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EST130 : BEE

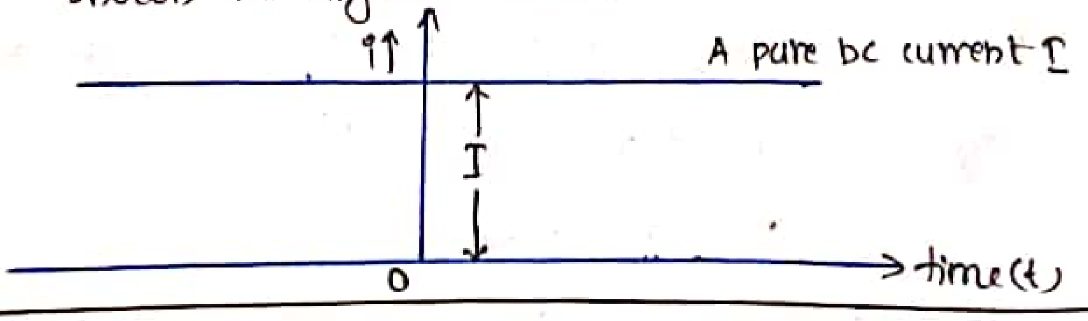
Module 1

* Introduction :

Electrical energy is convenient and efficient for production of light, mechanical energy and in information processing. It can be transported conveniently and economically over long distances so as to be available at the point of use. Electric energy doesn't occur naturally in usable form and must therefore be centrally generated and instantly transported to various points of use spread graphically over vast areas even beyond state or national boundaries.

* Elementary concepts of DC electric circuits

Electricity occurs in two different forms AC and DC. Unidirectional current is known as direct current (D.C). It is assumed to have constant value with time as shown in figure below.



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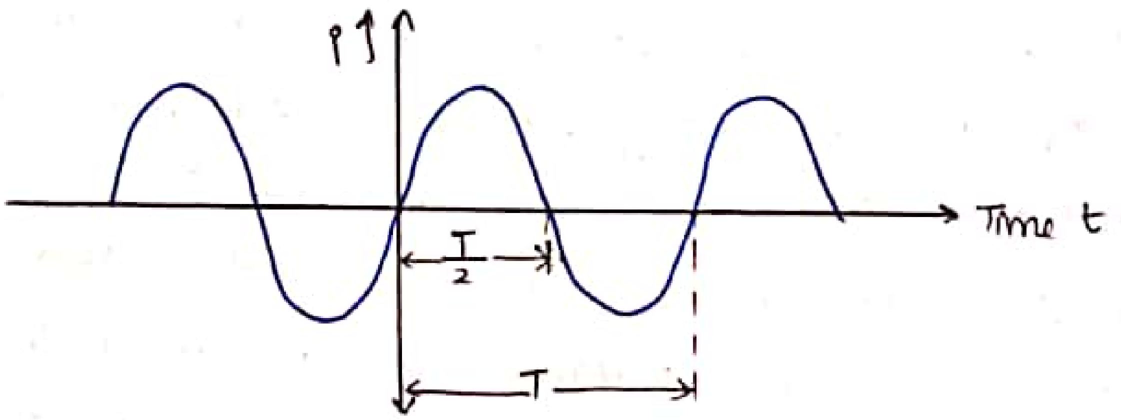
→ Alternating current or AC is cyclic in nature, with current flowing in positive direction in half the cycle and in negative direction (reverse direction) in the other half. Most commonly used AC waveform, sine wave is shown below.



We will confine discussions to direct current (DC) circuits only in present module.

* Electric Current :

↳ It is the rate of flow of electric charges through a conducting path. Unit of current is ampere A. One ampere is the charge flow rate of 1C/sec.

↳ Symbol used for current. 'i' or I

↳ If Q coulomb of charge flow through a conductor in T seconds then current 'I' is given by

$$\boxed{I = \frac{Q}{T}} \text{ amperes.}$$

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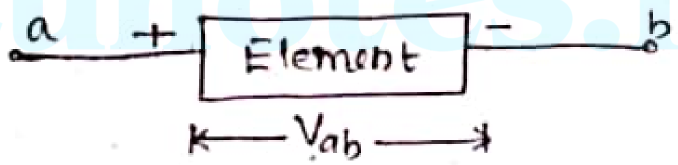
* Electromotive force (EMF):

The potential difference between the battery terminals is known as the electromotive force or EMF. The emf represents the driving influence that causes a current to flow. EMF is usually represented by a symbol 'E' and has the unit 'volt'.

Potential Difference:

Potential difference is the difference between the voltages at two ends of a conductor.

Unit of potential difference is volts (V)



Vab represents the voltage at point 'a' relative to point 'b'. Here voltage at point 'a' is higher than voltage at point 'b'

* Power (P):

Power is defined as work done or energy per unit time

$$\text{Power} = \frac{\text{work}}{\text{Time}} = \frac{\text{work } (dw)}{\text{charge } (dq)} \times \frac{\text{charge } (dq)}{\text{time } (dt)}$$

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Unit of electric power — watts (W) or Joules/second

* **Electric energy:**

Unit is kWh = Electric power (kW) × time (h)

An electric energy consumer pays bill for the number of units (kWh) of energy consumed by him.

* **Components in an electric circuit**

An electric circuit consists of closed paths formed by interconnection of various electrical components like batteries, resistors, capacitors, switches, other loads like lamps, motors etc.

Basic elements of an electric circuit are classified as,

Circuit elements (Components) → Passive components (or) Sinks

Circuit elements (Components) → Active components (or) sources.

→ Passive components are not capable of injecting power in to a circuit. They are only capable of receiving power and hence also known as sinks.

Eg: Resistors, Inductors and capacitors.

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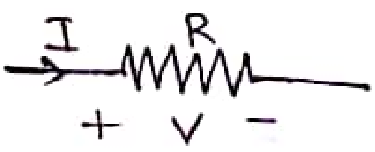
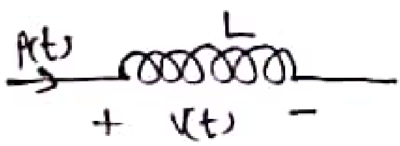
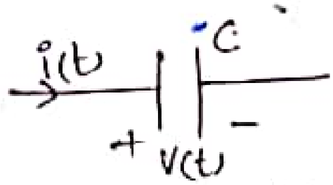
Active components are capable of injecting or supplying power in to a circuit.

Eg: Voltage sources (batteries)

Passive Components.

<table>
<tr><th>Resistors</th><th>Inductors</th><th>Capacitors</th></tr>
<tr>
<td>
$V = IR$

<u>Energy stored</u>
Resistor will not store energy
Unit : ohm (Ω)</td>
<td>
$V(t) = L\frac{di(t)}{dt}$

Energy stored in inductor,
$E = \frac{1}{2}LI^2$ Joules
Unit :- Henry (H)</td>
<td>
$i(t) = C\frac{dV(t)}{dt}$

Energy stored in capacitor,
$E = \frac{1}{2}CV^2$ Joule
Unit : Farad (F)</td>
</tr>
</table>

Active Components :

Commonly used active components in electrical circuits are energy sources which are broadly classified in to current sources and voltage sources.

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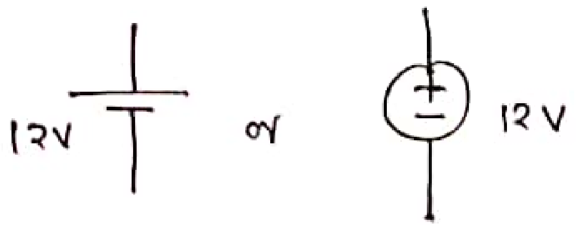
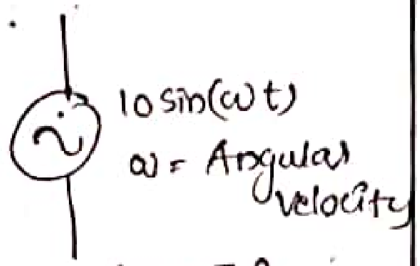
(i) Voltage sources : Provide voltage to a circuit

Symbols :- v, V, v(t)



DC voltage source.



$\omega = 2\pi f$.

AC voltage source

Eg: Examples of DC voltage sources are batteries, solar cell etc.

Example of AC voltage sources are AC generator, battery-inverter s/m

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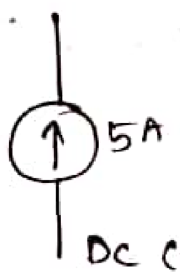
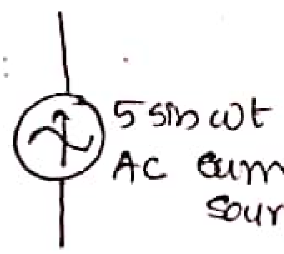
(ii) Current sources : Provide current in to a circuit

Symbol :- i, I, i(t)



DC current source.



AC current source.

Eg: 1) A DC series generator can be modelled as a DC current source.

2) Van de graff generator is an example of a nearly ideal current source.

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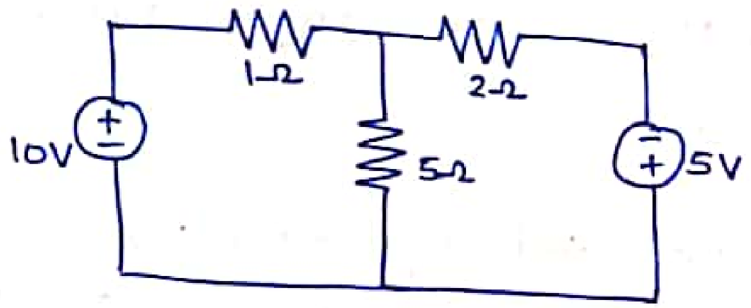
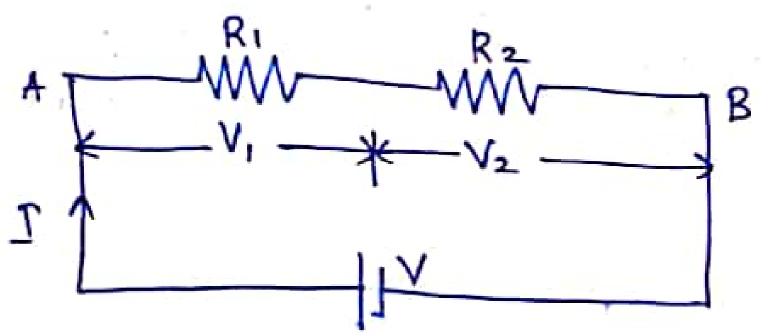
* Methods of solving electric circuits

An electrical circuit is an interconnection of various electrical components like battery, resistors, capacitors, switches etc.



Different techniques are used for solving electrical circuits like, solving series connected and parallel connected resistors, voltage and current divider rules, Kirchhoff's laws, Star- delta conversion, mesh analysis, nodal analysis etc.

(i) Series connected resistors



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↳ Current is same through all the resistors

↳ Voltage drop across each resistor will be different if the values of resistors are different.

By Kirchhoff's voltage law

$$V = V_1 + V_2 = IR_1 + IR_2 = I(R_1 + R_2)$$

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

where $\frac{V}{I}$ is the total equivalent resistance between points A and B or resistance seen by the voltage source ie,

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

where R_{eq} = Equivalent resistance of the circuit.

* Voltage Divider rule

we can directly find V_1 and V_2 by using formula given below

$$\boxed{V_1 = \frac{V R_1}{R_1 + R_2}} \qquad \boxed{V_2 = \frac{V R_2}{R_1 + R_2}}$$

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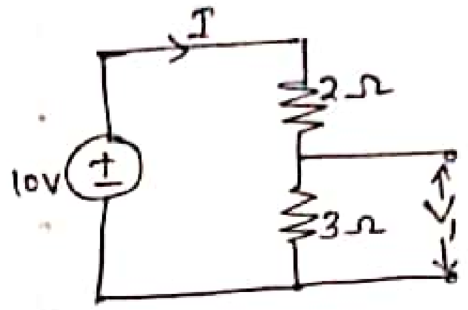
Q: Find the value of current in the circuit. Also find the value of V_1



Ans: Total equivalent resistance in the circuit, $R_{eq} = 3+2 = 5\Omega$

Current $I = \frac{V}{R_{eq}} = \frac{10}{5}$

$= \underline{2A}$.

Voltage divider Rule

$$V_1 = \frac{V \times 3}{3+2} = \frac{10 \times 3}{5} = \underline{6V}.$$

or.

$$V_1 = IR = 2 \times 3 = \underline{6V}$$

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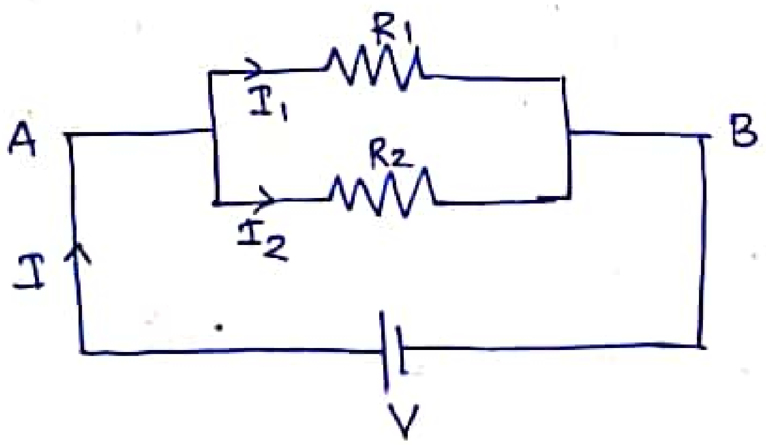
* Parallel Connection of Resistors

↳ Let two resistors R_1 and R_2 are connected in parallel



↳ Voltage will be same across both resistors

↳ Current will be different if resistance values are different

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By Kirchhoff's current Law

$$I = I_1 + I_2$$

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

$$\frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2}$$

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

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

where R_{eq} = Equivalent resistance across A and B

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* Current Divider Rule

shortcut formula to find I_1 and I_2

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

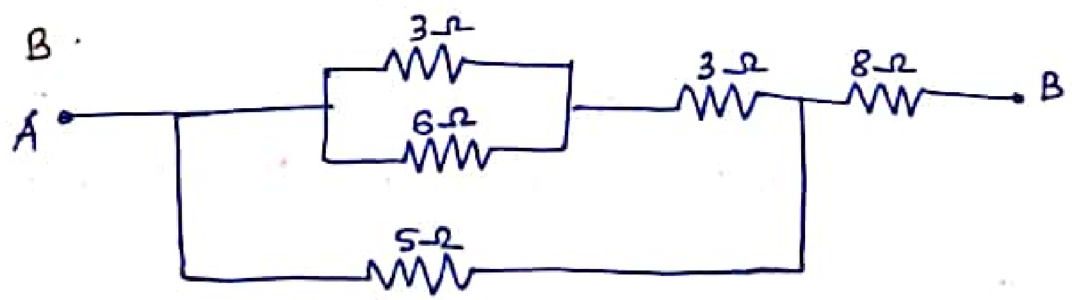
$$\boxed{I_2 = I \frac{R_1}{R_1 + R_2}}$$

→ other resister

current through R_2

Q: Numerical Problems

1) Find the effective equivalent resistance between A and B.



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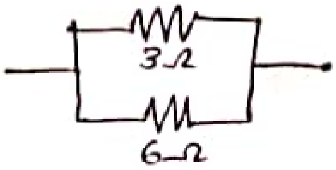
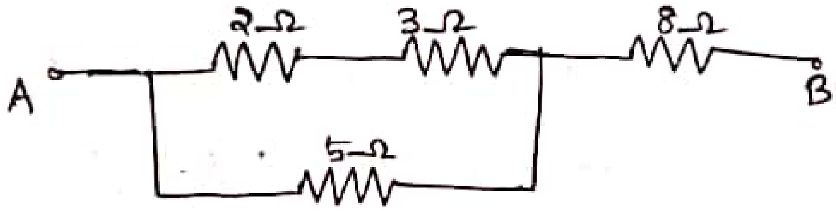
Ans. 3Ω and 6Ω in parallel ∴ 

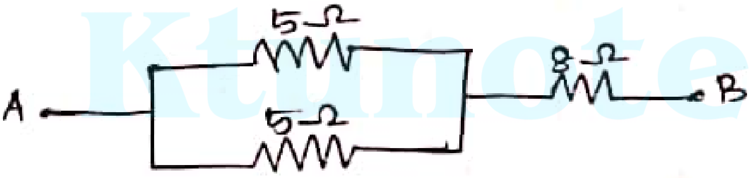
= 

$\frac{6\times3}{9} = 2\Omega$

Circuit becomes,



8Ω and 2Ω in series and that combination is parallel to 5Ω



5Ω and 5Ω are in parallel, that combination is series with 8Ω

∴ $R_{AB} = 2.5 + 8 = \underline{\underline{10.5\Omega}}$

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Kirchhoff's Laws

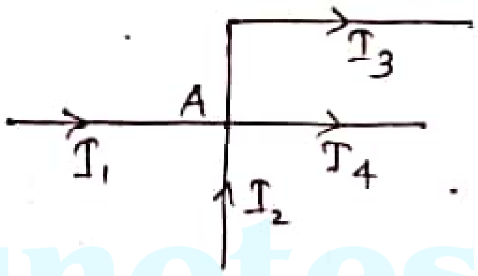
There are two laws

① Kirchhoff's current law (KCL)

or Kirchhoff's first law

↳ It states that the total current entering into a junction is equal to total current leaving a junction or node.

Eg:



By KCL at node A

$$I_1 + I_2 = I_3 + I_4$$

Note: A node is a point of interconnection between 2 or more components

② Kirchhoff's Voltage Law (KVL)

or Kirchhoff's second law.

It states that in any closed path the algebric sum of the emf's and the voltage drop in various components is equal to zero.

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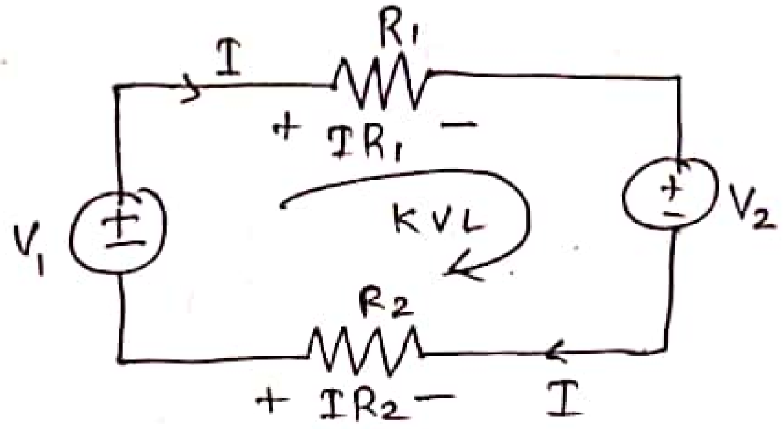
Eg:



Procedure:

↳ Move clockwise starting from any point in circuit. If positive side of voltage appears put '+' and if −ve side of voltage appears put '−ve' in the equation

By KVL in the circuit

$$-V_1 + IR_1 + V_2 + IR_2 = 0$$

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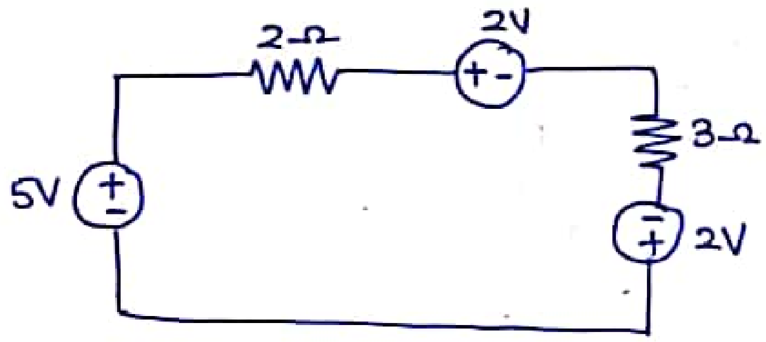
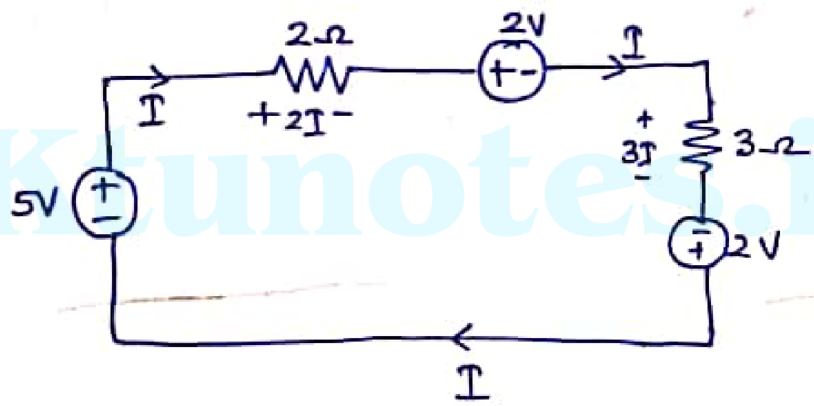
1. Q:, Find the current in the circuit using KVL



Ans: We can apply KVL in the circuit.



By KVL,

$$-5+2I+2+3I-2 = 0$$

$$5I = 5$$

$$I = \underline{\underline{1A}}.$$

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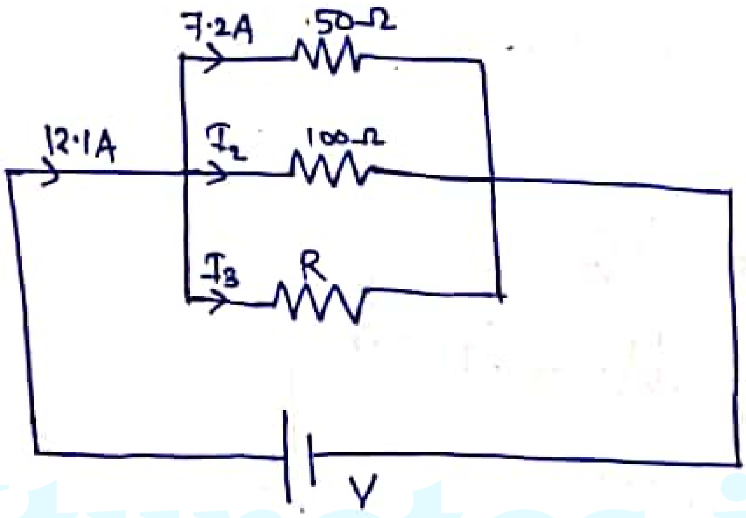
2, Q: A 50Ω resister is in parallel with a 100Ω resister current in 50Ω is 7·2A. What is the value of third resistance to be added in parallel to this current to make the total current 12·1A.



Since they are all parallel, voltage is same across all three.

$$V_{50\Omega} = 7·2 \times 50 = \underline{\underline{360V}}$$

$$\therefore V_{50\Omega} = V_{100\Omega} = V_{R\Omega} = \underline{\underline{360V}}$$

$$\therefore I_2 = \frac{360}{100} = \underline{\underline{3·6\,A}}$$

$$\therefore I_3 = 12·1 - 7·2 - 3·6 = \underline{\underline{1·3\,A}}$$

$$\therefore R = \frac{360}{1·3} = \underline{\underline{276·9\Omega}}$$

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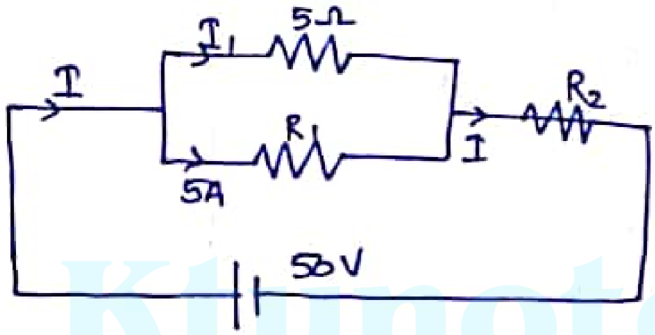
3, Q: A resistor of 5Ω is connected in parallel with a resistor of R_1 Ω. This combination is connected in series with an unknown resistor of R_2 Ω and the complete circuit is then connected to 50V DC supply. Calculate the values of R_1 and R_2 if the power dissipated by the unknown resistor R_1 is 150W with a 5A passing through it.



Given $P_{R_1} = 150W$

$I_{R_1} = 5A$

Voltage across R_1, $V_{R_1} = \frac{P_{R1}}{I_{R1}} = \frac{150}{5} = 30V$

∴ Voltage across 5Ω is also same, $V_{5Ω} = 30V$

∴ Voltage across R_2, $V_{R2} = 50-30 = 20V$

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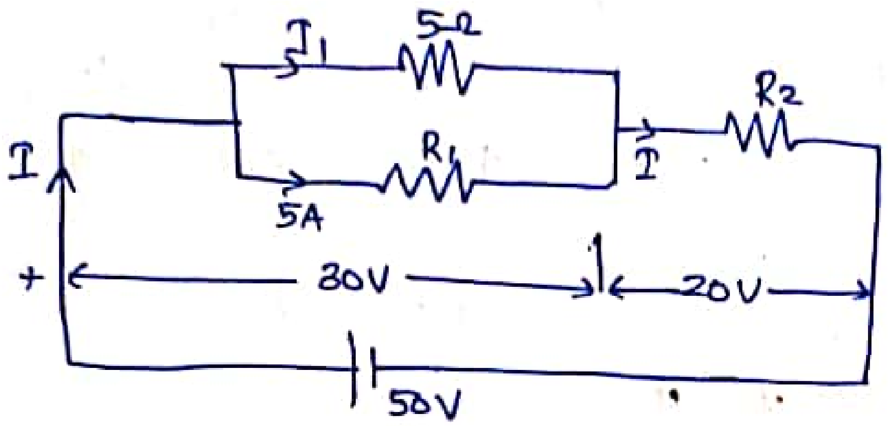

For finding R_1

We have $P_{R1} = 5^2 \times R_1 = 150W$

$\therefore R_1 = 6\Omega$

For finding R_2

$$I_1 = \frac{V_{5\Omega}}{5} = \frac{30}{5} = \underline{\underline{6A}}$$

$\therefore I = 5+6 = \underline{\underline{11A}}$.

$\therefore$ 11A flows through R_2 and voltage across it is 20V.

$$\therefore R_2 = \frac{20}{11}$$

$$= \underline{\underline{1.81\,\Omega}}$$

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4Q. How much more current can be safely drawn from a 120V outlet fused at 15A if a 600W curling Iron and a 1200W hairdryer are already operating in the circuit ?

Ans. Voltage of the current = 120 V

Fuse is bermed at 15 A.

∴ Maximum power that can be drawn from this ckt = VI = 120 × 15

= 1800W

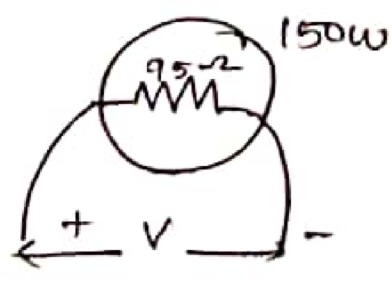
Power of devices already operating = 600 W + 1200W = 1800W

∴ No more device can be connected or no more current can be drawn from circuit.

5Q. A certain light bulb with a resistance of 95Ω is labelled '150W'. Was this bulb designed for use in a 120V circuit or a 220V current ? Justify your answer

$P = 150W$

$R = 95\Omega$



We have, $P = \frac{V^2}{R}$

ie, $150 = \frac{V^2}{95}$

$\therefore V = 119.4 \simeq 120V$.

∴ Bulb is designed for 120V.

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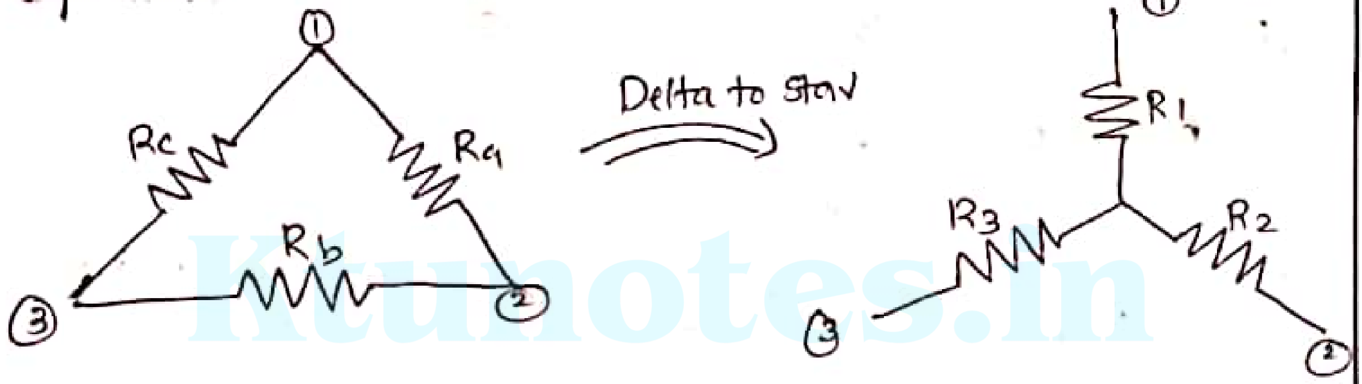
Star- Delta Conversion

Star- Delta conversion technique is useful in solving complex networks

(a) Delta to star conversion (Δ to Y conversion)

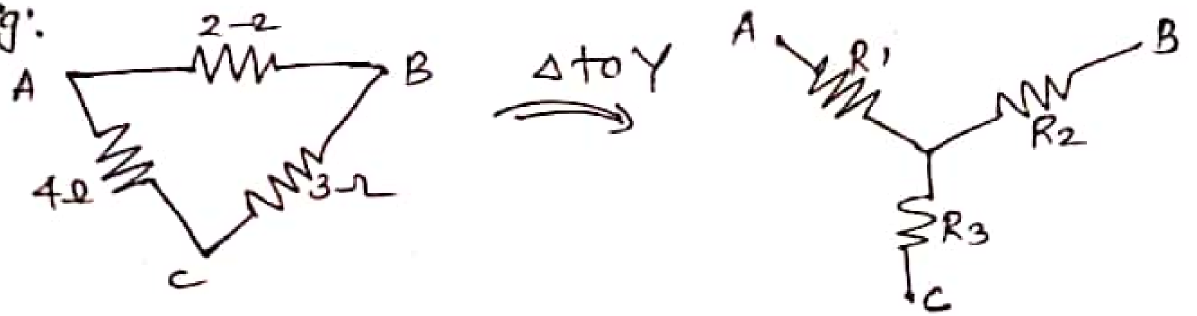
Consider three resistors R_a, R_b and R_c connected in delta form (Δ) as shown below. They can be converted in to star (Y) shape by using equations.



We can do delta- star conversion using equations

$$\boxed{R_1 = \frac{R_a R_c}{R_a + R_b + R_c}} \quad \boxed{R_2 = \frac{R_a R_b}{R_a + R_b + R_c}} \quad \boxed{R_3 = \frac{R_b R_c}{R_a + R_b + R_c}}$$

Eg:



$$R_1 = \frac{4 \times 2}{4+2+3} = \frac{8}{9}\Omega, \quad R_2 = \frac{2 \times 3}{4+2+3} = \frac{2}{3}\Omega, \quad R_3 = \frac{4 \times 3}{4+2+3} = \frac{4}{3}\Omega$$

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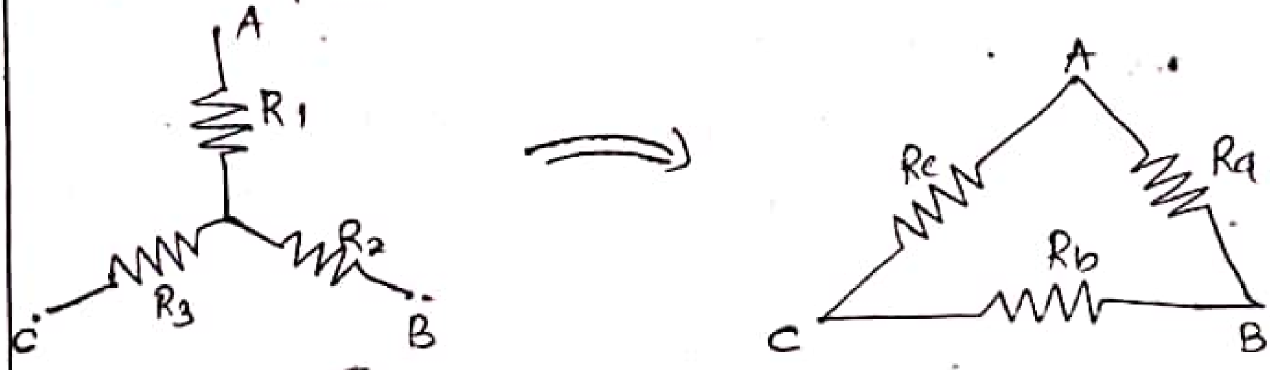
(b) Star to Delta conversion (Y to Δ)

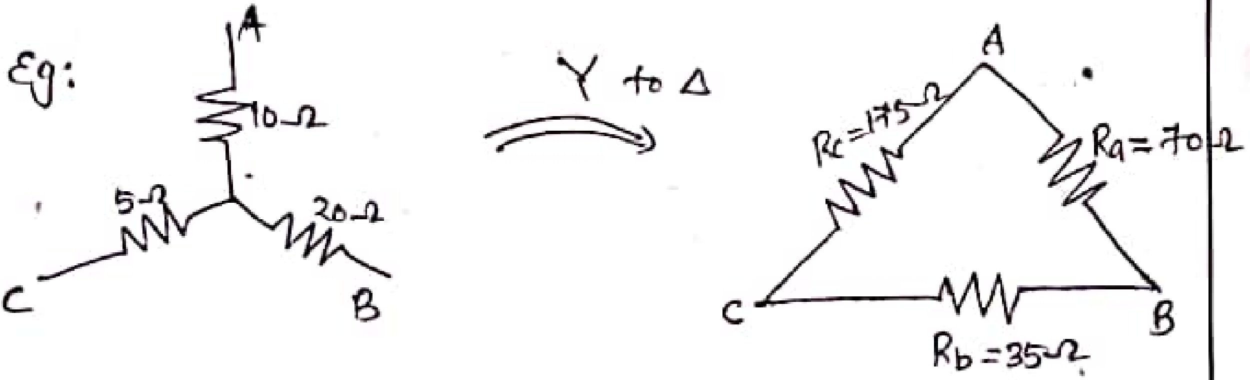
Consider three resistors connected in star shape. They can be converted into Delta form using below equations.



$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}, \quad R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

Eg:



$$R_a = \frac{10\times20 + 20\times5 + 5\times10}{5} = \underline{\underline{70\,\Omega}}$$

$$R_b = \frac{10\times20 + 20\times5 + 5\times10}{10} = \underline{\underline{35\,\Omega}}$$

$$R_c = \frac{10\times20 + 20\times5 + 5\times10}{20} = \underline{\underline{17.5\,\Omega}}$$

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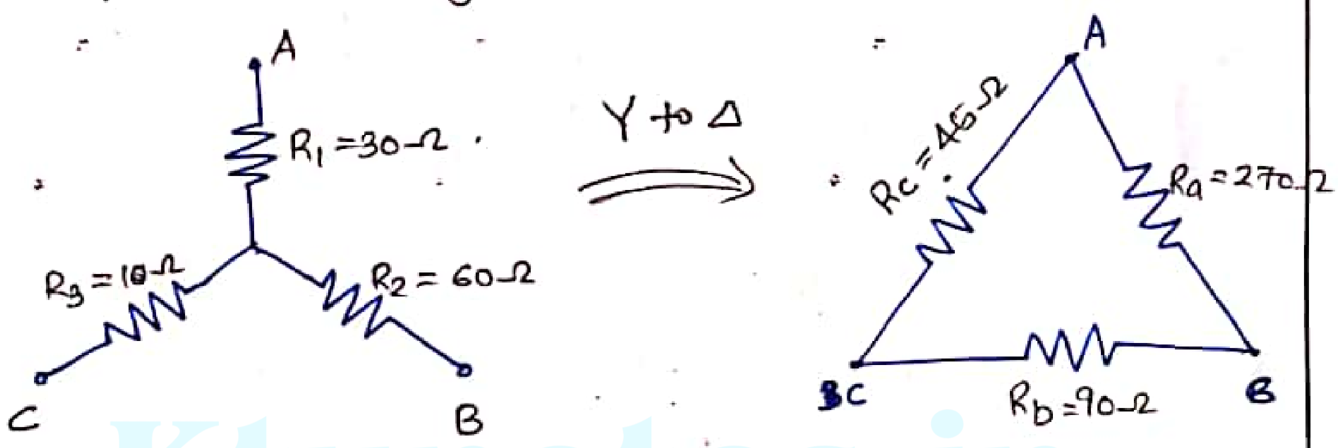
1) Q: Three resistors $R_1 = 30\Omega$, $R_2 = 60\Omega$ and $R_3 = 10\Omega$ are connected in star. Obtain the equivalent delta circuit

Given star configuration of R_1, R_2 and R_3



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We have $R_a = \dfrac{30 \times 60 + 60 \times 10 + 10 \times 30}{10}$

$= \underline{\underline{270\Omega}}$

$R_b = \dfrac{30 \times 60 + 60 \times 10 + 10 \times 30}{30}$

$= \underline{\underline{90\Omega}}$

$R_c = \dfrac{30 \times 60 + 60 \times 10 + 10 \times 30}{60}$

$= \underline{\underline{45\Omega}}$

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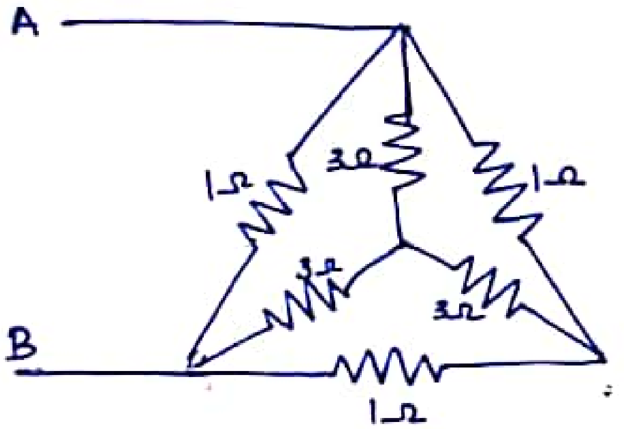
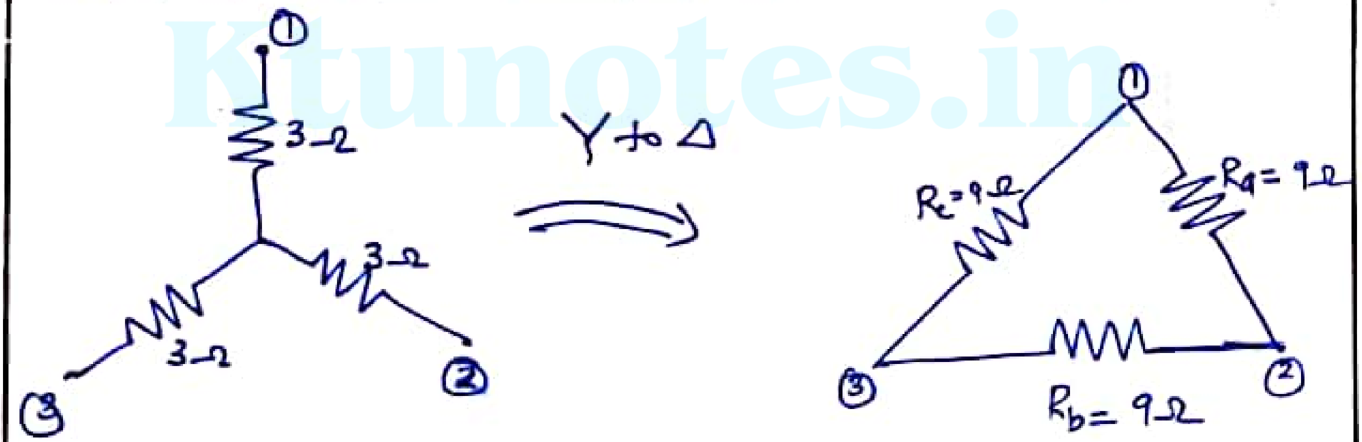
2 Q: Determine the equivalent resistance R_{AB} using Star - Delta transformation



We have three 3Ω resistor connected in star form. It can be converted into delta shape.



$$R_a = \frac{3\times3 + 3\times3 + 3\times3}{3} = \underline{9\Omega}$$

All resistors are same Ra.

$$\therefore R_b = R_c = \underline{9\Omega}$$

∴ Re inserting R_a, R_b and R_c in to original circuit replacing Star connected 3Ω resistors.

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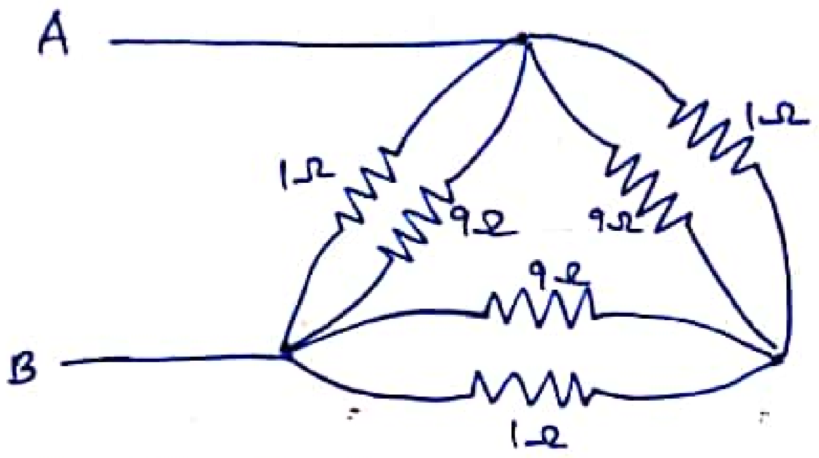
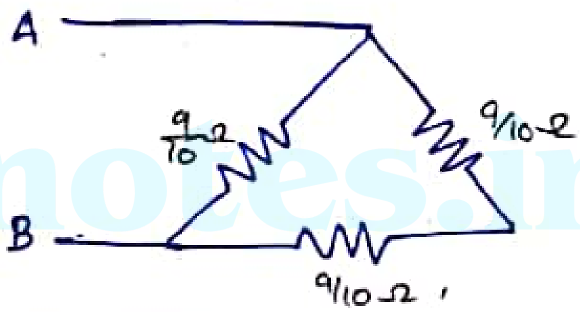


9Ω and 1Ω are in parallel

$$\therefore 9 \| 1 = \frac{9 \times 1}{9+1} = \frac{9}{10}\,\Omega$$

∴ circuit become.



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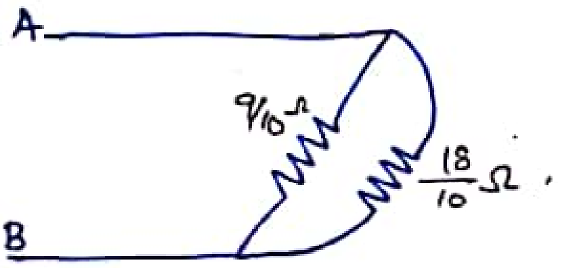
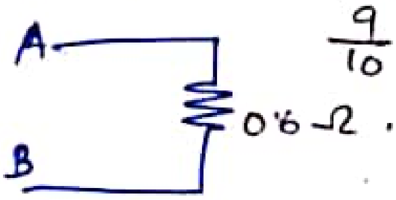
9/10 and 9/10 are in series.

$$\therefore \frac{9}{10} + \frac{9}{10} = \frac{18}{10}$$



$\frac{9}{10}$ and $\frac{18}{10}$ are in parallel $= \dfrac{\frac{9}{10} \times \frac{18}{10}}{\frac{9}{10} + \frac{18}{10}} = 0.6\,\Omega$

$\therefore R_{AB} = 0.6\,\Omega$.



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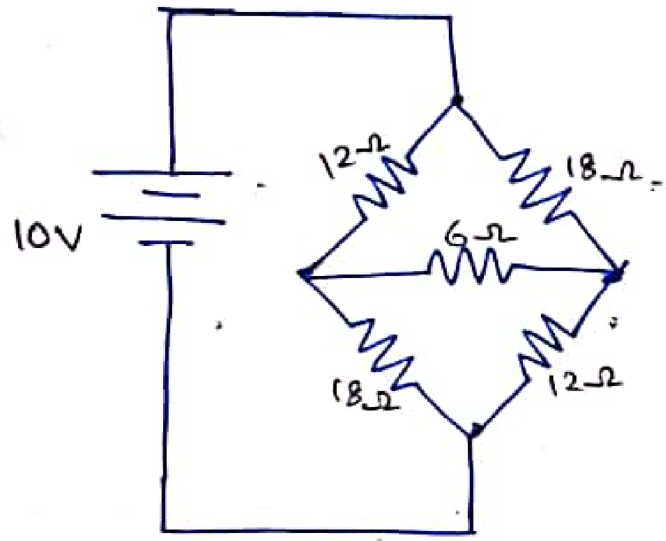
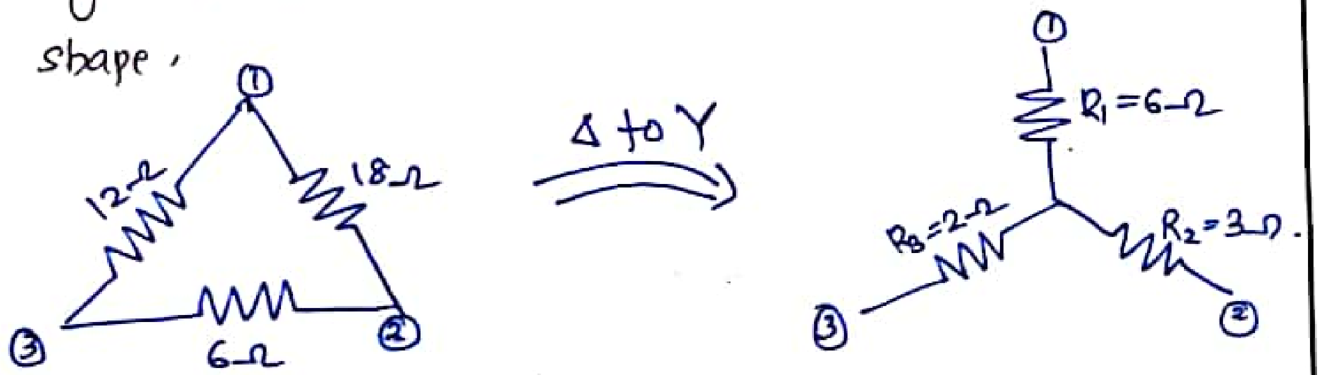
3 Q. Determine circuit drawn from supply using star delta conversion.



Ans: Circuit contains two sets of Δ connected resistors. Any one delta connection can be converted in to star shape.



$$R_1 = \frac{18 \times 12}{12+18+16} = 6Ω$$

$$R_3 = \frac{12 \times 6}{12+18+16} = 2Ω$$

$$R_2 = \frac{18 \times 6}{12+18+16} = 3Ω$$

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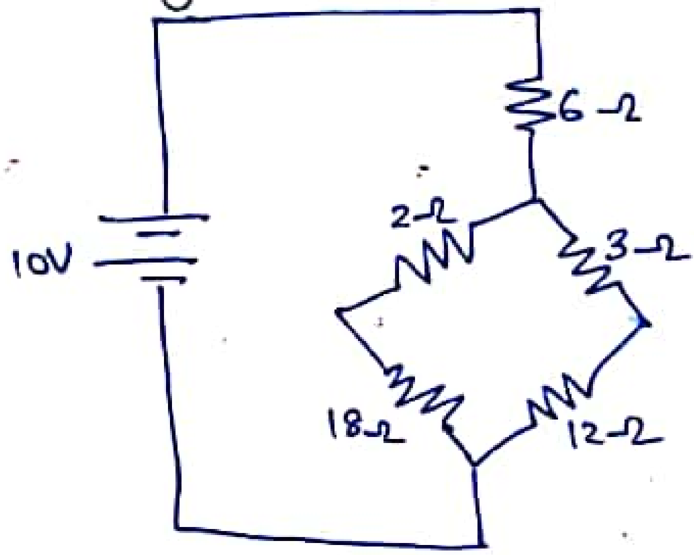
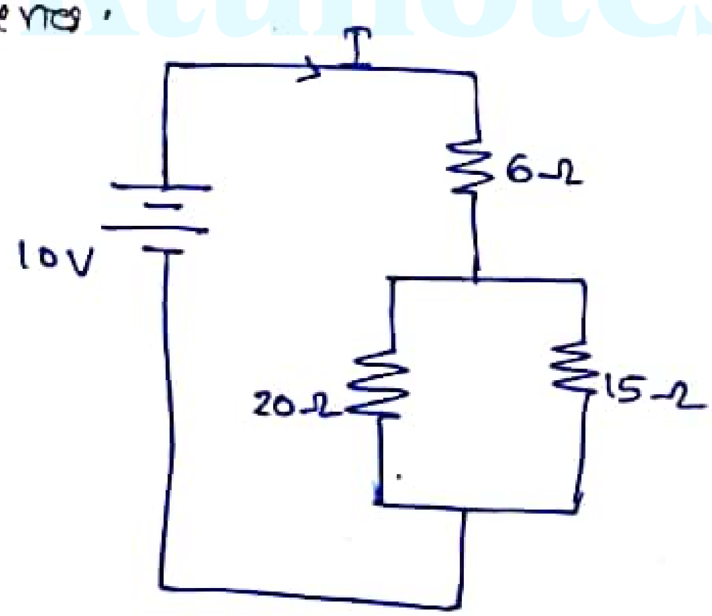
we can substitute the new star connected resistors R_1, R_2, R_3 replacing upper delta connection without disturbing other components in the circuit.



we have 18Ω and 2Ω in series, 12Ω and 3Ω in series.



20Ω and 15Ω are parallel and this combination is series with 6Ω.

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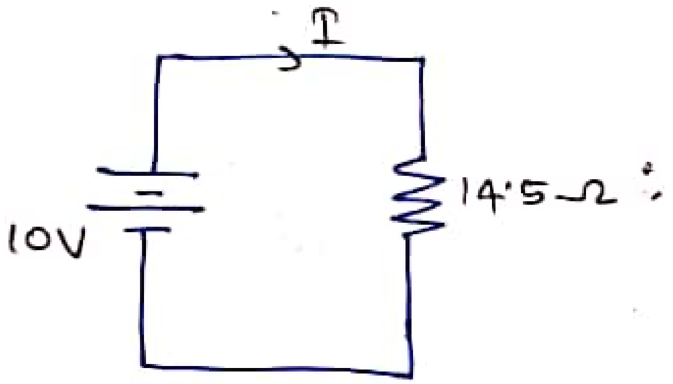
$$20 \| 15 = \frac{20 \times 15}{20+15} = \underline{8.5\,\Omega}$$

$8.5\,\Omega$ series to $6\,\Omega$ = $\underline{\underline{14.5\,\Omega}}$

∴ circuit becomes



current in circuit $I = \frac{V}{R}$

$$= \frac{10}{14.5} = \underline{\underline{0.69\,A}}$$

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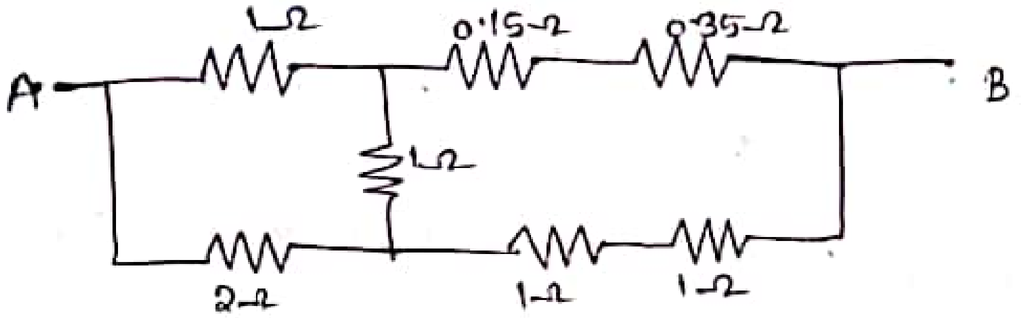
Q.4 Use Star-Delta / delta-Star transformation to determine the equivalent resistance between the points A and B of the circuit below.

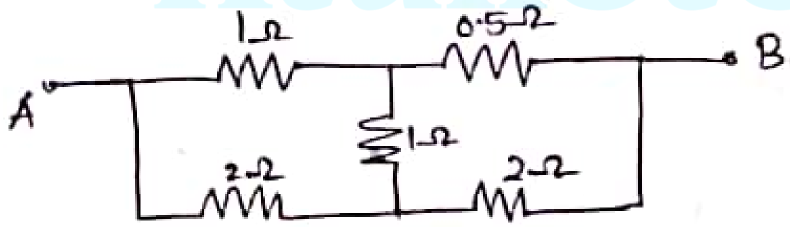


Ans: We have 0.15Ω and 0.35Ω in series

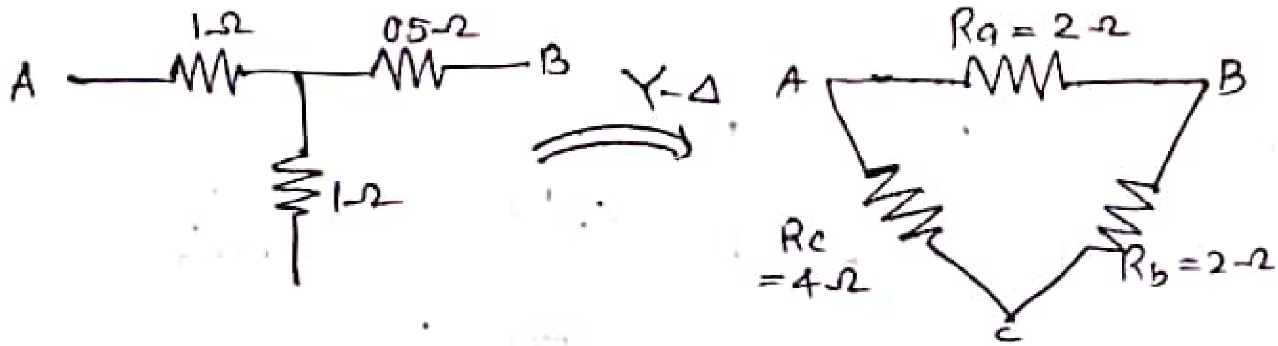
∴ $0.15 + 0.35 = \underline{\underline{0.5\,\Omega}}$

1Ω and 1Ω in series ∴ 2Ω

∴ circuit becomes



converting star connected resistors 1Ω, 1Ω and 0.5Ω into delta



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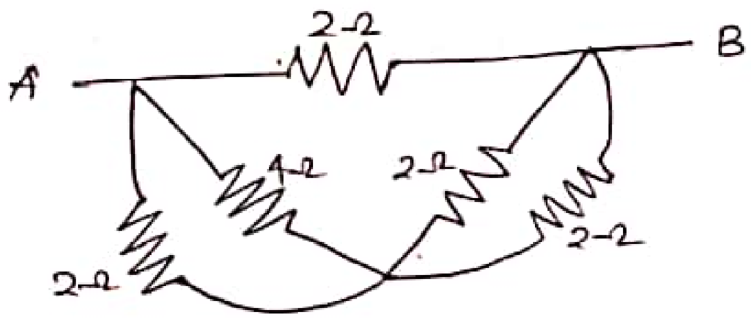
$$R_a = \frac{1\times1 + 1\times0.5 + 0.5\times1}{1} = \underline{\underline{2\Omega}}$$

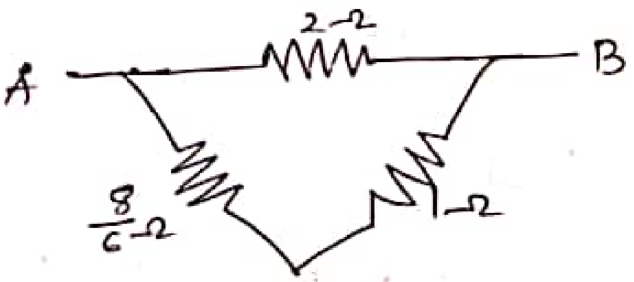
$$R_b = \frac{1\times1 + 1\times0.5 + 0.5\times1}{1} = \underline{\underline{2\Omega}}$$

$$R_c = \frac{1\times1 + 1\times0.5 + 0.5\times1}{0.5} = \underline{\underline{4\Omega}}$$

Re inserting Δ connection instead of Y in the ckt.



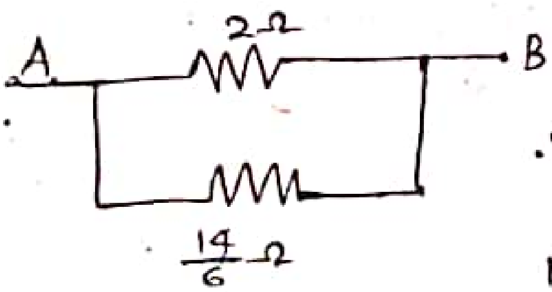
4Ω and 2Ω in parallel, 2Ω and 2Ω in parallel



$$4 \| 2 = \frac{4\times2}{6} = \underline{\underline{\frac{8}{6}}}$$

$$2 \| 2 = \frac{2\times2}{4} = \underline{\underline{1\Omega}}$$

$\frac{8}{6}$ and 1Ω in series



$$\therefore R_{AB} = \frac{2\times(\frac{14}{6})}{2+(14/6)}$$

$$R_{AB} = \underline{\underline{1.07\Omega}}$$

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* Methods of analysing electrical circuits

Electrical circuits can be easily solved and analysed by two different methods.

(i) Mesh current method (or) Mesh analysis

(ii) Node voltage method or Nodal analysis

(i) Mesh current method (or) mesh analysis

↳ A mesh is a closed loop which does not contain any other loops within it.

↳ Mesh analysis = KVL + Ohms law

Procedure for mesh analysis.

Step 1 : Identify all the meshes in the given circuit

Step 2 : Assign mesh currents as I_1, I_2, I_3 etc in clockwise direction

Step 3 : Write KVL equation for each mesh

Step 4 : Solve KVL equations to obtain I_1, I_2, I_3 etc.

Step 5 : Find unknown parameter in the circuit using ohms law or any other relevant equation.

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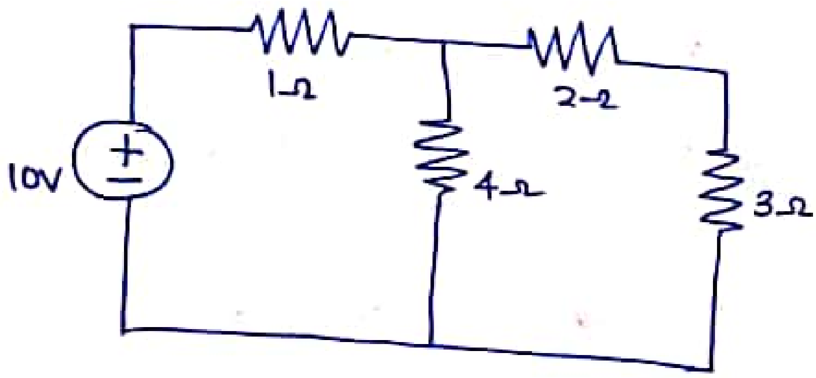
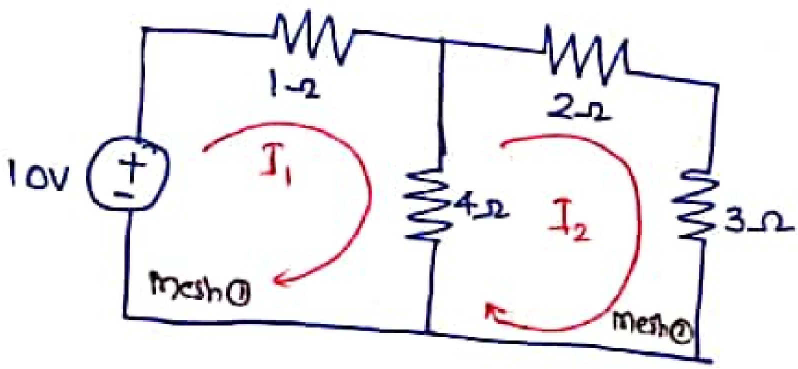
Numerical

1, Find currents through all resistors using mesh analysis.



Ans: Step 1: - There are 2 meshes in this network.

Step 2: Taking mesh ~~clock~~ currents as I_1 and I_2 in Clock wise direction



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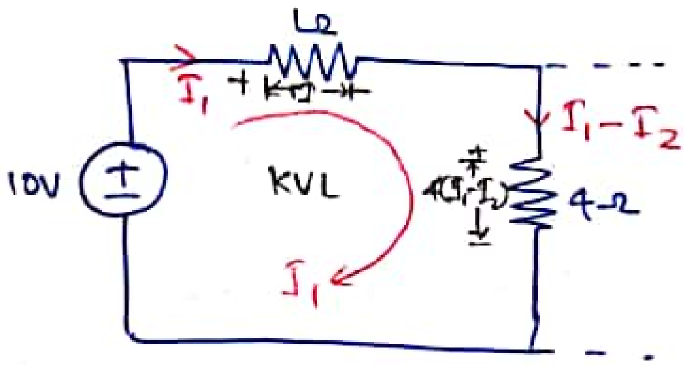
Step 3:- KVL in mesh 1

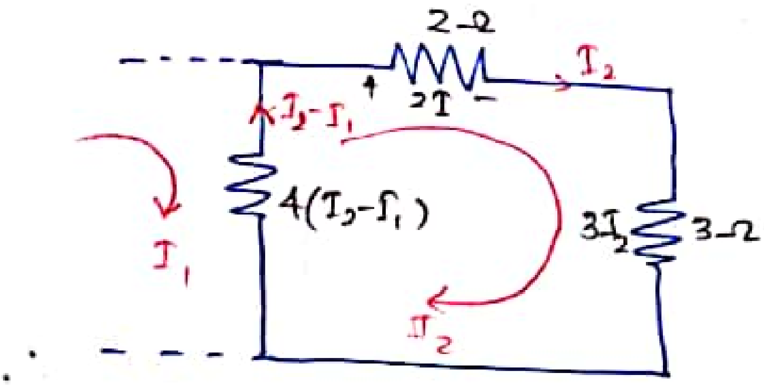
Assume $I_1 > I_2$



$$-10 + 1I_1 + 4(I_1 - I_2) = 0$$

$$5I_1 - 4I_2 = 10 \quad \text{--- (1)}$$

KVL in mesh 2 ; Assume $I_2 > I_1$



$$4(I_2 - I_1) + 2I_2 + 3I_2 = 0$$

$$-4I_1 + 9I_2 = 0 \quad \text{--- (2)}$$

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Step 4: Solving equation ① and ②

We get $I_1 = 3.1A$

$I_2 = 1.38A$

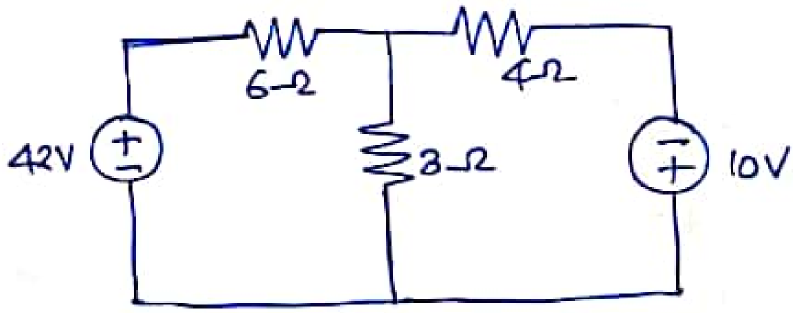
Step 5: $I_{1\Omega} = I_1 = 3.1A$, $I_{2\Omega} = I_2 = 1.38A$

$I_{3\Omega} = I_2 = 1.38A$, $I_{4\Omega} = I_1 - I_2$

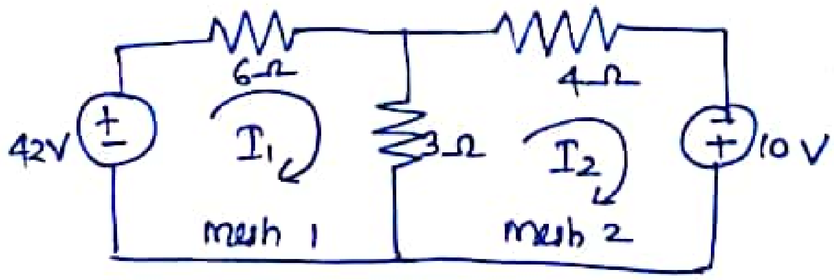
$= 3.1 - 1.38$

$= 1.72A$

2\. U.Q. By mesh analysis find the current flowing through 4Ω and 3Ω resistors in the following circuit



Ans: There are 2 meshes in the circuit ∴ taking mesh currents as, I_1, I_2 clockwise



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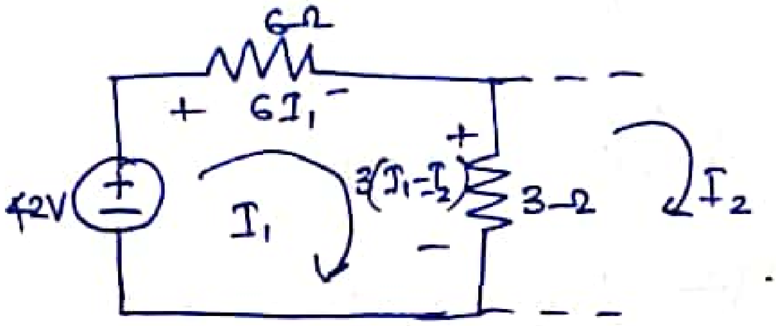
KVL in mesh 1 Assume $I_1 > I_2$

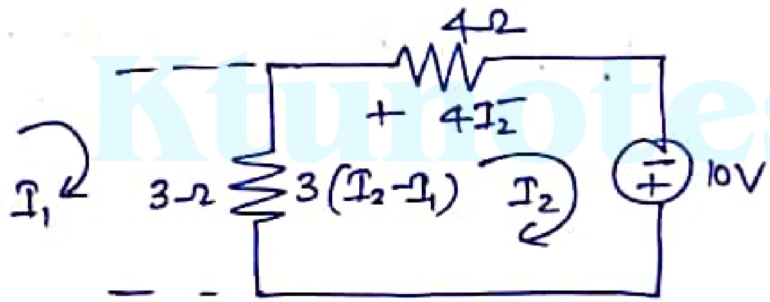


$$-42 + 6I_1 + 3(I_1 - I_2) = 0$$

$$9I_1 - 3I_2 = 42$$

$$3I_1 - I_2 = 14 \quad \text{—} (1)$$

KVL in mesh 2 Assume $I_2 > I_1$



$$3(I_2 - I_1) + 4I_2 - 10 = 0$$

$$-3I_1 + 7I_2 = 10 \quad \text{—} (2)$$

solving eqn (1) and (2)

$$I_1 = \underline{\underline{6A}}.$$

$$I_2 = \underline{\underline{4A}}$$

∴ current through 4Ω resister, $I_{4\Omega} = \underline{\underline{4A}}$.

" " 3Ω resistor, $I_{3\Omega} = I_1 - I_2$

$= 6 - 4 = \underline{\underline{2A}}$.

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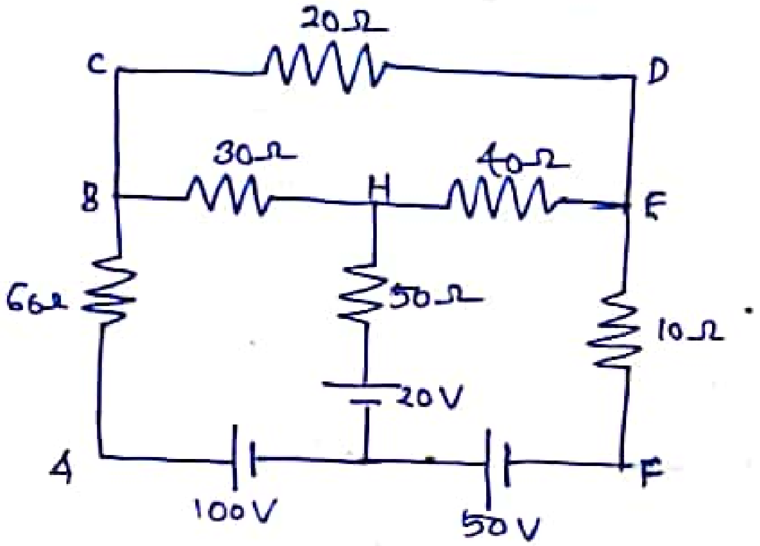
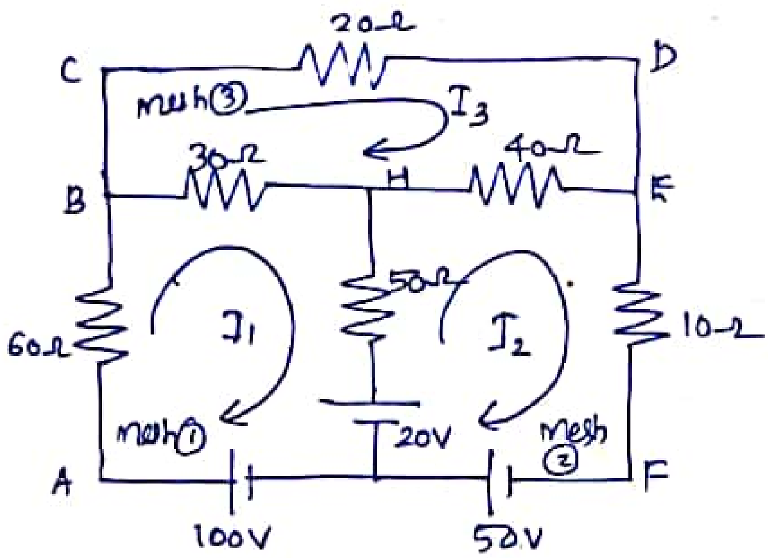
3, Q: U.Q. Calculate current in each branch of the circuit shown using mesh analysis



Ans: There are 3 meshes in this circuit. ∴ taking mesh currents as, I_1, I_2 and I_3 in clockwise direction.



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Mesh 1 equation

$$-100+60I_1+30(I_1-I_3)+50(I_1-I_2)+20=0$$

$$140I_1-50I_2-30I_3=80 \quad \text{--- (1)}$$

Mesh 2 equation

$$-50-20+50(I_2-I_1)+40(I_2-I_3)+10I_2=0$$

$$-50I_1+100I_2-40I_3=70 \quad \text{--- (2)}$$

Mesh 3 equation

$$20I_3+40(I_3-I_2)+30(I_3-I_1)=0$$

$$-30I_1+40I_2+90I_3=0 \quad \text{--- (3)}$$

Solving equations (1), (2) and (3)

$I_1 = 1.65A$

$I_2 = 2.12A$

$I_3 = 1.49A$

Current in GAB $= I_1 = 1.65A$

" " EFG $= I_2 = 2.12A$

" " BCDE $= I_3 = 1.49A$

" " BH $= I_1 - I_3 = 1.65 - 1.49 = 0.16A$

" " HE $= I_2 - I_3 = 2.12 - 1.49 = 0.63A$

" " HG $= I_2 - I_1 = 2.12 - 1.65$

$= 0.47A$

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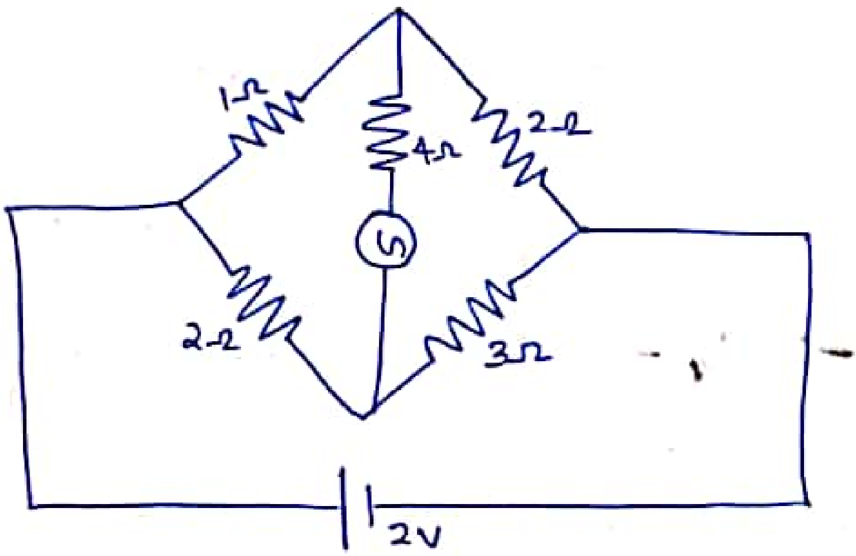
4.Q.
U.Q.

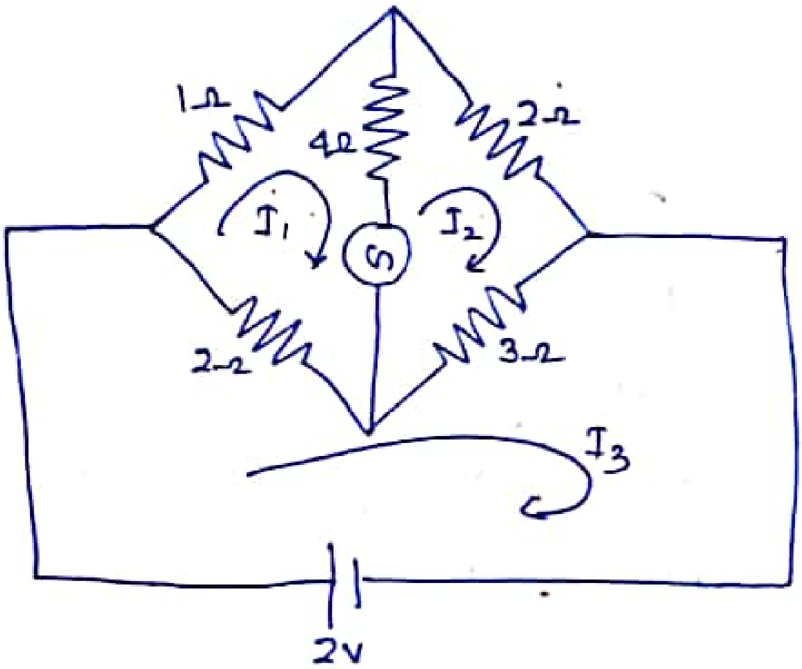
Find the current through galvanometer



Ans: This can be solved using mesh analysis (or) Nodal analysis.

Mesh analysis will be easier for this circuit

There are three meshes.



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Mesh 1 equation

$$1I_1 + 4(I_1 - I_2) + 2(I_1 - I_3) = 0$$

$$7I_1 - 4I_2 - 2I_3 = 0 \quad \text{——} (1)$$

Mesh 2 equation

$$4(I_2 - I_1) + 2I_2 + 3(I_2 - I_3) = 0$$

$$-4I_1 + 9I_2 - 3I_3 = 0 \quad \text{——} (2)$$

Mesh 3 equation

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

$$-2I_1 - 3I_2 + 5I_3 = 2 \quad \text{——} (3)$$

Solving (1), (2) and (3)

$$I_1 = 0.68\,A$$

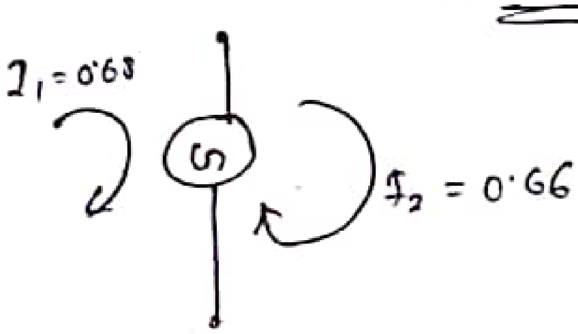
$$I_2 = 0.66\,A$$

$$I_3 = 1.07\,A$$

Current through galvanometer

$$I_G = I_1 - I_2 = 0.68 - 0.66$$

$$= 0.02\,A$$



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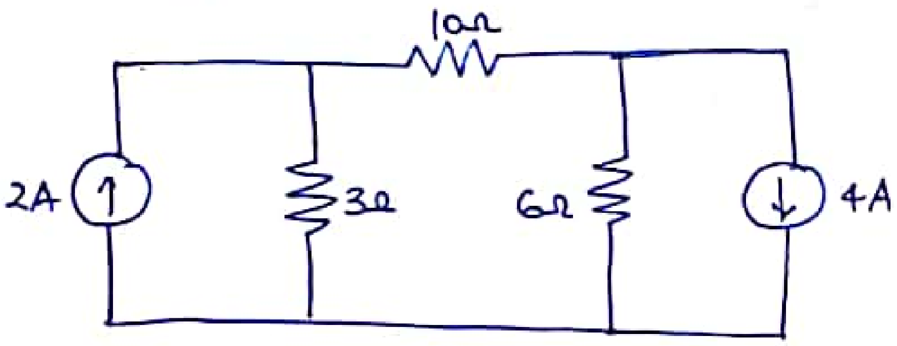
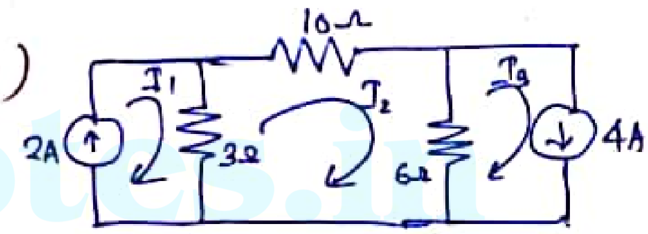
5, Q.) For the given circuit, find the current through 3Ω resistor using mesh analysis. Also find the power dissipated by 3Ω resistor.



Ans: There are 3 meshes in the circuit.

Mesh 1 equation

$I_1 = 2A$ (given directly)



Mesh 2 equation

$$3(I_2 - I_1) + 10 I_2 + 6(I_2 - I_3) = 0$$

$$-3I_1 + 19I_2 - 6I_3 = 0 \quad \text{—} (1)$$

Mesh 3 equation

$I_3 = 4A$ (given directly)

Substituting I_1 and I_3 in equation (1)

$$-3 \times 2 + 19 I_2 - 6 \times 4 = 0$$

$$I_2 = \frac{30}{19} = \underline{1.58 A}$$

Current through 3Ω resistor $= I_1 - I_2$

$= 2 - 1.58$

$= \underline{0.42 A}$.

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Power dessipated by 3 Ω resistor,

$$P_{3\Omega} = I_{3\Omega}^2 \times 3$$

$$= 0.42^2 \times 3$$

$$= 0.53 \text{ watt}$$

* Node Voltage analysis (or) Nodal Analysis

↳ Nodes are the points where two or more elements are interconnected.

↳ Series node : Nodes connecting only two elements (or 2 branches)

↳ Nodal analysis = KCL + Ohms Law

* Procedure for nodal Analysis

Step 1 :- Identify the nodes of a given network. Series nodes can be neglected.

Step 2 :- Select any one node as reference node and assign its potential as '0' volts.

Step 3 :- Apply KCL at each node except reference node. Assume current direction as away from the node.

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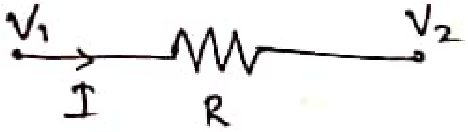
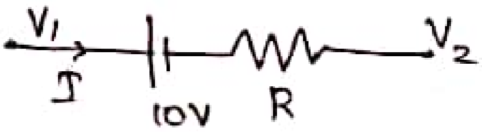
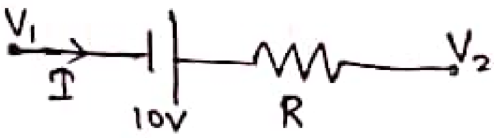
* Following rules can be used to express branch currents.

(a) 

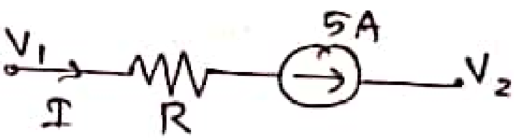
$\Longrightarrow \quad I = \dfrac{V_1 - V_2}{R}$

(b) 

$\Longrightarrow \quad I = \dfrac{(V_1 - 10) - V_2}{R}$

(c) 

$\Longrightarrow \quad I = \dfrac{(V_1 + 10) - V_2}{R}$

(d) 

$\Longrightarrow \quad I = 5A$

(Given current source value).

Step 4 :- Solve KCL equations to find V_1, V_2, V_3 etc.

Step 5 :- Use ohms Law or any relevant equation to find unknown parameter.

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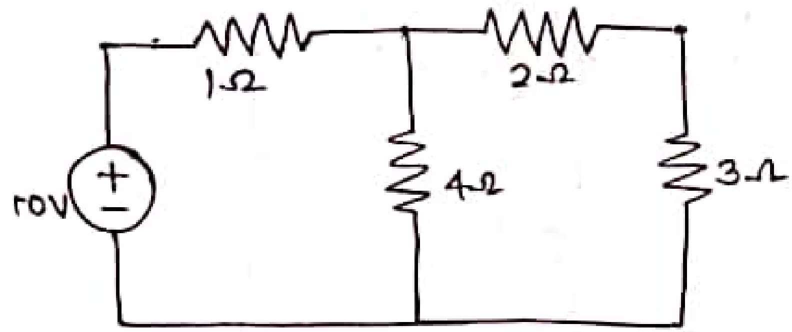
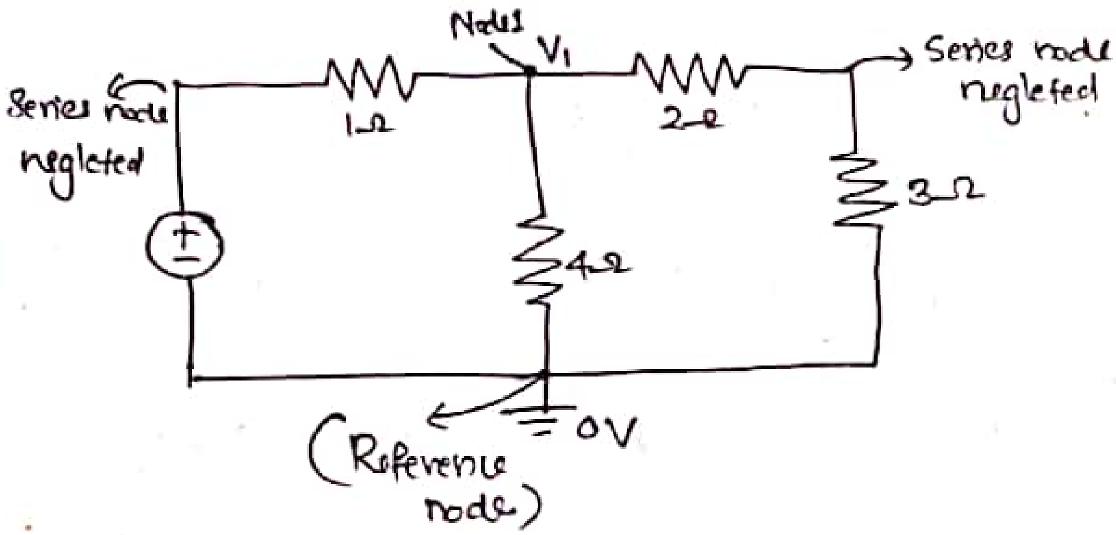
Q; Numerical Questions

1, Find current through 4Ω using Nodal analysis



Ans. Step 1:- There are two nodes in this circuit after neglecting two series nodes.

Step 2:- Taking one node as reference node and its potential is 0V. Other node voltage is V_1



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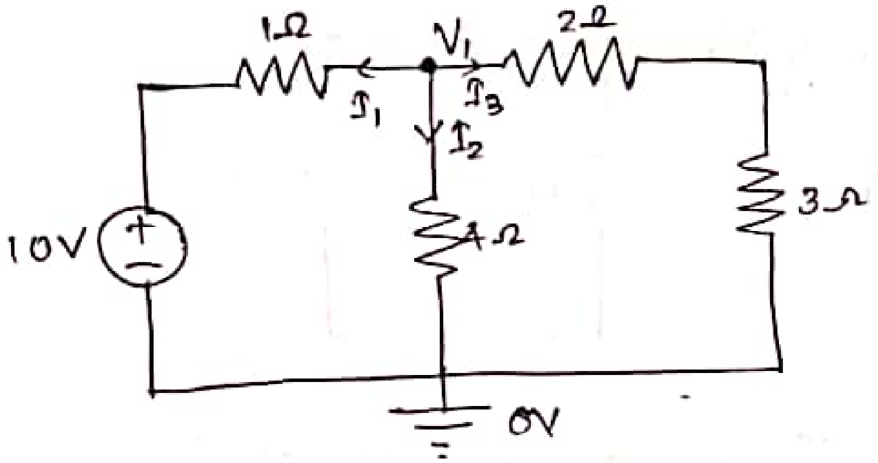
Step 3: KCL at node 1

Assume all currents leaving node 1



$\therefore I_1 + I_2 + I_3 = 0$

current leaving (current entering)

we have, $I_1 = \frac{V_1 - 10}{1}$, $I_2 = \frac{V_1 - 0}{4}$

$I_3 = \frac{V_1 - 0}{2+3}$

$\therefore$ KCL $\frac{V_1 - 10}{1} + \frac{V_1}{4} + \frac{V_1}{5} = 0$

Step 4: -

$V_1 \left(1 + \frac{1}{4} + 1/5\right) = 10 \Longrightarrow V_1 = \underline{\underline{6.89V}}$

Step 5: -

current through 4Ω resistor $= \frac{V_1 - 0}{4}$

$= \frac{6.89}{4} = \underline{\underline{1.72 A}}$

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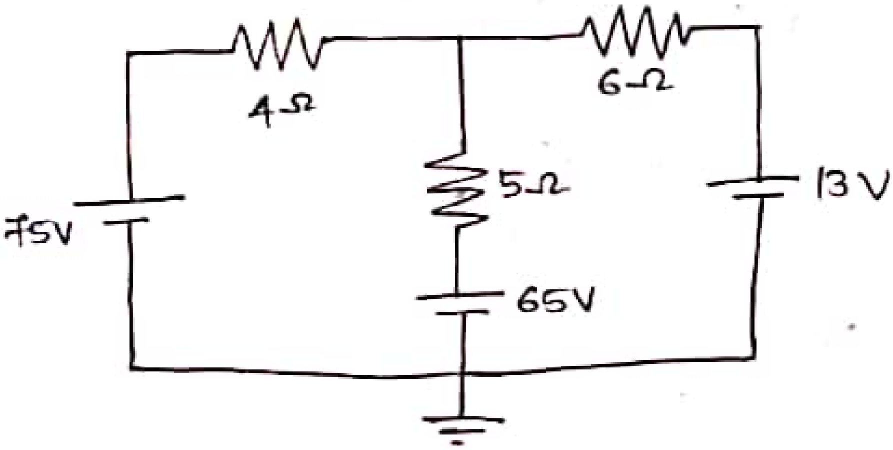
2,Q. Find the current through 5Ω resistor using nodal analysis



Step 1: there are 2 nodes only in this circuit after neglecting other 3 series nodes.

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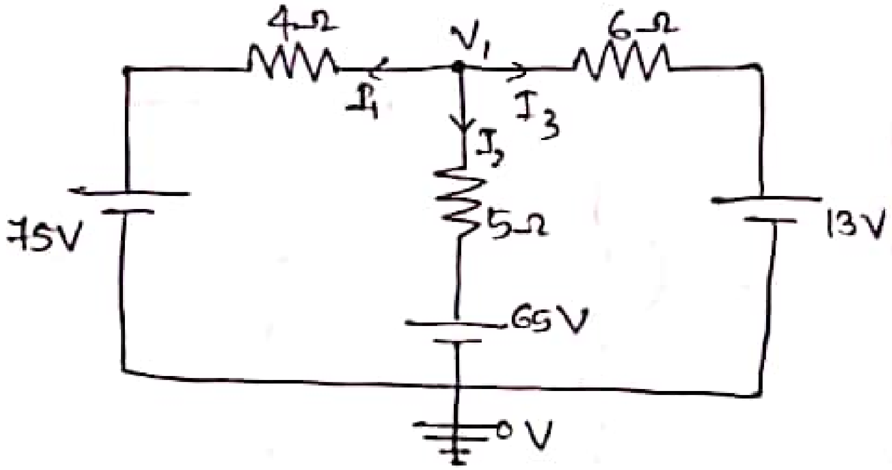
Step 2: Taking node 1 voltage as V_1 and other node as reference node with 0V.

Step 3:



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Assuming currents I_1, I_2, I_3 away from node

By KCL $I_1 + I_2 + I_3 = 0$

$$\frac{V_1 - 75}{4} + \frac{V_1 - 65 - 0}{5} + \frac{V_1 - 13}{6} = 0$$

Step 4 $$V_1\left[\frac{1}{4} + \frac{1}{5} + \frac{1}{6}\right] = \frac{75}{4} + \frac{65}{5} + \frac{13}{6}$$

$$V_1 = \underline{\underline{55\ V}}$$

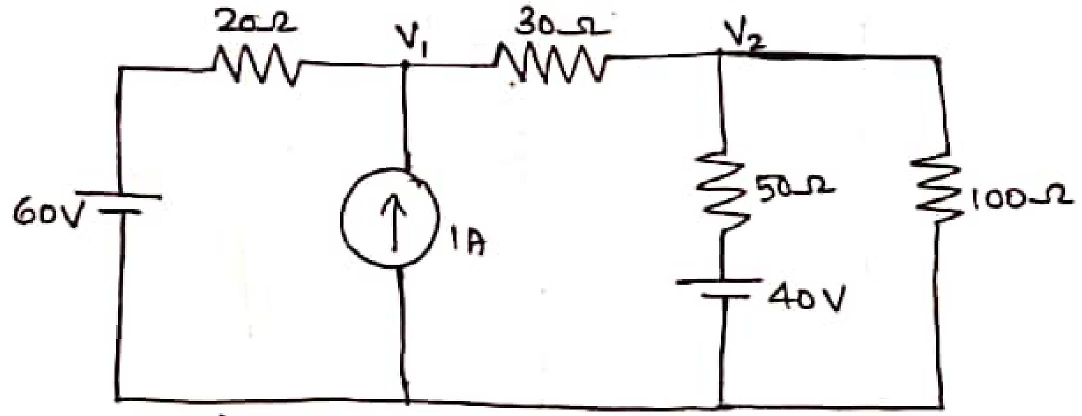
Step 5: To find, $$I_{5\Omega} = \frac{V_1 - 65 - 0}{5}$$

$$= \frac{55 - 65}{5}$$

$$I_{5\Omega} = \underline{\underline{-2\ A}}$$

−Ve sign indicates that current is flowing opposite to assumed direction.

Q13, Find current in 100Ω resistor using nodal analysis



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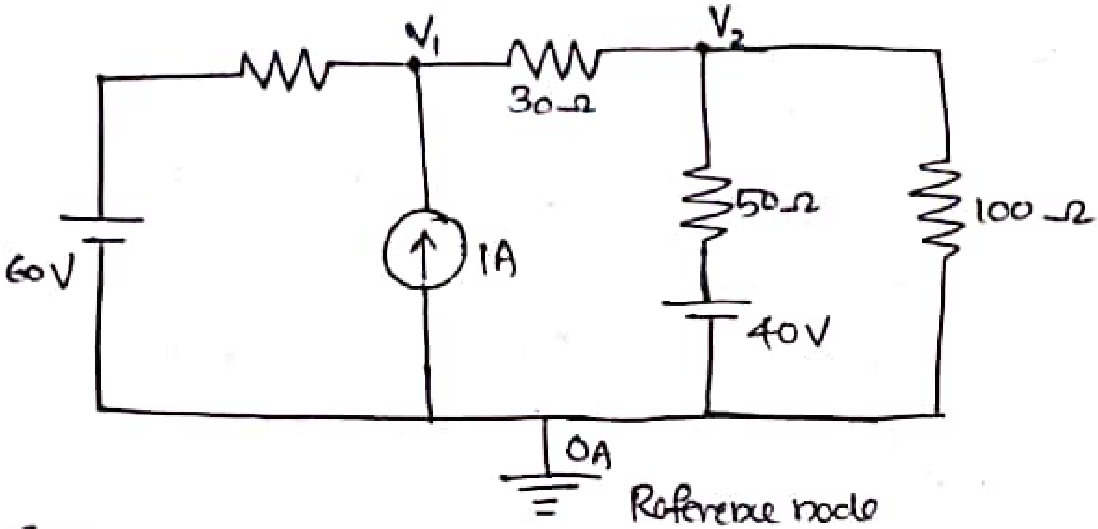
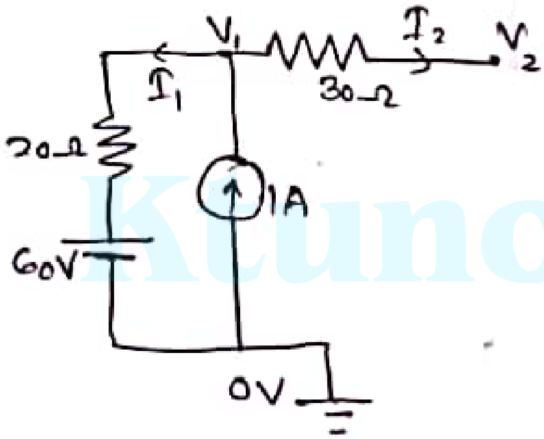


There are 3 nodes, one taken as reference.

KCL at node 1

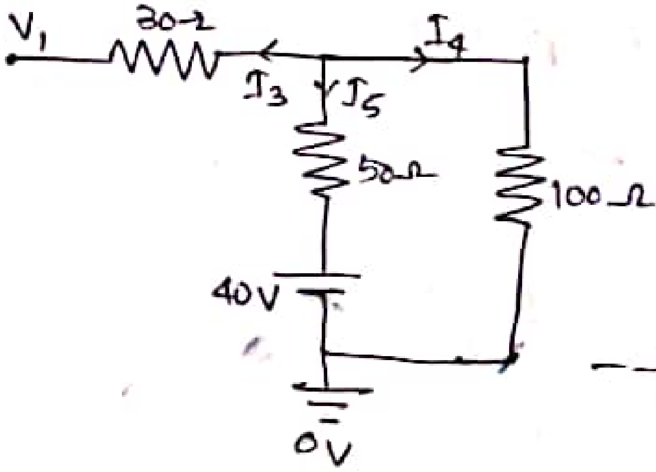


$$I_1 + I_2 = 1$$

$$\frac{V_1 - 60}{20} + \frac{V_1 - V_2}{30} = 1$$

$$V_1\left(\frac{1}{12}\right) - \frac{1}{30}V_2 = 4 \quad \text{—}(1)$$

KCL at node 2



$$I_3 + I_4 + I_5 = 0$$

$$\frac{V_2 - 40}{50} + \frac{V_2}{100} + \frac{V_2 - V_1}{30} = 0$$

$$-\frac{1}{30}V_1 + \frac{19}{300}V_2 = \frac{4}{5} \quad \text{—}(2)$$

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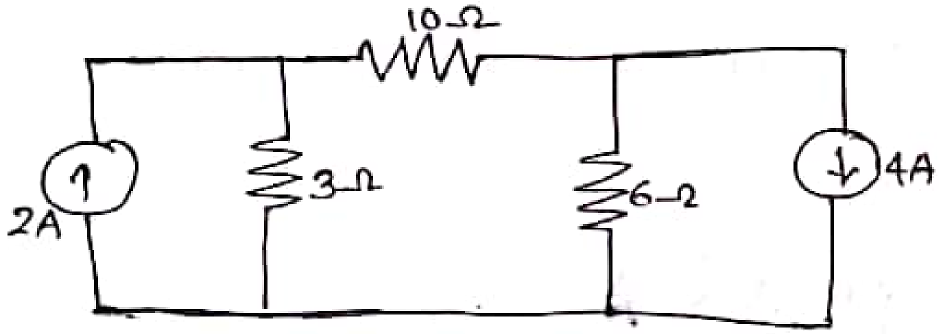
Solving $V_1 = 67.2\,V$

$V_2 = 48\,V$

Current in $100\Omega = \frac{V_2}{100} = \frac{48}{100} = 0.48A$.

4. Q.P. For the given network find the current through 3Ω resistor



↳ There are 3 nodes of which one is taken as reference node.

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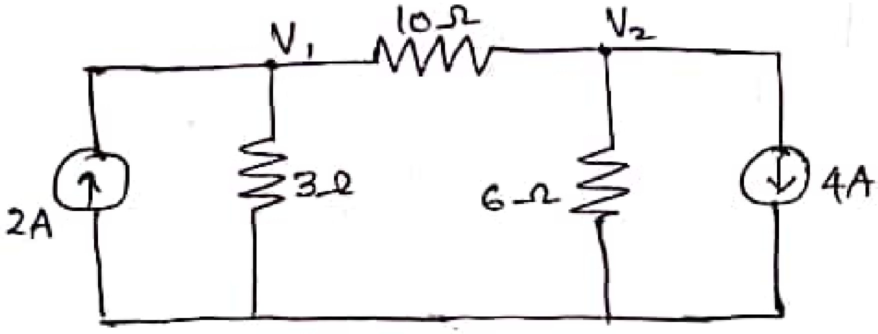
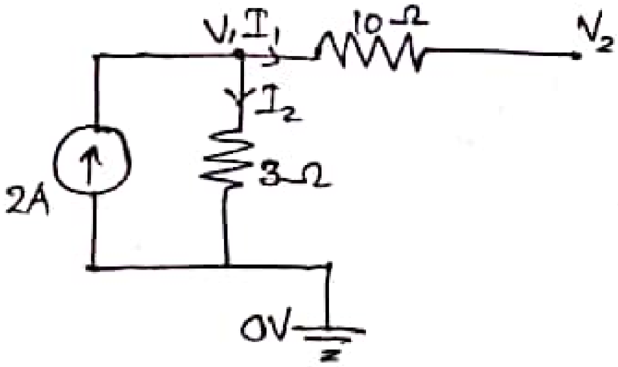


KCL at node 1 (Assume $V_1 > V_2$)



$I_1 + I_2 = 2\,A$

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

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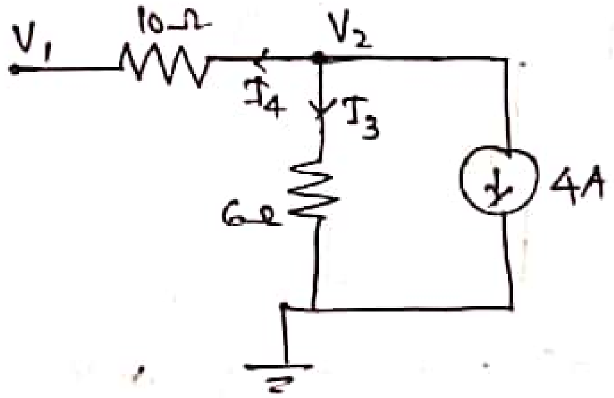
$$V_1\left(\frac{1}{10}+\frac{1}{3}\right)-\frac{1}{10}V_2 = 2$$

$$\frac{13}{30}V_1 - \frac{1}{10}V_2 = 2 \quad \text{—— (1)}$$

KCL at node 2 (Assume $V_2 > V_1$)



$$I_3 + I_4 + 4 = 0$$

$$\frac{V_2}{6} + \frac{V_2 - V_1}{10} + 4 = 0$$

$$-\frac{1}{10}V_1 + \frac{8}{30}V_2 = -4 \quad \text{—— (2)}$$

Solving equations (1) and (2)

$$V_1 = 1.26\ V$$

$$V_2 = -14.5\ V$$

$\therefore$ Current through 3Ω, $I_{3\Omega} = \frac{V_1 - 10}{3}$

$$= \frac{1.26}{3} = 0.42\ A$$

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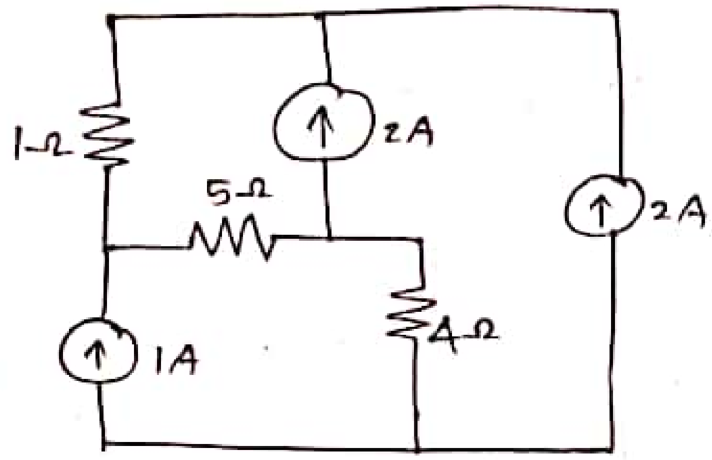
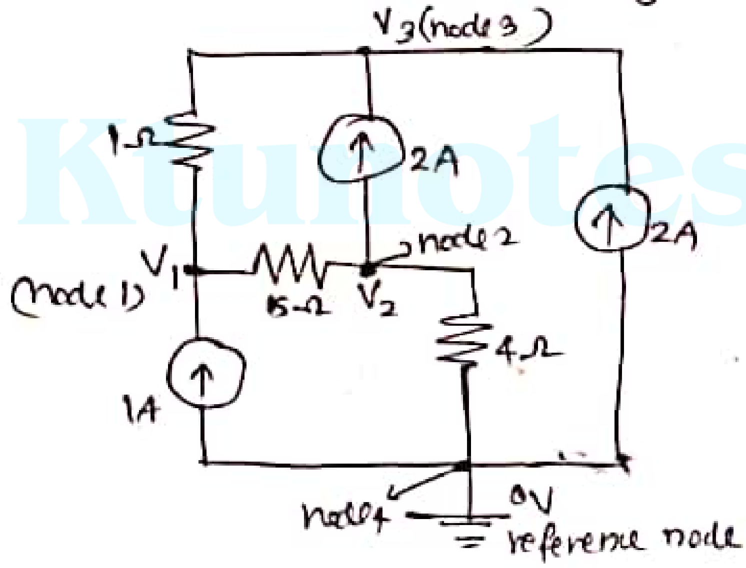
5/ Q: Obtain the voltage drops across all resistors of the circuit shown below using nodal analysis.



↳ we have 4 nodes after negleting series nodes.



Assume node voltages as V_1, V_2 and V_3 and assigning 1 node as reference node.

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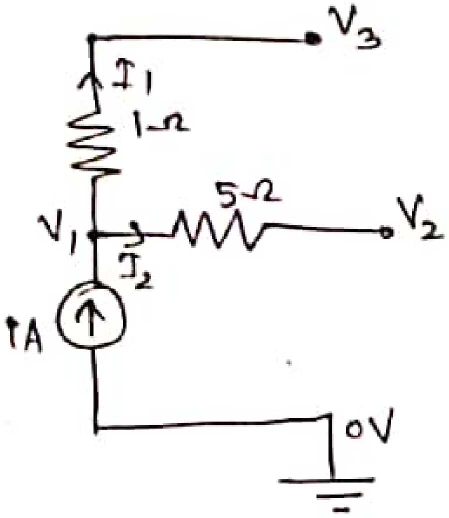
KCL at node 1



Assume $V_1 > V_2$ and $V_1 > V_3$

all currents away from node.

By KCL

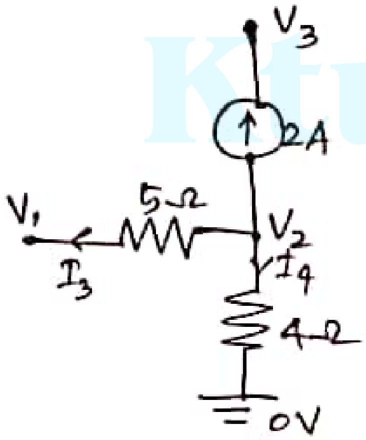
$$1 = I_1 + I_2$$

$$1 = \frac{V_1 - V_3}{1} + \frac{V_1 - V_2}{5}$$

$$1 = \frac{5V_1 - 5V_3 + V_1 - V_2}{5}$$

$$6V_1 - V_2 - 5V_3 = 5 \quad \text{--- (1)}$$

KCL at node 2



Assume $V_2 > V_1$ and $V_2 > V_3$

By KCL

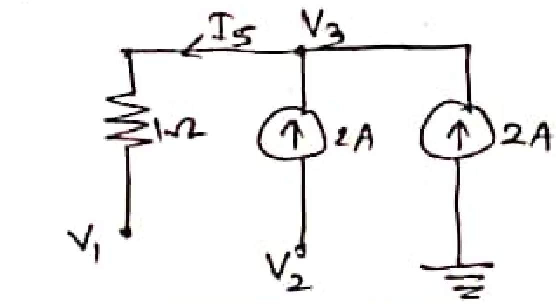
$$I_3 + I_4 + 2 = 0$$

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

$$\frac{4V_2 - 4V_1 + 5V_2 + 40}{20} = 0$$

$$-4V_1 + 9V_2 = -40 \quad \text{--- (2)}$$

KCL at node 3 :



Assume $V_3 > V_1$ and $V_3 > V_2$

By KCL

$$I_5 = 2 + 2$$

$$\frac{V_3 - V_1}{1} = 4$$

$$-V_1 + V_3 = 4 \quad \text{--- (3)}$$

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Solving equations ①, ② and ③

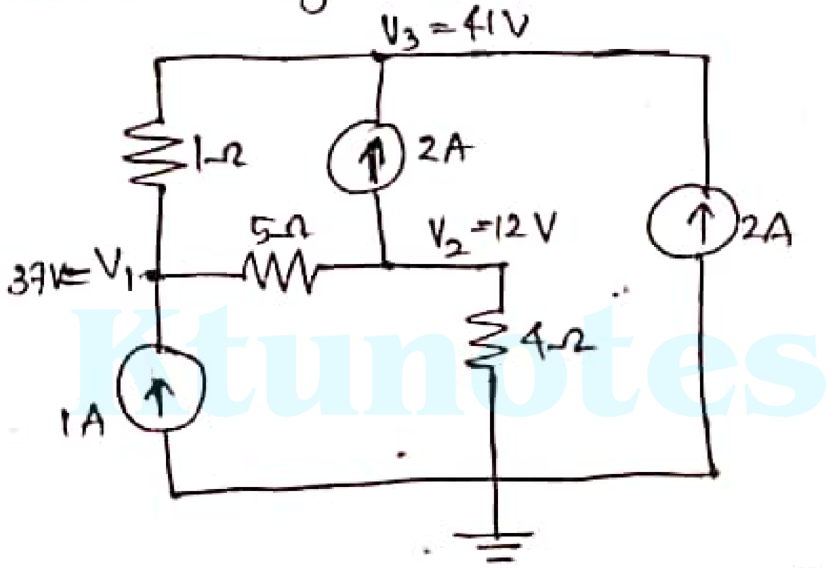
$$6V_1 - V_2 - 5V_3 = 5$$

$$-4V_1 + 9V_2 + 0V_3 = 40$$

$$-V_1 + 0V_2 + V_3 = 4$$

we get $V_1 = \underline{\underline{37\,V}}$, $V_2 = \underline{\underline{12\,V}}$, $V_3 = \underline{\underline{41\,V}}$.

To find voltage drop across each resister



Voltage drop across 1Ω = $V_{1\Omega} = V_3 - V_1 = 41 - 37$
$= \underline{\underline{4V}}$

" " 5Ω = $V_{5\Omega} = V_1 - V_2 = 37 - 12$
$= \underline{\underline{25\,V}}$.

" " 4Ω, $V_{4\Omega} = V_2 - 0$
$= \underline{\underline{12V}}$

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