Electrical Engineering.

Branch of science which deals with the study of electricity and its effects.

Fundamental Parameters.

- **Charge.**
  - → Represented by 'q' or 'Q'
  - → Unit of electric charge is Coulomb (c).
  - → 1C - 6.25×10^{16} electrons.
  - → e - 1.6×10^{-25} C

- **Electric Current**
  - → Time rate of flow of electric charge.
  - → $i = \frac{dq}{dt}$, $I = \frac{Q}{t}$.
  - → Unit of electric current is Ampere (A).
  - → Current flowing through a given area is $I = nAve$, where n is the no. of electrons per unit area of conductor, A is the area of cross-section of conductor, V is the drift velocity and e is the electronic charge.

• Voltage

→ Represented by 'V'.

→ Defined as the work done in bringing a charge from one point to another.

→ Unit of voltage is volt (V).

• Power

→ Defined as the rate of change of energy.

→ $P = \frac{dW}{dt}$

→ $P = \frac{dW}{dq} \times \frac{dq}{dt} = \underline{\underline{VI}}$.

→ Unit of electric power is Watt (W).

→ The power in a circuit is 1W when 1 joule of energy is consumed.

• Energy.

→ Represented by 'W'

→ Unit of energy is Joules (J).

Resistance

→ Defined as the property of a substance by which it opposes the flow of an electric current through it.

→ Unit of resistance is Ohm (Ω).

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

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

$\rho \rightarrow$ resistivity / specific resistance

$$\boxed{\rho = \frac{RA}{l}}$$

Conductance

→ It is the property of a material by virtue of which it allows the passage of current through it easily.

→ It is the inverse of resistance.

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

$\sigma \rightarrow$ conductivity / specific conductance

$$\sigma = \frac{1}{\rho}$$

→ Unit of conductance is mho ($\mho$) / siemens (s)

Temperature Coefficient of Resistance.

$$R_2 = R_1(1+\alpha \Delta t)$$

If the initial temperature is zero.

$$R_2 = R_0(1+\alpha_0 t)$$

$\alpha \rightarrow$ temp coefficient of resistance.

→ If the resistance of a material increases with temperature, the material is said to have positive temperature coefficient.

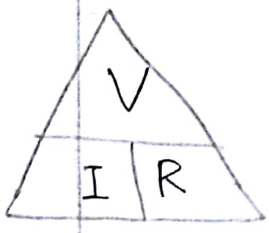
→ If the resistance of a material decreases with temperature, the material is said to have negative temperature coefficient.

Ohm's Law.

At constant temperature, the voltage produced by the conductor is proportional to current flowing through it.

Ohm's law applies through electric conduction through good conduction and is stated as .

Temperature remaining constant, current flowing through a conductor is directly proportional to potential difference across two ends of conductor .

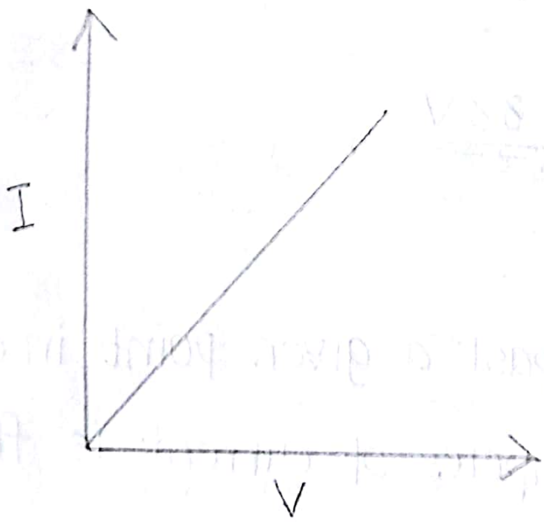


$$V \propto I$$

$$V = RI$$

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

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



Ohm's Law is applicable to both AC and DC .

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

Determine the potential difference to be applied across a conductor of resistance 12 Ω for that current of 15 A may flow through it.

15
12
30
15

$R = 12\,\Omega$ $\quad$ $I = 15A$.

$V = IR$

$= 12 \times 15$

$= \underline{\underline{180V}}$

If 70 Joules of energy is available for every 30 C of charge. What is the voltage?

$W = 70$ $\quad$ $Q = 30$.

$V = \frac{W}{Q} = \frac{70}{30} = \frac{7}{3} = \underline{\underline{2.33V}}$

5C of charge flow past a given point in a wire in 2s. How many amperes of current is flowing?

$I = \frac{Q}{t} = \frac{5}{2} = \underline{\underline{2.5A}}$

What is the power in watts if energy = 50J is used in 2.5s?

$$P = \frac{W}{t} = \frac{50}{2.5} = \underline{20 \text{ Watts}}.$$

How much energy in kWh is required to light a 60W bulb continuously for 1 year

$$E = P \times t = \frac{60 \times 1 \times 365 \times 24}{1000}$$

$$= \underline{525.6 \text{ KWh}}.$$

The resistance of a conductor 1mm² in cross-sectional area and 20m long is 0.346 Ω. Determine the specific resistance of conducting material.

$$\rho = \frac{RA}{l} = \frac{.346 \times 10^{-6}}{20}$$

$$= \underline{1.73 \times 10^{-8} \, \Omega m}.$$

A current of 3A flows through resistance of 20Ω. Find the power absorbed in the resistor and the energy dissipated in the resistor in 1 min and the charge flow through the resistor per min?

$I = 3A \qquad R = 20\,\Omega$

$V = 3 \times 20 = \underline{\underline{60\,V}}$.

$P = VI = 60 \times 3 = \underline{\underline{180\,W}}$.

$W = Pt = 180 \times 60 = \underline{\underline{10800\,J}}$.

$Q = It = 3 \times 60 = \underline{\underline{180\,C}}$.

A winding has a resistance of 40 Ω at 0°C. What is the resistance at 50°C. Temperature coefficient of the resistance at 0°C is 0·003 ?

$$R_t = R_0 (1 + \alpha_0 t)$$

$$R_{50°C} = 40 (1 + .003 \times 50)$$

$$= \underline{\underline{46\,\Omega}}$$

A lamp takes a current of 2·1 A when a supplied voltage of 220V is applied. Calculate the resistance and power of the lamp.

$I = 2{\cdot}1A \qquad V = 220V$

$$R = \frac{V}{I} = \frac{220}{2{\cdot}1} = \underline{\underline{104.76\,\Omega}}$$

$P = VI = 2.1 \times 220$

$= \underline{\underline{462\,W}}$

A heater of 1000 W is connected with a supply voltage of 250V. Calculate the current and resistance of heater.

$P = 1000W \qquad V = 250\,V$

$I = \frac{P}{V} = \frac{1000}{250} = \underline{\underline{4\,A}}$

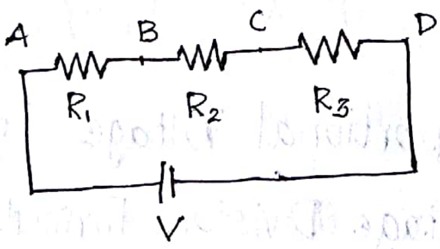
$R = \frac{V}{I} = \frac{250}{4} = \underline{\underline{62.5\,\Omega}}$

~~B Black~~

Series & Parallel Connection of Resistances.

1. Serial Connection.

→ end to end



1) I is same.
2) V is different.
3) $V_1 + V_2 + V_3 = V$
4) $R_{eq} = R_1 + R_2 + R_3$.
5) Power is additive.
6) $\frac{1}{G_{eq}} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3}$.

That single resistance that replaces the entire set of resistances is called equivalent resistance (R_{eq})

$$V = V_1 + V_2 + V_3 .$$

$$IR_{eq} = IR_1 + IR_2 + IR_3 .$$

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

For any number of resistances in series, the equivalent resistance is the sum of all resistances.

$$I = I_1 + I_2 + I_3 .$$

$$\frac{V}{R_{eq}} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} .$$

$$V_1 = V\frac{R_1}{R_{eq}} = \frac{VR_1}{R_1+R_2+R_3}$$

$$V_2 = \frac{VR_2}{R_{eq}} = \frac{VR_2}{R_1+R_2+R_3}$$

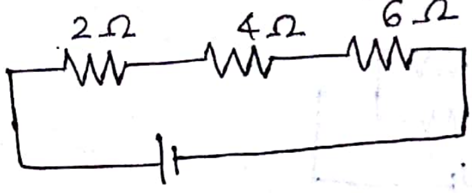
$$V_3 = \frac{VR_3}{R_{eq}} = \frac{VR_3}{R_1+R_2+R_3} .$$

$$V_n = V\frac{R_n}{R_{eq}} .$$

Proportional Voltage Formula

Voltage Division Formula.

Find the individual voltages .

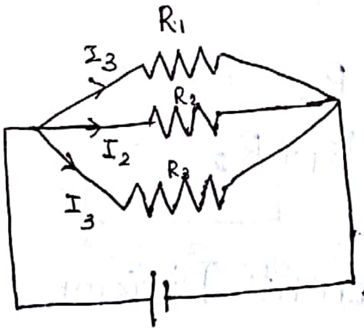


$$V_1 = 24 \times \frac{2}{12} = \underline{\underline{4}}\ V$$

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

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

Parallel Connection .



1) V same .

2) I different .

3) $I = I_1 + I_2 + I_3$.

4) $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$.

5) $G_{eq} = G_1 + G_2 + G_3$.

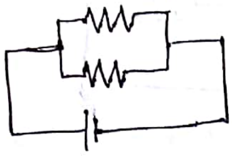
6) $P = P_1 + P_2 + P_3$

$$I = I_1 + I_2 + I_3$$

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

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

2 Resistance in Parallel.



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

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

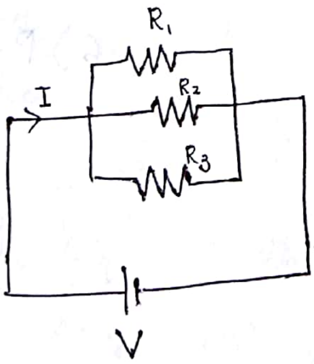
$$V_1 = V_2 = V$$

$$I_1 R_1 = I_2 R_2 = I R_{eq}.$$

$$I_1 = I \cdot \frac{R_{eq}}{R_1} = \frac{I\, R_1 R_2}{(R_1+R_2) R_1}$$

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

$I_2 = I \frac{R_1}{R_1+R_2}$ Current Division Rule.



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

$$= \frac{R_1R_2 + R_2R_3 + R_1R_3}{R_1R_2R_3}$$

$$R_{eq} = \frac{R_1R_2R_3}{R_1R_2 + R_2R_3 + R_1R_3}$$

$$= \frac{R_1R_2R_3}{\Sigma R_1R_2}.$$

$$I_1R_1 = I_2R_2 = I_3R_3 = IR_{eq}.$$

$$I_1 = \frac{I \cdot R_{eq}}{R_1}$$

$$= I \frac{R_1R_2R_3}{(R_1R_2 + R_2R_3 + R_1R_3)R_1}$$

$$I_1 = I \cdot \frac{R_2R_3}{R_1R_2 + R_2R_3 + R_3R_1}$$

$$I_2 = I \cdot \frac{R_1R_3}{R_1R_2 + R_2R_3 + R_3R_1}$$

$$I_3 = I \cdot \frac{R_1R_2}{R_1R_2 + R_2R_3 + R_3R_1}$$

Three resistances $2\Omega, 5\Omega, 6\Omega$ are connected first in parallel and then in series. Find equivalent resistances in both the cases.

$$R_{eq}(\text{parallel}) = \frac{2 \times 5 \times 6}{2\times5 + 2\times6 + 5\times6} = \frac{60}{10+12+30} = \frac{60}{52} = 1.153\Omega$$

R_{eq} (series) $= 2+5+6 = \underline{13\,\Omega}$

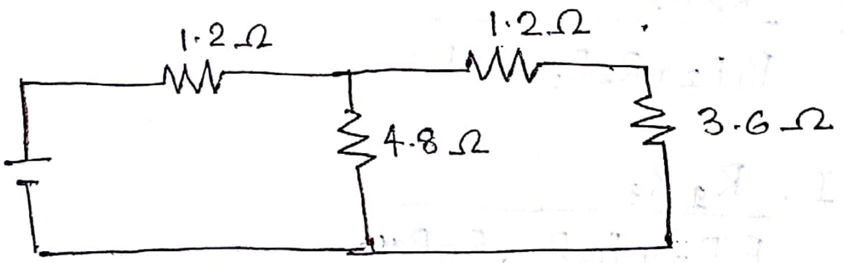
Calculate the values of two resistances which when connected in series gives $50\,\Omega$ and $8\,\Omega$ in parallel.

$$R_1 + R_2 = 50$$

$$\frac{R_1 R_2}{R_1 + R_2} = 8$$

$$\frac{R_1 R_2}{8} = R_1 + R_2$$

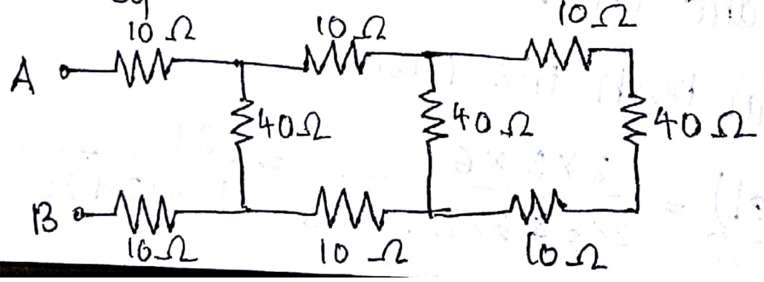
$R_1 = 40 \qquad R_2 = 10$



Find equivalent resistance

$R_{eq} = \underline{3 \cdot 6\,\Omega}$

Find Req.



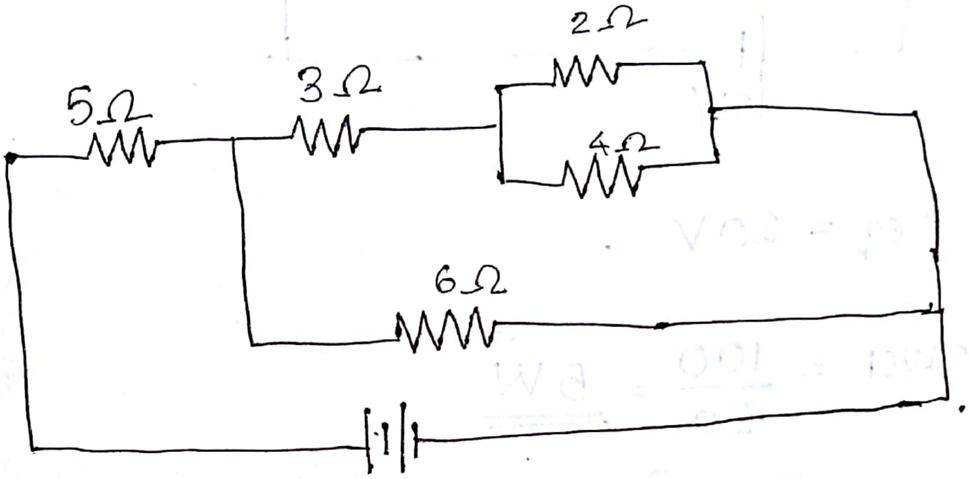
$\frac{1}{R} = \frac{1}{60} + \frac{1}{40}$

$\frac{60 \times 40}{100} = \frac{240}{}$

24

$R_{eq} = \underline{\underline{40.95\ \Omega}}$.

Find the current

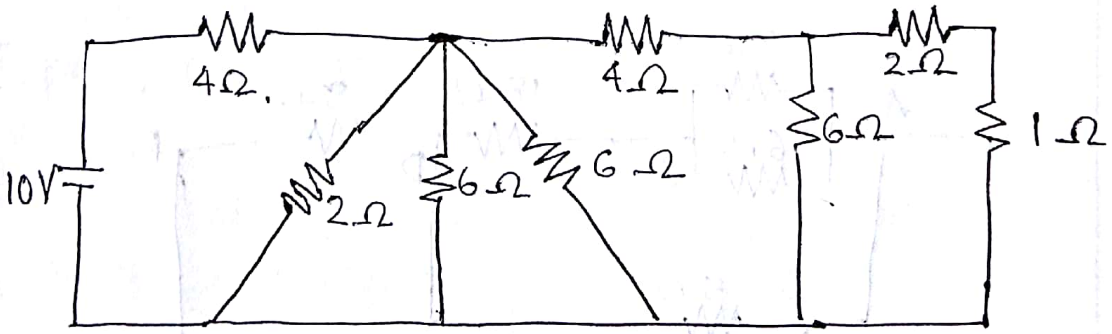


$$\begin{array}{r} 1.33r \\ 3 \\ \hline 4.33 \end{array}$$

$$\frac{4.33 \times 6}{10.33}$$

$R_{eq} = \underline{\underline{7.5\ \Omega}}$.

$I = \frac{V}{R_{eq}} = \frac{100}{7.5} = \underline{\underline{13.33\ A}}$



$\frac{6 \times 3}{9} = \frac{18}{9}$

2

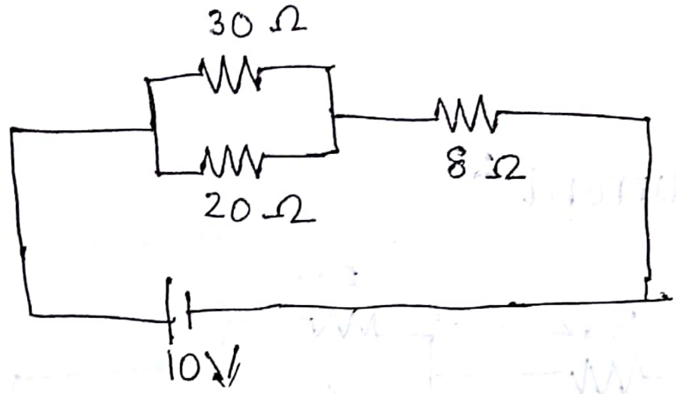
3 6

$R_{eq} = \underline{\underline{5\ \Omega}}$

$I = 10/5 = \underline{\underline{2A}}$

Find the power in the current

I



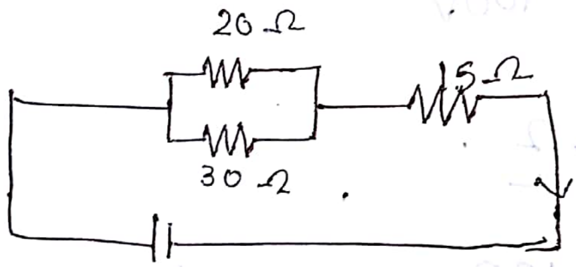
$R_{eq} = 20\,V$.

$\text{Power} = \frac{100}{20} = \underline{5\,W}$

$\frac{30 \times 20}{50} = \frac{600}{50} = 12$

20.

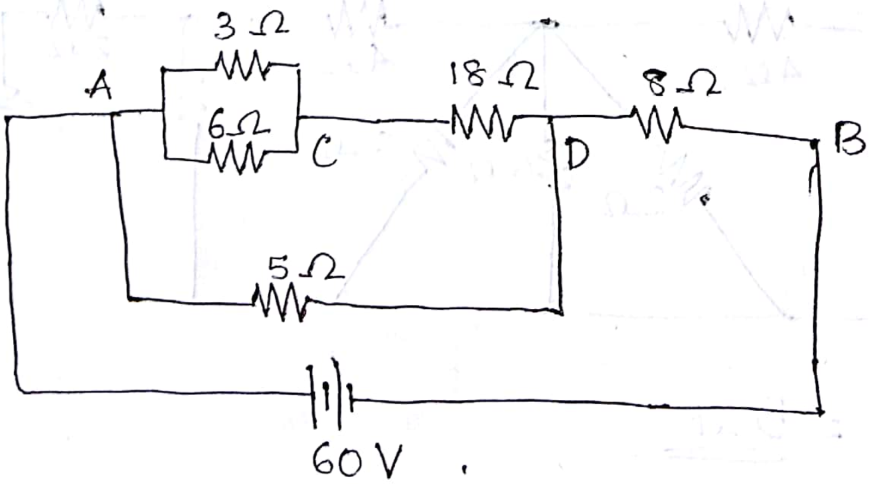
II



12
15
27

$R_{eq} = 27\,V$

$\text{Power} = I^2 R = 9 \times 27 = \underline{243\,W}$



Find R_{eq}, voltage drop across each R .

$R_{eq} = 12$.

$\frac{2R \times 5}{25}$

$I = \frac{60}{12} = \underline{\underline{5A}}$.

21

$DB = 8 \times 5 = 40V$

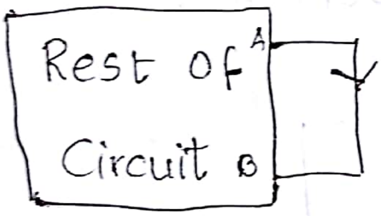
$AD = 4 \times 5 = 20V$.

$CD = 18V$

$AC = 2V$

Short Circuits & Open Circuits.

Short Circuit .

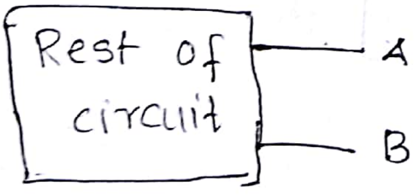


$R = \underline{\underline{0}}$

$I = \frac{V}{R} = \frac{V}{0} = \underline{\underline{\infty}}$

$V = IR = \underline{\underline{0}}$

Open Circuit .

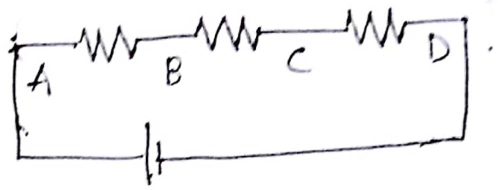


$R_{oc} = \infty$

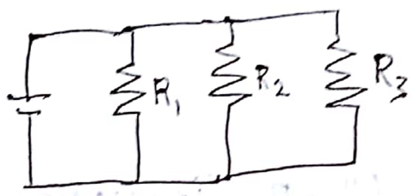
$I = 0$

$V_{oc} = V_{AB}$.

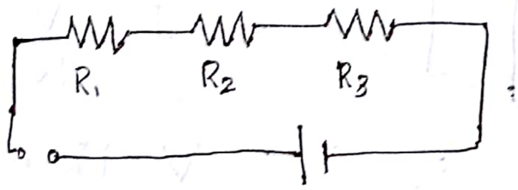
Short Circuit ~~and~~ in Series



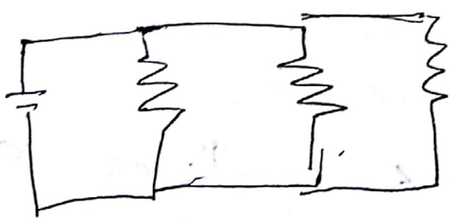
Short Circuit in Parallel.



Open circuit in Series.



Open Circuit in Parallel

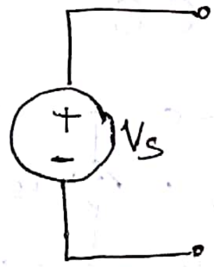


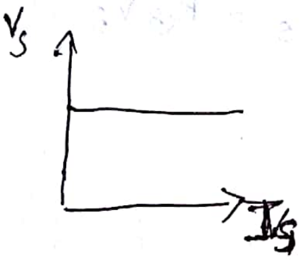
Energy Sources.

→ Independent ~~Day~~
- Ideal Const. Voltage Source
- Ideal Const. Current Source.

→ Dependent ~~Do~~

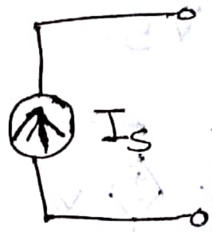
Ideal Constant Voltage Source.

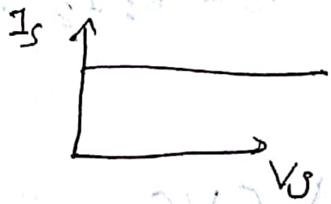




V-I chara

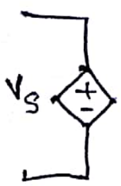
Ideal Constant Current Source



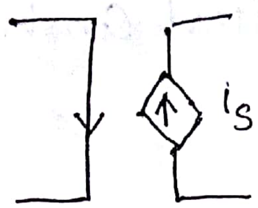


Dependent Sources.

- Current Controlled
  - CCVS
  - CCCS
- Voltage Controlled.
  - VCVS
  - VCCS

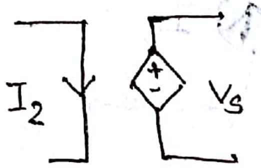


Current Controlled Current Source .



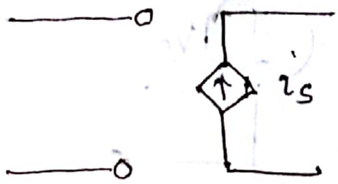
$i_s = k_1 I_1$

CCVS



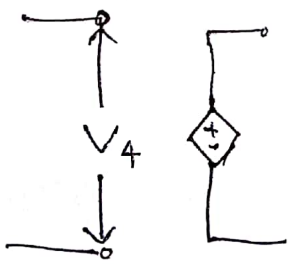
$V_s = k_2 I_2$

VCCS



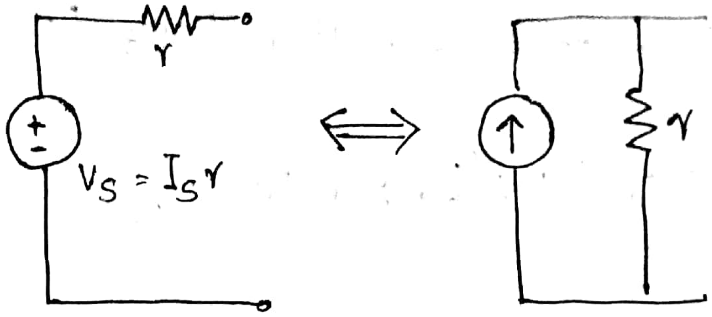
$i_s = k_3 V_3$

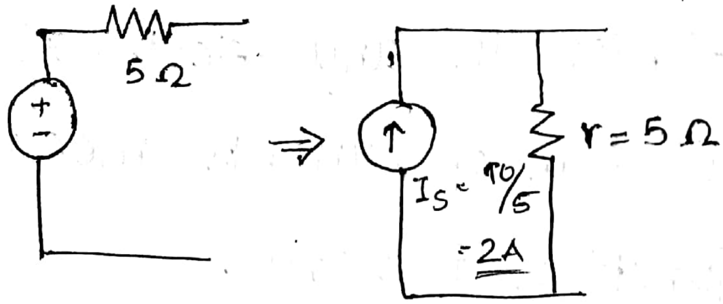
VCVS

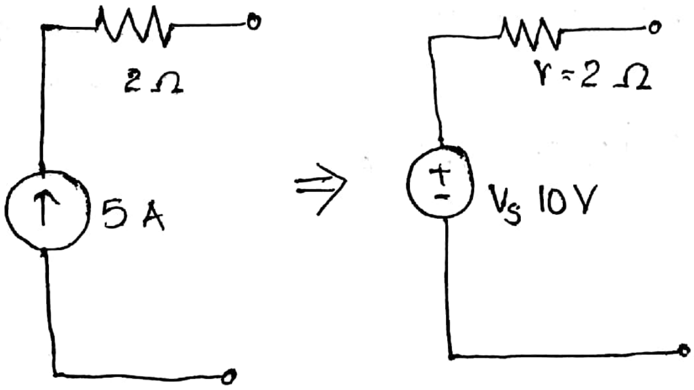


$V_s = k_4 V_4$

Source Conversions







Write a note on grouping of cell

Kirchoff's Laws.

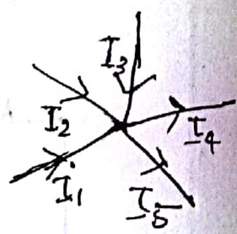
1. KCL (Kirchoff's Junction Rule / Point law)

2. KVL (Mesh Law/Loop rule).

KCL

~~The algebraic~~ In any electrical network, the algebraic sum of currents meeting at a point or junction is zero.

$$I_1 + I_2 + I_3 + I_4 + I_5 = 0.$$



$$i_1 + i_2 + i_3 = I_4 + I_5$$

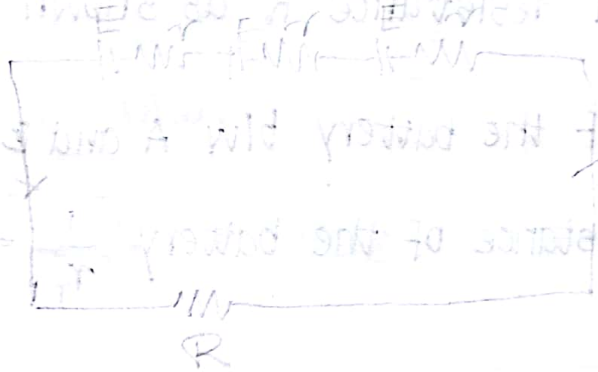
KVL.

The algebraic sum of the product of currents and resistances in each of the conductors in any closed path/mesh in a network and the algebraic sum of emfs in that path is zero

$$\Sigma E + \Sigma IR = 0.$$

Grouping of Cells.

Cells In Series



Consider n identical cells, each of emf E and internal resistance r, connected in series across an external resistance R as shown.

Total emf of the battery $= nE$.

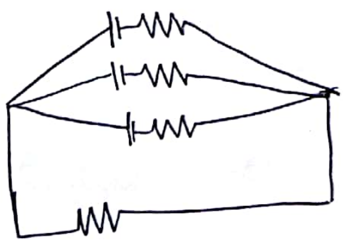
Internal resistance of the battery $= r + r + \dots + r = nr$.

Total circuit resistance $= R + nr$.

The current on the circuit, $I = \dfrac{\text{total emf}}{\text{total resistance}}$

$$= \frac{nE}{R + nr}$$

Cells in Parallel



Consider 'm' identical cells each of emf E and internal resistance r connected in parallel across an external resistance R as shown .

Emf of the battery b/w A and B = E

Total internal resistance of the battery $\frac{1}{r_T} = \frac{1}{r} + \frac{1}{r} + \cdots \frac{1}{r}$

$$= \frac{n}{r}$$

or $r_T = \frac{r}{n}$.

Total circuit resistance $= R + \frac{r}{m}$.

$$= \frac{mR + r}{m}$$.

Total current in the circuit, $I = \frac{\text{total emf}}{\text{total resistance}}$

$$= \frac{E}{(mR+r)/m}$$

$$= \frac{mE}{mR+r}$$

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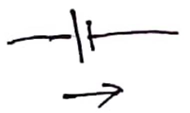
Along the direction of flow of current, v.d is -ve and vice versa.

For EMF,

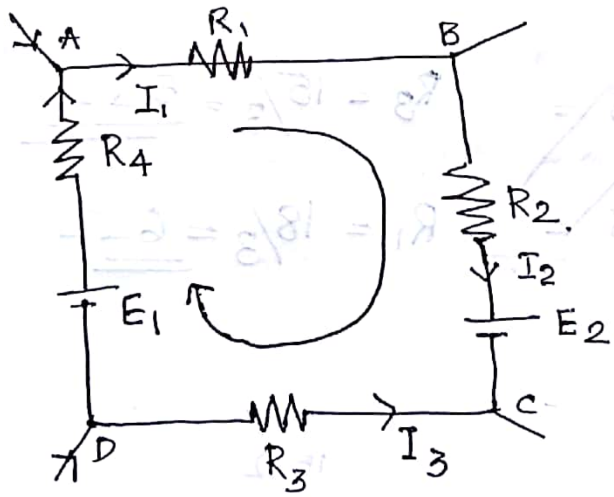
Rise in potential

$\Rightarrow +E$

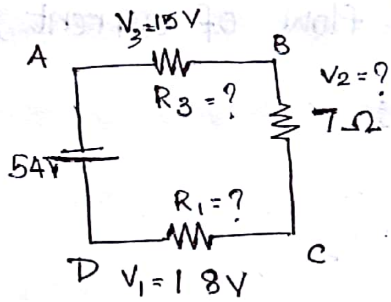
Fall in potential



$\Rightarrow -E$



$$E_1 - E_2 - I_1 - R_1 - I_2R_2 + I_3R_3 - I_4R_4 = 0$$



Using KVL, determine V_2, I, R_1 and R_3.

$$54 - 18 - V_2 - 15 = 0$$

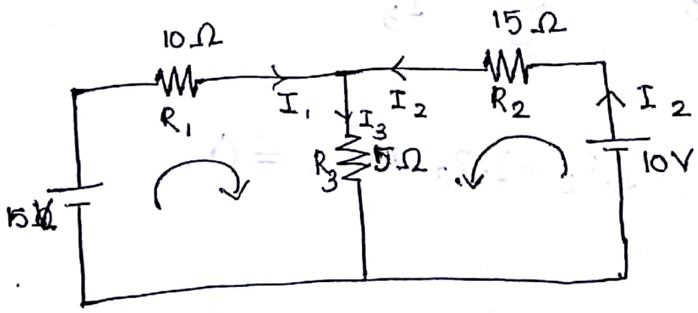
$$V_2 = 54 - 18 - 15$$

$$= \underline{\underline{21\,V}}$$

$$I = \frac{21}{7} = \underline{\underline{3A}}$$

$\cancel{R_1 = 18 \times 3 =}$ $\quad R_3 = 15/3 = \underline{\underline{5\,\Omega}}$

$\cancel{R_3 = 15 \times 3 =}$ $\quad R_1 = 18/3 = \underline{\underline{6\,\Omega}}$



Find currents in R_1, R_2 and R_3 using KVL.

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$15 - I_1R_1 - I_3R_3 = 0$.

$10 - I_2R_2 - I_3R_3 = 0$.

$15 - 10I_1 - 5I_3 = 0 \Rightarrow 3 - 2I_1 - I_3 = 0$.

$10 - 15I_2 - 5I_3 = 0 \Rightarrow 2 - 3I_2 - I_3 = 0$.

$2I_1 + I_3 = 3$.

$3I_2 - I_3 = 2$

$I_1 = 0.909A$

$I_3 =$

$I_2 = \frac{13}{11}$

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Network Analysis.

→ Network is a combination of two or more elements.

→ ~~A~~ network having atleast one closed path is called a circuit.

→ Node or Junction is the point in a circuit where two or more elements are joined.

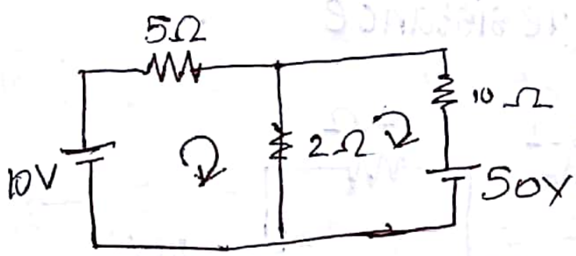
→ Branch is a simple element which has node at each ends.

→ Loop is a closed path formed by interconnecting a number of branches with no nodes traversed more than once.

→ Mesh is a loop which does not contain any other loops in it.

Network Analysis consists of finding the response or output when the stimulus or input and network ~~com~~ system components are given.

Mesh Analysis (Maxwell's Loop/Circulation Current Method)



This method employs the method of loop/mesh currents instead of branch currents. The currents in different meshes are assigned a continuous path so that they do not split at the junction to branch current.

Direction of any loop current is arbitrary and maybe chosen independently of the direction of other currents. But it is easier to take all loop current ~~loop~~ in one direction.

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

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

$$10 - 5I_1 - 2I_1 - 2I_2 = 10 - 7I_1 - 2I_2 = 0$$

$$-50 - 12I_2 - 2I_1 = 0$$

$I_2 = -4.625$

$.25$
-4.125

$-7I_1 - 2I_2 = 10$

$-2I_1 - 12I_2 = 50$

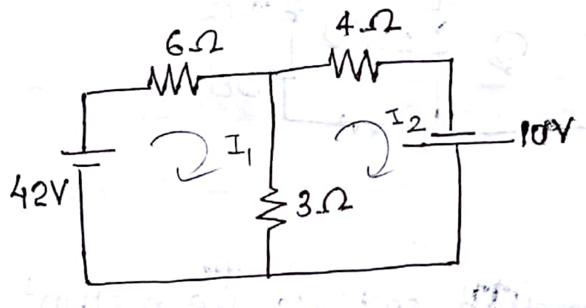
$-14I_1 - 4I_2 = -20$

$-14I_1 - 84I_2 = 350$

$80I_2 = 370$

$I_2 =$

Write the Mesh equations and find the current in the 4Ω resistance.



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

$$42 - 6I_1 - 3I_1 - 3I_2 = 0$$

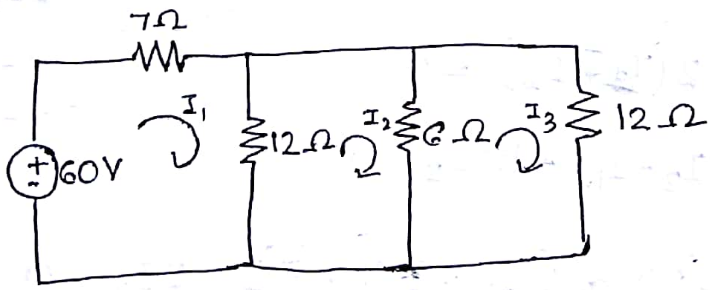
$$42 - 9I_1 - 3I_2 = 0$$

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

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

$$10 - 7I_2 - 3I_1 = 0$$

$I_1 = 4A$ $\quad$ $I_2 = 6A$



I) $60 - 7I_1 - 12(I_1 - I_2) = 0$

$$60 - 7I_1 - 12I_1 + 12I_2 = 0$$

$-3I_1 - 7I_2 = -10$

$-9I_1 - 3I_2 = -42$

$$-19I_1 + 12I_2 = -60$$

II) $-12(I_2 - I_1) - 6(I_2 - I_3) = 0$

$$-12I_2 + 12I_1 - 6I_2 + 6I_3 = 0$$

$$+12I_1 - 18I_2 + 6I_3 = 0$$

III) $-6(I_3 - I_2) - 12(I_3) = 0$

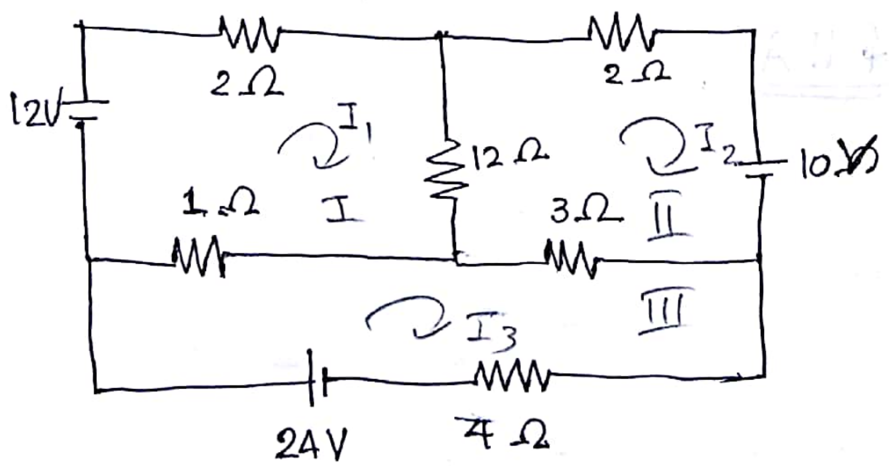
$$-6I_3 + 6I_2 - 12I_3 = 0$$

$I_1 = \underline{6A}$

$I_2 = \underline{4.5A}$

$I_3 = \underline{1.5A}$

Q



Write mesh eqn and find current.

I. $12 = 2I_1 + 12(I_1 - I_2) + (I_1 - I_3)$.

$12 = 2I_1 + 12I_1 - 12I_2 + I_1 - I_3$

$12 = 15I_1 - 12I_2 - I_3$

II. $2I_2 + 3(I_2 - I_3) + 12(I_2 - I_1) = -10$.

$2I_2 + 3I_2 - 3I_3 + 12I_2 - 12I_1 = -10$

$-17I_1 - 83I_2 - 3I_3 = 10$

III. $3(I_3 - I_2) + 4I_3 + (I_3 - I_1) = 24$

$3I_3 - 3I_2 + 4I_3 + I_3 - I_1 = 24$.

$-I_1 - 8I_3 - 3I_2 = 24$.

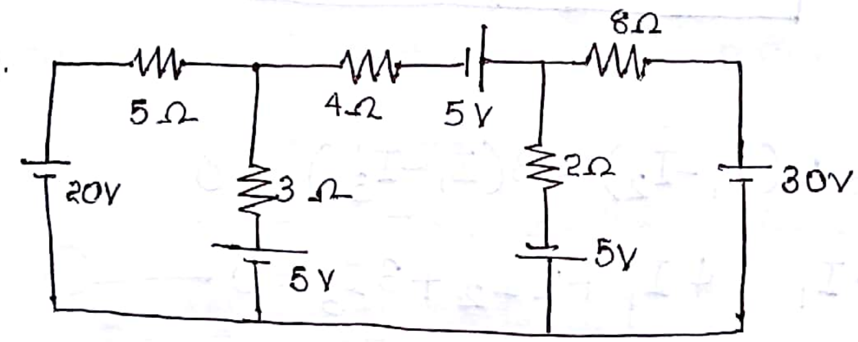
$I_1 = \underline{\underline{2.71A}}$

$I_2 = \underline{\underline{2.05A}}$

$I_3 = \underline{\underline{4.11A}}$.

Cramer's Rule .

$I_1 = \frac{\Delta_1}{\Delta}$ $\quad$ $I_2 = \frac{\Delta_2}{\Delta}$



I. $20 - 5I_1 - 3(I_1 - I_3) - 5 = 0$

$15 - 8I_1 + 3I_2 = 0 \longrightarrow (1)$

$5 - 3(I_2 - I_1) - 4I_2 + 5 - 2(I_2 - I_3) + 5 = 0$

$15 + 3I_1 - 9I_2 + 2I_3 = 0 \text{ —— } (2)$

$-5 - 2(I_3 - I_2) - 8I_3 - 30 = 0$

$-35 - 10I_3 + 2I_2 = 0 \text{ —— } (3)$

$I_1 = \underline{2.55\text{ A}}$

$I_2 = \underline{1.82\text{ A}}$

$I_3 = \underline{-3.13\text{A}}$

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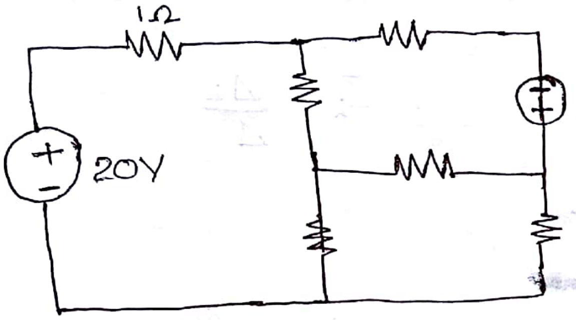
Find the VOLTAGE across 3Ω using mesh analysis



$$-6I_1 - 2(I_1 - I_2) - 3(I_1 - I_3) = 0$$

$$20I_1 - 4I_1 + 2I_2 + 3I_3 = 0 \quad \text{—— (1)}$$

$$10 - 2(I_2 - I_3) - 2(I_2 - I_1) - 2I_2 = 0 \quad \text{—— (2)}$$

$$10 + 2I_1 - 6I_2 + 2I_3 = 0 \quad \text{—— (2)}$$

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

$$-3I_1 + 2I_2 - 10I_3 = 0 \quad \text{—— (3)}$$

$I_1 = 5.11\ A$.

$I_2 = 1\ A$

$I_3 = 2.8\ A$

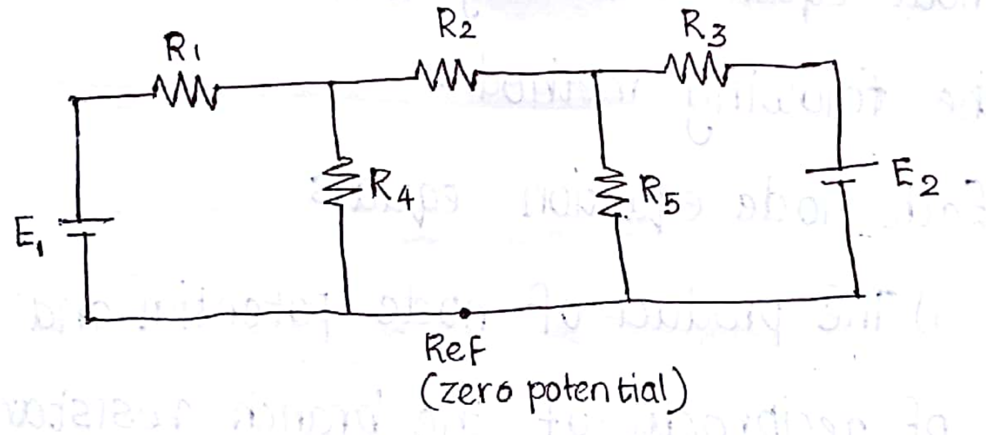
Nodal Analysis

→ Based on KCL

→ Parallel circuit

→ Common point/Reference.

→ Meeting point of three or more branches is considered a node.



Node 1

$I_1 = I_4 + I_2$

$$\frac{E_1 - V_1}{R_1} = \frac{V_1}{R_4} + \frac{V_1 - V_2}{R_2}$$

Node 2

$I_5 = I_2 + I_3$

$$\frac{V_2}{R_5} = \frac{V_1 - V_2}{R_2} + \frac{E_2 - V_2}{R_3}$$

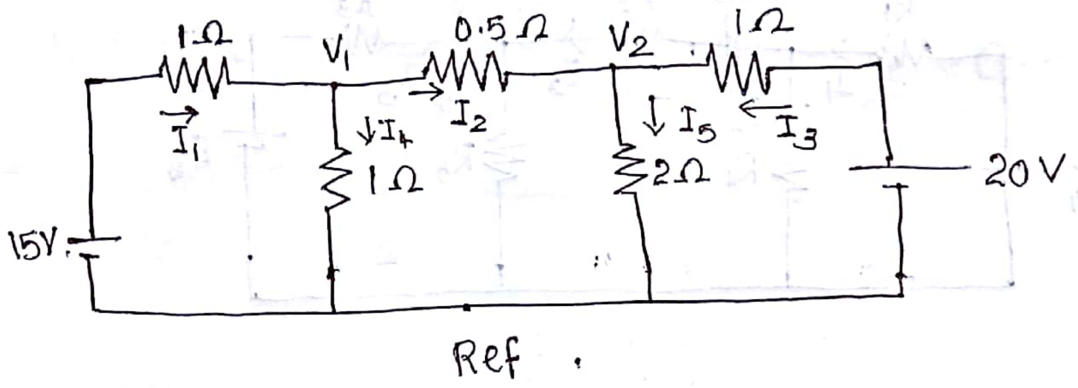
① $V_1\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_4}\right)-\frac{V_2}{R_2}-\frac{E_1}{R_1}=0$ —— (1)

② $V_2\left(\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_5}\right)-\frac{V_1}{R_2}-\frac{E_2}{R_3}=0$ —— (2)

By observing the equations, it is found that node equation for any node can be obtained by the following method.

Each node equation equals

i) The product of node potential and the sum of reciprocal of the branch resistances connected to the node | minus the ratio of the adjacent potential and the interconnecting resistance | minus/plus the ratio of adjacent battery voltage to the interconnecting resistance | all set to zero.



Node 1

$I_1 = I_2 + I_4$

Node 2

$I_5 = I_2 + I_3$

$$V_1\left(\frac{1}{1}+\frac{1}{.5}+\frac{1}{1}\right)-\frac{V_2}{.5}-\frac{15}{1}=0$$

$$V_1(4)-\frac{V_2}{.5}-15=0$$

$$4V_1-2V_2=15$$

$$V_2\left(\frac{1}{.5}+\frac{1}{1}+\frac{1}{2}\right)-\frac{V_1}{.5}-\frac{20}{1}=0$$

$$V_2(3.5)-2V_1-20=0$$

$$3.5V_2-2V_1=20$$

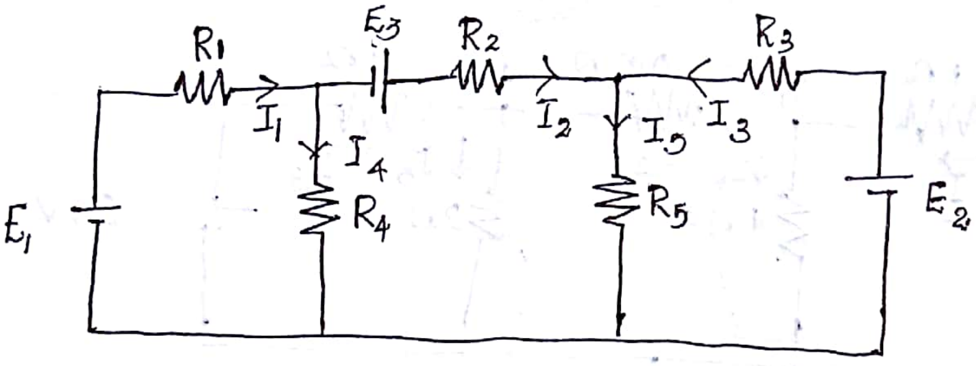
$V_1 = \underline{9.25\,V}$

$V_2 = \underline{11\,V}$

$I_1 = 5.75A$ $\quad I_2 = 3.5A$ $\quad I_3 = 9A$ $\quad I_4 = 9.25A$

$I_5 = 5.5A$

Q.



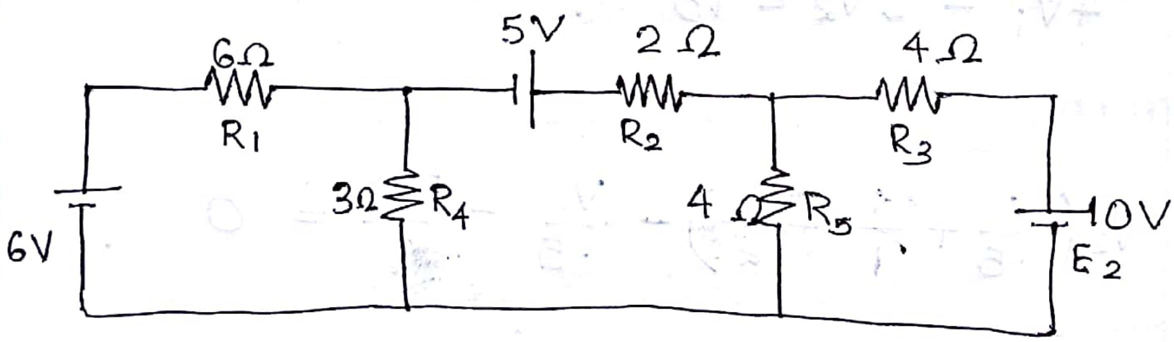
Node 1

$$V_1\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_4}\right)-\frac{V_2}{R_2}-\frac{E_1}{R_1}+\frac{E_3}{R_2}$$

Node 2 .

$$V_2\left(\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_5}\right)-\frac{V_1}{R_2}-\frac{E_1}{R_3}-\frac{E_3}{R_2}$$

Q



Apply nodal analysis and find out the current

$$V_1\left(\frac{1}{6}+\frac{1}{2}+\frac{1}{3}\right)-\frac{V_2}{2}-\frac{6}{6}+\frac{5}{2}=0$$

$$V_1-\frac{V_2}{2}-1+\frac{5}{2}=0$$

$$2V_1-V_2-2+5=0$$

$$2V_1-V_2+3=0$$

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$$V_2\left(\frac{1}{4}+\frac{1}{4}+\frac{1}{2}\right)-\frac{V_1}{2}-\frac{5}{2}-\frac{10}{4}=0$$

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

$$2V_2-V_1=10 \quad \text{——— (2)}$$

$$2V_1-V_2=-3 \quad \text{——— (1)}$$

$$4V_1-2V_2=6 \quad \text{——— (3)}$$

(2) + (3)

$$3V_1=+4$$

$$V_1=4/3=1.33V.$$

$$\underline{\underline{V_2=5.66V}}.$$

$$I_1=\frac{E_1-V_1}{R_1}=\underline{\underline{0.778A}}$$

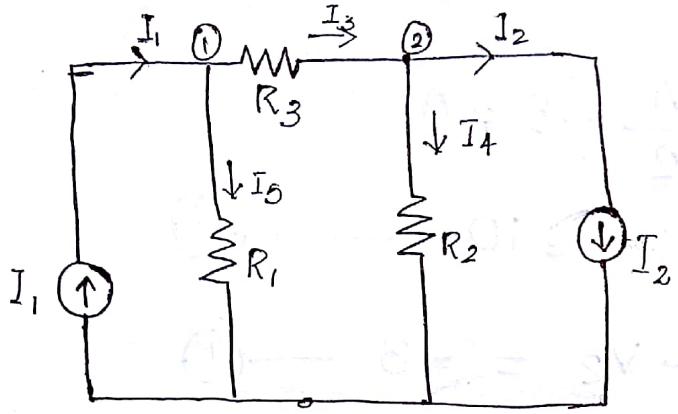
$$I_2=\frac{V_2-V_1}{R_2}=\frac{4.33}{2}=\underline{\underline{2.165A}}$$

$$I_3=\frac{10-5.66}{4}.=\underline{\underline{1.085}}$$

$$I_4=\frac{1.33}{3}=\underline{\underline{0.443A}}$$

$$I_5=\frac{5.66}{4}=\underline{\underline{1.415A}}.$$

Case III. Nodal Analysis with Current Sources



Node 1

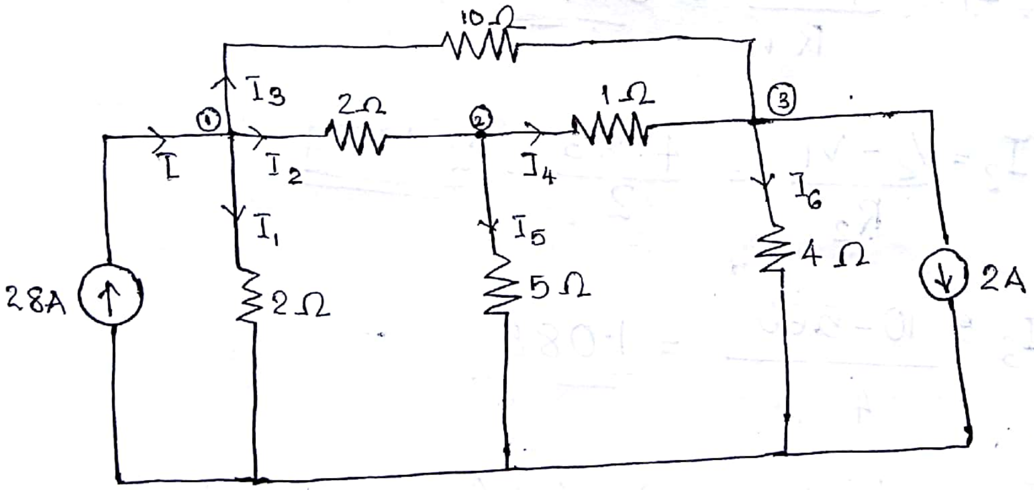
$I_1 = I_3 + I_5$

$$V_1\left(\frac{1}{R_1} + \frac{1}{R_3}\right) - \frac{V_2}{R_3} = I_1$$

Node 2

$I_3 = I_2 + I_4$

$$V_2\left(\frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{V_1}{R_3} = -I_2$$



Apply nodal analysis and find all currents.

Node I

$$V_1\left(\frac{1}{2}+\frac{1}{2}+\frac{1}{10}\right)-\frac{V_2}{2}-\frac{V_3}{1}=28$$

Node II

$$V_2\left(\frac{1}{5}+\frac{1}{2}+\frac{1}{1}\right)-\frac{V_1}{2}-V_3=0$$

Node III

$$V_3\left(\frac{1}{1}+\frac{1}{4}+\frac{1}{10}\right)-\frac{V_2}{1}-\frac{V_1}{2}=-2$$

$$\frac{11V_1}{10}-\frac{V_2}{2}-V_3=28$$

$$\frac{17V_2}{10}-\frac{V_1}{2}-V_3=0$$

$$\frac{27V_3}{20}-V_2-\frac{V_1}{10}=-2$$

$$11V_1-5V_2-V_3-280=0 \quad (1)$$

$$5V_1-17V_2+10V_3=0 \quad (2)$$

$$V_1+10V_2-13.5V_3-20-0 \quad (3)$$

$\cancel{V_1 = 10.73}$ $\quad V_1 = -36$

$\cancel{V_2 = -23.36}$ $\quad V_2 = -20$

$\cancel{V_3 = -45}$ $\quad V_3 = -16$

$\frac{7}{10}+\frac{10}{10}$

$\frac{7}{10}+\frac{5}{10}$

$\frac{5}{20}+\frac{2}{20}+\frac{20}{20}$

$I_1 = 36/2 = 18\ A$

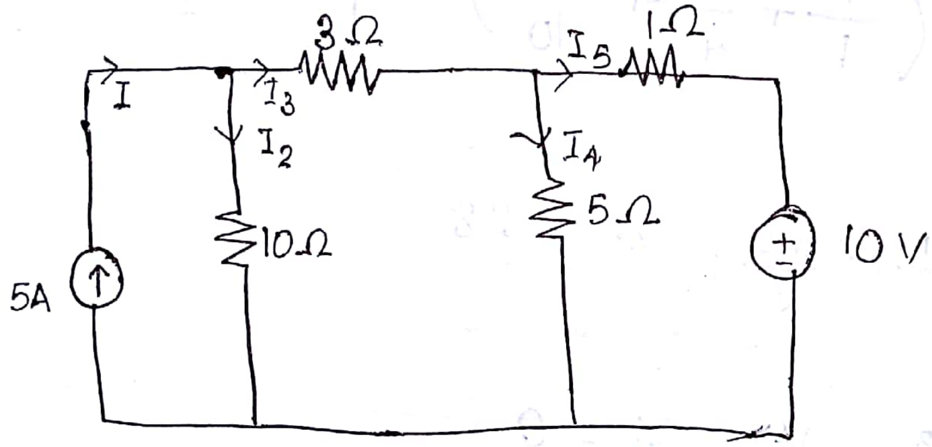
$I_2 = 8A$

$I_3 = 2A$

$I_4 = 4A$

$I_5 = 4A$

$I_6 = 4A$



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

$V_2\left(\frac{1}{3}+\frac{1}{5}+1\right) - \frac{V_1}{3} - 10 = 0$ —— (2)

$13V_1 - 10V_1 = 30I = 150$ —— (1)

$23V_2 - 5V_1 - 150 = 0$ —— (2)

$13V_1 - 10V_2 = 23V_2 - 5V_1$

$V_1 = 19.87$

$V_2 = 10.84$

$I_1 = \underline{5A}$

$$I_2 = \frac{19.87}{10} = \underline{1.987\,A}$$

$$I_3 = I - I_2 = 5 - 1987 = \underline{3.013\,A}$$

$$I_4 = \frac{10.84}{5} = \underline{2.168\,A}$$

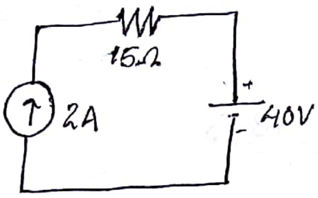
$$I_5 = I_3 - I_4 = 3013 - 2168 = \underline{0.845\,A}$$

Superposition Principle .

1) Linear and non linear networks .
2) Active and passive (R, L, C) elements .
3) Unilateral and Bilateral networks .
4) Lumped and Distributed Parameters

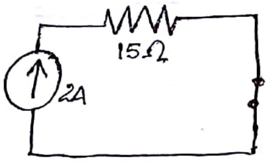
· In an active bilateral network containing more than one source of emf or current or both , the current which flows at any point or the voltage across any two points is the algebraic sum of all the currents or voltages which would be present at that point if each source where considered seperately and all the other sources replaced at that time by their internal resistances which is short circuit for ideal voltage sources and open circuit for ideal current sources .

Eg.



Apply SPP, find V_1.

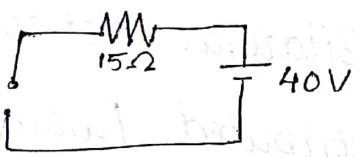
Case I . Current 2A alone.



$V_1' = IR = 2 \times 15$

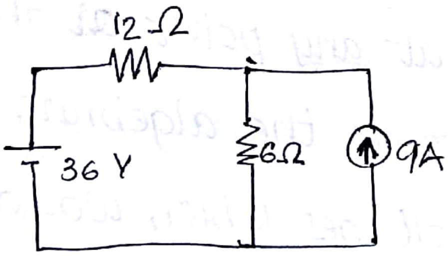
$= \underline{30V}$

Case II . Voltage 40V alone.



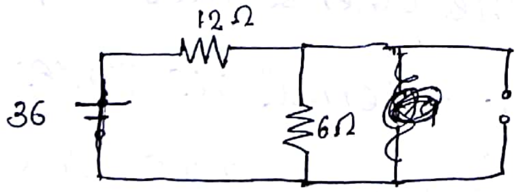
$V_1'' = \underline{0V}$

$V_1 = V_1' + V_1'' = 30 + 0 = \underline{30V}$



Apply SPP, find current through 6Ω res.

Case I . 36V alone.

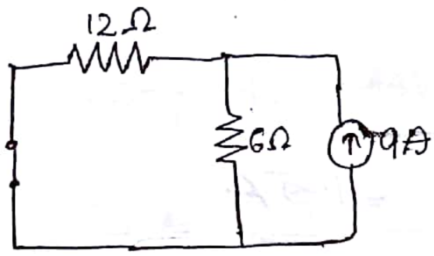


$V_1' = 36$

$R_{eq} = 12 + 6 = 18\Omega$

$I = \frac{36V}{18\Omega} = \underline{2A}$

Case II.



$R_{eq} = \frac{12 \times 6}{12+6} = \underline{4\Omega}$.

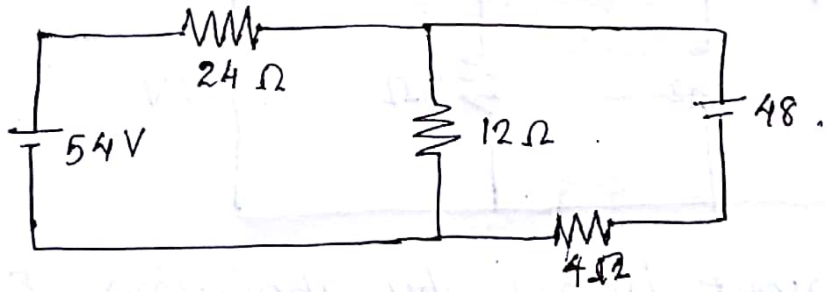
$V = IR = 9 \times 4$

$= \underline{36V}$

$I_1 = 36/12 = \underline{3A}$

$I_2 = \frac{36}{6} = \underline{6A}$

Current through $6\Omega = 2 + 6 = \underline{8A}$.

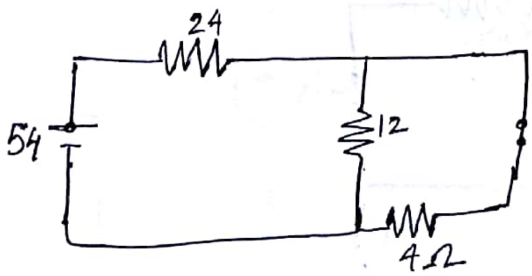


Apply SPP and find current in 4Ω.

$\frac{12 \times 4}{16} = \frac{48}{16}$

$= 3$

Case I. 54 V alone.



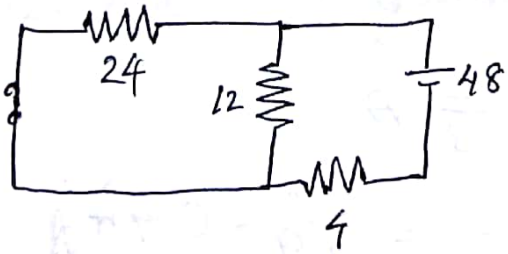
$R_{eq} = 27\Omega$.

$\frac{24 \times 12}{24+12}$

$I = 54/27 = \underline{2A}$

$V_{24\Omega} = 48V$ $V_{12\Omega} = 24V$ $V_{4\Omega} = 8V$

Case II 48 V alone



$R_{eq} = 12\Omega$

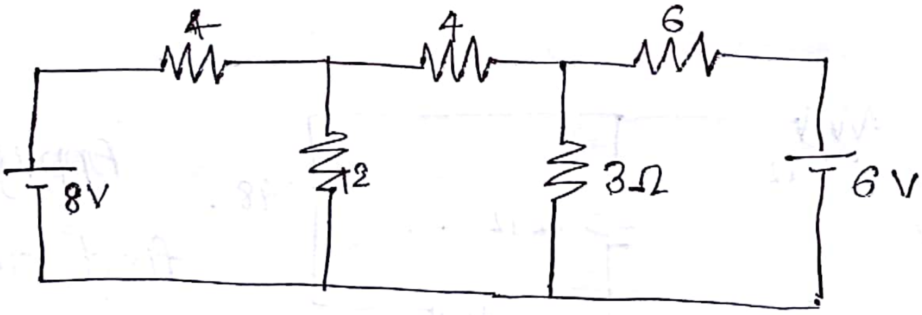
$I = 48/12 = \underline{4A}$

$$I_1 = I_T \cdot \frac{R_2}{R_1 + R_2}$$

$$= 2 \times \frac{12}{12+4} = \underline{1.5A}$$

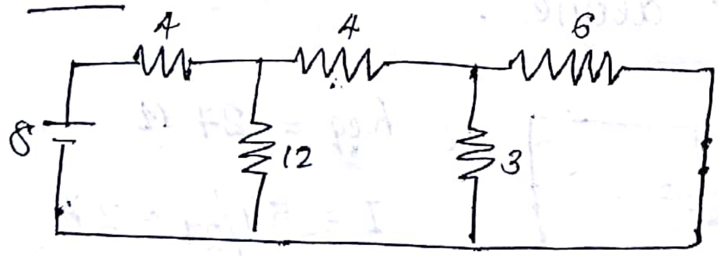
$\cancel{I_2 = (2 \times \frac{12}{16}}$ -

$$I_{4\Omega} = -4 + 1.5 = \underline{-2.5}$$



Find current in 3Ω by applying SPP.

Case I



$\frac{6\times3}{9} = 18$ 2.

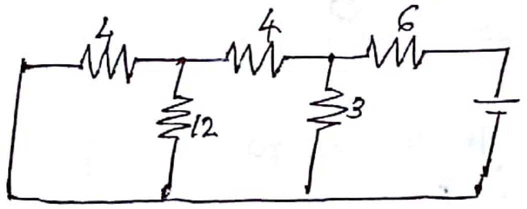
$R_{eq} = 8.$ $\quad I = 1A.$

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

$$= 1 \times \frac{12}{12+6} = \frac{2}{3} A$$

$$I_{6\Omega} = I_3 = \frac{2}{3} \times \frac{3}{6+3} = 4/9 = 0.44A$$

Case II 6V alone



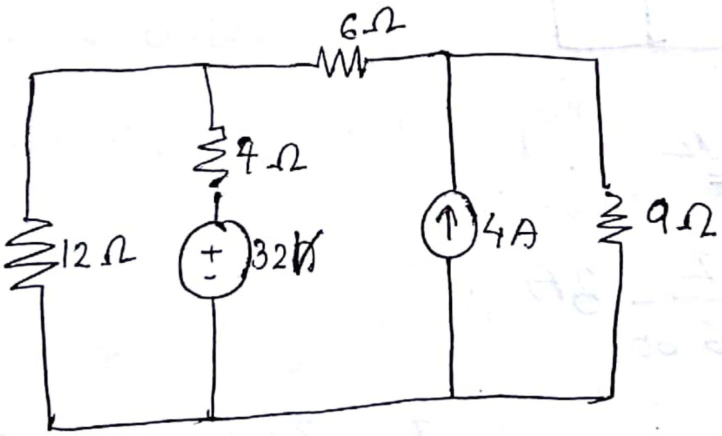
$R_{eq} = 8.1\,\Omega$

$$I_T = \frac{V}{R_{eq}} = \frac{6}{8.1} = 0.74\,A$$

$$I''_{3\Omega} = I_2 = I_T \cdot \frac{R_1}{R_1+R_2} = 0.74 \times \frac{7}{7+3} = \underline{0.518\,A}$$

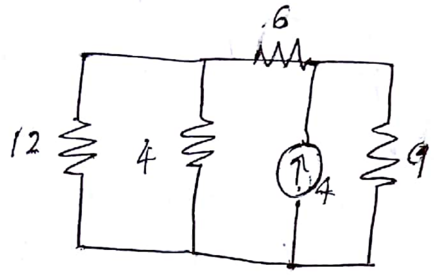
$$I_{3\Omega} = I'_{3\Omega} + I''_{3\Omega}$$

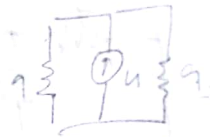
$$= 0.44A + 0.518 = \underline{0.96\,A}$$



Compute the power dissipated in the 9Ω resistance applying SPP.

Case II : 32V ~~only~~ shorted 4A only.

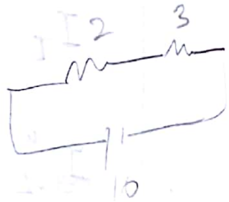




$\frac{4.9}{9+9}$

$Req = 4.5$

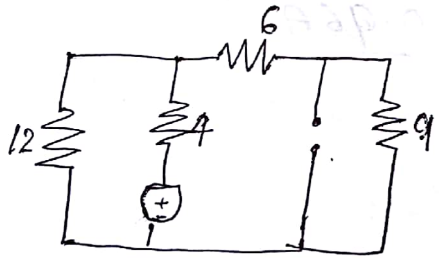
$V_1 = 10 \cdot \frac{2}{5}$



$V = 4.5 \times 4$

$= 18$

$P = \frac{V^2}{R} = \frac{18^2}{\cancel{4.5}9} = \frac{18 \times \cancel{18}^{2}}{\cancel{9}} = \underline{\underline{36\ W}}$.



$Req = \underline{\underline{10.66\,\Omega}}$.

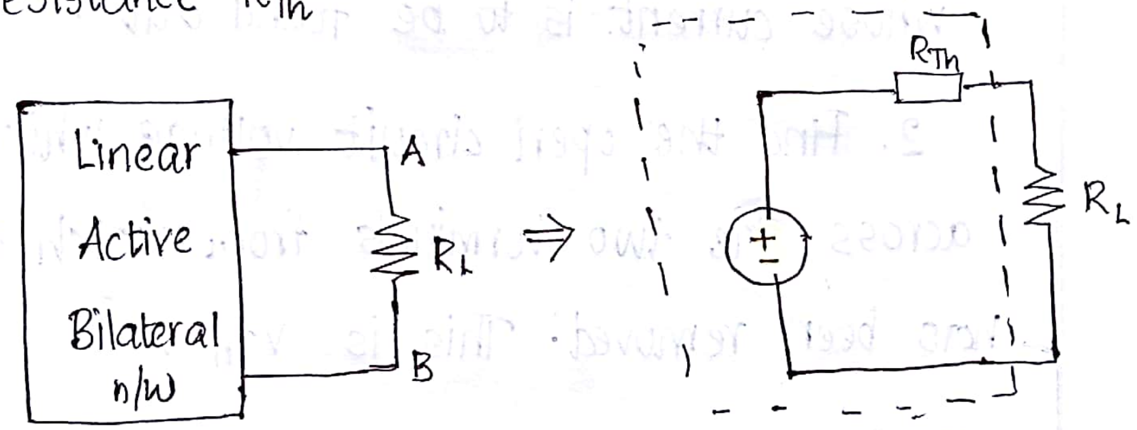
$I = \frac{V}{R} = \frac{32}{10.66} = 3A$.

$I_2 = \frac{32}{15} = 2.133$ $\qquad I_1 = \frac{3 \times 12}{27} = \frac{4}{3}\ A \downarrow$

$P = \cancel{32}\ 68.26$

Thevenins Theorems.

This theorem states that between any two output points of a linear active bilateral network the whole network can be replaced by a single voltage source V_{Th} in series with a single resistance R_{Th}



The voltage 'V_{Th}' is known as Thevenins voltage and it is the open circuit voltage measured across the two output points. The resistance 'R_{Th}' is the Thevenins resistance and it is the equivalent resistance of the network as seen from the output points when all sources are replaced by their internal resistances. The ideal voltage source are replaced by short circuit and ideal current sources are replaced by open circuit.

After Thevenizing a network, the load current

I_L is given by $\frac{V_{Th}}{R_{Th}+R_L}$

How to Thevenize a given circuit.

Step 1. Temporarily remove the load resistance R_L whose current is to be found out.

2. Find the open circuit voltage which appears across the two terminals from which the load has been removed. This is V_{Th}.

3. Compute the resistance of the whole network as looked into from the load terminals after all sources are replaced by their internal resistances. This is R_{Th}.

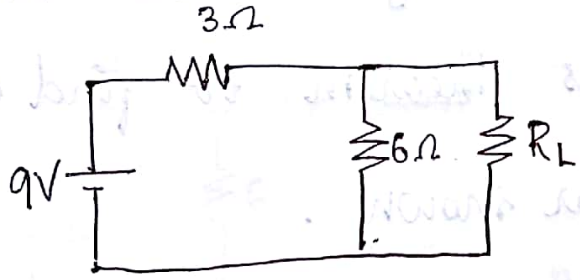
4. Draw the Thevenins Equivalent Circuit (TEC) of the network by connecting V_{Th} and R_{Th} in series.

5. Connect the load resistance R_L back to the terminal from where it was previously removed.

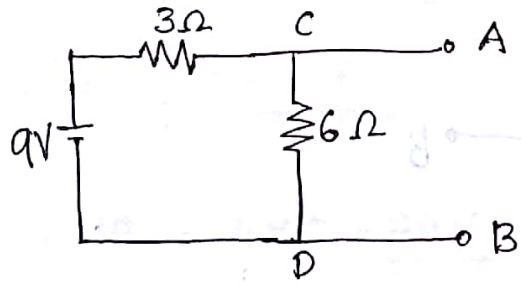
6. Finally calculate the current flowing through R_L using the equation

$$I_L = \frac{V_{Th}}{R_{Th} + R_L}.$$

Find TEC.

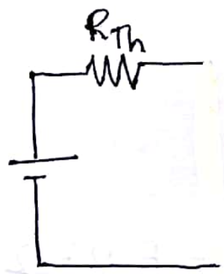


1.

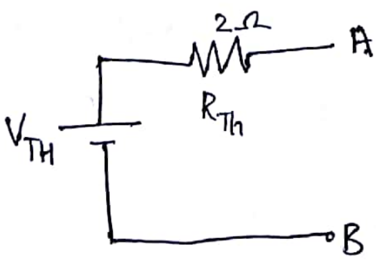


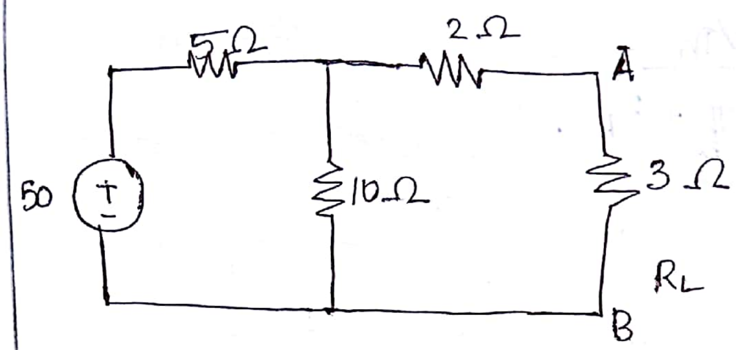
2. $V_{6\Omega} = I_{6\Omega} \times 6 = 1 \times 6 = 6\Omega$ $\left(I = \frac{V}{Req} = \frac{9}{9} = 1A\right)$

2.



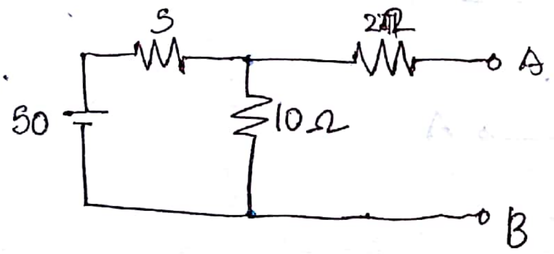
$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2} = \frac{6 \times 3}{6+3} = 18/9 = \underline{\underline{2\Omega}}.$$





Using Thevenins Theorem to find current in the 3Ω resistor shown.

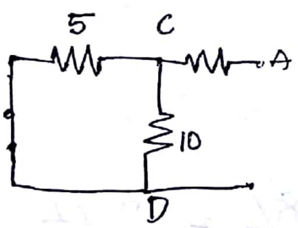
1.



V_{Th} =

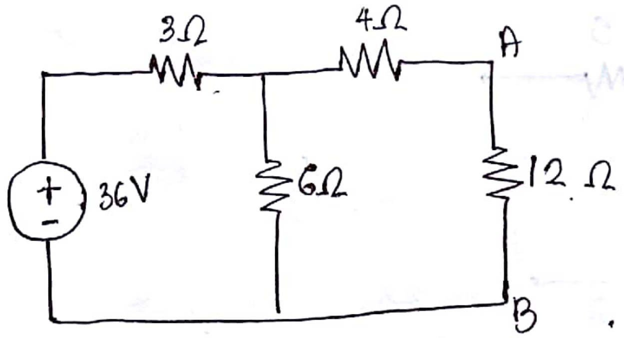
$I_{10} = \frac{50}{15} = \underline{\underline{3.33\,A}}$

$V_{Th} = IR = 10 \times 3.33 = \underline{\underline{33.3\,V}}$

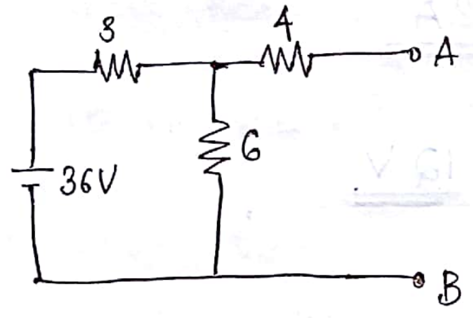


$R_{eq} = \frac{50}{15} + 2 = \underline{\underline{5.33\Omega}}$

$I_L = \frac{V_{TH}}{R_{Th} + R_L} = \frac{33.3}{8.33} = \underline{\underline{4A.}}$

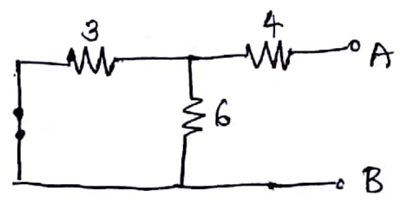


Find current in 12Ω resistor shown.



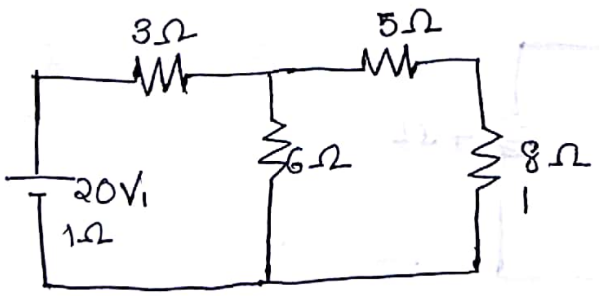
$$I_{6\Omega} = \frac{36}{9} = \underline{4\,A}$$

$$V_{Th} = IR = 4 \times 6 = \underline{24\,V}$$

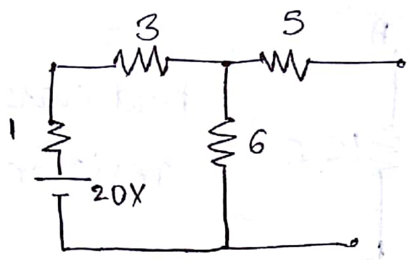


$$R_{Th} = \underline{6\Omega}$$

$$I_L = \frac{24}{6+12} = \underline{1.33\,A}$$

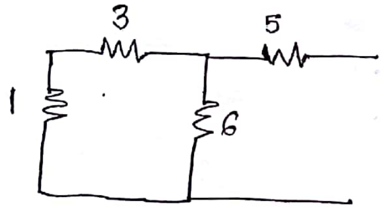


Find current in 8Ω resistor using Thevenins theorem.



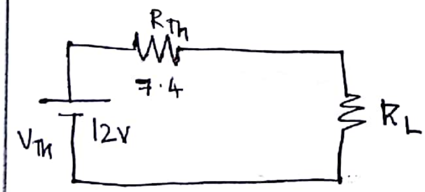
$I_{6\Omega} = \frac{20}{10} = \underline{\underline{2A}}$

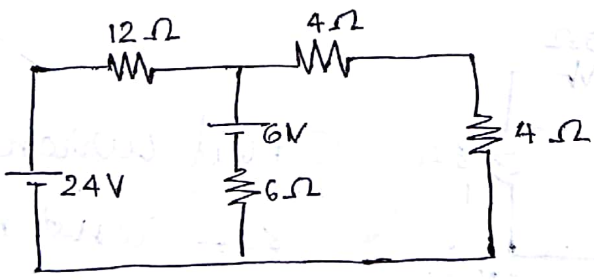
$V_{TH} = IR = 2 \times 6 = \underline{\underline{12\ V}}$



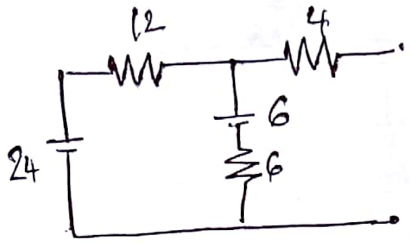
$R_{Th} = \underline{\underline{7.4\ \Omega}}$

$I_L = \frac{12}{7.4 + 8} = \underline{\underline{077A}}$





Find Thevenins Theorem to find current in the 4Ω resistor shown.



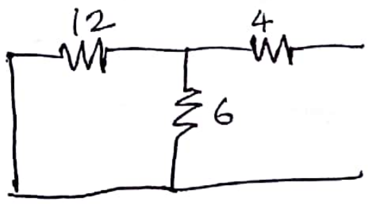
$$I = \frac{\text{Total emf}}{\text{total } R_{eq}} = \frac{24-6}{12+6} = \frac{18}{18} = \underline{\underline{1A}}$$

$$V_{6\Omega} = IR = 1 \times 6 = 6V$$

$$V_{Th} = V_{6\Omega} \pm 6V$$

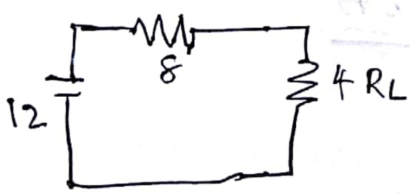
$$= 6 \pm 6V$$

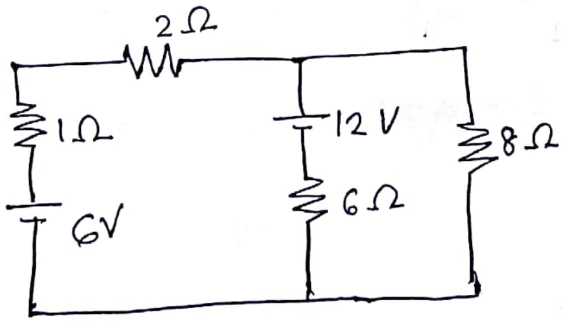
$$= 6+6 = \underline{\underline{12V}}$$



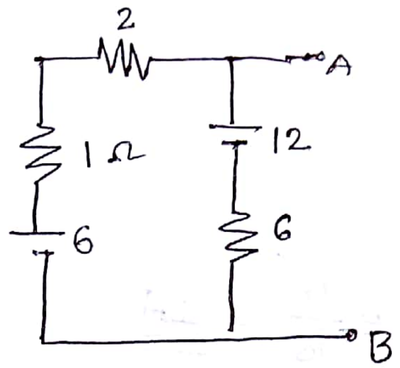
$$R_{Th} = \frac{12 \times 6}{18} + 4 = \underline{\underline{8\Omega}}$$

$$I_L = \frac{V_{Th}}{R_{Th}+R_L} = \frac{12}{8+4} = \underline{\underline{1A}}$$





Using Thevenins Theorem to find current in the 8Ω resistor. What will be the value of load current if connections of 6V battery is reversed?

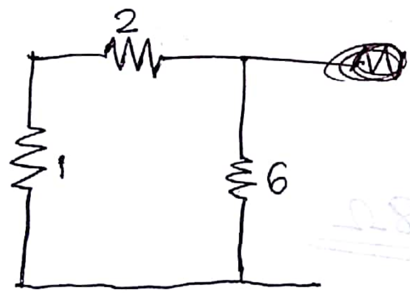


$$I = \frac{12-6}{9} = \frac{6}{9} = \frac{2}{3}\,A = \underline{\underline{0.66\,A}}$$

$$V_{6\Omega} = IR = 0.66 \times 6 = \underline{\underline{4\,V}}$$

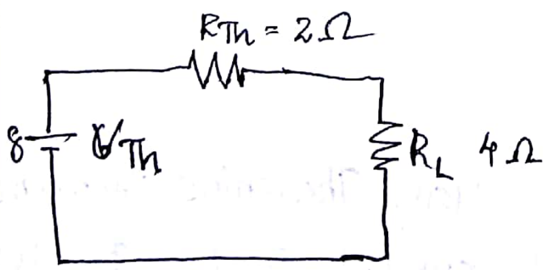
$$V_{Th} = V_{6\Omega} \pm 12$$

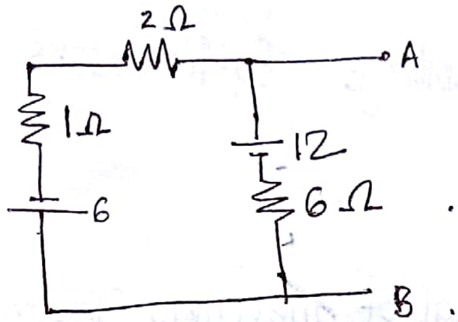
$$= 12 - 4 = \underline{\underline{8V}}$$



$$R_{Th} = 2\Omega.$$

$$I_L = \frac{V_{Th}}{R_{Th} + R_L} = \frac{8}{2+8} = \frac{8}{10} = \underline{\underline{0.8\,A}}$$





$$I = \frac{12+6}{9} = \frac{18}{9} = 2A$$

$$V_{6\Omega} = IR = 2 \times 6 = 12V$$

$$V_{Th} = V_{6\Omega} \pm 12$$

$$= 12 - 12 = 0$$

$$I_L = 0$$

Active : The circuit element which supply energy to the circuit are called active circuit element

Bilateral : Conduction of current in both directions in a circuit element with same magnitude is termed as bilateral circuit element. It offers same resistance to the current of either directions.

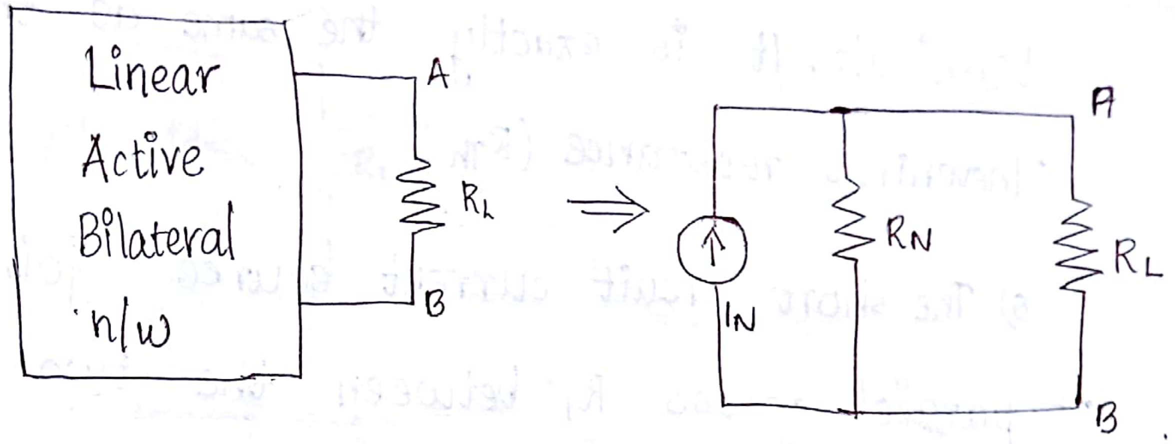
Lumped : When the voltage across the current through the element don't vary with dimensions of the element.

Linear : It is an electrical element with a linear relationship between current and voltage. Eg. Resistors.

Norton's Theorem (Dual of Thevenins Theorem)

It is the alternative or dual of Thevenins theorem. This theorem states that between any two output points of a linear active bilateral network, the whole network can be replaced by a single current source (I_N) in parallel with a single resistance R_N. ~~The~~

The current source is called Norton's Equivalent Current source and it is the current to a short circuit applied to the two output points. The resistance is called Norton's resistance R_N and it is the equivalent resistance of the network as seen from the output points after replacing ~~the~~ all sources by their internal resistances. The ideal current sources are replaced by an open circuit and ideal voltage sources are replaced by short circuit.



After Nortonizing the circuit, the load current is given by

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

How to Nortonize a given Circuit.

1) Remove the load resistance across the two terminals and put a short-circuit across them.

2) Compute the short-circuit current.

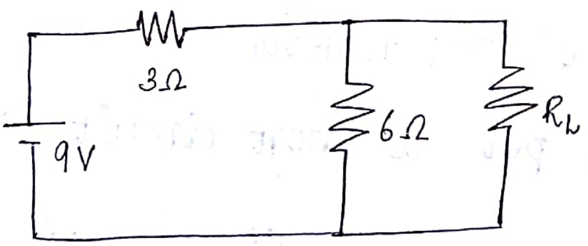
3) Remove all voltage sources but retain their internal resistances, it any. Similarly, remove all current sources and replace them by open-circuit. That is by infinite resistance.

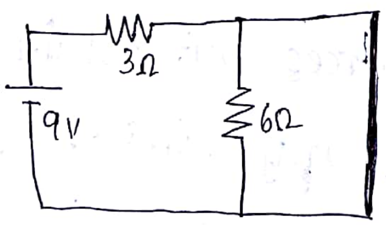
4) Next, find the resistance R_i (also called R_N) of the network as looked into from the given

terminals. It is exactly the same as the Thevenin's resistance (R_{Th}).

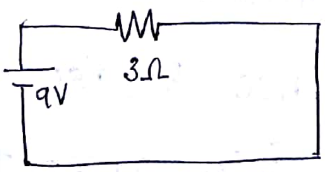
5) The short circuit current source joined in parallel across R_1 between the two terminals gives Norton's equivalent circuit.

1. Find Norton's equivalent circuit.

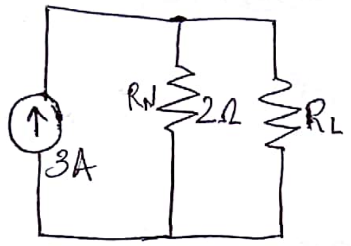




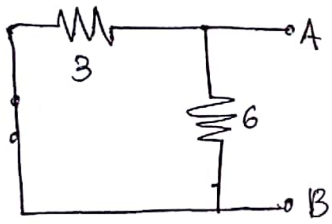
6Ω is bypassed



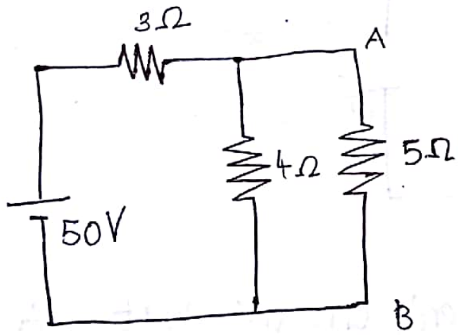
$$I_N = \frac{V}{R} = \frac{9}{3} = \underline{\underline{3\ A}}$$



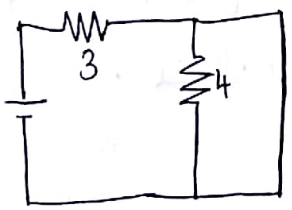
NEC

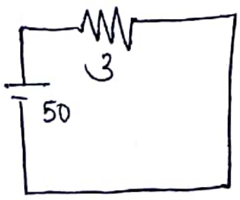


$$R_N = \frac{6\times3}{6+3} = \underline{\underline{2\Omega}}$$

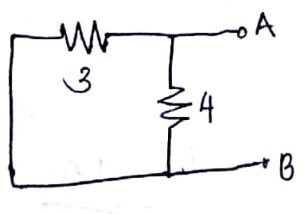


Apply Norton's Theorem. Find current in the 5Ω resistance.





$$I_N = \frac{50}{3} = \underline{\underline{16.66A}}$$



$$R_N = \frac{3\times4}{3+4} = \frac{12}{7} = \underline{\underline{1.71\Omega}}$$

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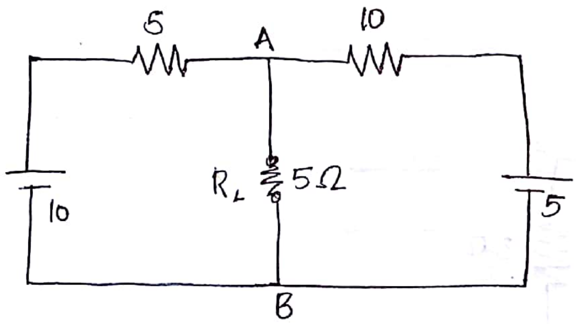
$I_L = I_N \cdot \dfrac{R_N}{R_L + R_N}$

$= 16.66 \times \dfrac{1.71}{(1.71+5)}$

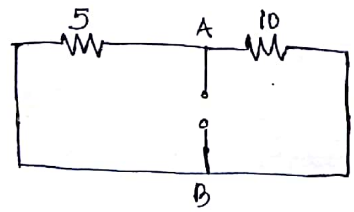
$= \underline{\underline{4.24\,A}}$

3.



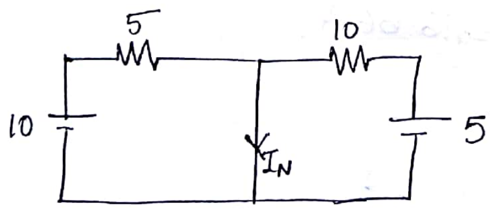
Obtain Norton's Equivalent circuit wrt A & B and hence determine I_L if $R_L = 5\Omega$ b/w A & B

1.



wrt A & B, 5Ω & 10Ω are in parallel.

$R_N = 50/15 = \underline{\underline{3.33\,\Omega}}$



$I_N = 10/5 + 5/10 = \underline{\underline{2.5\,A}}$

$I_L = \underline{\underline{1A}}$

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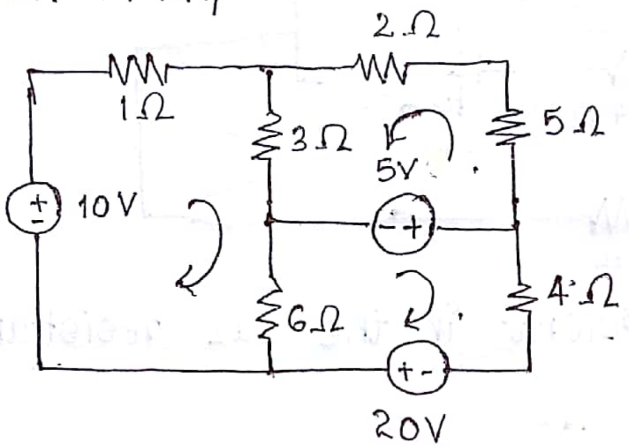
Mesh Analysis.



Write the MESH eqns & find current through all resistors.

I.

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

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

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

II.

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

$$5 - 10I_2 + 3I_1 = 0.$$

III.

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

$$25 - 10I_3 + 6I_1 = 0$$

$I_1 = 4.27A$

$I_3 = 5.06A$

$I_2 = 0.78A$

$I_{1\Omega} = 4.81A.$

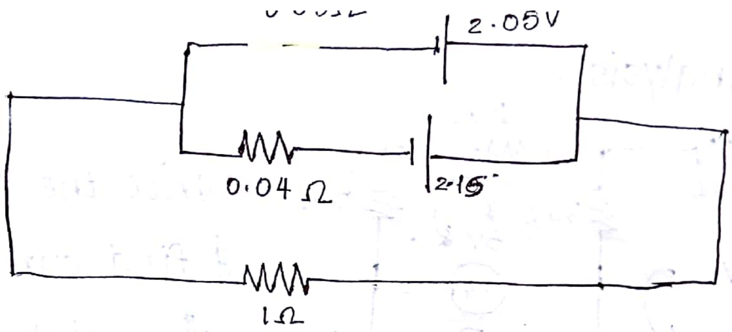
$I_{3\Omega} = 3.49A$

$I_{6\Omega} = 0.79A$

$I_{2\Omega} = 0.78A$

$I_{5\Omega} = 0.78A$

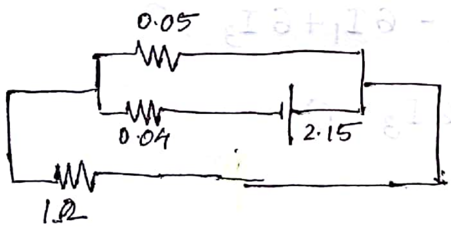
$I_{4\Omega} = 5.06A$



Find the current in the 1Ω resistance using SPP.

Case I

2.15V only

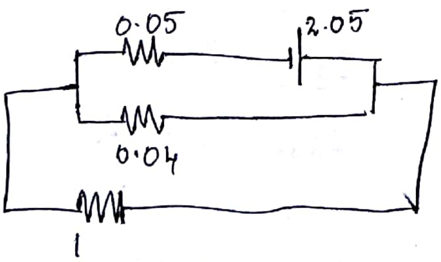


$$R_{eq} = \frac{0.05}{1.05} + 0.04 = 0.08\,\Omega$$

$$I_{0.04} = \frac{2.15}{0.08} = \cancel{26.8A} \quad 24.53A$$

Case II

2.05V only



$$R_{eq} = \frac{0.04}{1.04} + 0.05 = 0.08\,\Omega.$$

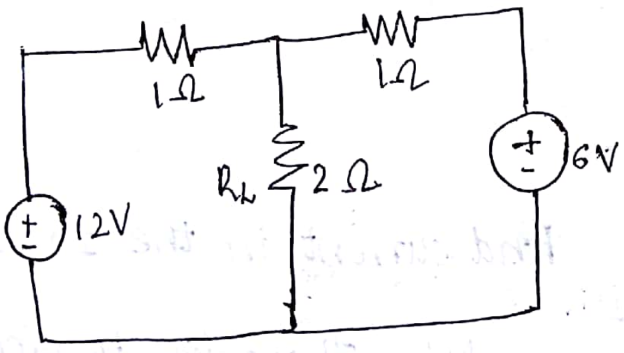
$$I_{0.05} = \frac{2.05}{0.08} = \overset{23.17}{25.6\,A}.$$

$$I'_{1\Omega} = \frac{24.53 \times 0.05}{1.05} = 1.16A.$$

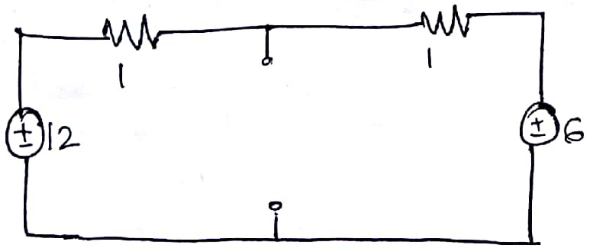
$$I''_{1\Omega} = \frac{25.6 \times 0.04}{1.04} = 0.89A$$

$$I = I_1' + I_1'' = \cancel{1.2A}\ \cancel{0.98A}\ 1.16 + 0.89$$

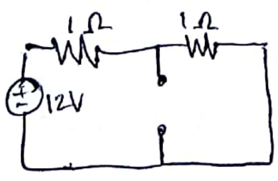
$$= \cancel{2.18}\ 2.05A.$$



Find current in the 2Ω resistance applying Thevenins theorem



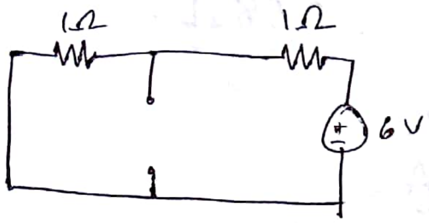
12V alone.



$R_{eq} = 2\Omega.$

$I = \frac{12}{2} = 6A.$

$V_{AB} = 6V$



$R_{eq} = 2\Omega$

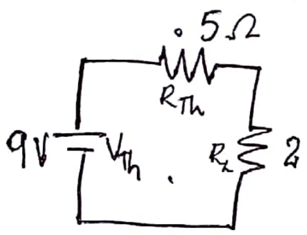
$I = \frac{6}{2} = \underline{\underline{3A}}$

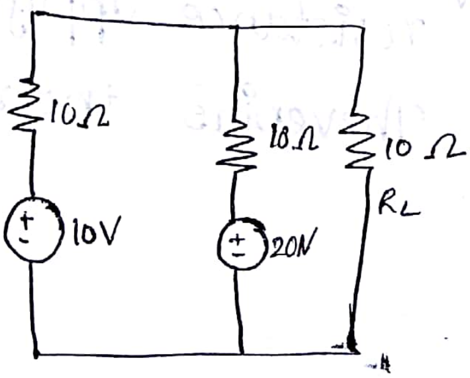
$V''_{AB} = \underline{\underline{3V}}$

$V_{Th} = 6 + 3 = 9$

$R_{Th} = 1/2 = .5$

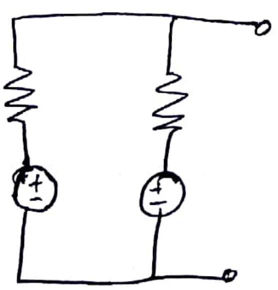
$I_L = \frac{V_{Th}}{R_{Th} + R_L} = \frac{9}{2.5} = \underline{\underline{3.6A}}$





Find current in the 10Ω res

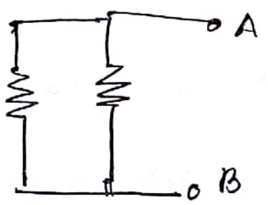
apply Thevenins theorem .



$$I = \frac{20-10}{10+10} = \underline{\underline{.5A}}$$

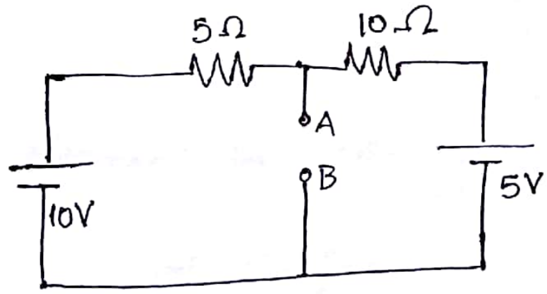
$$V_1 = 10 \times .5 = \underline{\underline{5V}}$$

$$V_{Th} = 10+5 = \underline{\underline{15V}}$$

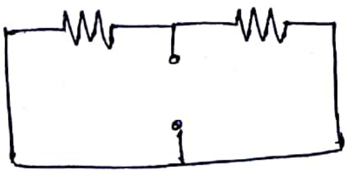


$$R = \frac{10 \times 10}{10+10} = \underline{5}$$

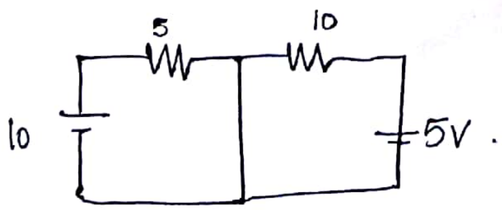
$$I_L = \frac{V_{Th}}{R_{Th}+R_L} = \frac{15}{10+5} = \frac{15}{15} = \underline{\underline{1 A}}$$



Apply Nortons theorem & Find current through a load resistance of 5Ω.



$$R_N = \frac{50}{15} = \frac{10}{3} = 3.33\Omega$$



$$I' = \frac{V}{R} = \frac{10}{5} = 2$$

$$I'' = \frac{V}{R} = \frac{5}{10} = .5$$

$$I_N = \underline{2.5 A}$$

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

$$= 2.5 \cdot \frac{10/3}{10/3 + 5} = \underline{\underline{1A}}$$

Electrostatics.

Branch of science which deals with the study of electrons at rest.

Electric field

It is the region around a charge where its effect is felt.

Electric Flux (Ψ)

It is the total lines of force

Electric Flux Density (D)

Number of lines of force passing normally

$$D = \frac{\Psi}{A} = \frac{Q}{A}$$

Electric Field Intensity (E)

Force experienced by a positive unit charge when placed in the electric field

$$E = \frac{kQ}{r^2} \text{ or } \frac{F}{Q}.$$

$$E = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q}{r^2} = \frac{1}{\varepsilon_0\varepsilon_r}\frac{q}{4\pi r^2} = \frac{D}{\varepsilon_0\varepsilon_r}$$

Electric Potential (V).

Work done in bringing a unit positive charge from infinity to that point.

Potential gradient = $\frac{V}{d} = E$.

$$E = \frac{F}{Q} = \frac{kQ}{r^2} = \frac{V}{d}.$$

Coulomb's Law.

I. Like charges repel and unlike charges attract each o

II. The force of interaction between two charges at rest is directly proportional to the product of magnitude of charges and inversely proportional t the square of distance between them.

$$F \propto \frac{q_1 q_2}{r^2}$$

$$F = k\frac{q_1 q_2}{r^2}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$ $\varepsilon_0 \rightarrow$ permittivity of free space

Capacitor

It is a device used to store electric charge.

Symbol - $\dashv\vdash$

$$Q \propto V$$

$$Q = CV$$

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

Current in a capacitor.

$$i = \frac{dq}{dt} = \frac{d}{dt} CV = C\frac{dV}{dt}$$

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

$$V(t) - V(0) = \frac{1}{C}\int i\,dt + V(0)$$

$$P = VI = V \cdot C\frac{dV}{dt}$$

$$W = \int P\,dt = \int VC\frac{dV}{dt} \cdot dt$$

$$= C\int V\,dV = \frac{CV^2}{2}$$

Parallel Plate Capacitor.

$$D = \varepsilon_0 \varepsilon_r E$$

$$\frac{Q}{A} = \varepsilon_0 \varepsilon_r \frac{V}{d}$$

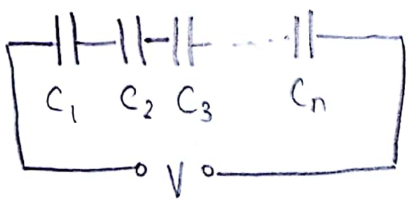
$$\frac{Q}{V} = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

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

If plates are not uniform

$$C = \frac{\varepsilon_0 A}{\left(\frac{d_1}{\varepsilon_{r_1}} + \frac{d_2}{\varepsilon_{r_2}} + \frac{d_3}{\varepsilon_{r_3}}\right)}$$

Capacitors in Series.

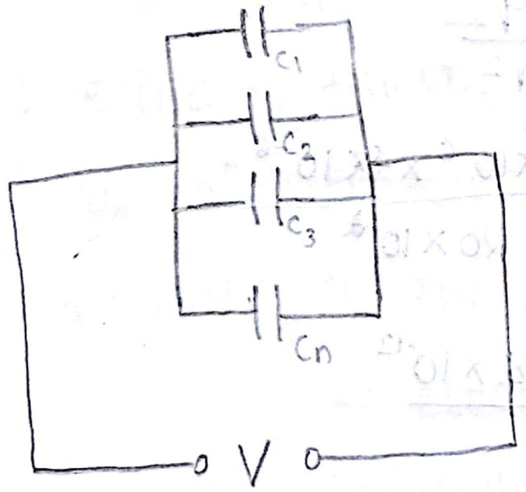


$V = V_1 + V_2 + V_3 + \cdots V_n$ $\quad V = Q/C$.

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} + \cdots \frac{Q}{C_n}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$$

Capacitors in Parallel.



Q different

V same

$Q = Q_1 + Q_2 + \cdots Q_n$.

$C_{eq}V = C_1V + C_2V + \cdots C_nV$

$C_{eq} = C_1 + C_2 + \cdots C_n$

Derive the equation for energy stored in a capacitor

State and explain Coulomb's law.

Calculate the force experienced by the point charge of $2\mu C$ due to a point charge $-4\mu C$ in free space. Distance is 20cm.

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2\times10^{-6}\times4\times10^{-6}}{20\times10^{-2}}$$

$$= \frac{9\times10^{9}\times8\times10^{-12}}{\cdot2}$$

$$= -1.8N$$

Two spheres with equal but opposite charge experience a force of $20\times10^{5}N$. They are placed 4cm apart in a medium of relative permittivity 2. Determine the charge on each sphere.

$$F = \frac{1}{\varepsilon_0\varepsilon_r 4\pi}\frac{q^2}{r^2}$$

$$20\times10^{5} = \frac{\cancel{4}}{4\times\cancel{2}\times4}\ \frac{9\times10^{9}\times q^2}{\cdot04\times2}$$

$$q^2 = \frac{20\times10^5 \times .0016\times 2}{9\times10^9}$$

$$q = 8.4\times10^{-4}C$$

A pd of 1000V is applied across the plates of a parallel plate capacitor. The plates are seperated by a dielectric of thickness 2mm and relative permittivity of 5.5. Area of each plate is 350 sqcm. Calculate (1) the capacitance (C)

(2) electric field intensity (E)

(3) electric flux density. (D)

(4) Energy stored in a capacitor.

(5) Energy density

$V = 1000V$

Thickness = 2mm.

$\varepsilon_r = 5.5$

$A = 350\ cm^2$

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \qquad E = \frac{V}{d} \qquad D = \varepsilon_0 \varepsilon_r E \qquad W = \frac{1}{2}CV^2$$

w (Energy density) $= \frac{W}{A \times d}$

i) $C = \frac{8.85 \times 10^{-12} \times 5.5 \times 350 \times 10^{-4}}{2 \times 10^{-3}}$

$= 8518.12 \times 10^{-13} = 8.518 \times 10^{-10} F$

$= 0.8518 nF$

ii) $E = \frac{V}{d}$

$= \frac{1000}{2 \times 10^{-3}} = 5 \times 10^{5} V/m$

iii) $D = \varepsilon_0 \varepsilon_r E$

$= 8.85 \times 10^{-12} \times 5.5 \times 5 \times 10^{5}$

$= 243.37 \times 10^{-7} C/m^2$

iv) $W = \frac{1}{2} C V^2$

$= \frac{1}{2} \times 0.8518 \times 1000^2 \times 10^{-9}$

$= 0.426 \times 10^{-3} J$

v) $w = \frac{W}{A \times d} = \frac{0.426 \times \cancel{10^{-3}}}{350 \times 10^{-4} \times 2 \times \cancel{10^{-3}}}$

parallel

$= 6.085\ J/m^3$

Three capacitors of capacitance 200 μF, 50 μF and 10 μF are connected in series to 60 V DC supply

Find

i) total capacitance.

ii) the charge on each capacitor.

iii) Voltage across each capacitor.

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

$\frac{1}{C_{eq}} = \frac{1}{200} + \frac{1}{50} + \frac{1}{10}$

$= \frac{25}{200}$.

9.
148

$C_{eq} = 200/25 = 8\mu F$.

ii) $Q = CV = 8 \times 60 = 480$

iii) $V_1 = \frac{Q}{C_1} = \frac{48\cancel{0}}{20\cancel{0}} = 2.4 V$. $V_2 = \frac{48\cancel{0}}{5\cancel{0}} = 9.6 V$.

$V_3 = \frac{480}{10} = 48 V$

2. i) $C_{net} = 200 + 50 + 10 = 260\,\mu F$

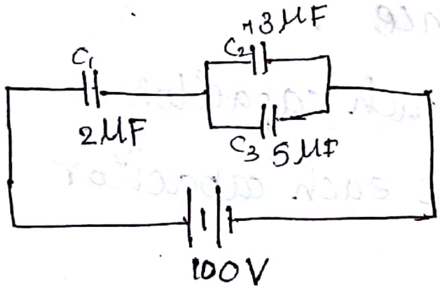
ii) $Q_1 = C_1 V = 200 \times 60 = 12000\,C$

$Q_2 = C_2 V = 50 \times 60 = 3000\,C$

$Q_3 = C_3 V = 10 \times 60 = 600\,C$

iii) 60V

3.



Find charges on each capacitor & the pd across each.

$C_1 = 2\,\mu F$ $\quad C_2 = -3\,\mu F$ $\quad C_3 = 5\,\mu F$ $\quad V = 100V$.

$C_{eq} = \underline{1.6\,\mu F}$ $\left(\frac{(5+3) \times 2}{(5+3)+2}\right)$

$Q = 1.6 \times 10^{-6} \times 10^2$

$= \underline{1.6 \times 10^{-4}\,C}$.

$Q_1 = \underline{1.6 \times 10^{-4}\,C}$ $\quad V_1 = \frac{1.6 \times 10^{-4}}{2 \times 10^{-6}} = 80V = \underline{80V}$

$V_2 = V_3 = 100 - 80 = \underline{20V}$.

$Q_2 = (3)(20) = \underline{60 \times 10^{-6}\,C}$ $\quad Q_3 = (5)(20) \times 10^{-6}\,C$

$= \underline{10^{-3}}$

Energy stored in a capacitor.

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

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

$$\int_0^T dv = \frac{1}{C}\int i dt + k$$

$$v(t) = \frac{1}{C}\int i dt + (v(0))$$

$$W = \int P dt$$

$$= \int v C \frac{dv}{dt} dt$$

$$= C\int v dv$$

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

$$= \underline{\underline{\frac{1}{2} C v^2}}$$

1) Magnetic field .

2) Magnetic flux (ϕ) Unit → weber (wb)

3) Magnetic Flux Density (B)

$B = \phi/A$. Unit → wb/m^2 ⇒ Tesla

4) Magnetic Field Intensity Unit → Ampere turns/m

$H = \frac{NI}{L}$ or $\frac{MMF}{l} = F/L$ magnetic motive force $= F$

NI = Ampere turns

5) Permeability - Measure of how good a medium is to conduct magnetic field lines .

$\mu_0 = 4\pi \times 10^{-7}$

$\mu_r = \frac{\mu}{\mu_0}$ $\mu = \mu_0 \mu_r$.

If a bar of magnetic ~~b~~ material placed in a uniform magnetic field of strength H resulting in a magnetic flux density B in the bar, then the absolute permeability of the material of bar is μ .

$$\boxed{\begin{aligned} B &= \mu H \\ &= \mu_0 \mu_r H \end{aligned}}$$

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Magnetic Circuit : The path through which magnetic flux flows .

$$\mu = BH$$
$$= \mu\left(\frac{NI}{l}\right)$$

$$\phi = B \cdot A$$
$$= \left(\frac{\mu NI}{l}\right) A$$

$$\phi = \frac{\mu_0 \mu_r NIA}{l}$$

$$= \frac{NI}{l/\mu_0 \mu_r A}$$

$$= \frac{F}{S}$$

$S \rightarrow$ Reluctance

$$S = \frac{l}{\mu A}$$

$\frac{1}{S} \rightarrow$ Permeability

Compare electric & magnetic circuit and electric circuit ,

Magnetic Circuit	Electric Circuit
1. Flux $(\phi) = \frac{MMF\ (F)}{Reluctance\ (S)}$	1. Current $(I) = \frac{Emf}{Resistance}$ (E/R)
2. MMF (F)	2. EMF (E)
3. Flux, ϕ (wb)	3. $I^2 R$
4. Flux density, B (wb/m²)	4. Current Intensity
5. Reluctance, $S = l/\mu A$	5. Resistance. $R = \frac{l}{}$
6. Permeance $= \frac{1}{Reluctance}$	6. Conductance
7. Reluctivity	7. Resistivity.
8. Permeability $= \frac{1}{Reluctivity}$	8. Conductivity $= \frac{1}{Resistivity}$

6 A ~~current~~ current flowing in a solenoid bound with 200 turns of wire. If the length of solenoid is 60 cm. Calculate the field strength of solenoid.

$H = \frac{NI}{l}$

$= \frac{1200 \times 6}{160 \times 10^{-2}}$

$= 4.5 \times 10 \times 10^{2} = \underline{\underline{4500\ AT/m}}$.

A mild steel ring has a mean circumference of 500mm and a uniform cross-sectional area of 300mm². Calculate the MMF required to produce a flux of 500 μwb. Assume

$\mu_r = 1200$.

$l = 500mm$.

$A = 300\ mm^2$

$F = \phi S$.

$\phi = 500\ \mu wb$.

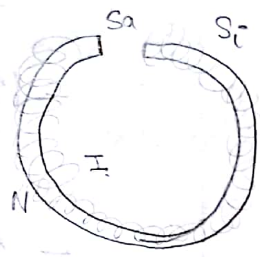
$S = l / \mu_0 \mu_r A = \frac{500 \times 10^{-3}}{4\pi \times 10^{-7} \times 1200 \times 300 \times 10^{-6}}$.

$= 0.0552 \times 10^{4}$

$= 552.9$

Composite Magnetic Circuit.

$$\phi = \frac{NI}{S_{eq}}.$$



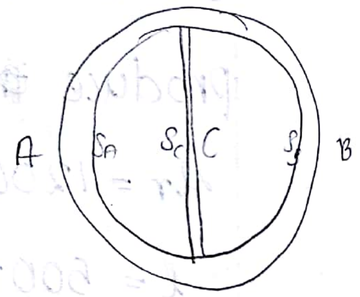
$$S_{eq} = S_i + S_a$$

$$\frac{l_i}{\mu_i A_i} + \frac{l_a}{\mu_a A_a}$$

$$= \frac{1}{\mu_0 A}\left(l_a + \frac{l_i}{\mu_r}\right)$$

$$S_{eq} = S_A + S_B \parallel S_C.$$

$$= S_A + \frac{S_B \cdot S_C}{S_B + S_C}$$



A circular iron ring of cross-sectional area $12\,cm^2$ and length 15cm in iron has an air gap of 1mm made in it. Find the ampere turns needed to produce a flux of $24.84\,\mu Wb$. μ_r of iron is 800. Neglect fringing and leakage.

$A = 12 cm^2$.

$l_i = 15 cm$.

$l_a = 1 mm$.

$\phi = 24.84 \mu wb = 24.84 \times 10^{-6} wb$

$\mu_r = 800$

$S_{eq} = S_i + S_a$

$$= \left(\frac{15}{800} + 0.1\right) \frac{1}{4\pi \times 10^{-7} \times 12} = \underline{\underline{7.87 \times 10^{5}}}$$

$NI = \underline{\underline{19.571 \text{ AT}}}$

An iron ring has a mean diameter of 25cm and cross sectional area 4 cm^2. It is wound with a coil of 1200 turns. An air gap of 1·5mm ~~thick~~ width is cut in the ring. Determine the current required in the coil to produce a flux of 0·48 mWb in the air gap if the relative permeability of iron under these condition is 800. Neglect leakage and fringing

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$d = 25\ cm$

$l_i = \pi d = 3.14 \times 25 - 0.015$

$= \underline{78.35}$

$$S_{eq} = \left(\frac{78.35}{800} + \frac{0.15}{1}\right) \frac{10^7}{4\pi \times 4} \times 10^2$$

$194.9151 \times 10^4 + 298.41 \times 10^4$

$= \underline{4935061.704}$ AT/m.

$I = \underline{1.97 A}$ $\qquad I = \frac{S \times \phi}{N}$

ElectroMagnetic Induction.

Michael Faraday in 1831.

Faraday's 1st law

When flux linked with coil changes, an emf is produced in it.

Faraday's IInd law

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

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A coil of 1200 turns gives rise to a magnetic flux of 3mwb when carrying a certain current. If the current is reversed in .2 s. What is the avg value of emf induced in the coil.

N=1200 ϕ = 3mwb = 3×10^{-3} wb t=0.2 s

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

$$= -1200\times\frac{-6\times10^{-3}}{.2}$$

$$= \underline{\underline{36V}}$$

Induced EMF

- Dynamically Induced (Blvsinθ)
- Statically Induced < Self / Mutually

A straight conductor of length 2m move at right angle to a uniform magnetic field of flux density 2wb/m² with a uniform velocity of 40m/s. Calculate the induced emf in the conductor. Also find the value of induced emf when the conductor moves at an angle of 45° with the direction of field.

$l = 2m$

$e = Blv$

$= 2 \times 2 \times 40$

$= 160V$

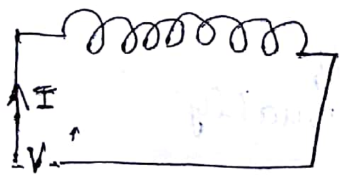
$e = Blv \sin\theta$

$= Blv \sin 45$

$= 160/\sqrt{2}$

$= 113.13V$

Self Inductance.



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

$$\frac{d\phi}{dt} \propto \frac{dI}{dt}.$$

$$e \propto \frac{dI}{dt}$$

$$e = L\frac{dI}{dt}.$$

$L \rightarrow$ Self inductance / Coefficient of self induction).

$L = e/\frac{di}{dt}$ = Henry (unit).

1 Henry is defined as the inductance of a coil when a voltage of 1V is used to vary the current in the circuit @ 1A/s.

$$N\frac{d\phi}{dt} = L\frac{dI}{dt}$$

$$N\phi = LI$$

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

A coil is wound with 220 turns and has R of 50Ω. If the existing voltage is 200V and the magnetic flux is 0.08 wb. Calculate the self inductance of the coil.

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

$$= \frac{220 \times 0.08 \times \cancel{200}^{50}}{200} = \underline{4.4\ H}$$

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The coil of 200 turns, carries a current of 4A. The magnetic flux linked with coil is 0.02 Wb. Calculate the inductance of the coil if the current is uniformly reversed in 0.02 seconds Calculate the self induced emf in the coil.

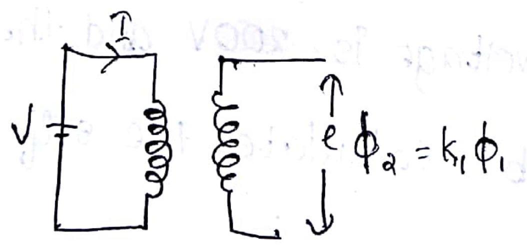
$$L = \frac{N\phi}{I} = \frac{200 \times 0.02}{4} = \underline{\underline{1H}}$$

$$E = -L\frac{dI}{dt}$$

$$= \frac{-1 \times 8}{0.02} = \underline{\underline{400V}}$$

Mutual Induction

The phenomenon of generation of emf in a coil due to neighbouring coil.



$e_1 = N_1\frac{d\phi}{dt}$ $\quad$ $e_2 = N_2\frac{d\phi}{dt}$

$e_2 \propto \frac{dI_1}{dt}$

$$e_2 = M \frac{dI_1}{dt}$$

$M \rightarrow$ Mutual Inductance

$$M = \frac{e_2}{dI_1/dt}$$ Unit $\rightarrow$ Henry

$$N_2 \frac{d\phi}{dt} = M \frac{dI_1}{dt}$$

$$N_2\phi = M I_1$$

$$M = \frac{N_2 \phi_2}{I_1} \quad \text{or} \quad \frac{N_1\phi_1}{I_2}$$

Assumption.
$\phi_1 = \phi_2 = \phi$

$$= \frac{N_2 k_2 \phi_1}{I_1} \quad \text{or} \quad \frac{N_1 k_2 \phi_2}{I_2}$$

$$M^2 = k_1 k_2 \left(\frac{N_1\phi_1}{I_1}\right)\left(\frac{N_2\phi_2}{I_2}\right)$$

$$M^2 = k^2 L_1 L_2$$

$$k = \frac{M}{\sqrt{L_1 L_2}}$$ $\rightarrow$ Coefficient of coupling.

Two identical coils of 400 turns each lie in parallel plane. If a current of 8A flowing in one coil produces a flux .04 wb. Find the mutual induction b/w 2 coils.

$$M = \frac{N.\phi}{I}$$

$$= \frac{400 \times .04}{8}$$

$$= 2 H$$

Two identical coils P and S having 500 turns each lie in parallel planes. Current in coil P changing @ 500A/s induces an emf of 12 V in coil S. Calculate the mutual inductance b/w two coils. If the self inductance of each coil is 50 mH. Calculate the flux produced in coil P per ampere of current and the coefficient of coupling b/w two coils.

$N = 500$ $\quad \frac{dI}{dt} = 500$

$e_2 = 12 V$

$M = \frac{N\phi}{I_1} = 50$

$$e_2 = M\frac{dI}{dt}$$

$$M = \frac{e_2}{dI/dt} = \frac{12}{500} = \underline{\underline{0.024H}}$$

$$\frac{\phi_1}{I_1} = \frac{L_1}{N_1} = \frac{50\times10^{-3}}{500} = \underline{\underline{10^{-4}}}\ wb/A$$

$$k = \frac{M}{\sqrt{L_1L_2}}$$

$$= \frac{0.024}{50\times10^{-3}}$$

$$= \underline{\underline{0.48}}$$, or 48% of flux.

$$\phi = \frac{F}{S} = \frac{NI}{S} \quad —① $$

$$\phi = \frac{LI}{N} \quad —② $$

① = ② : $\frac{LI}{N} = \frac{NI}{S}$

$$\boxed{L = \frac{N^2}{S}}$$

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HW Derive Energy stored in M.F.

$$B = \frac{\phi}{A} = \mu_0 \mu_r H$$

$$H = \frac{NI}{l}$$

$$\phi = BA = \frac{F}{S} = \frac{NI}{S}$$

$$S = \frac{l}{\mu_0 \mu_r A}$$

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

$$L = \frac{N\phi}{I} = \frac{N^2}{S}$$

$$e_2 = M\frac{dI_1}{dt}$$

$$M = \frac{N_2 \phi_2}{I_1} = \frac{N_1 \phi_1}{I_2}$$

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

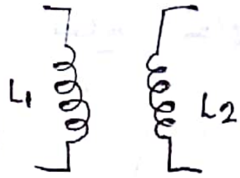
$$M = k\sqrt{L_1 L_2}$$

$$W_m = \frac{1}{2} L I^2$$

$$\boxed{\begin{aligned} L_{eq} &= L_1 + L_2 + 2M \\ &= L_1 + L_2 - 2M \end{aligned}}$$

(magnetization in same direction)

(opp. direction)



An air core solenoid has 300 turns. Its length is 25 cm and cross-sectional area 3 cm². Calculates its self inductance if the coil current of 10 A is completely interrupted in ·04 sec. Calculate the induced emf in the coil.

$N = 300$ turns $\quad l = 25 cm \quad A = 3 cm^2 \quad I = 10A$

$t = .04$

$$L = \frac{N^2}{S}$$

$$= \frac{300 \times 300}{\frac{25}{4\pi \times 10^{7} \times 3}}$$

$$= \frac{90000 \times 4\pi \times 10^{7} \times 3}{25}$$

$$= \underline{\underline{1.35 \times 10^{-4} H}}$$

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$$e = \frac{L\,dI}{dt} \qquad e = L\frac{dI}{dt}$$

$$= \frac{1.35\times10^{-8}\times 200}{.04} \qquad = \frac{1.35\times10^{-4}}{.04}$$

$$= 6.75\times10^{-6}\,V \qquad = \underline{\underline{0.034\,V}}$$

An air core torroidal coil has 450 turns and a mean diameter of 30cm and cross sectional area $3cm^2$. Calculate

1) Inductance of coil.

2) The avg emf induced if a current of 2A is reversed in 0.04 s. 1.

A magnetic field is produced by a coil of 300 turns which is wound on a closed iron ring. The ring has a cross-section of $20cm^2$ and a mean length of 120cm. Permeability of iron is 800. If current in coil A is 10A find the energy stored in m.f.

Two similar coils connected in series gives a total inductance of 600mH. When 1 coil is reversed the total inductance is 300mH. Determine mutual inductance b/w two coils. and the coefficient of coupling.

Find the inductance of a torroid of 12.5 cm mean radius, 6.25 cm² circular cross-section wound uniformly with 300 turns of wire.

N=450 d=30cm A=3cm²

$$L = \frac{N^2}{S} = \frac{450 \times 450}{30} \times 4\pi \times 10^{-7} \times 3 \times 10^{-2}$$

$$= \underline{8.1 \times 10^{-5} H}$$

ii) $e = L \frac{dI}{dt}$

$$= \frac{8.1 \times 10^{-5} \times \cancel{4} \times 10^{2}}{\cancel{0.04}}$$

$$= \underline{8.1 \times 10^{-3} V}$$

2. $N = 300$ $A = 200\,cm^2$ $l = 120\,cm$

$\mu_i = 800$ $I = 10A$

$$L = \frac{N^2}{S} = \frac{300 \times 300 \times 4\pi \times 10^{-7} \times 4 \times 20}{120}$$

$= 0.15072H$

$$W = \frac{1}{2} L I^2$$

$$= \frac{1}{2} \times 0.15072 \times 10^2$$

$= 7.536 J$

3. $L = 600 \times 10^{-3} H$ $L_{TR} = 300 \times 10^{-3}$

$600 \times 10^{-3} = 2L + 2M$

$300 \times 10^{-3} = 2L - 2M$

$900 \times 10^{-3} = 4L$

$L = \cancel{450 \times 10^{-3}}\ 0.225$

$M = 0.075$

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$$k = \frac{0.075}{0.225} = \frac{1}{3}$$

$$= 0.33 = 33\%$$

$r = 12.5$ $\quad A = 6.25\ cm^2$ $\quad N = 300$

$$L = \frac{N^2}{S} = \frac{300 \times 300}{2\pi \times 12.5} \times 4\pi \times 10^{-7} \times 625 \times 10^{-2}$$

$$= 9 \times 10^{-5}\ H$$