = I \times \frac{Z_2}{Z_2+Z_3}$$

$$= 0.207\angle 88^\circ \times \frac{(2+j0.31)}{10+2+j0.31}$$

$$I_2 = 0.034\angle 95.46^\circ \text{ A}$$

$$I = I_1 + I_2 = 0.17\angle 86.48^\circ + 0.034\angle 95.46^\circ$$

$$I = 0.207\angle 88^\circ \text{ A}$$

$$P = VI\cos\phi = 110 \times 0.207 \times \cos(-88)$$

$$= 0.802 \text{ W}$$

$$Q = VI\sin\phi = 110 \times 0.207 \times \sin(-88)$$

$$= -22.7 \text{ Vars}$$

$$S = VI = \sqrt{P^2+Q^2} = \sqrt{(0.80)^2+(-22.7)^2}$$

$$= 22.71 \text{ VA}$$

* Analysis of series Resonance :—

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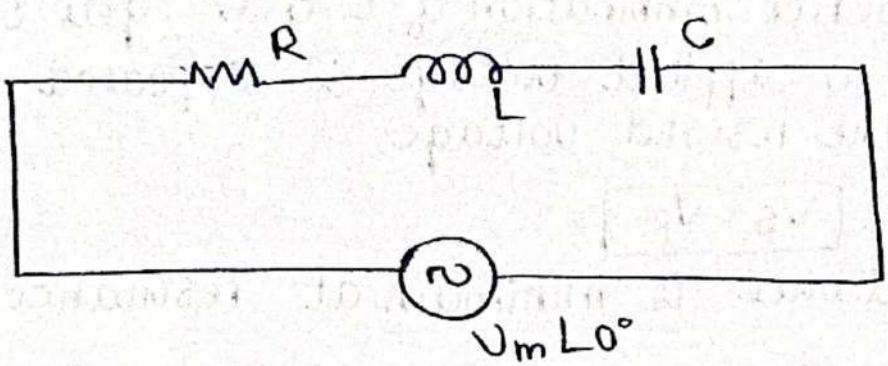
* Resonance is helpful to frequency response of the circuit. Consider a series RLC circuit, the impedance of the circuit is.



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

The imaginary part of Z (or) impedance is equal to zero.

$$X_L - X_C = 0$$

$$\Rightarrow X_L = X_C$$

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

$$\omega L = \frac{1}{\omega C}$$

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

$$* \quad \omega = \frac{1}{\sqrt{LC}} \text{ rad/sec}$$

The value of ω that satisfies the condition is known as resonance frequency.

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

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

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Note:-

→ At resonance impedance is purely resistive

$\boxed{Z = R}$

→ This series combination of L & C gets short circuited & applied voltage is appeared across the resistor voltage.

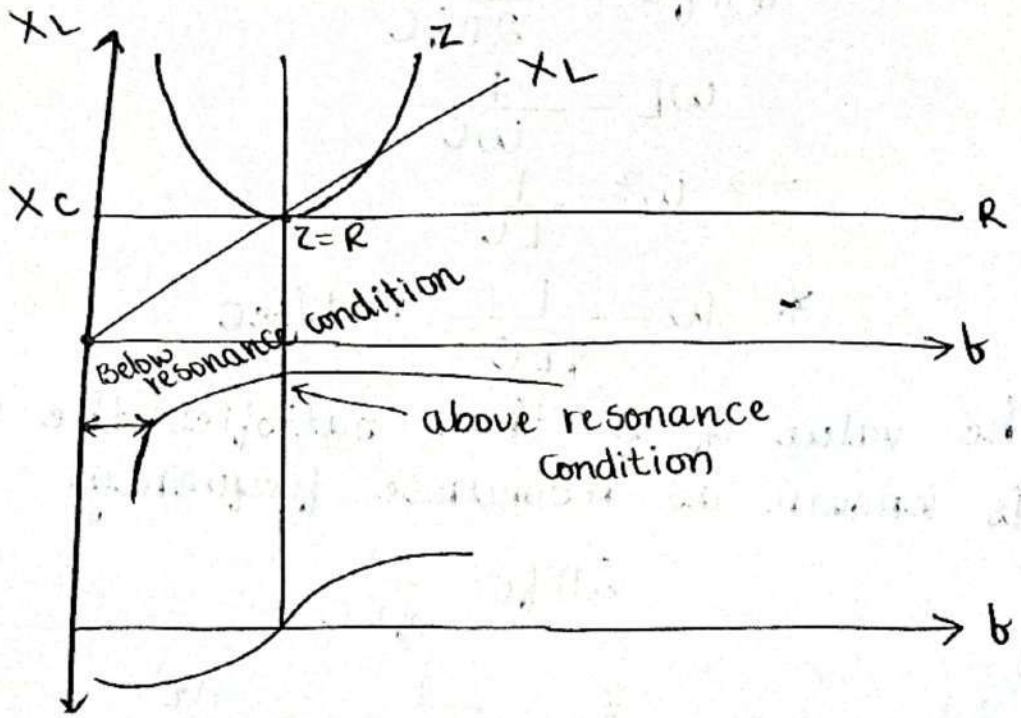
$\boxed{V_S = V_R}$

→ Impedance is minimum at resonance condition.

→ Current is maximum, Z is minimum.

→ The phase angle b/w voltage & current is 0° ⟹ $\boxed{\phi = 0^\circ}$. ⟹ $\cos\phi = 1$

Frequency analysis (Series resonance circuit):-



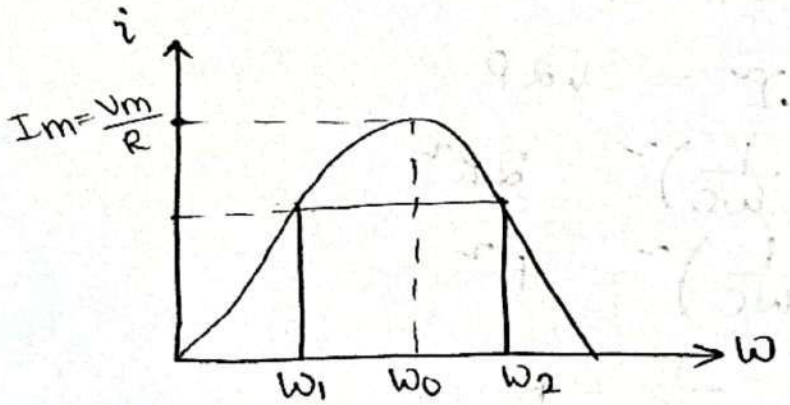
$$Z = R + jX_L - jX_C$$
$$= R + j(X_L - X_C)$$
$$Z = R + j\left(2\pi f L - \frac{1}{2\pi f C}\right) = \sqrt{R^2 + (X_L - X_C)^2}$$

→ Below resonance condition, Z decreases along with X_C. Impedance decreases with X_C ($X_C > X_L$), then circuit behaves like capacitive nature (current leads the voltage).

→ After resonance condition, Z increases alongwith X_L ($X_L > X_C$) then circuit behaves like inductive nature (current lags the voltage).

→ At resonance condition, Z is minimum ($Z = R$) then circuit behaves like pure resistor (current in phase with voltage).

Band width of quality factor:—



$\omega = 0 = 2\pi f \Rightarrow f = 0$

$Z \to \infty$

$I = \frac{V}{Z} = 0$

$\omega = \infty$

$Z \to \infty$

$I = \frac{V}{Z} = 0.$

→ The average power dissipated at resonance

$$P(\omega_0) = I_m^2 R = \left(\frac{I_m}{\sqrt{2}}\right)^2 R = \frac{1}{2} I_m^2 R \ (\text{or}) \ \frac{V_m^2}{2R}$$

→ At certain frequency, $\omega = \omega_1 \cdot \omega_2$ then dissipated power $= \frac{1}{2}$ (max-power)

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$$P(\omega_1) = P(\omega_2) = \frac{1}{2}\left(\frac{I_m}{\sqrt{2}}\right)^2 R$$

$$= \frac{1}{4} I_m^2 R$$

(or)

$$= \frac{\frac{1}{2}\left(\frac{V_m}{\sqrt{2}}\right)^2}{R} = \frac{1}{4}\frac{V_m^2}{R} \text{ watts.}$$

where $\omega_1 \rightarrow$ lower cut of frequency

$\omega_2 \rightarrow$ higher cut of frequency.

$\rightarrow$ The half power frequencies are obtained by equating $\boxed{Z = \sqrt{2}R}$

$$\left\{ I = \frac{V}{Z} \right.$$

$$\left. Z = \frac{V}{I} = \frac{V_m}{\frac{1}{\sqrt{2}} \cdot \frac{V_m}{R}} = \sqrt{2}R. \right\}$$

$$R + i(X_L - X_C) = \sqrt{2}R.$$

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

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

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

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

$$\omega^2 LC - 1 = \omega RC$$

$$\omega^2 LC - \omega RC - 1 = 0 \quad \left\{ \begin{array}{l} a = LC \\ b = -RC \\ c = -1 \end{array} \right\}$$

$$\omega_1, \omega_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{RC \pm \sqrt{(RC)^2 - 4(LC)(-1)}}{2LC}$$

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$$= \frac{RC}{2LC} \pm \sqrt{\frac{(RC)^2}{(2LC)^2} + \frac{4LC}{(2LC)^2}}$$

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

$$\omega_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}} \text{ rad/sec}$$

$$\sqrt{\omega_1 \omega_2} = \frac{1}{LC} = \omega_0^2$$

$$\omega_0 = \sqrt{\omega_1 \omega_2}$$

$$\omega_2 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}} \text{ rad/sec}$$

Note: frequency should always be positive.

We can relate the half power frequency with resonance frequency.

$$\omega_0 = \sqrt{\omega_1 \omega_2}$$

Band Width:—

Band width is defined as difference b/w the two half power frequencies.

$$B = \omega_2 - \omega_1$$

$$\boxed{B = \frac{R}{L}}$$

The sharpness of resonance curve is quantatively measured by quality factor.

Quality factor is defined as ratio of resonance frequency to band width i.e,

$$\boxed{Q = \frac{\omega}{B}} = \frac{X_L}{R} = \frac{X_C}{R}$$

$$= \frac{\omega_0 L}{R} = \frac{\frac{1}{\omega_0 C}}{R} \longrightarrow \frac{1}{\omega_0 RC}$$

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$$\boxed{Q = \frac{\omega_0}{B} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}}$$

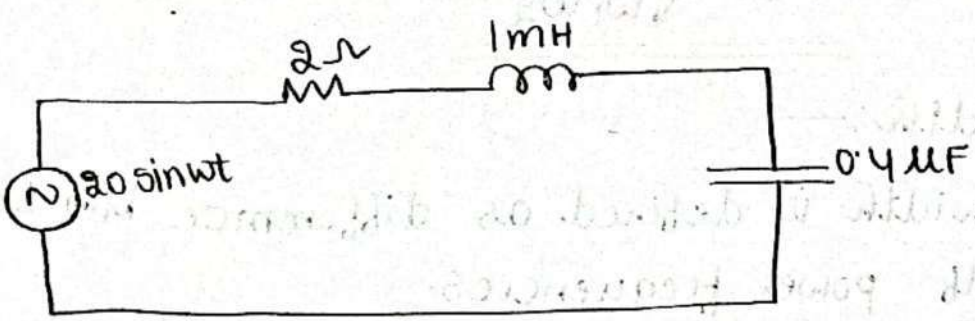
For higher quality factor $(Q>10)$, the half power frequencies are approximated as.

$$\boxed{\begin{aligned} \omega_1 &= \omega_0 - \frac{B}{2} \\ \omega_2 &= \omega_0 + \frac{B}{2} \end{aligned}}$$

$$|V_L| = I_m X_L = \frac{V_m}{R} \times \omega_0 L = V_m Q$$

$$|V_C| = I_m X_C = \frac{V_m}{R} \times \frac{1}{\omega_0 C} = V_m Q$$

Q1)



a) Find the resonance frequency, ω_0 & ω_1 & ω_2.

b) Calculate quality factor & B.

c) Determine the amplitude of current at ω_0, ω_1 & ω_2

$R = 2\Omega$, $L = 10^{-3}$ H, $C = 0.4 \times 10^{-6}$ F.

a) $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10^{-3} \times 0.4 \times 10^{-6}}}$

$\omega_0 = 50000$ rad/sec

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

$$= \frac{-2}{2\times 1\times 10^{-3}} + \sqrt{\left(\frac{2}{2\times 10^{-3}}\right)^2 + \frac{1}{10^{-3}\times 0.4\times 10^{-6}}}$$

$$\rightarrow \omega_1 = 49000 \text{ rad/sec}$$

$$\omega_2 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

$$= \frac{2}{2\times 1\times 10^{-3}} + \sqrt{\left(\frac{2}{2\times 10^{-3}}\right)^2 + \frac{1}{10^{-3}\times 0.4\times 10^{-6}}}$$

$$\Rightarrow \omega_2 = 51000 \text{ rad/sec}$$

b) $Q = \frac{\omega_0}{B} = \frac{50}{2} = 25$ $\left[B = \omega_2 - \omega_1 = 2000 \text{ rad/sec}\right]$

c) $I_m = \frac{V_m}{R} = \frac{20}{2} = 10\text{ A}$

$$I_m(\omega_1) = I_m(\omega_2) = \frac{10}{\sqrt{2}} = 7.07\text{ A}$$

Q2) A series connected circuit has $R = 4\Omega$ & $L = 25\text{mH}$ then calculate

a) The value of $C = ?$, that will produce a quality factor of 50.

b) Find ω_1 & ω_2

c) Determine the avg power dissipated at ω_0, ω_1, ω_2 at $V_m = 100\text{V}$.

$R = 4\Omega$

$L = 25\times 10^{-3}\text{ H}$

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a) $B = \frac{R}{L} = \frac{4}{25 \times 10^{-3}} = \underline{\underline{160}}$

$Q = \frac{\omega_0}{B} \Rightarrow 50 = \frac{\omega_0}{160}$

$\omega_0 = \underline{\underline{8000}}$

$Q = \frac{1}{\omega_0 RC} \Rightarrow 50 = \frac{1}{8000 \times 4 \times C}$

$C = \frac{1}{1600000} = \underline{\underline{0.625 \mu F}}$

b) $\omega_1 = \omega_0 - \frac{B}{2} = 8000 - \frac{160}{2} = \underline{\underline{7920 \text{ rad/sec}}}$

$\omega_2 = \omega_0 + \frac{B}{2} = 8000 + \frac{160}{2} = \underline{\underline{8080 \text{ rad/sec}}}$

c) $P(\omega_0) = \frac{1}{2} \frac{V_m^2}{R} = \frac{1}{2} \times \frac{10000}{4} = \underline{\underline{1250 W}}$

$P(\omega_1) = \frac{1}{2} P(\omega_0) = \underline{\underline{625 W}} = P(\omega_2)$

H.W

Q3) A series RLC circuit has $R = 5\Omega$; $L = 0.2H$, $C = 50 \mu F$. The applied voltage is 200V. Find

a) Resonance frequency $(\omega_0) = ?$

b) $Q = ?$

c) $B.W = ?$

d) $\omega_1, \omega_2 = ?$

e) $I(\omega_0) = ?$

f) $I(\omega_1) = I(\omega_2) = ?$

g) Voltage across inductor & capacitor at resonance $= ?$

h) $P_{avg}(\omega_0) = ?$, $P_{avg}(\omega_1) = P(\omega_2) = ?$

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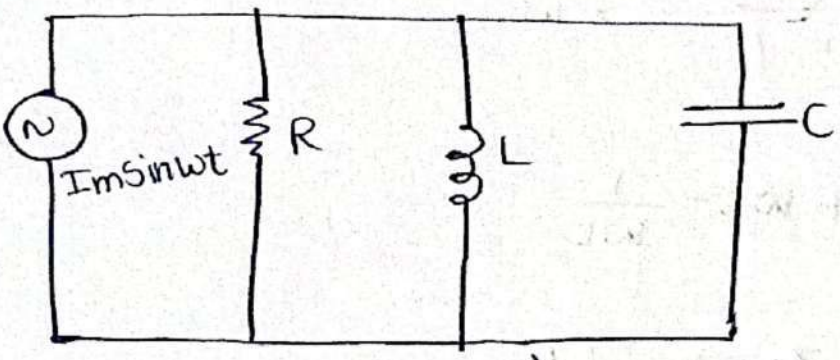
PARALLEL RESONANCE :—

Let us consider the parallel combination of RLC circuit as shown in below figure:



The admittance of network is parallel

$$Y = G + j(B_C - B_L)$$

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

Resonance occurs when imaginary part of Y becomes zero.

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

$$\omega C = \frac{1}{\omega L}$$

$$\omega^2 = \frac{1}{LC}$$

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

since $\omega_0 = 2\pi f_0$

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

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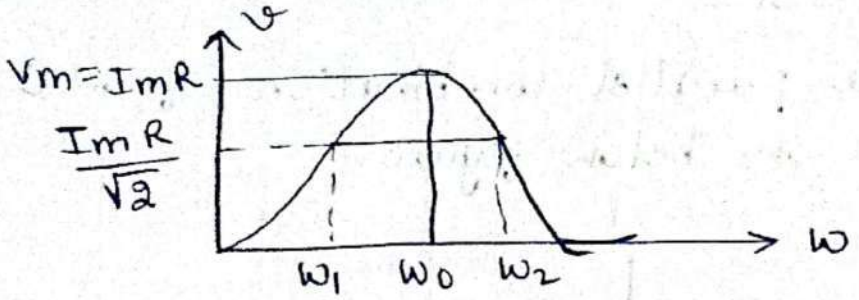
Graph b/w V & w



At $w=0$

$$Y = \frac{1}{R} + wC - \frac{1}{wL}$$

$$Y \rightarrow \infty$$

$$V = IZ \Rightarrow I/y$$

$$w = \infty$$

$$\frac{1}{R} + j\left(wC - \frac{1}{wL}\right) = \frac{\sqrt{2}}{R}$$

$$\sqrt{\left(\frac{1}{R}\right)^2 + \left(wC - \frac{1}{wL}\right)^2} = \frac{\sqrt{2}}{R}$$

S.O.B.S

$$\frac{1}{R^2} + \left(wC - \frac{1}{wL}\right)^2 = \frac{2}{R^2}$$

$$\left(wC - \frac{1}{wL}\right)^2 = \frac{1}{R^2}$$

$$\frac{1}{R} = wC - \frac{1}{wL}$$

$$wLR = w^2LC - 1$$

$$w^2LC - wLR - 1 = 0$$

$$w^2 - \frac{w}{RC} - \frac{1}{LC} = 0$$

$a = 1$

$b = \frac{-1}{RC}$

$c = \frac{-1}{LC}$

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$$\omega_1, \omega_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{\frac{1}{RC} \pm \sqrt{\frac{1}{R^2C^2} + \frac{4}{LC}}}{2}$$

$$= -\frac{1}{2RC} \pm \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}}$$

$$\omega_1 = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}}$$

$$\omega_2 = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}}$$

$B = \omega_2 - \omega_1 \rightarrow$ Band width

$$\boxed{B = \frac{1}{RC}}$$

$$Q = \frac{\omega_0}{B} = \frac{\omega_0}{1/RC} = \omega_0 RC = \frac{R}{\omega_0 L}$$

$$\boxed{Q = \omega_0 RC}$$

If $Q > 10$

$$\boxed{\begin{aligned} \omega_1 &= \omega_0 - \frac{B}{2} \\ \omega_2 &= \omega_0 + \frac{B}{2} \end{aligned}}$$

$$\Rightarrow |I_L| = \frac{V_m}{X_L} = \frac{I_m R}{\omega_0 L} = I_m Q$$

$$|I_C| = \frac{V_m}{X_C} = \frac{I_m R}{1/\omega_0 C} = I_m R \omega_0 C = I_m Q$$

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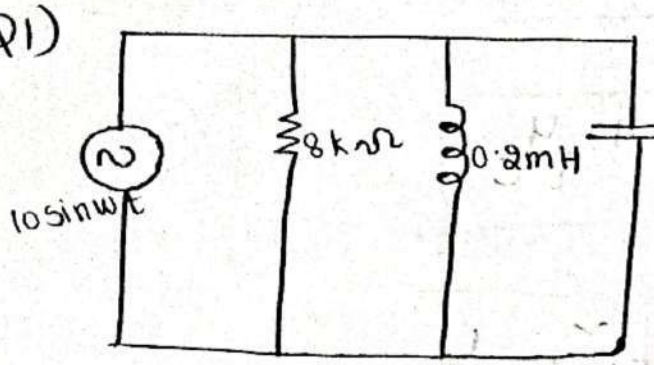
Q1)



Determine

(i) ω_0, B, Q

(ii) ω_1, ω_2

(iii) $P(\omega_0)$, $P(\omega_1) = P(\omega_2)$.

$V_m = 10$

(i) $$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.2\times10^{-3}\times 8\times10^{-6}}} = 25000 \text{ rad/sec.}$$

$$B = \frac{1}{RC} = \frac{1}{8\times10^{3}\times 8\times10^{-6}} = \frac{1000}{64} = 15.625$$

$$Q = \frac{\omega_0}{B} = \frac{25000}{15.625} = 1600$$

(ii) $$\omega_1 = \omega_0 - \frac{B}{2} = 25000 - \frac{15.625}{2} = 24992.1875 \text{ rad/sec}$$

$$\omega_2 = \omega_0 + \frac{B}{2} = 25000 + \frac{15.625}{2} = 25007.8125 \text{ rad/sec}$$

(iii) $$P = \frac{1}{2}\frac{V_m^2}{R} = \frac{1}{2}\times\frac{(10)^2}{8\times1000} = 6.25\times10^{-3}\,W$$

$$P(\omega_1) = P(\omega_2) = \frac{P(\omega_0)}{2} = \frac{6.25\times10^{-3}}{2}$$

$$= 3.125\times10^{-3}\,W$$

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Q2) Determine the parameters of series RLC circuit at resonance $(\omega_0) = 10kHz$, $B(\omega_0) = 1KHz$ & draw the power of 15.3 W from a 200V generator.

$V = 200V$

$$P = \frac{V^2}{R} \Rightarrow \frac{(200)^2}{15.3} = R$$

$$\Rightarrow R = 2.614\ k\Omega$$

$$Q = \frac{\omega_0 L}{R} = \frac{f_0}{B}$$

$$\frac{2\pi f_0 L}{R} = \frac{f_0}{B}$$

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

$$L = \frac{R}{2\pi B}$$

$$\Rightarrow L = \frac{2.614 \times 10^3}{2 \times 3.14 \times 10^3} = 0.416H$$

$$L\omega_0 = \frac{1}{\sqrt{LC}}$$

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

$$\Rightarrow 2 \times 3.14 \times 10 \times 10^3 = \frac{1}{\sqrt{0.416 \times C}}$$

$$C = 6.095 \times 10^{-10} F$$

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Q) A series RLC circuit has a $R = 1k\Omega$, half power frequencies are 20 & 100kHz.
(i) $B(\omega)$ (ii) ω_0 (iii) L, C

$f_1 = 20kHz$

$\omega_1 = 2\pi f_1 = 2 \times 3.14 \times 20 \times 10^3$

$= 12.56 \times 10^4$ rad/sec

$f_2 = 100kHz$

$\omega_2 = 2\pi f_2 = 2 \times 3.14 \times 100 \times 10^3$

$= 62.8 \times 10^4$ rad/sec

(i) $B = \omega_2 - \omega_1$

$= 50.24 \times 10^4$ rad/sec

(ii) $\omega_1 = \omega_0 - \frac{B}{2}$

$\Rightarrow \omega_0 = (12.56 + 25.12) \times 10^4$

$= 37.68 \times 10^4$ rad/sec

(iii) $B = \frac{R}{L}$

$50.24 \times 10^4 = \frac{10^3}{L}$

$L = \frac{1}{502.4} = 1.99 \times 10^{-3} = 1.99\,mH$

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

$$\omega_0^2 L = \frac{1}{C}$$

$$C = \frac{1}{\omega_0^2 L}$$

$$= 3.539 \times 10^{-4} \times 10^{-5} \text{ F}$$

$$= \underline{\underline{3.539 \times 10^{-9} \text{ F}}} \ldots$$

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UNIT-4

Transformer (T/F):—

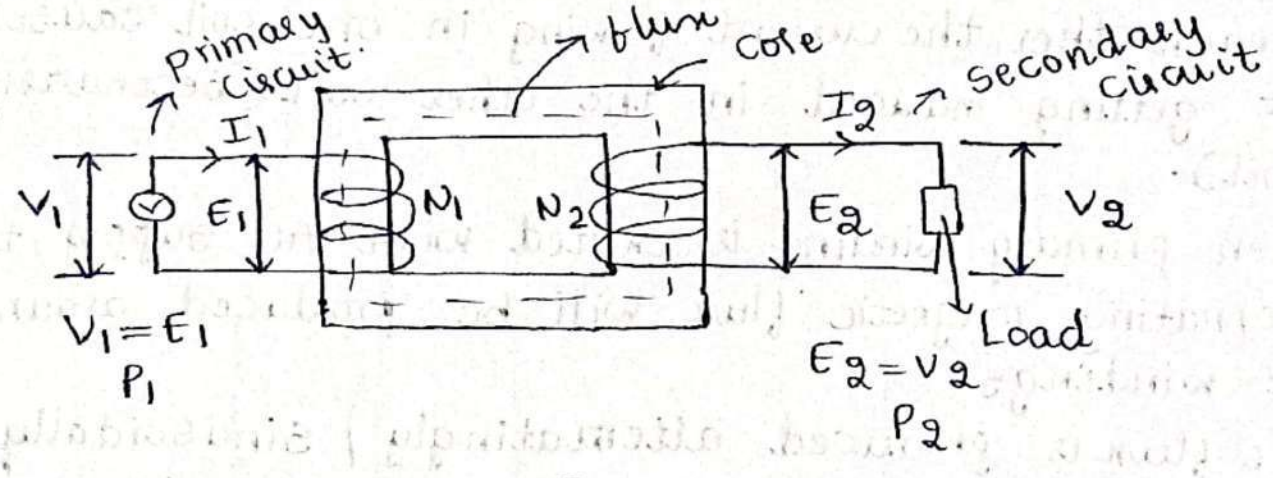
Transformer is a static device (no rotating parts) that is used for transforming the power from one circuit to another circuit.

→ Voltage can be raised / lowered in a circuit but with proportional increase or decrease in current ratings.

→ Transformer is a constant power device.

→ It is a constant flux device.

→ Constant frequency device.



$P_1 = P_2$ → constant power device

Working Principle:—

V_1 = supply voltage

N_1 = primary winding turns

I_1 = primary ~~volt~~ winding current

ϕ = flux. V_2 = Load voltage.

E_2 = Induced EMF / voltage in secondary circuit

N_2 = Secondary winding turns.

I_2 = secondary winding current

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→ T/F consists of two windings.

1) Primary winding (N_1)

2) Secondary winding (N_2)

→ Both windings are electrically isolated but magnetically coupled to each other.

→ The principle behind the working of transformer is the phenomenon of mutual induction b/w the two coils/windings, placed on same magnetic core

→ Mutual Induction: When alternating current (AC) is flowing in a coil then alternating magnetic flux will be produced around the coil. When 2 or more coils are magnetically coupled to each other, the current flowing in one coil causes EMF getting induced in the other coil (secondary coil).

→ When primary winding is excited with AC supply, then alternating magnetic flux will be produced around the windings.

→ As flux is produced alternatingly / sinusoidally, EMF gets induced across the secondary winding according to Faraday's laws of EMI.

→ Faraday's law states that the induced EMF ∝ rate of change of flux linkages / leakages

$$\mathcal{E} = -\frac{d\phi}{dt}$$

-ve sign indicates Lenz Law.

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→ Lenz law states that induced EMF always opposes the cause for production of it

Ex: V_1 ↑ ↓ E_1

→ The EMF induced in secondary winding is called mutual induced EMF.

→ If secondary circuit is closed (connected to load), the mutual current will be flowing through it.

Thus power is transformed from one circuit to other.

$$P_1 = P_2$$

$$V_1 I_1 = V_2 I_2$$

Construction of T/F :—

1) Windings or coils.
2) Core
3) Conservator.
4) Breather
5) Oil.
6) Bushings
7) winding leads
8) Tank.

1) windings are made up of high grade copper.
2) Core is made up of silicon steel; Core is used to provide magnetic path for the flux.
3) Conservator is present at the top of the transformer, which provides adequate space for expansion of oil. (acts as a reservoir). Conservator monitors oil levels.

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4) Breather consists of silica gel, which is used to filter out the moisture from air.
5) Oil is used for cooling & insulation.
6) Bushings are the insulated structures that facilitates energised current carrying to tank.
7) Winding leads are used for input & output side connections.
8) Tank is the body of the T/F which is used to hold & protect core & the windings.

15/7/23

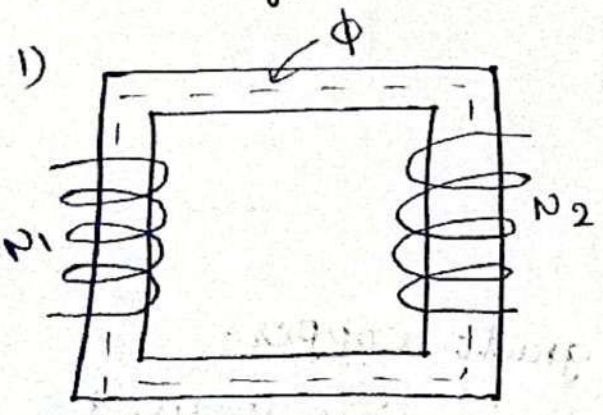
Types of Transformers:—

Two types.

① Core type T/F.
② Shell type T/F.

① Core Type T/F

1)



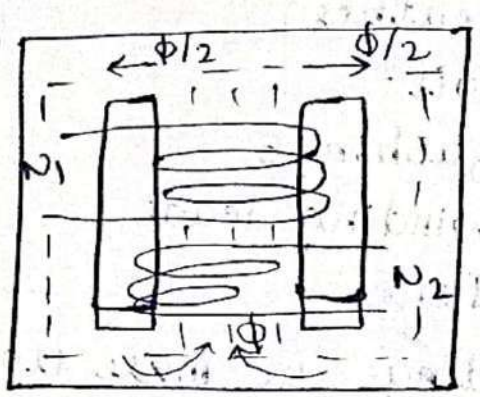
2) Winding surrounds the core.

3) Has only one magnetic circuit.

4) Has two limbs (legs)

Shell type T/F

1)



2) Core surrounds the winding.

3) Has two magnetic circuits.

4) Has three limbs (legs)

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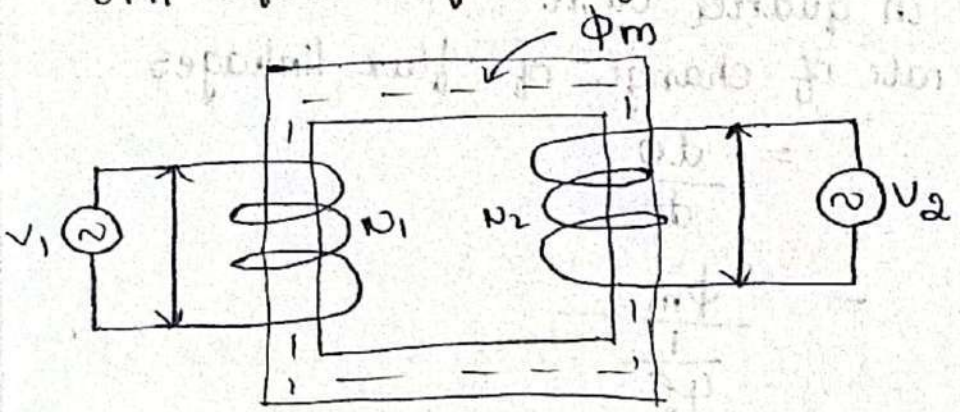
5) It has less mechanical (only two limbs) protection to winding	5) It has better mechanical production to winding.
6) It has better cooling (more surface is exposed to atmosphere).	6) It doesn't have effective cooling.
7) It is easy to repair	7) Not easy to repair.
8) It is used for high voltage applications.	
9) Natural cooling can be provided	9) Natural cooling cannot be provided.

EMF Equation of Transformer:—



N_1 — no. of turns of primary winding
N_2 — no. of turns of secondary winding.
ϕ_m — maximum flux in core (in webers)

$$\phi_m = B_m A.$$

B_m — maximum flux density (weber/m^2).
A — cross section area of the core.
E_1 — EMF induced in primary winding (volts)
E_2 — EMF induced in secondary winding. (volts)

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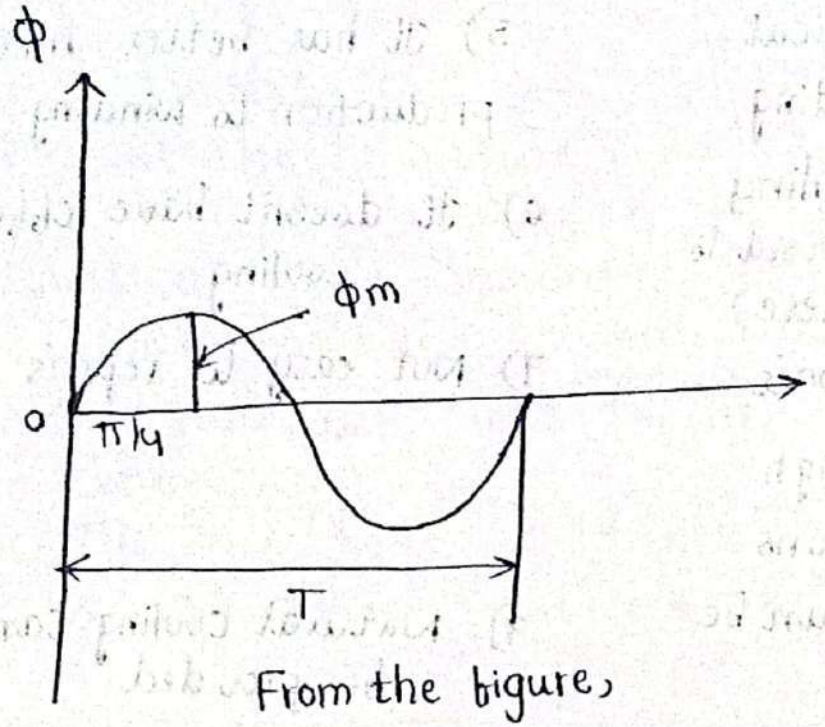

From the figure,

flux is varying from 0 to ϕ_m in quarter cycle.

→ Average rate of change of flux linkages

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

$$= \frac{\phi_m}{\frac{1}{4f}}$$

$$= 4f\phi_m \text{ weber/sec}$$

→ Average induced EMF $= \frac{d\phi}{dt}$

$$E = 4f\phi_m \text{ volts}$$

Since flux is varying sinusoidally, the RMS value of induced EMF is obtained by multiplying form factor with average value.

$$E_{RMS} = F.F \times E_{avg}$$

$$F.F \text{ for } AC = 1.11$$

$$= 1.11 \times 4f\phi_m \Rightarrow E_{RMS} = 4.44 f\phi_m \text{ volts.}$$

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This voltage is for single turn only.

RMS value of induced EMF for whole primary winding =

$$E_{RMS} = E_1$$

$$\Rightarrow \overset{E_1}{E_{RMS}} = (E_{avg}) \times N_1$$

for single turn.

$$= 4.44 f \phi_m N_1$$

$$\Rightarrow \overset{E_1}{E_{RMS}} = 4.44 f \phi_m N_1 \text{ volts} \quad \text{— 1}$$

Similary total RMS value of induced EMF in secondary winding $E_2 = (4.44 f \phi_m) N_2$ volts

Voltage Transformation Ratio (K) :—

from above 2 eq's :—

$$\frac{E_2}{E_1} = \frac{(4.44 f \phi_m) N_2}{(4.44 f \phi_m) N_1}$$

$$K = \frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{N_2}{N_1}$$

Current Transformation Ratio :— $(1/K)$:—

$$P_1 = P_2 \quad \text{(constant power device)}$$

$$V_1 I_1 = V_2 I_2$$

$$\frac{I_1}{I_2} = \frac{V_2}{V_1} = K$$

$$\Rightarrow \frac{I_2}{I_1} = \frac{1}{K}$$

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current transformation ratio is inversely propotional to voltage transformation ratio.

$$\boxed{\frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K}$$

If $V_2 > V_1 \Rightarrow K > 1 \rightarrow$ step up transformer.

If $V_2 < V_1 \Rightarrow K < 1 \rightarrow$ step down transformer.

Ideal Transformer, Characteristics:—

→ Core has zero leakage flux, the fluxes produced by primary & secondary currents are confined to the core.

→ Core has windings, windings have zero resistance.

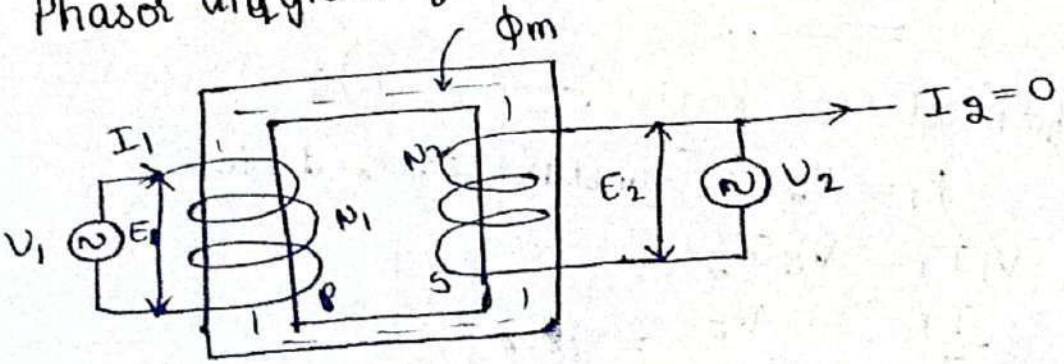
Supply voltage = Induced EMF.

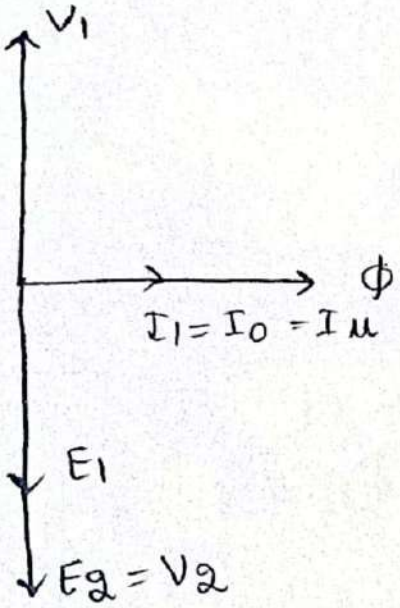
→ Core has infinite permeability.

→ Reluctance of the core is zero.

→ Loss-less Core, no eddy current & hysterlsis losses.

Phasor diagram for Ideal Transformer:—





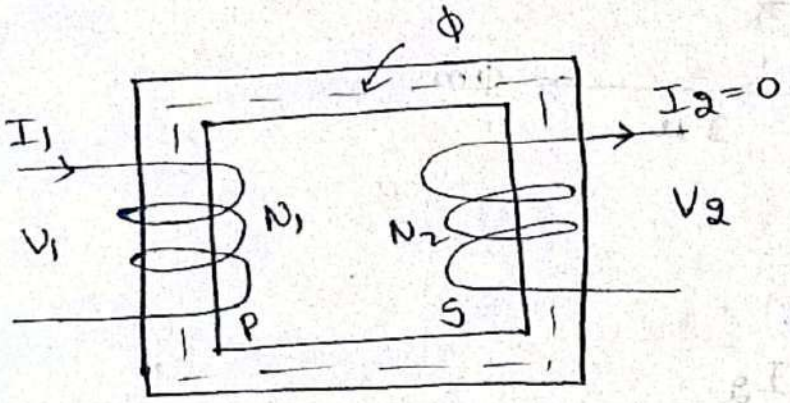
V_1 leads ϕ by $90°$

I_1 is always inphase with the flux.

I_2

$I_0 = I_1 = I_\mu$

Practical Transformer (No Load):—

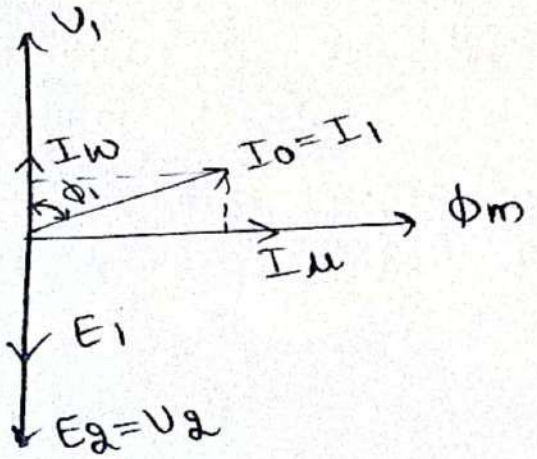


$I_0 = I_1$

$= I_\mu + I_w$ → working component of current.

I_μ → magnetising component of current

I_w is negligible as compared to I_μ



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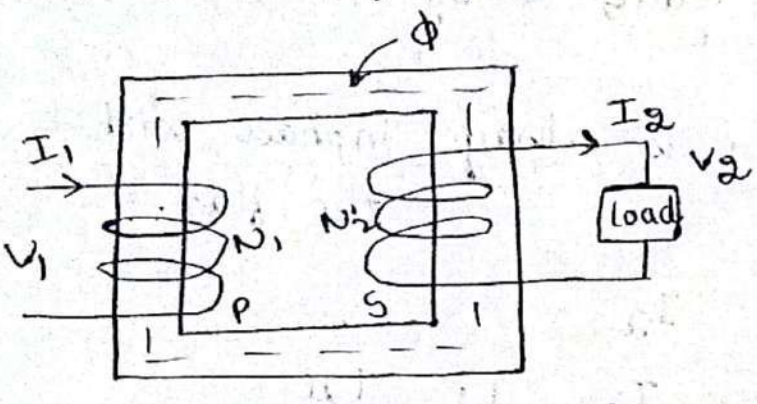
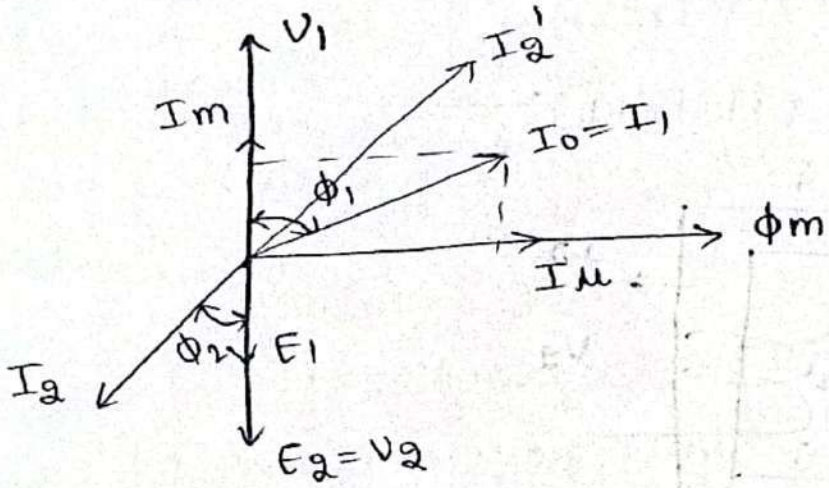
Practical Transformer (On Load):—



I_2 lags voltage V_2



$$I_1 = I_0 + I_2$$

$$I_1 = I_\mu + I_W + I_2$$

24/07/23

Q1) A 100kVA, 4000V/2000V, 1-phase transformer having 650 turns on primary winding. Find secondary winding turns. Find primary & secondary currents.

$P = 100kVA$

$V_1 = 4000V$

$V_2 = 2000V$

$N_1 = 650$

$N_2 = ?$

$I_1, I_2 = ?$

$$K = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = \frac{1}{2}$$

$$\Rightarrow \frac{2000}{4000} = \frac{N_2}{650}$$

$$\Rightarrow N_2 = \underline{\underline{325 \text{ turns}}}$$

$P = V_1 I_1$

$$\Rightarrow I_1 = \frac{100 \times 10^3}{4000}$$

$$I_1 = \underline{\underline{25A}}$$

$P = V_2 I_2$

$$\Rightarrow I_2 = \frac{100 \times 10^3}{2000}$$

$$I_2 = \underline{\underline{50A}}$$

$$K = \frac{I_1}{I_2} = \frac{25}{50} = \underline{\underline{\frac{1}{2}}}$$

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Q2) A primary winding of a 50Hz transformer has 480 turns & is from 6400V supply. & secondary winding has 20 turns. Find the peak value of flux & secondary voltage (V_2).

$f = 50Hz$, $N_1 = 480$, $V_1 = E_1 = 6400V$, $N_2 = 20$

$V_1 = E_1 = 4.44 f \phi_m N_1$

$6400 = 4.44 \times 50 \times \phi_m \times 480$

$\phi_m = \underline{\underline{0.06 Wb}}$

$K = \frac{N_2}{N_1} = \frac{V_2}{V_1}$

$\Rightarrow \frac{20}{480} = \frac{V_2}{6400}$

$V_2 = 266.66 = \underline{\underline{267V}}$

$E_2 = V_2 = 4.44 \times f \times \phi_m \times N_2$

$= 4.44 \times 50 \times 0.06 \times 20$

$= 266.4 V$

$\Rightarrow V_2 = \underline{\underline{267 V}}$

Q3) A single-phase 50Hz transformer, 80 turns primary & 400 turns are secondary windings. The net cross sectional area of the core is $200 cm^2$. If primary is connected to 240V, 50Hz supply. Then determine the EMF induced in the 2nd winding & flux density in the core.

$f = 50Hz$

$N_1 = 80$

$N_2 = 400$

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$A = 200 cm^2$

$V_1 = 240V$

$E_2 = ?$, $B_m = ?$ $(\phi_m = B_m A)$

$$K = \frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$\Rightarrow \frac{V_2}{240} = \frac{400}{80}$$

$$\Rightarrow V_2 = 1200 V$$

$$V_1 = E_1 = 4.44 f \phi_m N_1$$

$$\Rightarrow \phi_m = \frac{240}{4.44 \times 50 \times 80}$$

$$\phi_m = 0.013 Wb$$

$$B_m = \frac{\phi_m}{A} = \frac{0.013}{200 \times 10^{-4}}$$

$$B_m = 0.65 Wb/m^2$$

$$V_2 = 4.44 \times f \times B_m \times A \times N_2$$

$$1200 = 4.44 \times 50 \times B_m \times 200 \times 10^{-4} \times 400$$

$$B_m = 0.65 Wb/m^2$$

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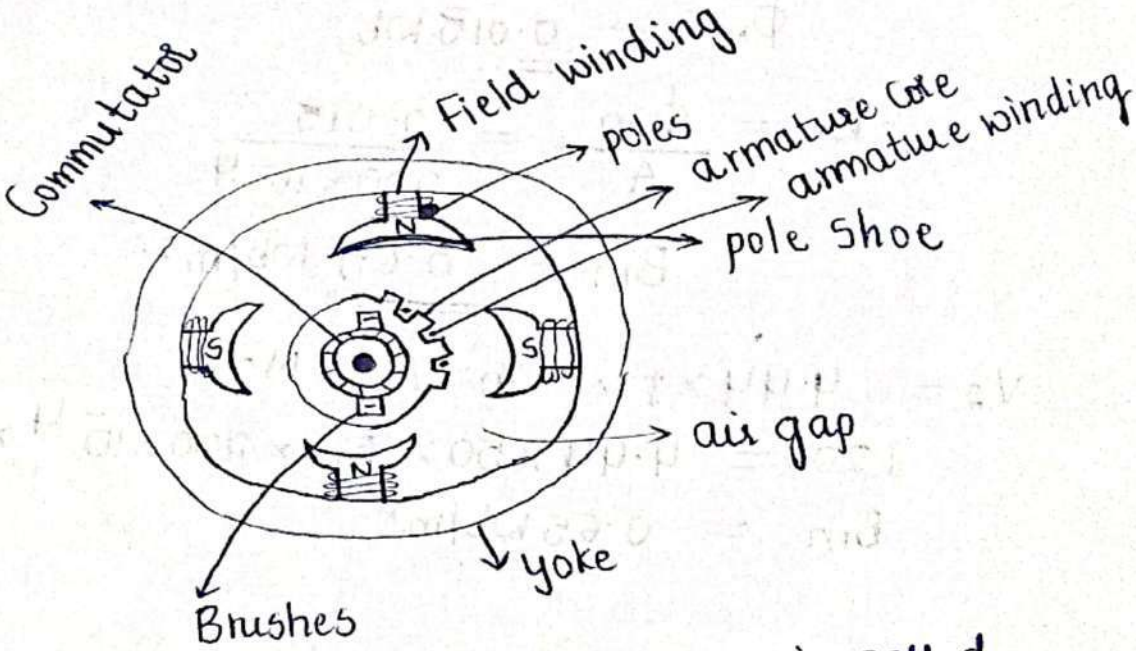
DC Machines

DC machine can be used as a DC generator or motor without any constructional changes, So, DC generator / motor can be named as DC machine.

When the machine is being assembled, we don't know whether it is a dc generator / motor.

DC motor can be used as a DC generator and viceversa.

Constructional Details:—



→ Any machine consists of stator or rotor

stator → is called stationary winding

rotor → is called rotating winding.

* Yoke:— outer frame of the machine. made up of cast iron or steel.

Yoke provides mechanical strength to the whole assembly of the machine.

* Poles :— supporting to the field windings. i.e, field winding is placed around the poles.

* pole shoe :— extended part of poles

2. functions.

1) prevents field winding from slipping.

2) to distribute the flux in air gap uniformly.

Poles are attached to yoke by welding | screws.

* Field Winding :— It is placed around the poles either series or parallel along with the armature winding.

- It is excited by DC supply.
- It is connected in such a way that the adjacent poles must have opposite polarities.

* Armature Core & Winding :—

→ It is the rotor of DC machine.

→ Armature Core is cylindrical in shape in which slots are provided to carry the armature winding.

→ Armature winding is connected ein any one of the fashion

Lap winding → A = P

wave winding → A = 2

A — no. of parallel ~~parts~~ paths

P — no. of poles

* Commutator :—

→ In a DC generator, commutator acts as rotating / mechanical rectifier which converts AC voltage to DC voltage.

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→ In DC motor, it acts as a rotating / mechanical invertor which converts DC to AC voltage.

→ Commutator is made up of copper segments which are insulated from each other by mica sheets. It is placed on the shaft.

* Brushes :—

→ Are made up of carbon & rest on the commutator, they are not rotating parts.

→ Function is to ensure the electrical connection b/w rotating commutator & external load.

(*) Field winding — stator of DC machine
armature winding — rotor " " "

Working Principle :— (of DC generator) :—
DC generator
Is a machine which converts mechanical to electrical energy.

→ Working principle of DC generator is based on flemings right hand rule.

→ According to faraday's laws of EMI, whenever conductor cuts the magnetic field, EMF gets induced across the conductor when there is a relative motion b/w them (conductor & field).

→ Relative motion is obtained by

1) Conductor rotating, field or flux must be stationary.

2) If flux is rotating, conductor must be stationary.

Here flux is obtained by relative motion.

DC generator coupled with dc motor; dc motor can be single.

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Magnitude of induced EMF is given by

$E = B l v$ volts

v → velocity of the conductor (m/s)

l → active length of the conductor (m)

B → flux density (wb/m² or Tesla)

Direction of induced EMF is given by Flemings right hand rule.

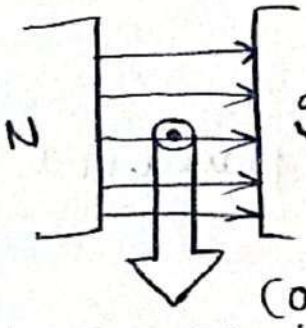
⇓

It says that, thumb → direction of motion of conductor.

index finger → direction of flux

middle → direction of induced EMF

when these three fingers are placed perpendicular to each other.

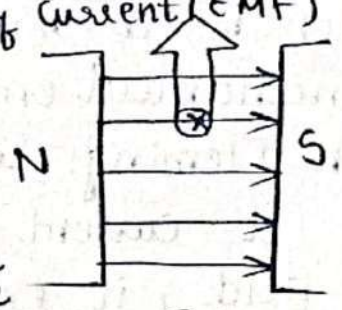


(a)

(i) Current coming out

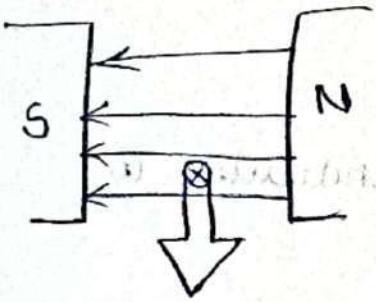
flux direction is same

(direction of current (EMF))



(b)

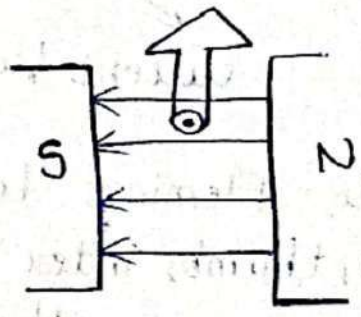
(i) current going in.



(c)

(i) going into (current)

flux direction is same



(d)

(d) Current coming out.

In (a), (C) flux is reversed, direction of motion of conductor is same, direction of induced EMF gets reversed (not same)

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Similarly
case (b) (d)
direction of flux is ~~same~~ reversed, direction of motion of conductor same, direction of induced EMF is reversed (not same)

Direction of induced EMF gets reversed by either changing (one only)
1) Direction of flux
2) Direction of motion of conductor.
If both change, no change in induced EMF.

Working Principle (DC Motor) :—

→ DC motor is a machine which converts electrical to mechanical energy
→ based on Flemings left Hand rule.
→ Whenever a current carrying conductor is placed in a magnetic field, it experiences a force.
→ Magnitude of force is obtained by

$$F = i\,B\,l$$

F → (Newtons)
l → conductor length (m)
B → flux density (wb/m^2)
i → current flowing through conductor (A)

According to Fleming's left hand rule,
middle, thumb, index are placed perpendicular to each other.
index — direction of flux
middle — direction of current (induced EMF)
thumb — direction of motion of conductor.

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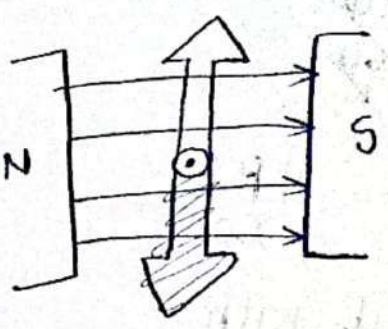
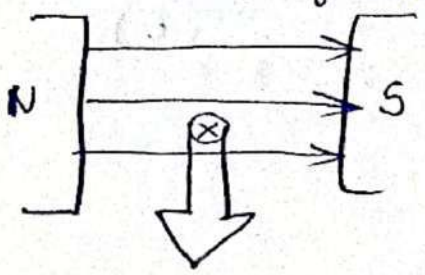
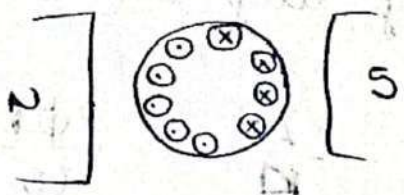
~~we determine~~ we determine direction of motion of conductor.







DC generator generates the voltage.

EMF Equation of DC generator:—

Let $Z = \dfrac{\text{Total no. of conductors}}{\text{no. of parallel paths}}$

$P =$ no. of poles

$A =$ no. of parallel paths

$A = P \rightarrow$ Lap winding

$A = 2 \rightarrow$ wave winding

$N =$ Speed of the machine (generator) in rpm.

$\phi =$ flux per pole (in Wb)

According Faraday's Laws of EMI,

$$\text{Average Induced EMF} = \frac{d\phi}{dt}$$

Consider one revolution of conductor. In one revolution total flux produced by the poles $= \phi P$. While time taken to complete one revolution $= \dfrac{60}{N}$

(as Speed $= N$ in rpm)

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Average induced EMF (E) $= \frac{d\phi}{dt} \neq \cancel{\frac{d\phi}{\left(\frac{60}{N}\right)}}$

$$= \frac{\phi P}{\left(\frac{60}{N}\right)} = \frac{\phi P N}{60}$$

Total no. of conductors Z is divided with no. of parallel paths, voltage drop across every parallel path is same:-

Total generated voltage $E = \frac{Z}{A} \times \frac{P\phi N}{60}$

$$= \frac{Z\phi P N}{A(60)} \text{ volts}$$

$A = P$ (for Lap)
$A = 2$ (for wave)

25/7/23

Q1) A 4 pole lap winding has 900 rpm. has 0.07 wb/pole. Calculate the generated EMF at Armature consists of 440 no. of conductors & also Calculate generated EMF if lap wound is replaced with wave wound generator.

for lap wound: $E = \frac{Z\phi PN}{A(60)} = \frac{440 \times 0.07 \times 4 \times 900}{60 \times 4}$

$$= 462V$$

for wave wound $E = \frac{Z P \phi N}{60A} = \frac{440 \times 0.07 \times 4 \times 900}{60 \times 2}$

$$= 924V$$

Note:-
for higher voltage, wave winding is used.

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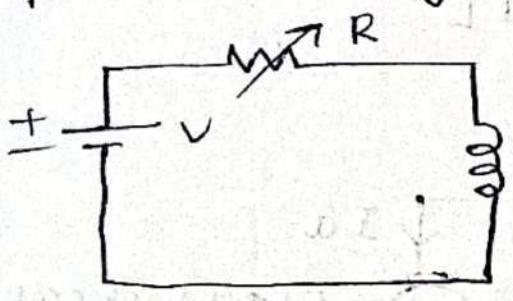
Types of DC generators:—

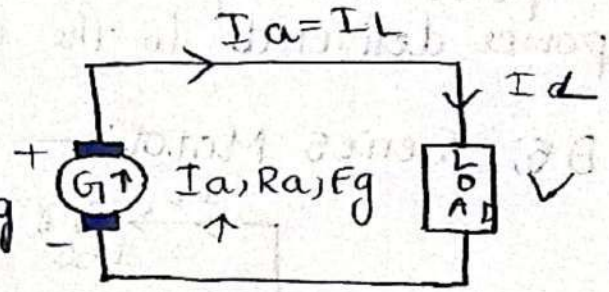
Two types based upon method of field excitation.

1) Seperately excited DC generator.
2) Self excited DC generator

- Series generator
- Shunt generator
- Compound generator

In seperately excited DC generator field is excited by seperate DC supply (battery).





I_a - armature current

I_L - Load current

Terminal voltage (V) = $E_g - I_a R_a$

power developed at armature = $E_g I_a$

power delivered to the load = $V I_L$

In self excited DC generator field winding is excited by output of the generator itself.

~~Field winding is e~~

1) DC series generator :- In this field winding is in series with the armature winding.

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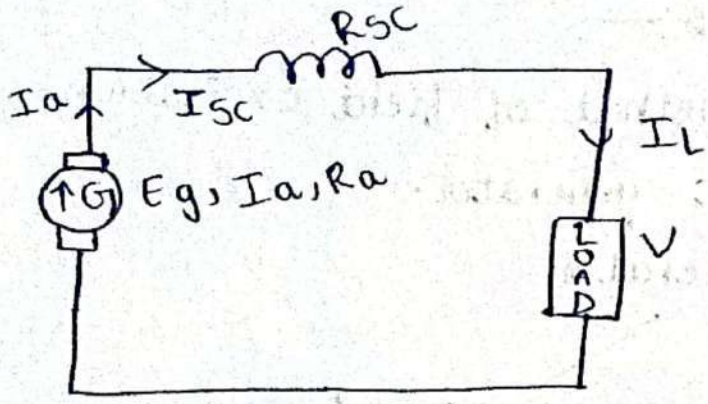


$I_a = I_{sc} = I_L$

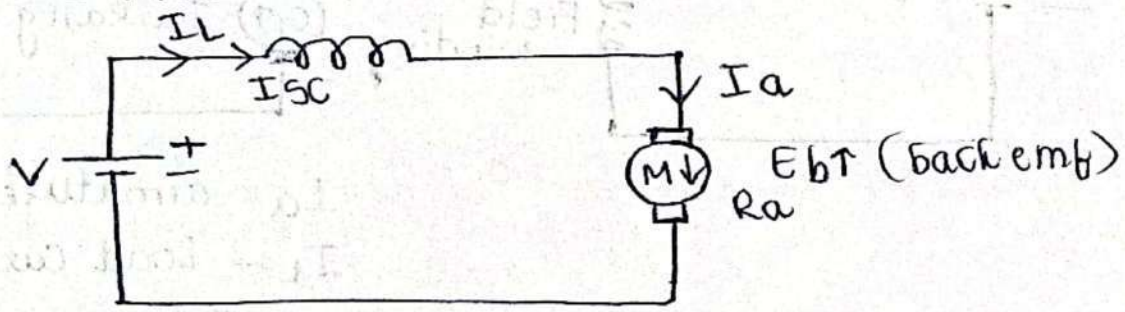
$V = E_g - I_a R_a - I_a R_{sc}$

$V = E_g - I_a(R_a + R_{sc})$

power developed $= E_g I_a$

power delivered to the load $= V I_L$

DC Series Motor:—



$I_L = I_{sc} = I_a$

$V = E_b + I_a (R_a + R_{sc})$

power developed $= V I_L$

power delivered $= E_b I_a / E_b I_{sc}$

DC shunt Generator:—

In this field winding is ||lel to armature winding.

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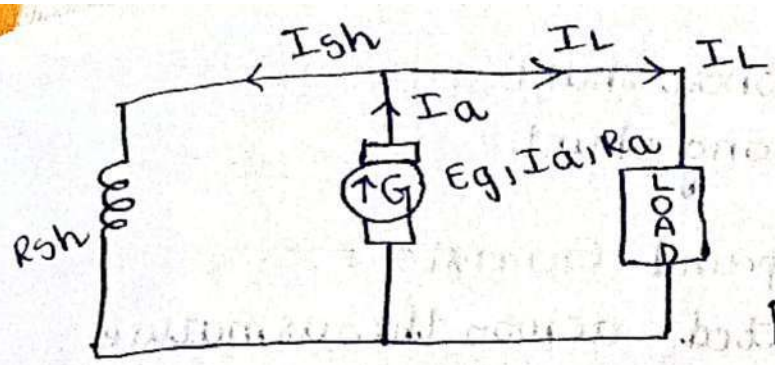


$I_a = I_{sh} + I_L$

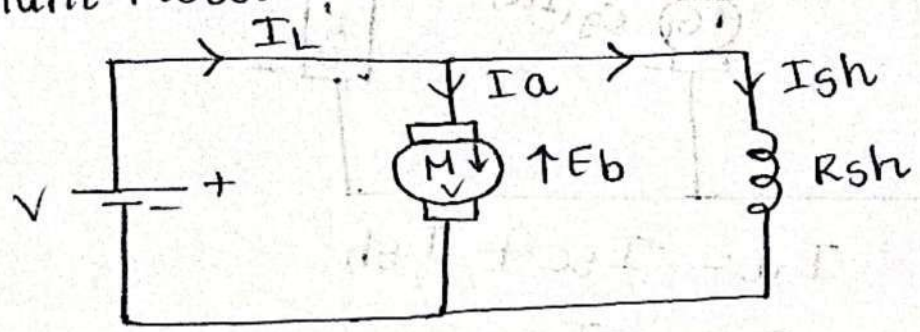
$V = E_g - I_a R_a$

power developed $= E_g I_a$

power delivered $= V I_L$

$I_{sh} = \frac{V}{R_{sh}}$

DC Shunt Motor :—



$I_L = I_a + I_{sh}$

$I_{sh} = \frac{V}{R_{sh}}$

$V = E_b + I_a R_a$

power developed $= V I_L$

power delivered $= E_b I_a$

DC Compound Generator :—

In this, there are 2 sets of field windings on each pole. One is connected in series and other in ||lel to the armature winding.

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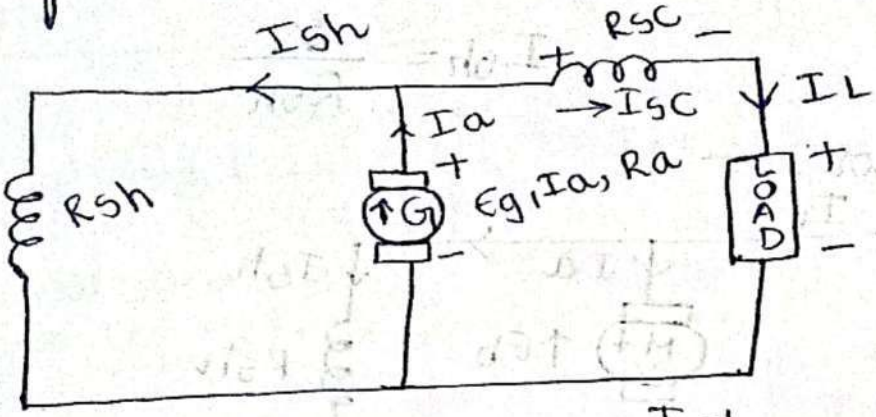
Further 2 types:— 1) Short shunt
2) Long shunt

1) Short shunt DC Compound Generator:—
field winding is connected across the armature only.



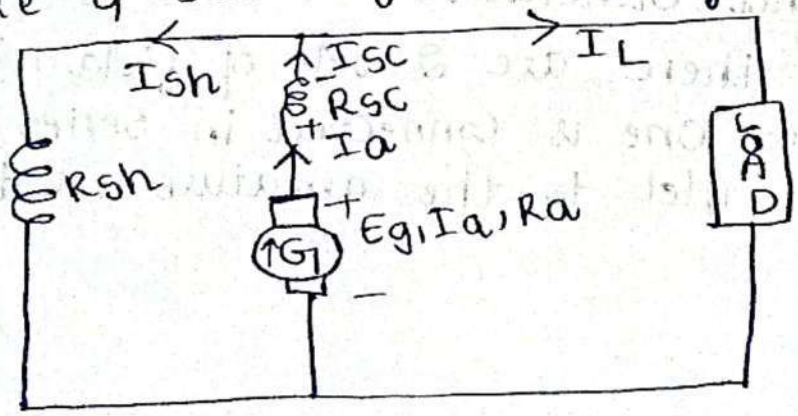
$$I_a = I_{sc} + I_{sh}$$

$$I_{sc} = I_L$$

$$V = E_g - I_a R_a - I_{sc} R_{sc}$$

power developed $= E_g I_a$
delivered $= V I_L$

2) Long shunt DC compound generator:—
In this, field winding is connected across armature & series field winding.



$$I_a = I_L + I_{sh}$$

$$I_a = I_{sc}$$

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$$V = E_g - I_a(R_a + R_{SC})$$

(or)

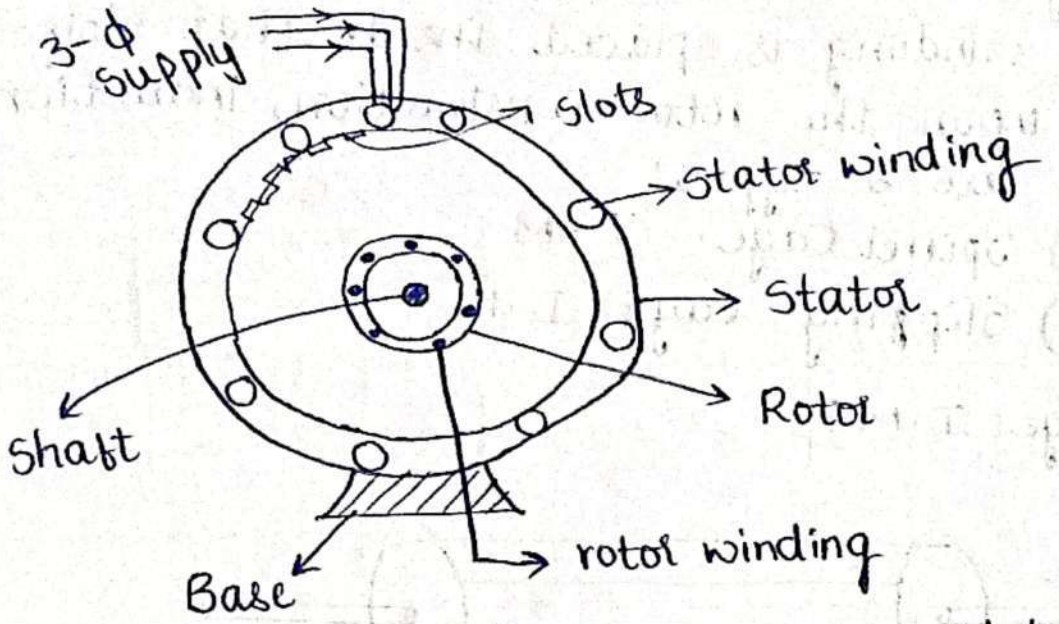
I_{SC}

power developed = $E_g I_a$

power delivered = $V I_L$

29/7/23

3-ϕ Induction Motor:—



3-phase induction motors are most widely used in almost all industries.

Speed of the machine is frequency dependent.

3-ϕ induction motor may also be considered as a rotating transformer with secondary short-circuited.

Like any other machine, it consists of 2 parts:—

1) Stator
2) Rotor

1) STATOR:—

It is stationary part on outer frame of the machine which is having no. of slots on its inner periphery.

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Three phase winding is placed inside the slots. The stator winding is wound per definite no. of poles as per speed requirement.

2) ROTOR :—

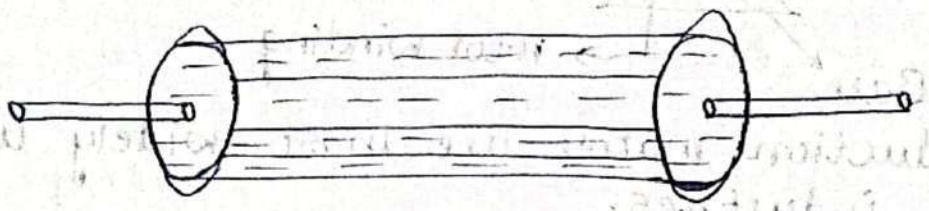
1) Rotating part of the machine which is also having no. of slots on its outer periphery.

2) Field winding is placed inside that slots.

Based upon the rotor construction, induction motors are 2 types:

1) Spirrel Cage I.M
2) Slipring ~~cage~~ I.M

1) Spirrel cage I.M :—

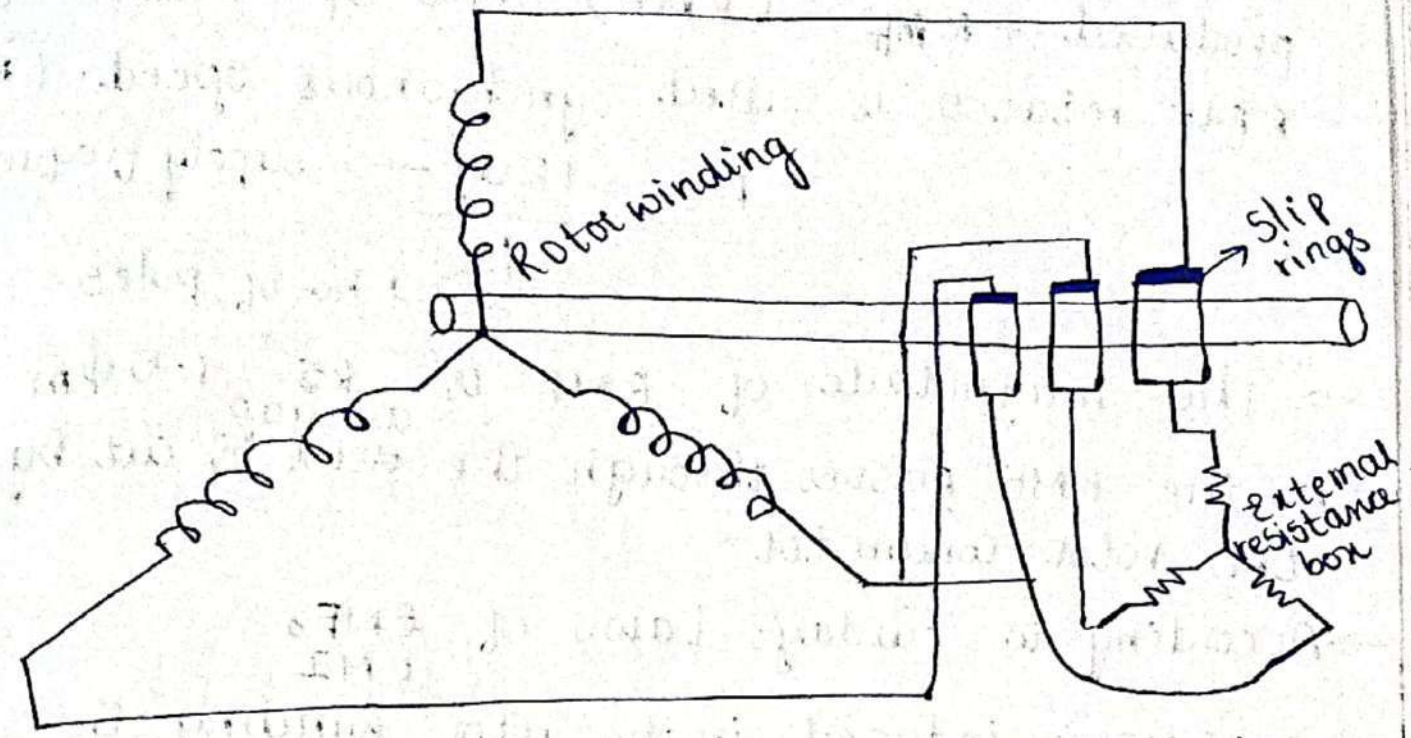


→ Most of the spirrel cage ~~I.M's~~ ~~are~~ rotor only.
↓
3-ϕ I.M are using

→ This rotor is made up of copper or Aluminium balls short circuited with end rings.

→ These spirrel cage I.M's / rotor are suffering from low starting torque.

2) Slip Ring I.M :—



Slip ring induction motor, an insulated 3-ϕ winding is similar to stator winding. & wound for same no. of stator holes. & placed inside the rotor slots.

The ends of the star connected rotor winding is connected to external resistance box through slip rings. to make higher starting torque.

At the time of starting, total resistance is included in the rotor winding. ($R_2 \propto \tau_{st}$)
R_2 → secondary circuit (rotor)

Gradually, resistance will becomes zero when rotor reaches its rated speed.

Principle of Operation:— (of 3-ϕ motor).

1) whenever 3-ϕ supply is given to the stator winding, rotating magnetic field will be

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produced ~~(RMF)~~ (RMF). The speed at which RMF rotates is called synchronous speed. (N_S).

$$N_S = \frac{120f}{P}$$

$f \rightarrow$ supply frequency

$P \rightarrow$ no. of poles.

→ The magnitude of RMF is ~~is~~ 1.5 ϕ_m

→ As the RMF passes through the ~~area~~ air gap & cut by the rotor conductor.

→ According to Faraday's Laws of ~~EMF~~ EMI,

→ EMF is induced in the rotor winding & current is also passing through the rotor winding since rotor winding is short-circuited.

→ According to Lorentz force Equation, a current carrying conductor placed in a magnetic field, it experiences a force to rotate the rotor.

→ The direction of rotation of rotor is given by Lenz Law. i.e, same as that of RMF or stator field.

→ But rotor never rotates at synchronous speed. ~~RMF is~~ due to inertia of rotor.

Advantages:—

1) It is simple & rugged connections.
2) Less maintanence is required.
3) Cost is low.
4) Efficiency is high (80-90%).

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Disadvantages:—

1) It is esentially constant speed motor. i.e, Speed control is difficult.

2) Low starting torque;

3) ~~shift~~ Difference b/w synchronous speed of RMF (Stator field) & actual speed of rotor is called slip speed.

$$= N_s - N_r$$

N_s → Stator field speed (or) armature speed.

N_r → rotor speed.

4) Slip speed is represented by %.

$$\% s = \frac{N_s - N_r}{N_s} \times 100.$$

~~Q2 3-φ~~

Q1) 4 pole 3-φ I.M is rotating at 1300rpm excited to 50Hz supply. Find slip speed, rotor frequency, slipping I.M.

$P = 4$

$N_r = 1300 rpm$

$f = 50Hz$

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 rpm.$$

$$\text{Slip speed} = N_s - N_r = 1500 - 1300 = 200 rpm.$$

$$\text{Slip} = \% s = \frac{1500-1300}{1500} \times 100 = \frac{\overset{40}{200} \times 100}{\underset{3}{1500}} = 13.33\%$$

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$f_r = s f$ → supply frequency (or stator frequency)

f_r → rotor frequency.

s → slip

$$= \frac{13.33}{100} \times 50$$

$f_r = 6.665\,Hz$ (rotor frequency)

usually induction motor; $s = 4$ to 6% (slip)

Q2) A 12 pole 3-ϕ alternator (frequency standard – 50Hz) drives a speed of 500 rpm supplies power to a 3-ϕ induction motor with 8 poles. If the slip at full load is 3%. Find the rotor speed at full load.

A/r:—

$P = 12$

$N_s = 500\,rpm$

3-ϕ I.M:—

$P = 8$

$s = 3\% = 0.03$

$N_r = ?$

$$s = \frac{N_s - N_r}{N_s} \times 100$$

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{8}$$

$$= 750\,rpm$$

$$sN_s = N_s - N_r$$

$$N_s - sN_s = N_r$$

$$N_r = N_s - sN_s$$

$$N_r = N_s - sN_s$$

$$= N_s(1-s)$$

$$= 750(1-0.03)$$

$$= 750 \times 0.97$$

$$= 727.5\,rpm$$

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(*) slip speed = $N_s - N_r$

$$S = \frac{N_s - N_r}{N_s} \times 100$$

$$f_r = Sf$$

$$N_r = (1-S)N_s$$

31/7/23

3-ϕ Alternator / Generator / Synchronous Generator :—

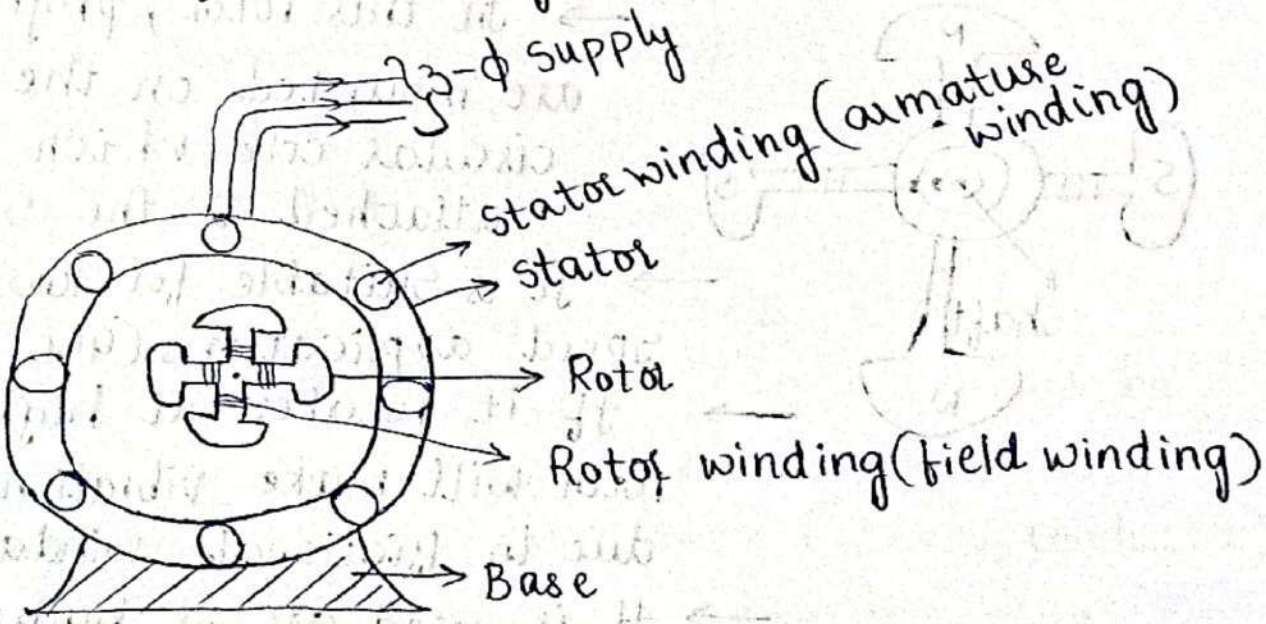
→ The machine which provides 3-ϕ power from mechanical power is called alternator.

→ Alternator always rotates at synchronous speed.

→ It consists of 2 parts namely stator & rotor.

→ Stator carries three phase winding & served as a armature winding.

→ Rotor carries field winding.



Stator :—

→ It is the stationary & outer frame of the machine which is made up of cylindrical core having no. of slots on its inner periphery.

→ 3-ϕ winding is placed inside that slots & serves as an armature winding.

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→ Armature winding is always connected in star fashion & neutrally grounded (for generation of higher voltage).

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

Rotor:—

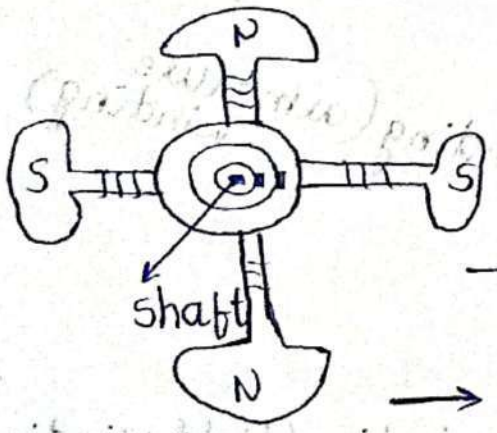
→ It is rotating path of the machine which is also having no of paths on its outer periphery.

→ Field winding is placed inside the slots.

→ Based upon the rotor construction, Alternators are of 2 types:-

1) Salient pole or projecting pole
2) Non-salient pole or Cylindrical.

1) Salient / Projecting Pole:—



→ In this rotor, projecting poles are mounted on the large circular core which is attached to the shaft.

→ It is suitable for low & medium speed applications (400–800rpm)

→ If it rotates at higher speed, rotor will make vibrations or noise due to frictional windage losses.

→ It is used ~~at~~ in hydroelectric power plants.

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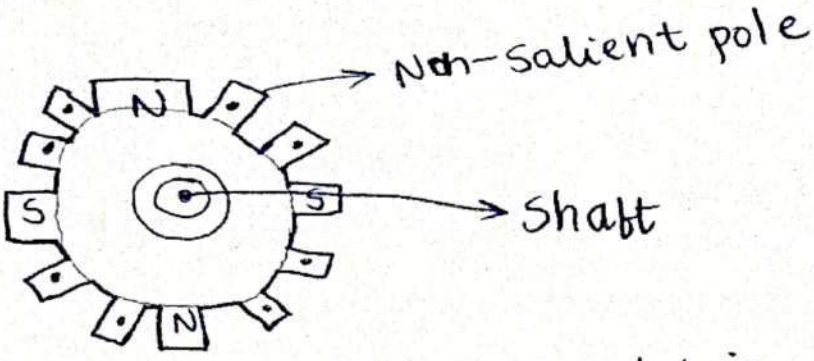
2) Non- salient pole / Cylindrical pole:—



→ This type of alternator rotor is madeup of cylindrical poles having no of slots on its outer periphery.

→ Field winding is placed inside that slots & excited by seperate DC supply.

→ It is suitable for high speed applications about 1500-3000rpm.

→ This type of rotor will not make any vibrations or noise due to even air gap b/w stator & rotor.

→ This type of alternators are used in thermal / nuclear power points.

Working Principle:—

→ According to faraday's law of EMI, whenever conductor cuts the magnetic field an emf will be induced across that conductor when there is a relative speed difference b/w them (flux & conductor)

→ Rotor carries the field winding which is excited by DC supply & alternate poles are found in rotor or field winding.

→ Rotor is rotating at synchronous speed (N_S) with the help of prime mover (DC motor / DC shunt motor)

→ As the rotor flux passes through the air gap & cuts the stator conductor, emf will be induced across the stator conductor.

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01/08/23

UNIT - 5

SENSORS, TRANSDUCERS & ACTUATORS

↓

one physical form to other.

Sensor - Input transducer - physical to electrical

actuator - Output transducer - electrical to physical

Transducer should have 1) Ruggedness

2) Linearity

3) Repeatability.

4) High output Signal quality

5) High reliability & stability

6) No hysteresis.

Downstream travel time:

$$T_{AB} = \frac{L}{C+V\cos\theta}$$

Upstream travel time:

$$T_{BA} = \frac{L}{C-V\cos\theta}$$

* Fresnel Lens.

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