classmate
Date 5/9/23
Page 1

Electrical Engineering

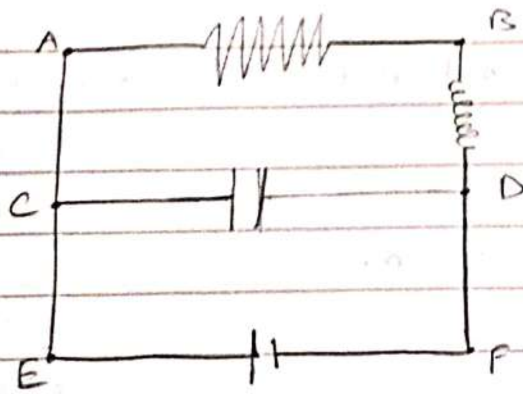
CIRCUIT

Circuit element — Network

Terminologies

- Network - connection of circuit elements
- Circuit element - parts of a circuit
- Branch - a wire connecting one side of circuit to another
- Junction - point of intersection of 2 or more wires
- Mesh / loop - a set of wires in a circuit which forms a complete path within the circuit. ~~like~~ - like a loop

Branch	Loop	Circuit element	Network
1. AB	1. ABDC	1. resistor	1. wires
2. CD	2. CDFE	2. capacitor	2. battery
3. EF	3. ABEF		

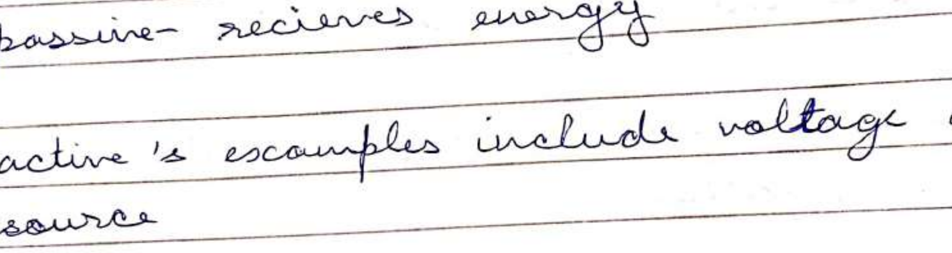


Electric Network

1. Active Vs. Passive
2. Linear Vs. Non-linear
3. Unilateral Vs. Bilateral
4. Lumped Vs. Distributed

1. Active Vs. Passive
- active - gives energy
- passive - recieves energy
- active's escamples include voltage and current source
- passive's escamples include resistor, capacitanc

2. Linear Vs. Non-linear
- linear
  → no change in temp. volt and current.
  → graph is a straight line
  →



- non-linear
  → value of temp, volt are not constant.
  → graph slope varies

3. Unilateral Vs. Bilateral
- Unilateral -
  → one directional

→ diode (⊣▷|⊢)
→ behaviour of circuit depends on direction of current

• bidirectional
→ behaviour/characteristics of circuit is independent of direction of current.

4. Lumped Vs. Distributed
• lumped.
→ network in which components are physically seperable
→ transmission towers

• distributed
→ network in which components are not physically seperable
→

VOLTAGE SOURCE

Ideal
→ internal resistance = 0

Practical
→ internal resistance ≠ 0

CURRENT SOURCE

Ideal

Practical

Resistance
Ability to oppose the flow of current.

• Factors that define resistance
→ length

→ area
→ temperature
→ material

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

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

- ρ
→ resistivity
→ unit : Ωm

Q. A coil consists of 2000 turns of Cu wire having cross-sectional area ~~0~~ 0.8 mm^2. The mean length per turn is 80cm and the resistivity of copper is 0.02 $\mu\Omega m$. Find the resistance of coil and power absorbed by the coil when connected across 110 V of DC supply.

Ans. Given

$A = 0.08\ mm^2 = 0.08 \times 10^{-6}\ m^2 = 8 \times 10^{-8}\ m^2$

$l = 1600\ m$

$\rho = 2 \times 10^{-8}\ \Omega m$

Solution

$R = \frac{\rho l}{A} = \frac{2 \times \cancel{10^{-8}} \times \cancel{1600}^{200}}{\cancel{8} \times \cancel{10^{-8}}}$

$= 400$

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

[P = power
V = voltage
I = current]

Date 7/9/23
Page 6

Q. A resistance of conductor 1 mm^2 in crossection and 20 m long is 0.346 Ω. Determine the specific resistance of the conducting material.

Ans. Given

$l = 20$ m

$R = 0.346\,\Omega$

$A = 1 \times 10^{-6}$ m

Solution

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

$$0.346 = \frac{\rho(20)}{1 \times 10^{-6}}$$

$$\frac{0.346}{20 \times 10^{-6}} = \rho$$

$$\rho = \frac{346 \times 10^{-3}}{20}$$

$$\rho = 0.0173$$

Q. A resistance of conductor 1 mm^2 in crossection and 20 m long is 0.346 Ω. Determine the specific resistance of the conducting material.

Ans. Given

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

$l = 20$ m

$R = 0.346\,\Omega$

Solution

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

Q.

11/4/23

Ohm's Law

$V = IR$

This occurs assuming physical conditions of a conductor doesnot change.

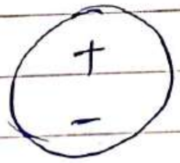
$I \propto V$

Types of energy sources

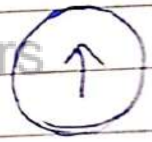
ENERGY SOURCES

CURRENT
- independent
- dependent

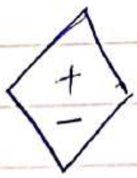
VOLTAGE
- independent
- dependent



independent voltage



independent current



dependent voltage

dependent current

1. VCVS (Voltage controlled voltage source)
   - → $k \cdot V_x$

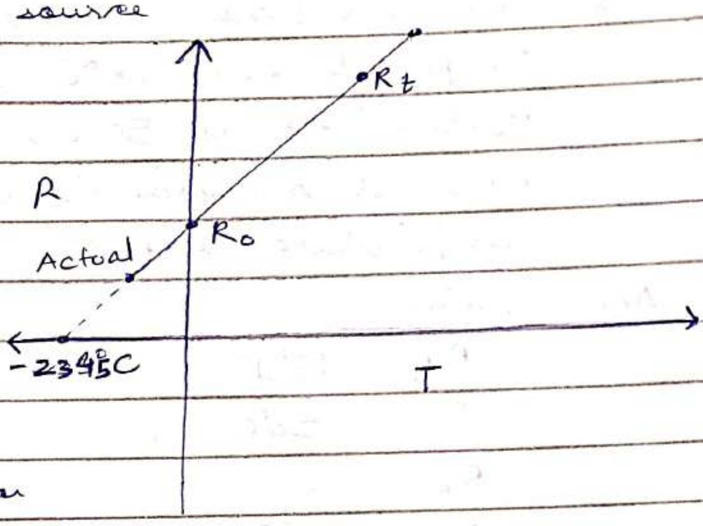
2. CCVS
   - current controlled voltage source
   - → $k \cdot I_x$

3. CCCS
   - current controlled current source
   - → $k \cdot I_x$

4. VCCS

→ voltage controlled current source

→ $k \cdot V_x$



~~Effect of~~ $R \propto T$

• the resistance ∝ material

→ resistance of pure metal. (Cu/Al) increases with temp

→ change in R is fairly regular for normal range

→ resistance of electrolyte insulator (mica, glass) and semic. (germanium, silicon) decreases with increase in temp.

→ R of alloy increases with temp. but is small and irregular.

→ theoretical value of Cu is 0 at $-234.5°C$

Temp. coefficient of R (RTC)

• $(R_t - R_0) \propto R_0$

→ $(R_t - R_0) \propto t$

Type of material

• $\alpha_0 = \dfrac{R_t - R_0}{(R_0)(t)} = \dfrac{\Delta R}{(R_0)(t)}$

• $\Delta R = R_t - R_0$

• $\dfrac{R_2}{R_1} = \dfrac{1 + \alpha_0 t_2}{1 + \alpha_0 t_1}$

Q. The coil has a resistance of ~~20~~ 18 Ω when its mean temperature is 20°C and of 20 Ω when its mean temperature is 50°C. Find its ~~mean~~ mean temperature rise when its resistance is 21 Ω and the surrounding temperature is 15°C.

Ans. Given

$R_1 = 18\,\Omega$

$T_1 = 20°C$

$R_2 = 20$

$T_2 = 50°C$

Solution

$$\frac{R_2}{R_1} = \frac{1+\alpha_0 T_2}{1+\alpha_0 T_1}$$

$$\frac{20}{18} = \frac{1+\alpha_0(50)}{1+\alpha_0(20)}$$

$$20 + 400\alpha_0 = 18 + 900\alpha_0$$

$$2 = 500\alpha_0$$

$$\frac{2}{500} = \alpha_0$$

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

$$21 = R_0\left(1+\left(\frac{1}{250}\right)\right)$$

$$\frac{R_t}{R_0} = \frac{1+\alpha_0 t}{1+\alpha_0}$$

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

$$R_1 = R_0(1+\alpha_0 T_1)$$

$$\frac{R_t}{R_1} = \frac{1+\alpha_0 t}{1+\alpha_0 T_1}$$

$$\frac{21}{18} = \frac{1+(0.004)(t)}{1+(0.004)(20)}$$

$$\frac{7}{6} = \frac{1+0.004t}{1+0.08}$$

$$\boxed{\begin{aligned} 20 + 400\alpha_0 &= 18 + 900\alpha_0 \\ 2 &= 500\alpha_0 \\ \frac{1}{250} &= \alpha_0 \end{aligned}}$$

$$\frac{7}{6} = \frac{1+0.004t}{1.08}$$

$$\frac{1.08\times 7}{6} - \frac{6}{6} = 0.004t$$

~~7.56~~ -6

$$\frac{1.56}{6\times 0.004} = t$$

$$\frac{\cancel{1560}}{\cancel{24}} = 65 = t$$

(~~780~~ 390, 12 6)

Q. The resistance of the ~~filled~~ field coils of ~~the~~ a dynamo is 173 Ω at 16°C ~~after wor~~. After working for 6 hours on full load, the resistance of the coil increases to 212 Ω. Calculate:

a) the temperature of the coils

b) mean rise of temperature of the coil.

Assume that temperature coefficient of resistance is 0.00426 °C at 0°C.

Ans. Given

$R_1 = 173\ \Omega$

$T_1 = 16^\circ C$

$R_2 = 212\ \Omega$

$T_2 = T_2$

$\alpha_0 = 0.00426$

Solution

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

$$\frac{R_1}{R_2} = \frac{1+(0.00426)(16)}{1+(0.00426)T_2}$$

$\cancel{\frac{173}{212} = 1}$

$$\frac{212}{173} = \frac{1.06816}{1+\alpha_0 T_2}.$$

$$1.23 = \frac{1.07}{1+0.00426 T_2}$$

~~1.23~~

$$0.00426 T_2 = \frac{1.07}{1.23} - \frac{1.23}{1.23} = -\frac{0.16}{1.23} = 0.00426$$

$$T_2 = \frac{+0.16}{1.23 \quad 0.00426}$$

$$= \frac{0.16}{0.005}$$

$= 32.$

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

$R_{50} = R_{20}(1+\alpha_{50}(30))$

$954 = 900(1+\alpha_{50} 30)$

$1.06 = 1+30\alpha_{50}$

$\frac{0.06}{30} = \alpha_{50}$

$0.002 = \alpha_{50}$

$$\begin{array}{r} 1.23 \\ -1.07 \\ \hline 0.16 \end{array}$$

Given

$R_1 = 173$

$T = 16°C$

$R_2 = 212\ \Omega$

$\alpha_0 = 0.00426.$

Solution

$$\frac{R_2}{R_1} = \frac{\cancel{R_0}(1+\alpha_0 T_2)}{\cancel{R_0}(1+\alpha_0 T_1)}$$

$$\frac{173}{212} = \frac{1 + 0.00426 \times T_2}{1 + 0.00426 \times 16}$$

$$0.82 = \frac{1 + 0.00426 T_2}{\cancel{1.06}\ 1.07}$$

$$\frac{0.82 \times 1.07 - 1}{0.00426} = T_2$$

$$\frac{0.88 - 1}{0.00426}$$

$$\frac{0.12}{0.00426}$$

classmate
Date 8/9/23
Page 10

Q. Two coils connected in series have resistances of 600 Ω and 300 Ω and temperature coefficient of 0.1% and 0.4% per °C at 20°C respectively. Find the resistance of combination at temperature of 50°C. What is the effective temperature coefficient of the combination at 50°C.

ANS. Given

$R_1 = 900\,\Omega$

$R_{10} = 600\,\Omega$

$R_{20} = 300\,\Omega$

$\alpha_1 = 0.001$

$\alpha_2 = 0.004$

$T_1 = 50°$

Solution

$R_1 = R_0(1+\alpha T_1)$

$R_2 -$

$R_1 = 600(1+\alpha_0 T_{50})$

$R_1 = 600(1+0.005 \times 50)$

$R_1 = 600 \times (1.05)$

$= 6 \times 105$

$= 630\,\Omega$

$R_2 = 300(1+0.004 \times 50)$ 0.2

$= 300(1.2)$

$= 360$

$R_1 = 600(1+\alpha(30))$

$= 600(1+0.001 \times 30)$

$= 600(1.03)$

$= 618$

$R_2 = 300(1+0.004(30))$ .12

$= 300(1.12)$

$= 336$

$R = 954\,\Omega$

SharkCoders

Q. A carbon resistor has a resistance of 800 Ω at 20°C. Determine its resistance at
a) 100°C
b) -100°C
The Temperature coefficient of resistance of C at 20°C is $-0.00047/°C$.

Ans. Given

$R_0 = 800\,\Omega$

$T_0 = 20°C$

$\alpha_0 = -0.00047$

a) $R = R_0(1 + (-0.00047)(100-20))$

$R = 800(1 - 0.00047 \times 80)$

$R_{100} = 769.92.$

b) $R = 800(1 + (-0.00047)(-100-20))$

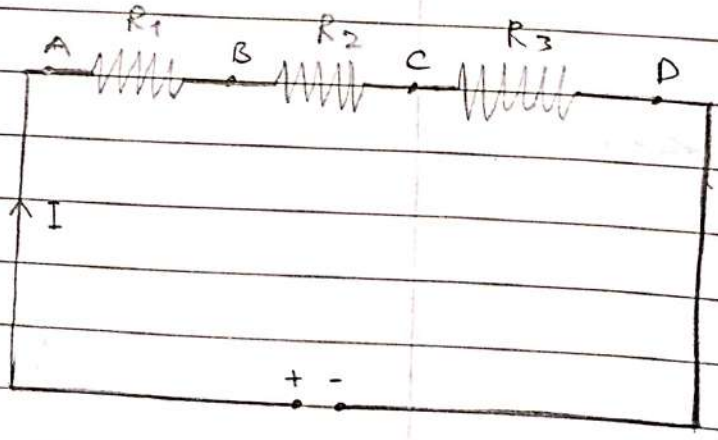
$= 800(1 + (-0.00047)(-120))$

$= 800(1 + 0.0564)$

$= 845.12$

Series parallel connections of ~~Resources~~ Resistances

1. Series connection



$V = V_1 + V_2 + V_3 + \dots$

By ohm's law,

$IR = IR_1 + IR_2 + IR_3 + \dots$ —— ①

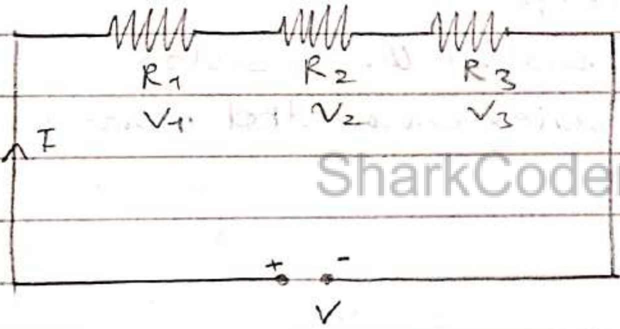
$\therefore R = R_1 + R_2 + R_3 + \dots$ —— ②

$\therefore \frac{1}{G} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3}$ [G = conductance]

- resistors are arranged along one wire.
- current is constant

<u>Voltage division rules</u> (series)

- determining V across each resistance



- $V = I(R_1 + R_2 + R_3)$ [From ①]

$\Rightarrow V = IR$ [From ②]

$\Rightarrow I = \frac{V}{R_1 + R_2 + R_3}$

- $V_1 = IR_1$

$V_2 = IR_2$

$V_3 = IR_3$

- $V_1 = V \cdot \frac{R_1}{R}$

$V_2 = V \cdot \frac{R_2}{R}$ and $V_3 = V \cdot \frac{R_3}{R}$

Date 9/9/23
Page

Practical application of VDR

- when resistances are connected in series across voltage source.

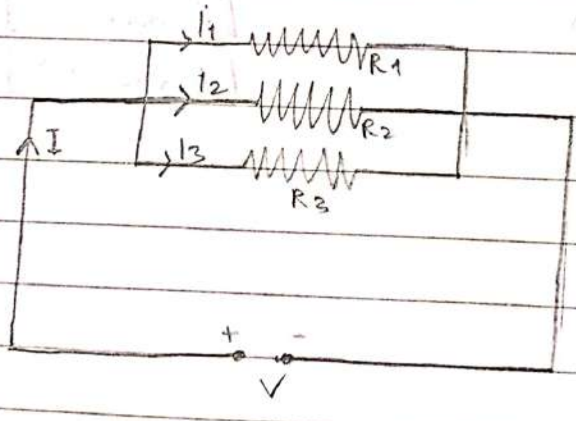
- the volt drop across resistor can be calculated easily

- the current I flowing through all the series connector is same.

- ~~V across resistor in series circuit = total voltage x voltage~~

- V_1 = volt across resistor in series circuit
  V = ~~vol~~ total voltage
  R_1 = resistance across the resistor
  R = sum of all series connected resistances

Parallel connection



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

$$\Rightarrow G = G_1 + G_2 + G_3 + \dots$$

$I = I_1 + I_2 + I_3$

By ohm's law,

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

Date 7/7/23

Page

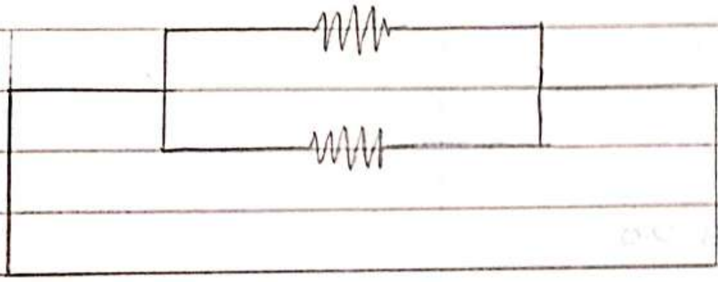
Current division rule (parallel)

- ~~used~~ useful for finding the current when resistances are connected in a parallel arrangement.

- the voltage applied across the || circuit is same. as

- the current supplied by the source is I.

- the current flowing through || resistances is I_1 and I_2.



$\cdot\ I = I_1 + I_2 + \dots$

By ohm's law,

$$I_1 = \frac{V}{R_1} \quad \text{and} \quad I_2 = \frac{V}{R_2}.$$

$$\Rightarrow V = I_1 R_1 = I_2 R_2$$

$$\Rightarrow I_2 = \frac{I_1 R_1}{R_2} \quad \text{——— (1)}$$

$$\cdot\ I = I_1 + I_2$$

$$I = I_1 + \frac{I_1 R_1}{R_2} \qquad [\text{From (1)}]$$

$$I = \left(1 + \frac{R_1}{R_2}\right) I_1$$

$$\therefore I_1 = \left[\frac{R_2}{(R_1 + R_2)}\right] \cdot I$$

$$I_2 = \left[\frac{R_1}{(R_1 + R_2)}\right] \cdot I$$

Date 7/4/23

• current flowing through resistor in $\parallel$ circuit = I_1
source current = I
value of opposite resistance = R_2/R_1
sum of all parallely connected resistors = R

Q. 3 resistors of 8.4 Ω, 6.8 Ω, and 4.8 Ω are conn-ected in series across 100V supply. Find :
a) total Re
b) current
c) voltage across each resistor

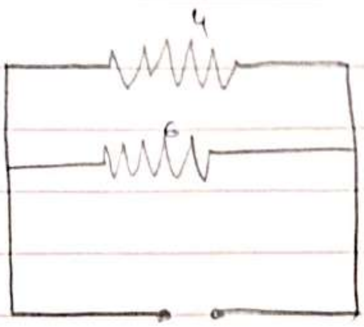
Ans. Given
$R_1 = 8.4$
$R_2 = 6.8$
$R_3 = 4.8$
$R = \cancel{18.0}\ 20$
$V = 100$

a) $R = R_1 + R_2 + R_3 = 20$

b) $V = IR$.
$100 = I \times 20$
$I = 5\ A$

c) $V_1 = 5 \times 8.4 = 42.0\ V$
$V_2 = 5 \times 6.8 = 34.0\ V$
$V_3 = 5 \times 4.8 = 24.0\ V$

Q. Two resistors (4 Ω and 6 Ω) are connected parallel if the current supplied by a source is Find the Re are current through each branch
Ans. (NEXT PAGE)



Given
$R_1 = 4\Omega$
$R_2 = 6\Omega$
$I = 30A$
$R = ?$

a) $\dfrac{1}{R_e} = \dfrac{1}{4} + \dfrac{1}{6} = \dfrac{10}{24}$

$\Rightarrow R_e = 2.4$

b) $V_1 = I_1 R_1$
$V = IR$
$V = 2.4 \times 30$
$V = 72$

$V = I_1 R_1$
$72 = I_1 (4)$
$18 = I_2$

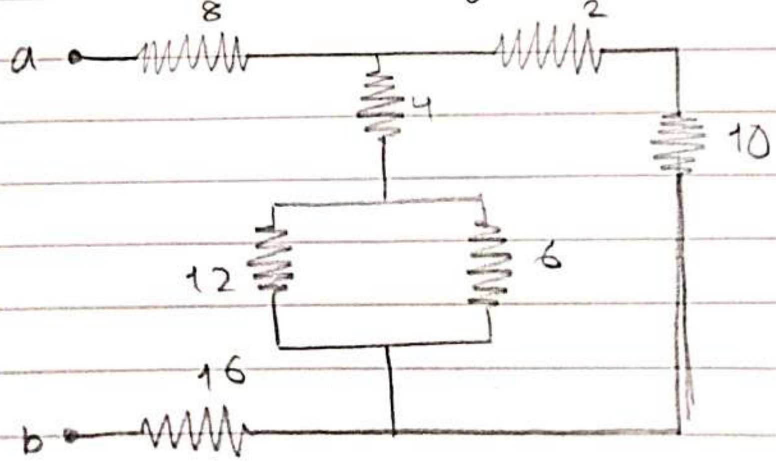
$I_2 = \dfrac{V}{R_2} = \dfrac{72}{6} = 12$

$$\boxed{\begin{aligned} \therefore I_1 &= 18\ A \\ I_2 &= 12\ A \end{aligned}}$$

$I_1 = \left(\dfrac{R_2}{R_1 + R_2}\right) \cdot I$
$= \dfrac{6 \times 30}{10}$
$= 18\ A$

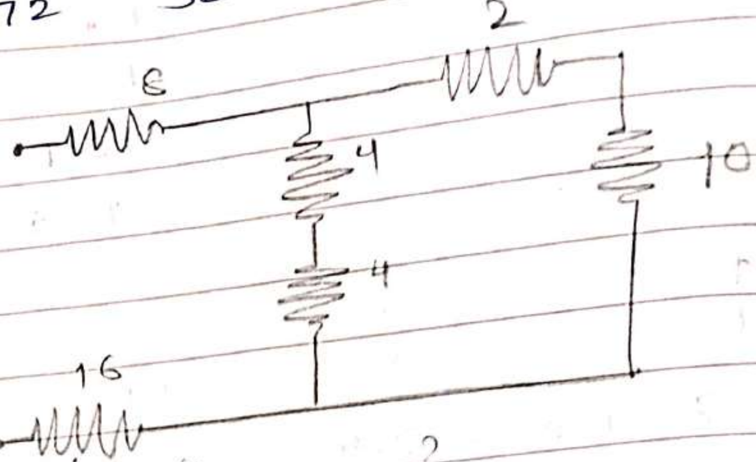
$I_2 = \left(\dfrac{R_1}{R_1 + R_2}\right) \cdot I$
$= \dfrac{4 \times 30}{10}$
$= 12\ A$

Q. Determine the R_e for the circuit shown.

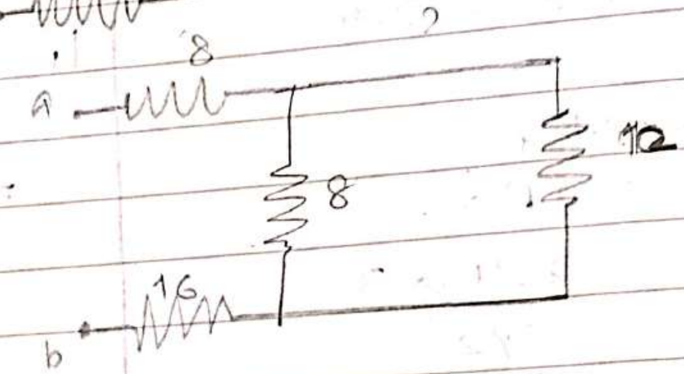


$$\frac{R_{eqn}'}{R_m} = \frac{18}{72} = \frac{9}{36} = \frac{1}{4}$$

$R_m = 4$



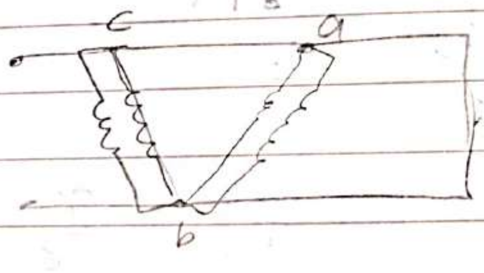
$\therefore R_m = 4+4 = 8$



$\cancel{\frac{8+10}{80} = \frac{18}{80} = \frac{9}{40}}$

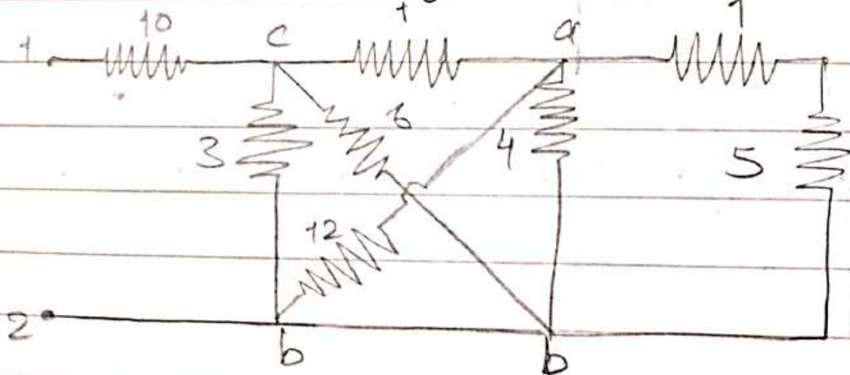
$$\frac{20}{96}\ \frac{10}{48} = \frac{5}{24}$$

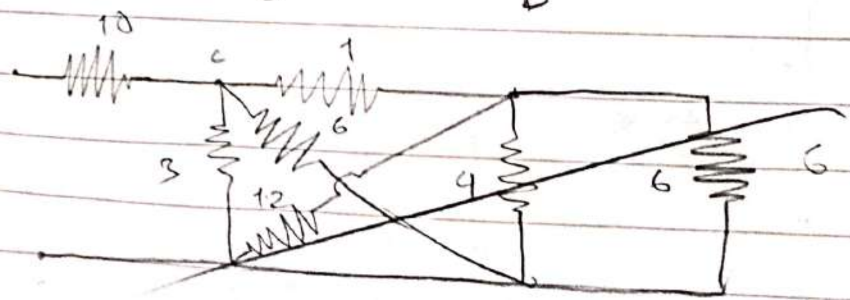
$$R_3 = \frac{24}{5} = 4.8$$

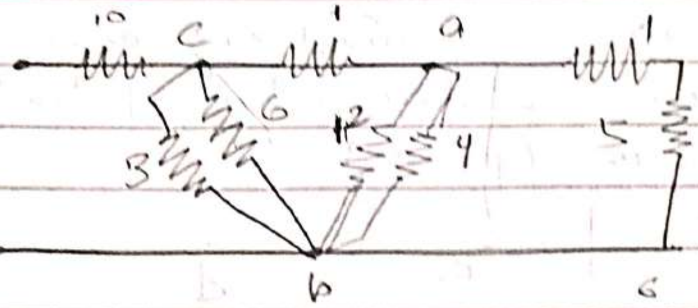


$\therefore R_e = 28.8$

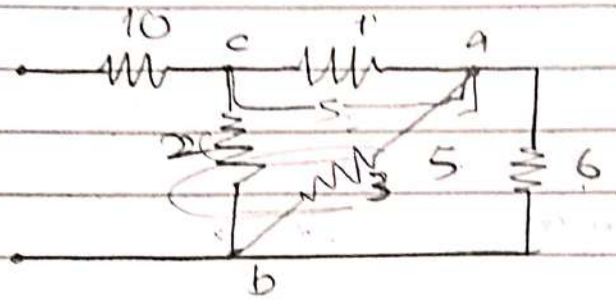
Q. Find the Re for the circuit shown.







$\frac{6}{5}$

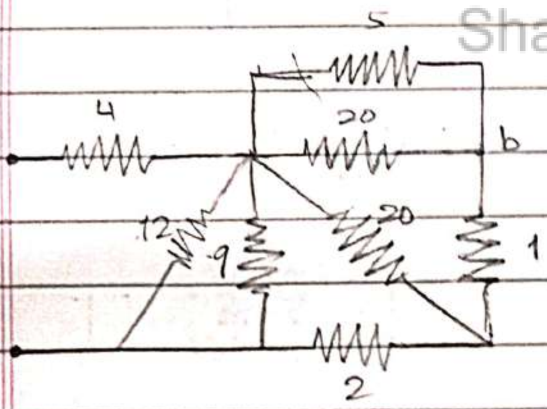


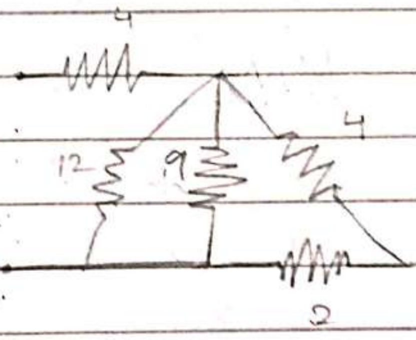
$\frac{5}{6}$ $\quad \frac{6}{5} = 1.2$

$\frac{6}{5} = 1.2$

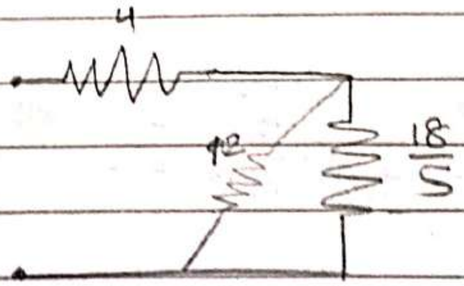
$\boxed{11.2}$

Q Find R_{12} in the following figure.

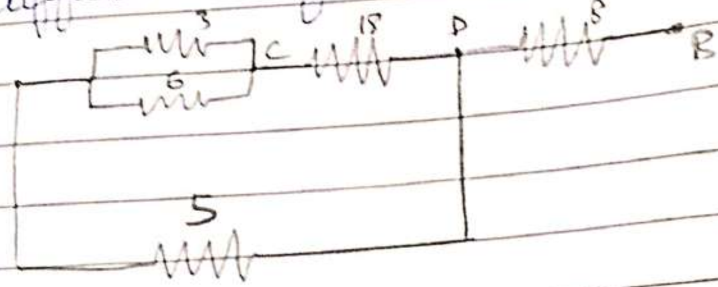




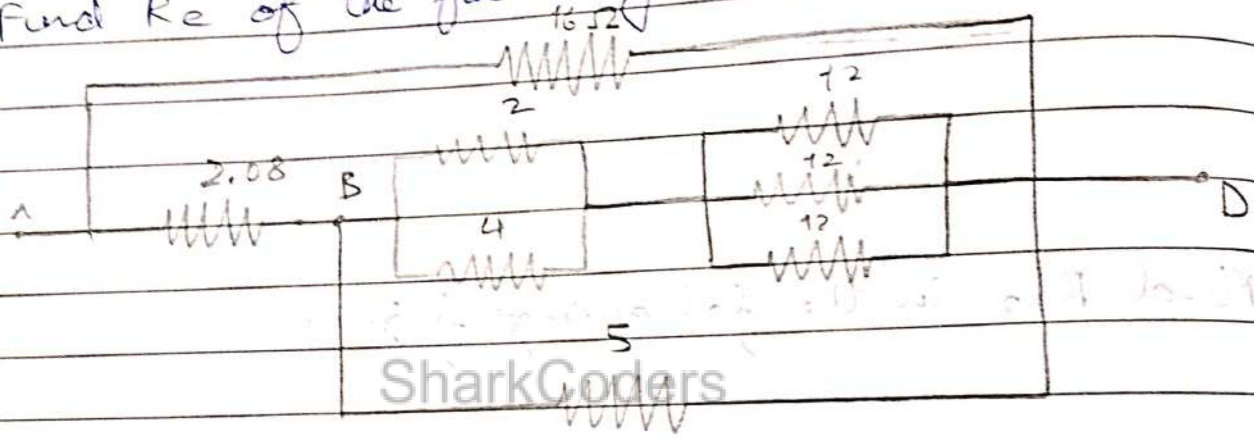
$R_{12} = \boxed{6.77}$



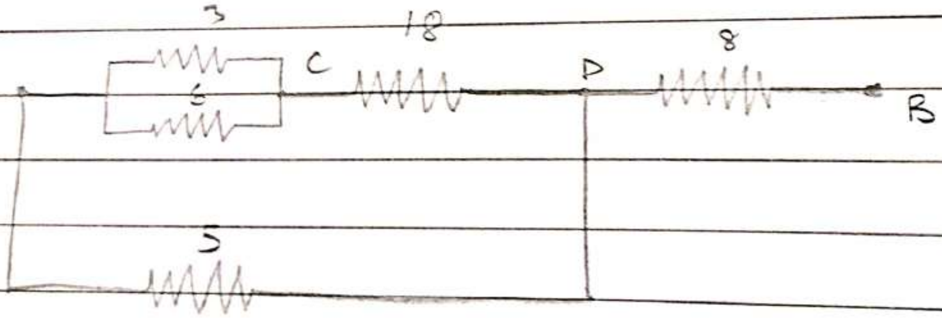
Q.1. Calculate Re of this combination and the voltage across each resistor when potential difference of 60Ω is applied.

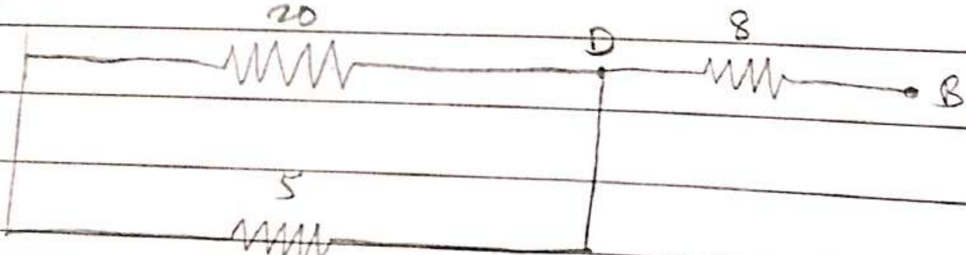


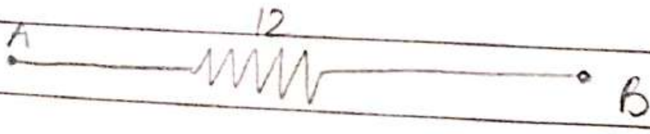
Q2. Find Re of the following.



Q-1.

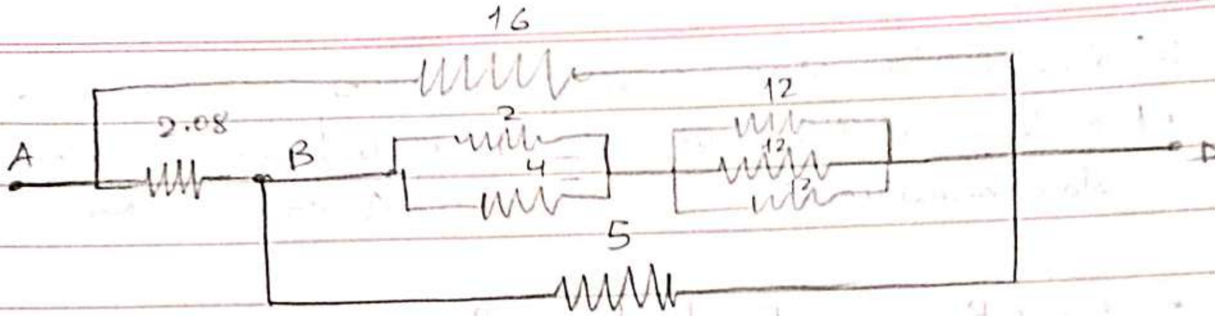


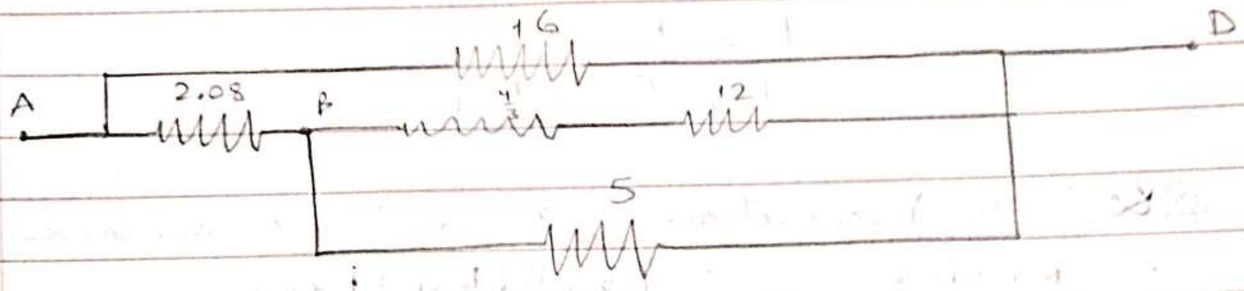


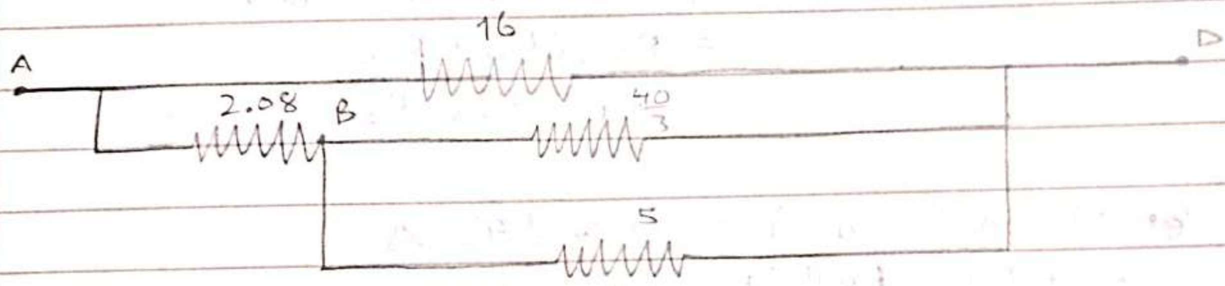


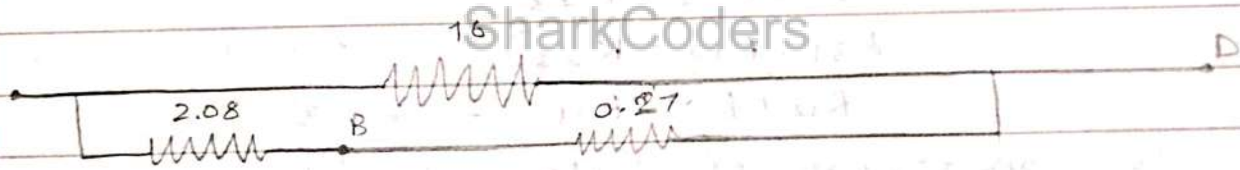
Req = 12 Ω

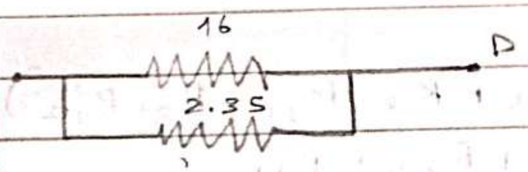
Q2.





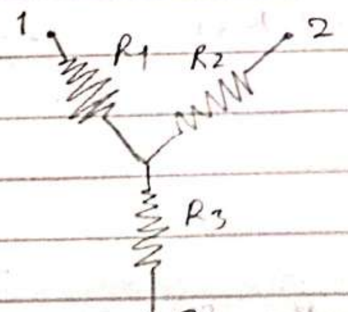




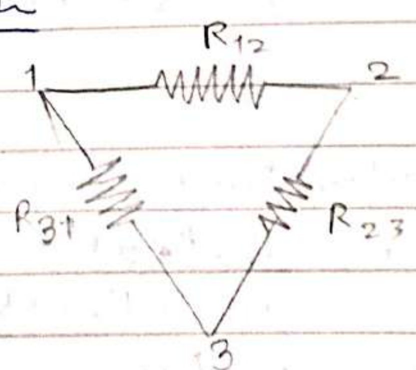


$R_{eq} = 0.49\ \Omega$

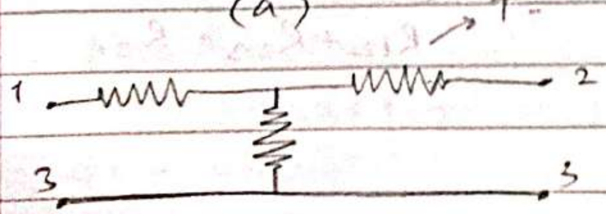
Star-delta transformation

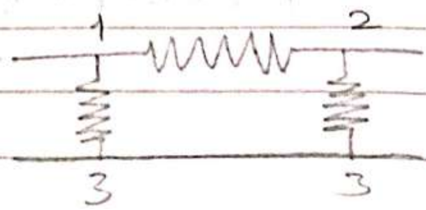


(a)



(b)





ation

of terminal ① & ② i

star connection

Δ connection.

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

$$= \frac{R_{12}(R_{23} + R_{31})}{R_{12} + R_{23} + R_{31}} \quad \text{——— ①}$$

② & ③ in Υ connection = ② and ③ in Δ connection.

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

$$= \frac{R_{23}(R_{31} + R_{12})}{R_{12} + R_{23} + R_{31}} \quad \text{——— ②}$$

3. ③ and ① in Υ = ③ and ④ Δ

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

$$= \frac{R_{31}(R_{12} + R_{23})}{R_{12} + R_{13} + R_{31}} \quad \text{——— ③}$$

$= R_{12} R_{31} - R_{23} R_{31}$

For conversion of delta into star,

Adding ①, ②, and ③,

$$2(R_1 + R_2 + R_3) = \frac{2(R_{12}R_{23} + R_{23}R_{31} + R_{31}R_{12})}{R_{12} + R_{23} + R_{31}}$$

$$\therefore R_1 + R_2 + R_3 = \frac{R_{12}R_{23} + R_{23}R_{31} + R_{31}R_{12}}{R_{12} + R_{23} + R_{31}} \quad \text{——— ④}$$

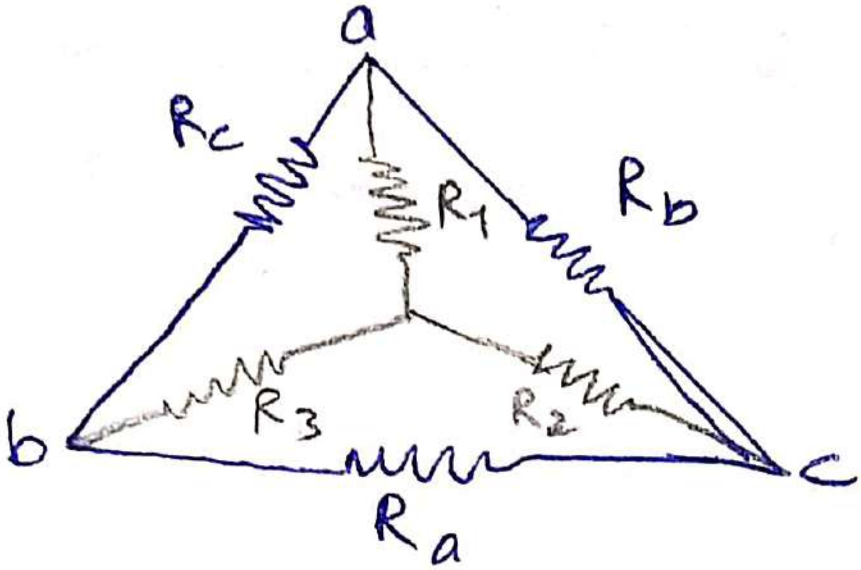
- Subtracting ② from ④,

$$R_1 = \frac{R_{12}R_{31} + 0}{R_{12} + R_{23} + R_{31}}$$

$$\cancel{R_2 = \frac{R_{23}R_{13}}{R_{12} + R_{23} + R_{31}}}$$

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

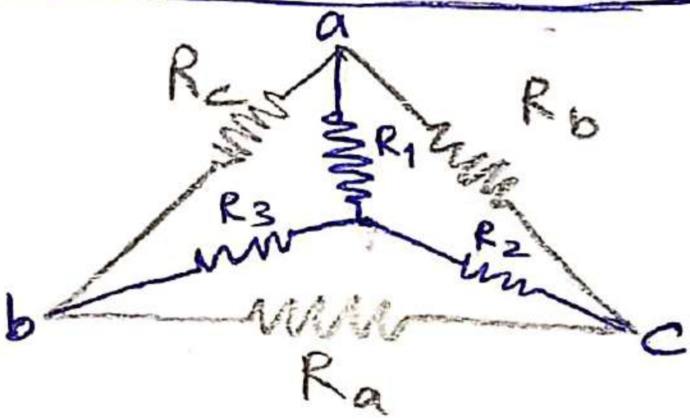
$\Delta \rightarrow *$ transformation



$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} \qquad R_2 = \frac{R_a R_b}{R_a + R_b + R_c}$$

$$R_3 = \frac{R_a \cdot R_c}{R_a + R_b + R_c}$$

$* \rightarrow \Delta$ transformation



$$R_a = R_2 + R_3 + \frac{R_2 R_3}{R_1} \qquad R_b = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

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

$\cancel{R_3 = R_{13}R_{32}}$

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

④, ⑤, ⑥ are the formulae for converting Δ-connection to star connection.

• It is seen that the R of any branch of the equivalent star connection is obtained by multiplying the adjacent resistances of the branch and dividing by the sum of the 3 resistances.

2. Star - delta transformation

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

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

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

Multiply ⑥ and ⑦, ⑤ and ⑥, and ⑦×⑤

$\cancel{R_{12} +}$

$\cancel{R_{12}}$

$$R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12}^2 R_{23} R_{31} + R_{23}^3 R_{31} R_{12} + R_{31}^2 R_{12} R_{23}}{(R_{12} + R_{23} + R_{31})^2}.$$

$$= \frac{R_{12} R_{23} R_{31}\,(R_{12} + R_{23} + R_{31})}{(R_{12} + R_{23} + R_{31})^2}.$$

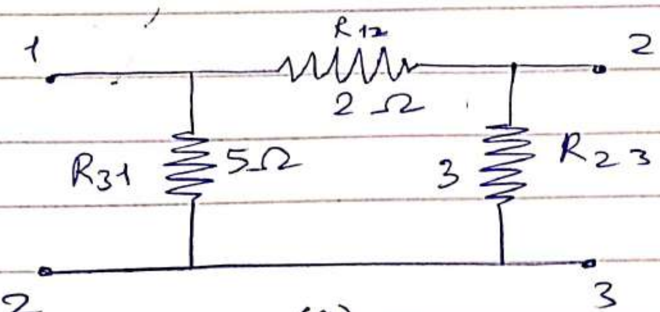
$$= \frac{R_{12}\,R_{23}\,R_{31}}{R_{12} + R_{23} + R_{31}}$$

Divide (8) / (7)

$$\frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = \frac{R_{12}\, R_{23}\, R_{31}}{R}$$

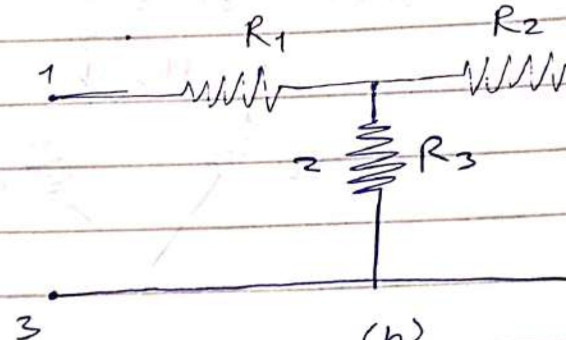
Date 15/9/23
Page

Q. Convert the π network in figure A to its equi-lent T network.



(a)

=>



(b)

Ans. Given

$R_{12} = 2\Omega$

$R_{23} = 3\Omega$

$R_{31} = 5\Omega$

~~Total~~ To find

R_1

R_2

R_3

Solution

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

$$R_1 = \frac{2 \times 5}{10} = 1$$

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

$$= \frac{3 \times 2}{10} = \frac{3}{5} = 0.6$$

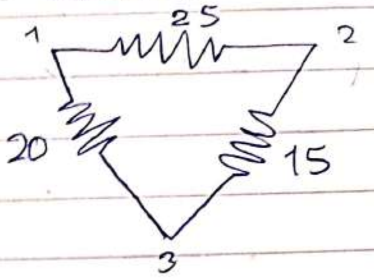
$$R_3 = \frac{R_{23} R_{31}}{R_{12} + R_{23} + R_{31}} = \frac{3 \times 5}{10} = \frac{3}{2} = 1.5$$

$\therefore R_1 = 1$

$R_2 = 0.6$

$R_3 = 1.5$

Q. Convert the Δ network in figure into its equivalent star network



Given

$R_{12} = 25$

$R_{23} = 15$

$R_{31} = 20$

To find

R_1

R_2

R_3

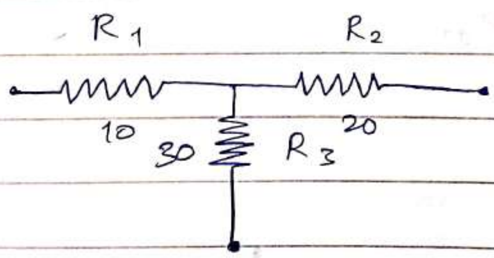
Sol^n

$$R_1 = \frac{R_{12}\, R_{31}}{R_{12}+R_{23}+R_{31}} = \frac{25 \times \cancel{20}}{\cancel{60}_{3}} \quad \frac{25}{3} = 8.34$$

$$R_2 = \frac{R_{23}\, R_{12}}{R_{12}+R_{23}+R_{31}} = \frac{\cancel{15}^{5} \times \cancel{25}^{5}}{\cancel{60}\ \cancel{12}\ 4} = \frac{25}{4} = 6.25$$

$$R_3 = \frac{R_{31}\, R_{23}}{R_{12}+R_{23}+R_{31}} = \frac{\cancel{20}^{1} \times 15}{\cancel{60}_{3}} = 5$$

Q. Transform the T-network into delta network.



Given

$R_1 = 10\Omega$

$R_2 = 20\Omega$

$R_3 = 30\Omega$.

To find

R_{12}

R_{23}

R_{31}.

$$R_{12} = \frac{R_1 (R_{12} + R_{23} + R_{31})}{R_{13}}$$

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

$$R_{12} = 10 + 20 + \frac{20\cancel{0}}{3\cancel{0}}$$

$$= 30 + 6.67 = 36.67$$

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

$$= 20 + 30 + \frac{60\cancel{0}}{1\cancel{0}}$$

$$= 110$$

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

$$= 30 + 10 + \frac{30\cancel{0}}{2\cancel{0}}$$

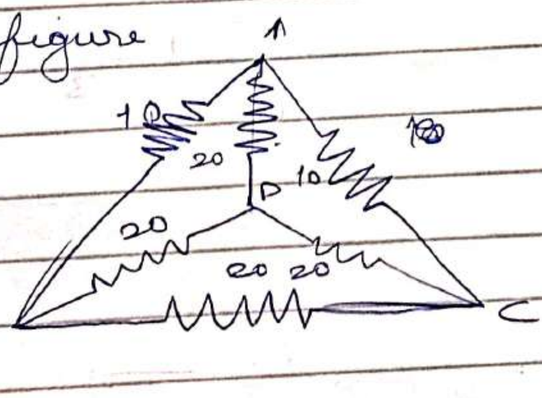
$$= 40 + 15 = 55$$

$\therefore$ $R_{12} = 36.67$

$R_{23} = 110$

$R_{31} = 55.$

Q. Find the R between point A and point D in the given figure



$$R_1 = \frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}} = \cancel{\frac{400}{90}} = \cancel{25.5\,\Omega}$$

$$= \frac{20\times 20}{20\times 3} = \frac{400}{60} = \frac{20}{3}$$

So $10\,\Omega$ and $20/3$ are connected in series.

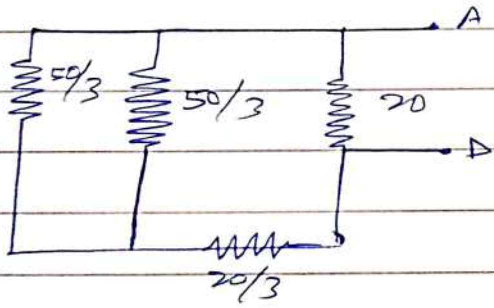
$$10 + \frac{20}{3} = \frac{50}{3}\,\Omega$$

10 and $20/3$ are connected in series.

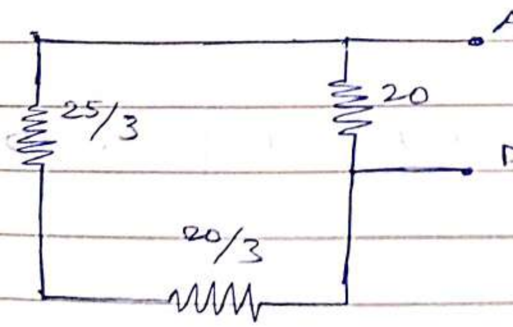
$$10 + \frac{20}{3} = \frac{50}{3}\,\Omega$$

So $50/3$ and $50/3$ are connected in parallel,

$$\frac{\frac{50}{3}\times\frac{50}{3}}{\frac{50}{3}+\frac{50}{3}} = \left(\frac{2500}{9}\right)\left(\frac{3}{100}\right) = \frac{25}{3}\,\Omega$$

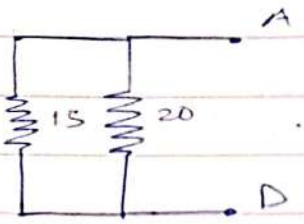


$\Downarrow$



$\frac{25}{3}$ and $\frac{20}{3}$ are in series

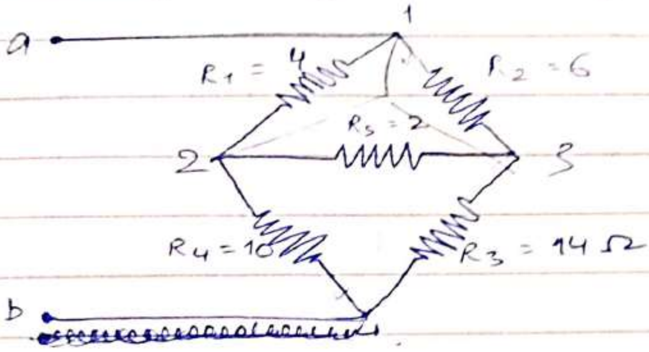
$$\frac{25}{3} + \frac{20}{3} = \frac{45}{3} = 15\,\Omega$$

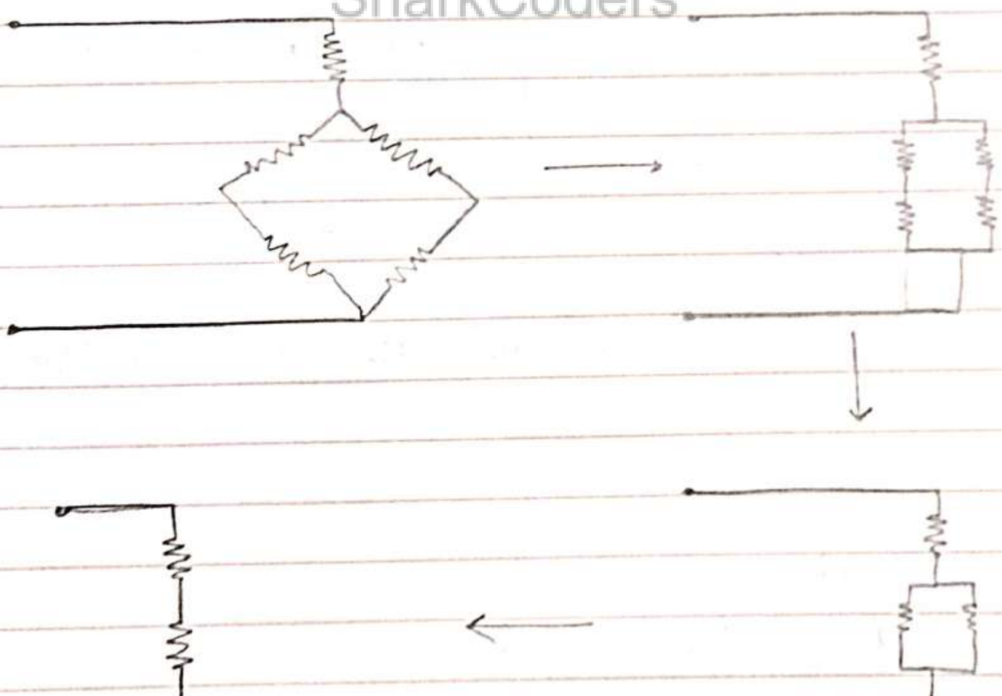


15 Ω and 20 Ω are connected in parallel.

$R(AB) = \frac{15 \times 20}{35} = \frac{60}{7} = 8.57\,\Omega$

Q. Find the R of the bridge circuit in the following figure by using Δ transformation method.





~~lab reco.~~

Lab

- lab records and observation notebook.

- lab records
  - → exp. no.
  - → exp. date.
  - → obj.
  - → apparatus required
  - →

S.No.	Name of equipment	Quantity	Range	Type (DC/AC)

  - → Theory + formula + circuit
  - → Procedure.
- ~~unifor~~
  - → one side plane and one side lined
    - → circuit diagram for plane side
    - → obs. table on plane side
  - → obs. table
  - → calculation (on plane side)
  - → result
  - → Conclusion (error < 10%)
  - → precautions
  - → questions

- observation notebook.
  - → back up ~~[illegible]~~ or lab r.

classmate
Date
Page

List of experiments

1. To study measuring instruments and safety precautions while working on electrical systems

2. To study and verify Kirchoff's Current Law (KCL) and Kirchoff's Voltage Law (KVL)

3. To study the V-I characters of an incand-escent lamp.

~~4. To perforce an open circuit test on a single-phase transformer~~

4. To perform a short circuit test on a single-phase transformer

5. To perform an open circuit test on a single-phase transformer

6. To measure 3-phase power by using 2 Wattmeter methods

7. To study and verify Thevenin's and Norton's theorem

8. To study and verify the superstition theorem

9. To study the R-L-C series and parallel circuits.

10. To study Star & Delta connection in a

3 - phase AC circuit.

11. To perform measurement of resistance of armature winding, series field winding and shunt field winding of a DC machine

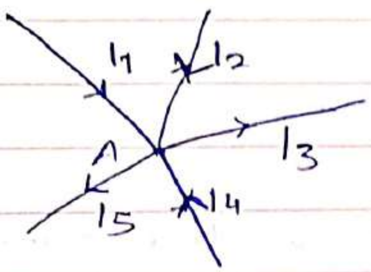
12. To s

KCL

The I law states that the algebraic sum of the current meeting at a point or junction is zero. OR

the incoming current = outgoing current
Consider a case of few conductors meeting at a point A as shown in figure. Some conductors have current leading to point A whereas some have a current leading away from point A assuming that incoming current to be +ve and outgoing -ve.

we have.

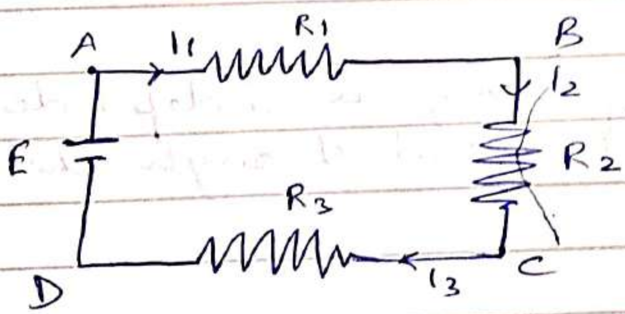


$I_1 + I_2 - I_3 + I_4 - I_5 = 0$
$I_1 + I_2 + I_4 = I_3 + I_5$
incoming currents = outgoing currents.

The algebraic and resistances in each of the conductors in a closed path. in a network + the algebraic sum of the e.m.f. in that path.

Kirchoff's Voltage Law

$\Sigma I \cdot R + \Sigma E = 0$ (closed path)

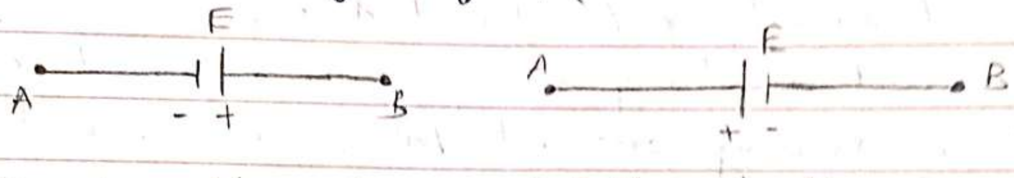


$I_1R_1 + I_2R_2 + I_3R_3 = E$

Determination of Kirchoff's Law

In applying, Kirchoff's law to specific probl, particular attention to should be given to the alg-ebraic sign of V law and emf following sign convention are suggested..

1. sign of battery emf.

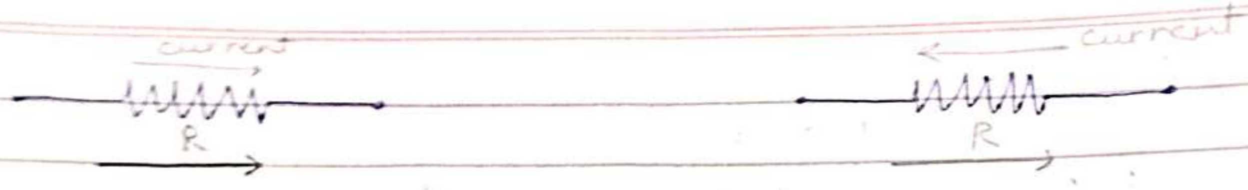


(Rise in voltage) (Fall in voltage)

- rise in voltage should be +ve
- fall in voltage should be -ve.

- it is clear that we go from -ve terminal of battery to its +ve terminal as shown in figure A.
- there is rise in potential hence this voltage should be given +ve sign if on other hand, we go from +ve terminal to -ve terminal, then there is fall in potential. voltage should be recieved by -ve side.
- the sign of battery e.m.f. is independent of the direction of current ~~to that~~ through that branch

2. Sign of IR drop.



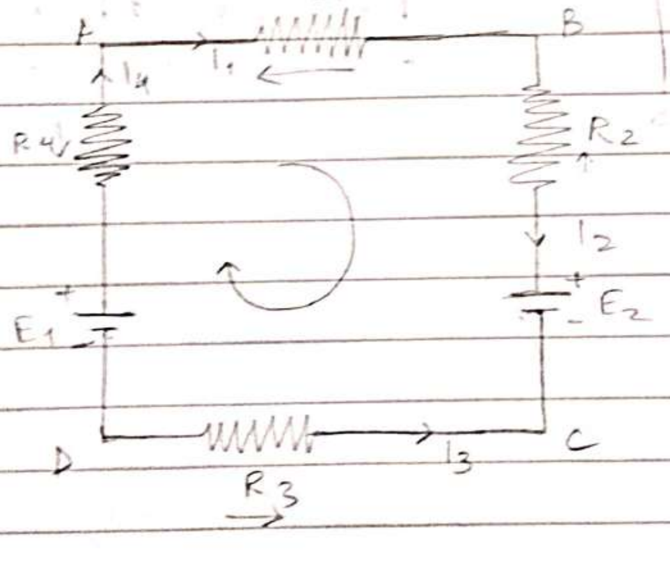
(fall in volt) $V = -IR$

(rise in volt) $V = IR$

Now, consider the case of R: if we go through the resistance in the same direction as the current then there is a fall in potential because current flows from higher to lower potential. Therefore, this voltage fall should be taken -ve.

- However, if you go in the direction against the current, then there is a rise of voltage. This voltage rise is given a +ve sign.

- it is clear that the sign of voltage drop across resistance depends on the direction of current through that resistance but it is independent of ~~any other source~~ the polarity of any other source of e.m.f. in the circuit under consideration.



$I_1 R_1 = +ve$ (~~fall~~ rise)

$I_2 R_2 = +ve$ (~~fall~~ rise)

$E_2 = -ve$ (fall)

$I_3 R_3 = -ve$ (~~rise~~ fall)

$E_1 = +ve$ (rise)

$I_4 R_4 = +ve$ (~~fall~~ rise)

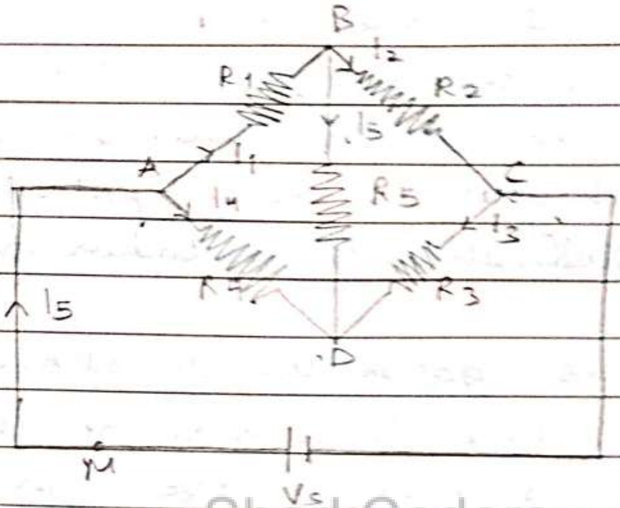
$E_2 > E_1$

• following figure shows a bridge network are the current as marked

i) Write a KCL at 4 nodes

ii) Write a KVL ~~at~~ in meshes in ABDA, then BCDB

iii) ~~ABDCA~~ ADCMA



Ans. i) At node A,

$I_5 = I_1 + I_4$

At node B,

$I_1 = I_2 + I_5$

At node C,

$I_2 = I_3 + I_5$

At node D,

$I_3 = -I_4 - I_5$

$I_3 + I_4 + I_5 = 0$

For mesh ABDA,

$-I_1R_1 - I_5R_5 + I_4R_4 = 0$

For mesh BCDB,

$-I_2R_2 - I_3R + I_5R_5 = 0$

For mesh ADCMA,

$-I_4R_4 + I_3R_3 + V_s = 0$

$$E_1 - I_1R_1 - R_2(I_1 - I_3) - R_2(I_1 - I_2) = 0$$
$$E_1 - I_1R_1 - I_1R_2 + I_3R_2 - I_1R_2 + I_2R_2 = 0$$
$$E_1 - (R_1 + R_2 + R_3)I_1 + I_2R_2 + I_3R_3 = 0$$
$$-(R_1 + R_2 + R_3)I_1 + I_2R_2 + I_3R_3 = -E_1$$
$$(R_1 + R_2 + R_3)I_1 + I_2R_2 + I_3R_3 = E_1$$

Apply KVL for Mesh 2.

$$E_2 - R_2(I_2 - I_1) - R_5(I_2 - I_3) - R_4I_2 = 0.$$
$$E_2 - I_2R_2 + I_1R_2 - I_2R_5 + I_3R_5 - I_2R_4 = 0$$
$$\cancel{E_2 - R_2 I_1 R}$$
$$E_2 - I_1R_2 - (R_2 + R_4 + R_3)I_2 + I_3R_5 = 0$$
$$R_2I_1 - (R_2 + R_4 + R_5)I_2 + I_3R_5 = -E_2$$
$$-R_2I_1 + (R_2 + R_4 + R_5)I_2 - I_3R_5 = E_2$$

Apply KVL for Mesh 3.

$$E_3 - R_3(I_3 - I_1) - R_6I_3 - R_7I_3 - R_5(I_3 - I_2) = 0$$
$$-I_3R_3 + I_1R_3 - I_3R_6 - I_3R_7 - I_3R_5 + I_2R_5 = -E_3$$
$$E_3 = \cancel{I_3R_3} - I_1R_3 + \cancel{I_3R_6} + \cancel{I_3R_7} + \cancel{I_3R_5} - I_2R_5$$
$$E_3 = I_3(R_3 + R_6 + R_7 + R_5) - I_1R_3 - I_2R_5$$

Arrange in matrix form,

$$\begin{bmatrix} (R_1+R_2+R_3) & -R_2 & -R_3 \\ -R_2 & (R_2+R_4+R_5) & -R_5 \\ -R_3 & -R_5 & (R_3+R_5+R_6+R_7) \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix}$$

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

$$\begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{13} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix}$$

where R_{11} = self resistance of mesh 1
R_{22} = self resistance of mesh 2
R_{33} = self resistance of mesh 3

i.e. sum of all resistances in each mesh

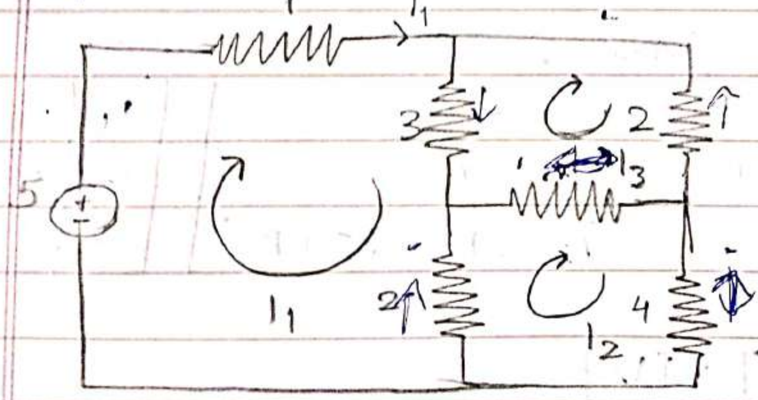
R_{12} and R_{21} = sum of all resistances common to mesh 1 and mesh 2.

R_{23} and R_{32} = sum of all resistances common to mesh 2 and mesh 3.

R_{31} and R_{13} = sum of all resistances common to mesh 1 and mesh 3

- if we assume each mesh current to flow in clockwise direction,
  - → all self resistances will always be +ve.
  - → all mutual resistances will always be -ve.

Q.



Apply to KVL to mesh 1,

$5 - 1(I_1) - 3(I_1 - I_3) - 2(I_1 - I_2) = 0$

$5 - I_1 - 3I_1 + 3I_3 - 2I_1 + 2I_2 = 0$

$5 - 6I_1 + 2I_2 + 3I_3 = 0$

$6I_1 - 2I_2 - 3I_3 = 5.$

Apply to KVL to mesh 2,

$E - I_3(2) - 3(I_3 - I_1) - 1(I_3 - I_2) = 0$

$E - 2I_3 - 3I_3 + 3I_1 - I_3 + I_2 = 0$

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

$6I_3 - I_2 - 3I_1 = 5 \qquad -3I_1 - I_2 + 6I_3 = 5$

Apply to KVL to mesh 3,

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

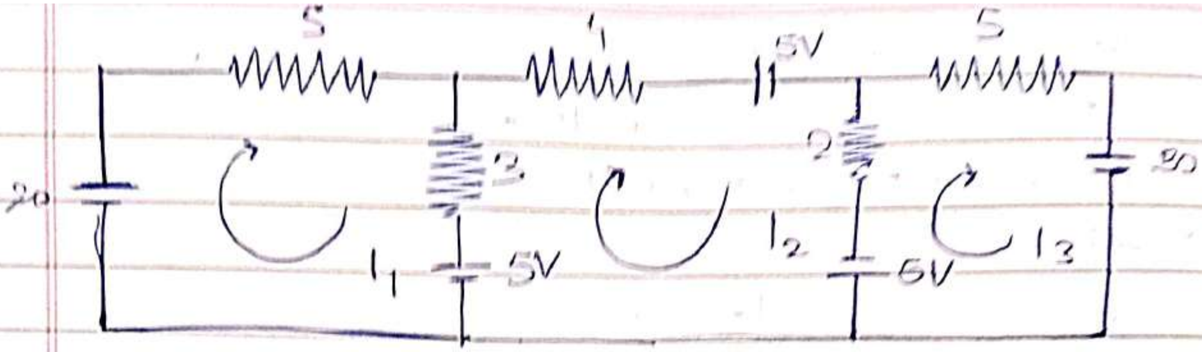
$5 + 2I_2 - 2I_1 + I_2 - I_3 - 4I_2 = 0$

$5 - I_2 - 2I_1 - I_3 = 0$

$2I_1 + I_2 + I_3 = 5$

$$\begin{bmatrix} 6 & -2 & -3 \\ 3 & 1 & -6 \\ 2 & 1 & 1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 5 \\ -5 \\ 5 \end{bmatrix}$$

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



Each battery in the circuit

Apply KVL to mesh 1

$20 - 5I_1 - 3(I_1 - I_2) - 5 = 0$

$20 - 5I_1 - 3I_1 + 3I_2 - 5 = 0$

$20 - 8I_1 + 3I_2 - 5 = 0$

$-8I_1 + 3I_2 + 15 = 0$

$8I_1 - 3I_2 = 15$

Apply KVL to mesh 2,

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

$\cancel{5} \cancel{- 3I_2} \cancel{+ 3I_1} \cancel{- 4I_2} + \cancel{5} \cancel{- 2I_2} + 2I_3 + \cancel{5} = 0$

$15 - 9I_2 + 3I_1 + 2I_3 = 0$

$\cancel{3I_1 + 2I_3}$

$3I_1 - 9I_2 + 2I_3 = -15$

$-3I_1 + 9I_2 - 2I_3 = 15$

Apply KVL to mesh 3,

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

$-5 - 2I_3 + 2I_2 - 8I_3 + 30 = 0$

$\cancel{2I_2 - 10I_3 + 35 = 0}$

$\boxed{10I_3 - 2I_2 = 35}$

$\cancel{5I_3 - I_2}$

$\cancel{-5 - 2I}$

$2I_2 - 10I_3 = 35$

higher to lower → -ve (potential)

$$\begin{bmatrix} 8 & -3 & 0 \\ -3 & 9 & -2 \\ 0 & -2 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 15 \\ 15 \\ 25 \end{bmatrix}$$

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

$= 8\,(90-4) + 3\,(-30-0) + 0$

$= 688 - 90$

$= 598$

$$\Delta_1 = \begin{bmatrix} 15 & -3 & 0 \\ 15 & 9 & -2 \\ 25 & -2 & 10 \end{bmatrix}$$

$= 15\,(90-4) + 3\,(150+50) + 0$

$= 15 \times 86 + 3 \times 200$

$= 1290 + 600 = 1890$

Cramer's Rule.

$$\Delta_2 = \begin{bmatrix} 8 & 15 & 0 \\ -3 & 15 & -2 \\ 0 & 25 & 10 \end{bmatrix}$$

$= 8\,(150+50) - 15\,(-30+0) + 0$

$= 8 \times 200 + 450$

$= 1600 + 450 = 2050$

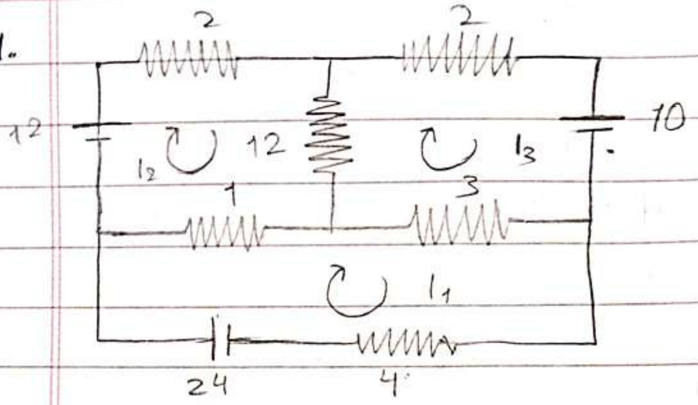
$$\Delta_3 = \begin{bmatrix} 8 & -3 & 15 \\ -3 & 9 & 15 \\ 0 & -2 & 25 \end{bmatrix}$$

$= 8\,(225+30) + 3\,(-75+0) + 15\,(6+0)$

$= 8 \times 255 - 225 + 90 \quad = 2040 - 225 + 90 =$

$= 2130 - 225 = 1905$

1.



Determine current through 4Ω resistance

Ans. Apply KVL to mesh 1,

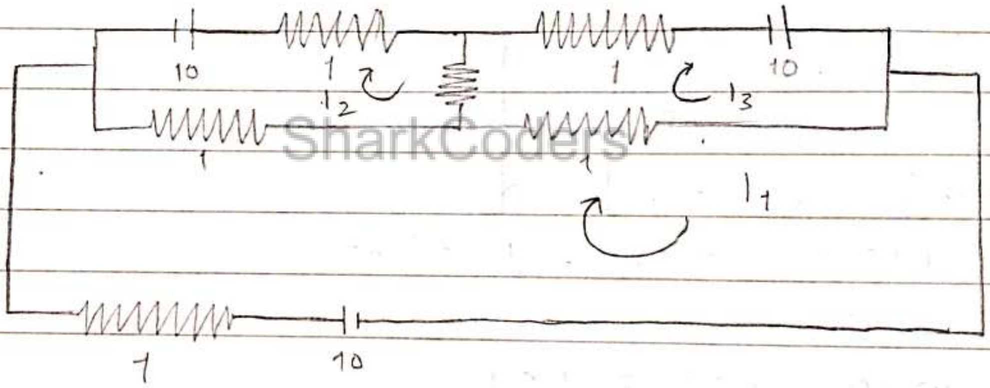
$$-4I_1 + 24 + 1(I_1 - I_2) + 3(I_1 - I_3) = 0$$

$$\cancel{-4I_1} + 24 + \cancel{I_1} - I_2 \cancel{+3I_1} - 3I_3 = 0$$

$$-3I_3 - I_2 + 24 = 0$$

$$\cancel{8}\; I_2 + 3I_3 = 24.$$

2.

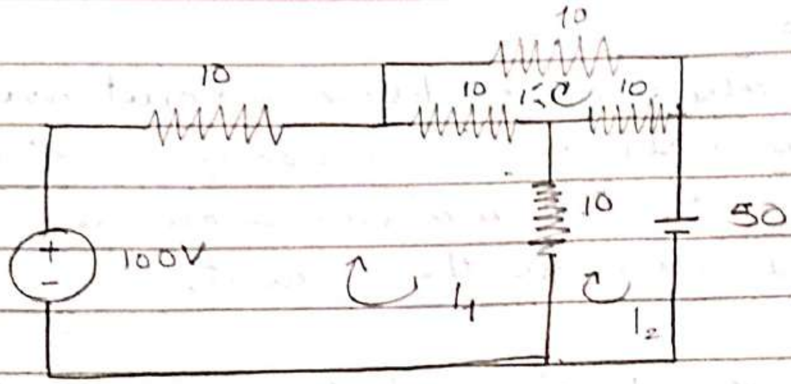


Find all the mesh currents.

Ans. Apply KVL to mesh 1,

$10 - I_1$

Q 3.



Find all the mesh currents

Ans. Apply KVL to mesh 1,

$100 - 10I_1 - 10(I_1 - I_3) - 10(I_1 - I_2) = 0$

$100 - 10I_1 - 10I_1 + 10I_3 - 10I_1 + 10I_2 = 0$

$100 - 30I_1 + 10I_2 + 10I_3 = 0$

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

$3I_1 - I_2 - I_3 = 10$

Apply KVL to mesh 2,

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

$50 - 10I_2 + 10I_1 - 10I_2 + 10I_3 = 0$

$50 + 10I_1 - 20I_2 + 10I_3 = 0$

$-10I_1 + 20I_2 - 10I_3 = 50$

Apply KVL to mesh 3,

$-10(I_3 - I_2) - 10($

Page

Nodal analysis

A method to analyse a complesc circuit using KCL, to find the voltage in the electric circuit. As the name suggests, the analysis is carried out w.r. reference to each node in the circuit.

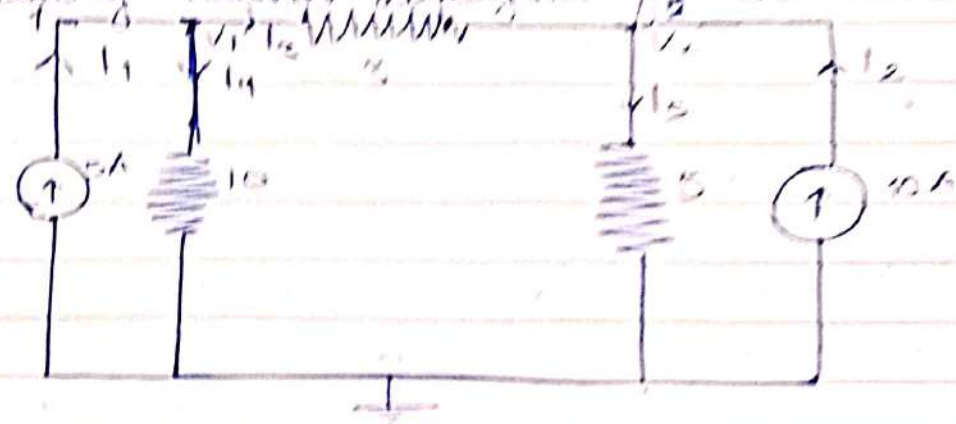
- just the complement of mesh / root analysis.

- in this analysis, the voltage drop is measured with respect to 2 nodes.
  - → ~~one~~ first, is the main node.
  - → second is the reference node.

- generally the grounded node is considered as the reference node.

- Steps to solve nodal analysis :-
  - → select the reference node i.e. usually the ground ones
  - → identify all the principle nodes in the circuit
  - → all the nodes escept the reference nodes are designated as V_1, V_2, and so on.
  - → assign the current to each branch. ~~Esplan~~ Express the branch current in terms of node voltages by using Ohm's Law.
  - → ~~A~~ apply KCL to all nodes (escept reference node) and write the nodal equation.
  - → solve the KCL eqn to get the node voltages.

Q. Determine the current in each branch using nodal analysis for the circuit shown.



Ans. Apply KCL at node 1,

$I_1 = (I_2) + (I_4)$

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

$$5 = \frac{10V_1 - 10V_2 + 3V_1}{30}$$

$$5 = \frac{13V_1 - 10V_2}{30}$$ [reference has the value of 0]

$150 = 13V_1 - 10V_2$

$13V_1 - 10V_2 = 150$

$13V_1 = 150 + 10V_2$

Apply KCL at node 2,

$I_5 = I_2 + I_3$

$I_2 = I_5 - I_3$

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

$$\frac{3V_2 - 5V_1 + 5V_2}{15} = 10$$

$50 = 2V_2 - V_1.$

$$\frac{8V_2 - 5V_1}{15} = 10$$

$$8V_2 - 5V_1 = 150$$

$$-10V_2 + 13V_1 = 150$$

$$-2V_2 + 8V_1 = 300$$

$$8V_1 - 2V_2 = 300$$

$$4V_1 - V_2 = 150$$

$$8V_1 - 2V_1 = 300$$

$$6V_1 = 300$$

$$V_1 = 50 = V_2$$

$$13V_1 - 10V_2 = 150$$

$$(-)\ -5V_1 + 8V_2 = 150$$

$$18V_1 - 18V_2 = 0$$

$$18V_1 = 18V_2$$

$$V_1 = V_2.$$

$$13V_1 - 10V_2 = 150$$

$$(-)\ -5V_1 + 8V_2 = 150$$

$$18V_1 - 18V_2 = 0$$

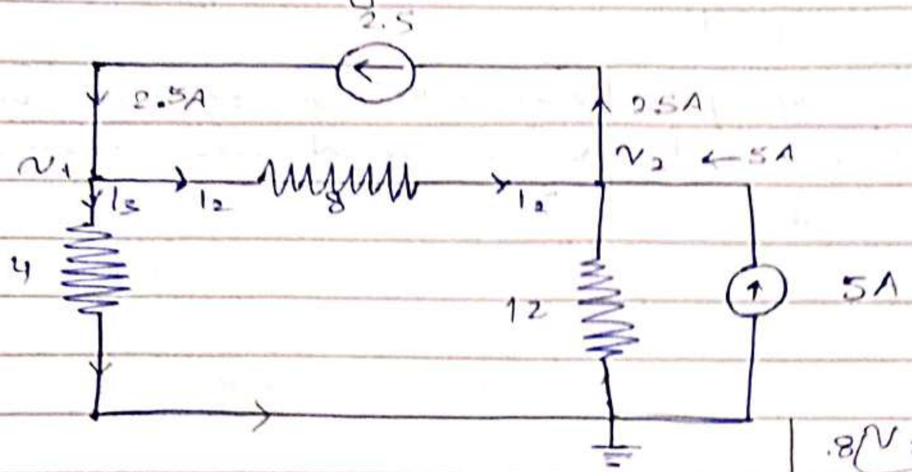
$$V_1 = V_2.$$

~~Q. Find the I in each branch using nodal an~~

$$I_{10} = \frac{50}{10} = 5$$

$$I_5 = \frac{V_2}{5} = \frac{50}{5} = 10$$

Q. Determine the node voltage in the circuit using nodal analysis.



$V_2 = I_1 + 2.5 - I_2$

$V_1 = I_2 + I_3 - 2.5$

$V_1 = I_2 + I_3 - 2.5$

$V_2 = -5 - I_2 + 2.5$

$V_1 = I_2 + I_3 - 2.5$

$V_2 = -I_2 - 2.5$

$V_1 = \frac{V_1}{8} + \frac{V_1}{4} - 2.5$

$V_1 = \frac{V_1 + 2V_1 - 10}{8}$

$8V_1 = 3V_1 - 10$

$5V_1 = -10$

$V_1 = -2$

$V_2 = -I_2 - 2.5$

$V_2 = \frac{V_1}{8} - 2.5$

$8V_2 = V_1 - 2.5$

$8V_2 = -2 - 2.5$

$V_2 = \frac{-4.5}{8}$

$V_2 = 0.25 - 2.5$

$V_2 = -2.25$

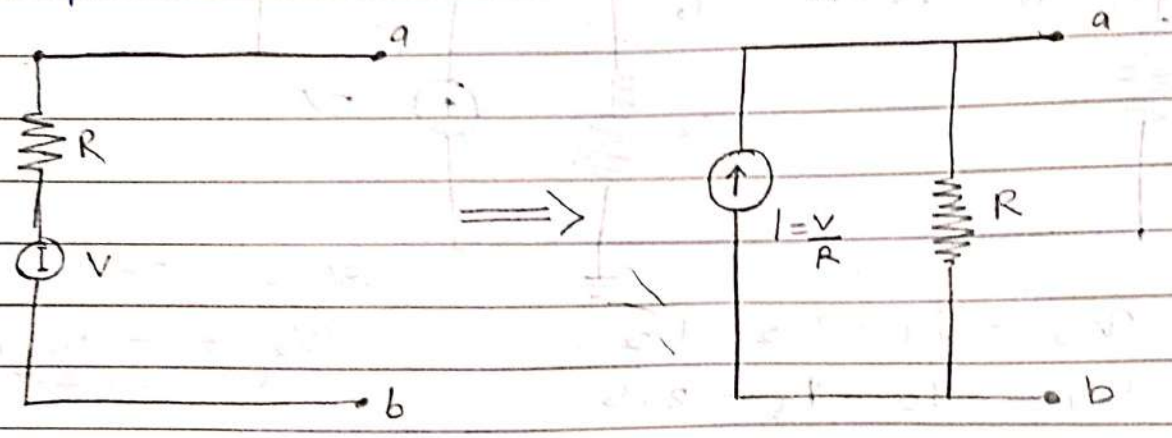
$V_1 = -2$

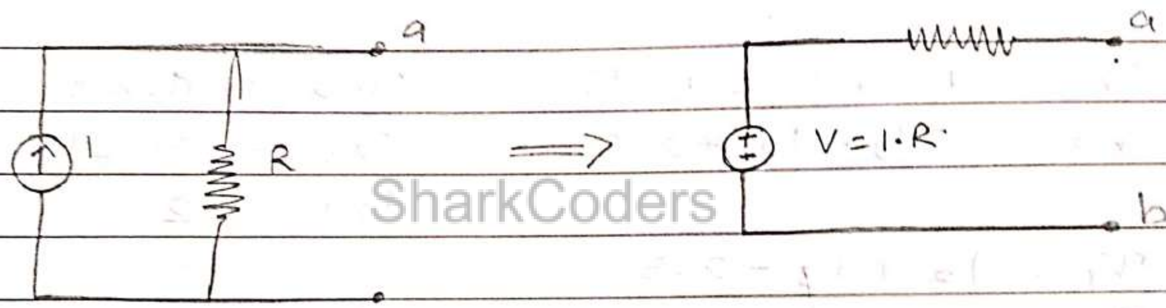
1.

Q. Determine Req for the given ckt.

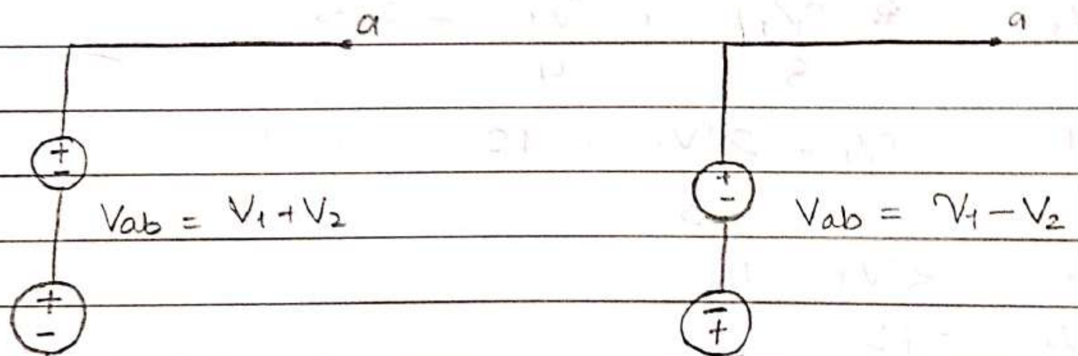
Source Transformation

1. Conversion of practical voltage source into practical current source and vice versa.

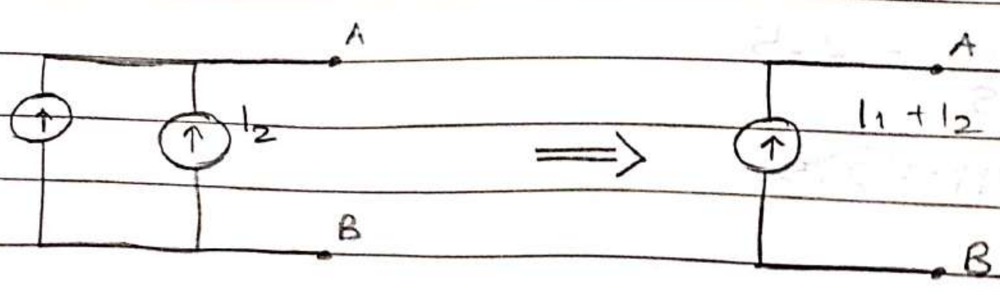


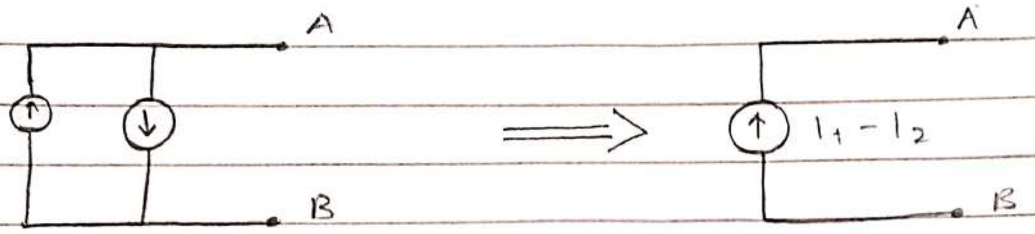


2. Series connection of voltage source

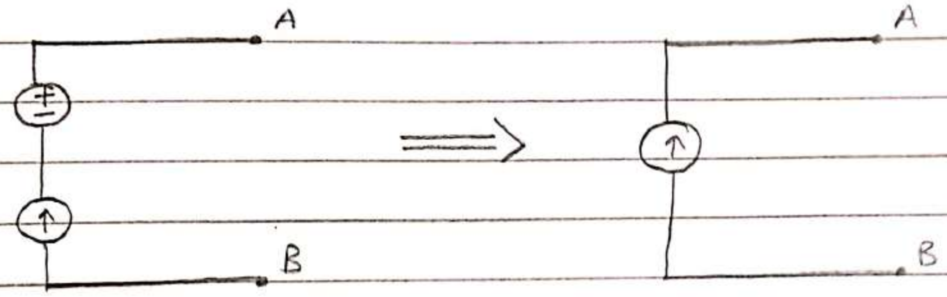


3. Parallel connection of current source

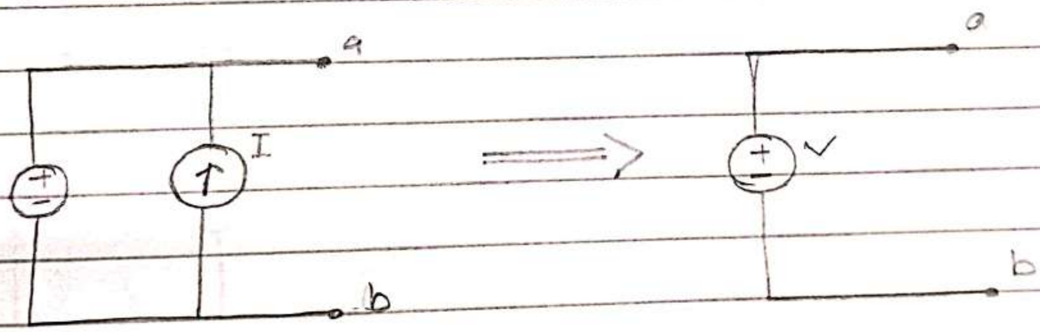




4. Series combination of ideal voltage source and current source.

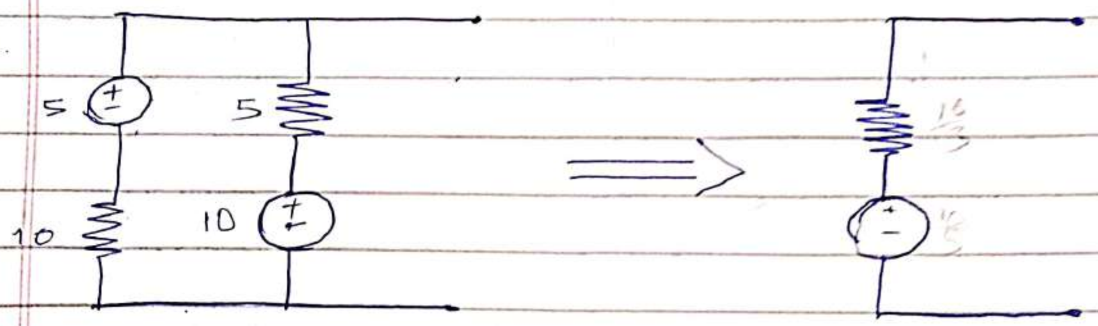


5. Parallel combination of ideal voltage source and ideal current source



Q. Convert the combination into a single voltage source ~~in series~~ with a single element.

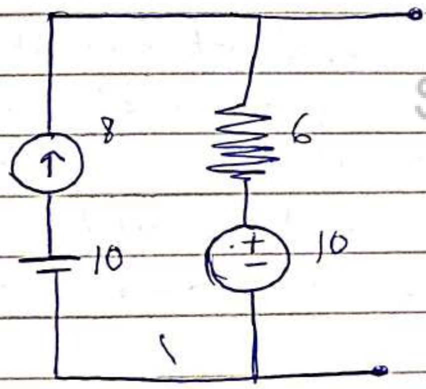
Ans.



$I' = \frac{V}{R} = \frac{5}{10} = 0.5$

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

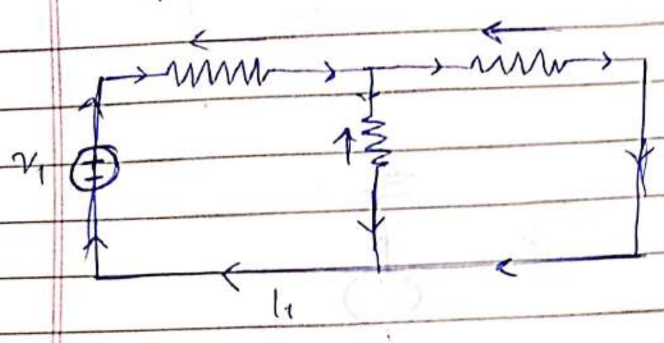
Q.



Q. Using force transformation find the V across 10 Ω resistor in the circuit shown below.

Ans.

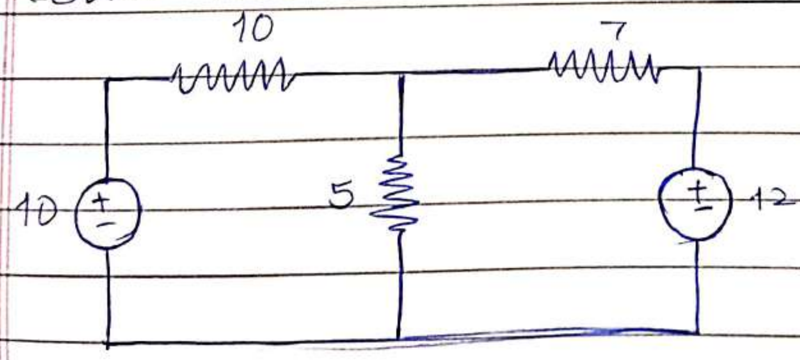
Superposition Theorem



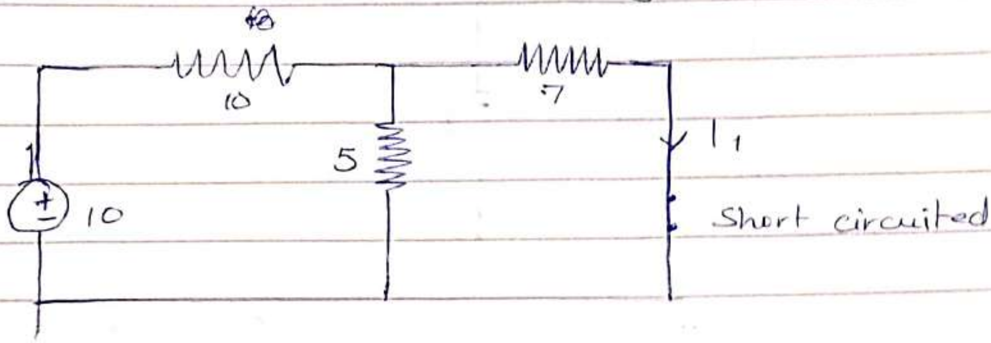
The super position is applicable to all linear networks.
the procedure for analysing a circuit by superposi-
-on theorem is as follows:

a) select any source in the circuit making the oth. source = 0.
b) ~~The~~ Replace the V source by short circuit.
c) Replace the current source by open circuit
d) In obtaining the algebraic sum, if the current flows in the same direction, they add each other
e) However, if they are in opposite direction, they subtract from each other.

Q. Using the method of superposition, determine the current through a 5Ω resistance for the circuit sh-
-own below.



Case I: 10V Source acting alone.



$$R_T = 10 + (5 \| 7)$$

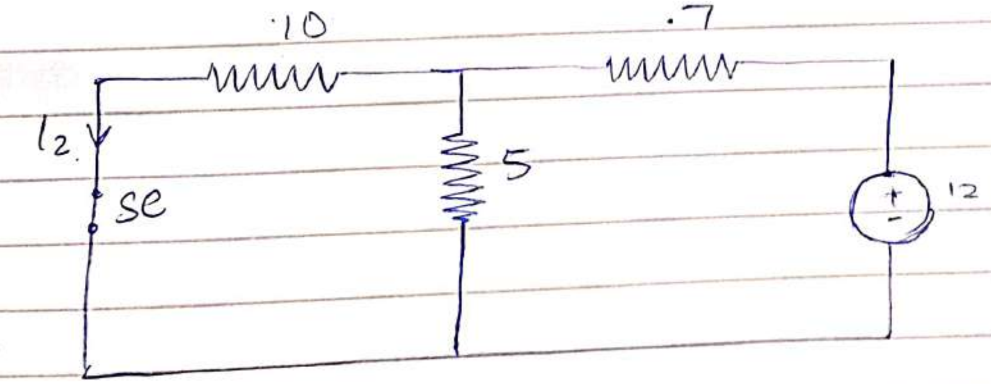
$$= 10 + \frac{5 \times 7}{5+7} = \frac{120}{12} + \frac{35}{12} = \frac{155}{12}$$

Total current

$$I_T = \frac{V}{RT} = \frac{10}{12.92} = 0.77 \text{ A}$$

$$I_1 = I_T \cdot \frac{7}{5+7} = \frac{0.77 \times 7}{12} = \frac{5.39}{12} = 0.45 \text{ A}$$

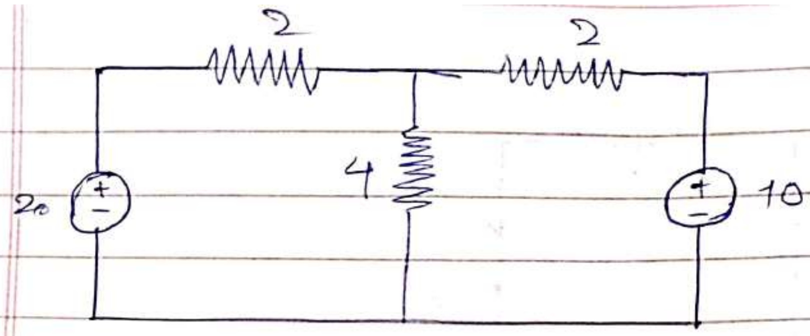
Case II: 12V source acting alone.



$$I_2 = I_T \times \frac{10}{10+5} = 0.77$$

Total current $I = I_1 + I_2 = 0.45 + 0.77 = 1.22$

$I_T = 1.46.$



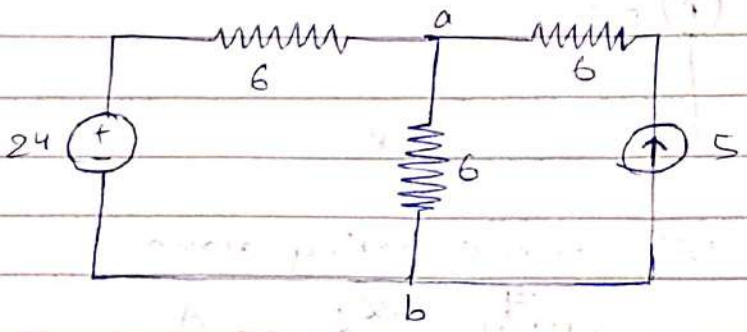
$R_T = 2 + \frac{4 \times 2}{6} = 2 + \frac{8}{6} = \frac{20}{6} = 3.34$

$I_T = \frac{V}{R_T} = \frac{20}{3.34} = 5.99$.

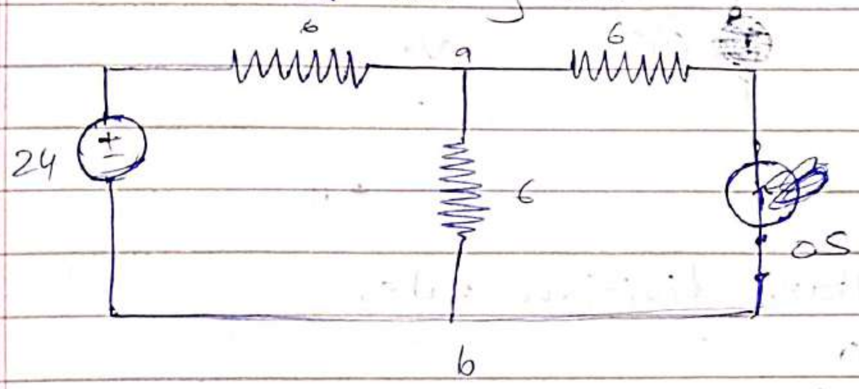
$I_1 = 1 \times \frac{2}{6} = 2$.

$R_T = 2 + \frac{8}{6} = 3.34$

Q. Determine the current I in the network by the principle of superposition.

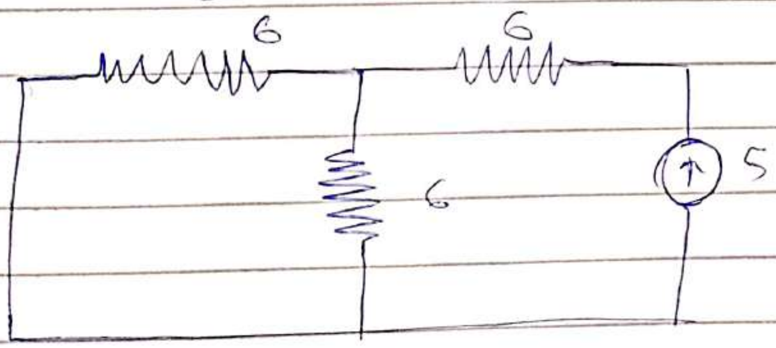


Ans. Case I : 24V acting alone



$$I_1 = \frac{V}{R} = \frac{24}{12} = 2$$

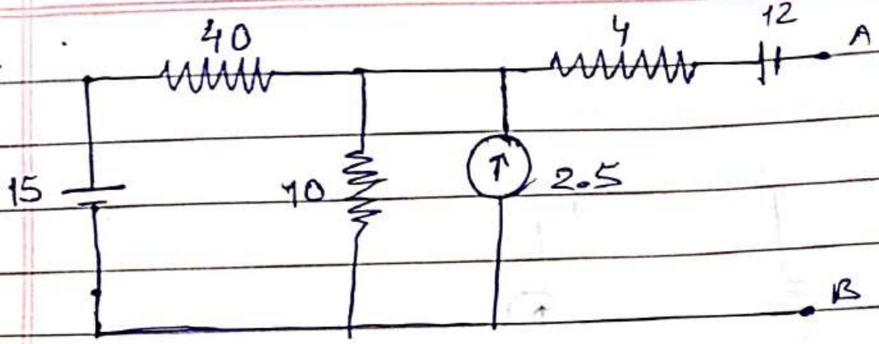
Case II : 5 V acting alone



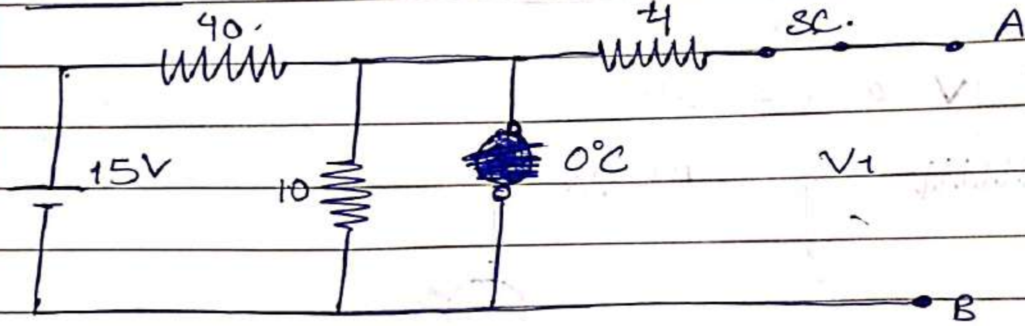
$$I_2 = 5 \times \frac{6}{6+6} = \frac{30}{12} = 2.5$$

$$I = I_1 + I_2 = 2 + 2.5 = 4.5$$

Q.



Case 1 : When 15V source acting alone

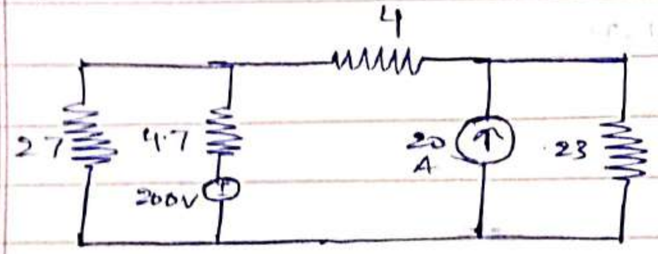


By using voltage division rule,

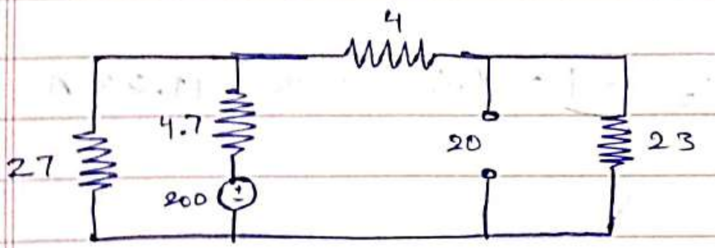
$$V_1 = \frac{15 \times 10}{10+40} =$$

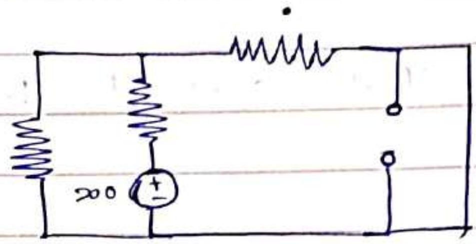
Q.

Q. Find the current in 23 Ω R in the circuit shown below.



Case I: When 200V acts alone.





$$R_T = 47 + (27 \| 27)$$

$$= 47 + \frac{27 \times 27}{27+27} = \cancel{47+}\ 60.5$$

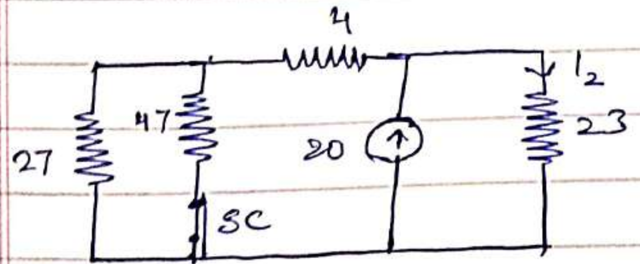
Total current

$$I_T = \frac{V}{R_T} = \frac{200}{60.5} = 3.31.$$

By using CDR,

$$I_1 = I_T \times \frac{27}{54} = 1.65$$

Case II: 20A source acting alone



Total resistance

$R_T = 4 + (27 \| 47)$

$= 4 + \frac{27 \times 47}{74} = 21.15$

By using CDR,

$I_2 = 20 \times \frac{21.15}{21.15 + 23} = 9.58$

Total current $= I_1 + I_2 = I = 1.65 + 9.58 = 11.23\ A$

Date
Page

Q. A ring shaped ~~bar~~ electromagnet has an air gap of 6 mm and cross-sectional area of . The mean length of core is 60 cm. Calculate the mmf required to produce a flux density of 0.4 Wb/m² in the gap. Take $\mu_r = 400$.

Ans. Given

$l_g = 6\,mm$
$= 6 \times 10^{-3}\,m$

$a = 12\,cm^2$
$= 12 \times 10^{-4}\,m^2$

$l_i = 60\,cm$
$= 0.6\,m$

$B = 0.4\,Wb/m^2$

mmf = ?

Flux $\phi = B \times a$
$= 0.4 \times 12 \times 10^{-4}$
$= 4.8 \times 10^{-4}$.

$\therefore \phi = 4.8$

$$\text{Total reluctance} = \frac{l_i}{\mu_0 \mu_{r_i} a} + \frac{l_g}{\mu_0 a}$$

$$= \left(\frac{l_i}{\mu_r a} + \frac{l_g}{a}\right) \frac{1}{\mu_0}$$

$$= \left(\frac{0.6}{400 \times 12 \times 10^{-4+2}} + \frac{6 \times 10^{-3+4}}{12 \times 10^{-4}}\right) \frac{1}{4\pi \times 10^{-7}}$$

$$= \left(\frac{60}{48} + 0.5 \times 10\right) \frac{1}{4\pi \times 10^{-7}}$$

$= 4{,}976{,}114.65$

Q. An iron ring of 50 cm mean length has an air gap of 1 mm and winding 200 turns. If the permeability of iron is 500, then current of 1 A flows through the coil, find the flux density.

Ans. Given

$l_I = 500$ cm $= 0.5$ m

$l_g = 1$ mm $= 1 \times 10^{-3}$ m

$N = 200$

$I = 1$

$B = ?$

$\phi = B \times a.$

Total mmf $= H_i l_i + H_g l_g$

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

$$= \frac{B}{\mu_0 \mu_r} l_i + \frac{B}{\mu_0} l_g$$

$$= \frac{B}{\mu_0}\left(\frac{l_i}{\mu_r} + l_g\right)$$

$$200 = B\left(\frac{0.5}{4 \times 3.14 \times 10^{-7} \times 500} + \frac{10^{-3}}{4\pi \times 10^{-7}}\right).$$

$$B = 7.96$$

SharkCoders

Q. A ring composed of 3 section of cross sectional a is 0.01 m^2 for each section. The mean are lengths 0.3 m, 0.2 m, 0.1 m. An air gap length of 0.1 mm cut in the ring. μ_r for ABC section are.

Ans. Given

$l_a = 0.3$ $\mu_{ra} = 5000$ $\phi = 7.5 \times 10^{-4}$ Wb/m^2

$l_b = 0.2$ $\mu_{rb} = 1000$

$l_c = 0$ $\mu_{rc} = 10000$

To find

i) mmf

ii) current if coil has

iii) Reluctance in 4 parts

a) Rel of air gap $S_{ag} = \frac{1}{\mu_0} \times \frac{l_g}{a}$

$$= \frac{l_g}{\mu_0 a}$$

$$= \frac{1 \times 10^{-4}}{4\pi \times 10^{-7} \times 0.001}$$

$S_{ag} = 79618$ AT/Wb

b) Reluctance of section of the ring S_a

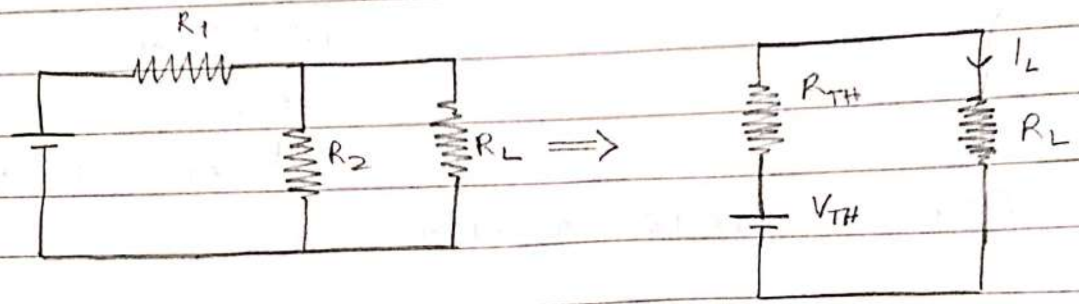
$$S_a = \frac{l_a}{\mu_0 \mu_{ra} a} = \frac{0.8}{4\pi \times 10^{-7} \times 5000 \times 0.001}$$

$$= 47770 \text{ AT Wb}^{-1}$$

c) S_L

Thevenin's Theorem

It states that any two terminal network can be replaced by an equivalent circuit consisting of a voltage source (V_{TH}) in series with resistance (R_{Th}). The voltage V_{TH} is the open circuit voltage across these two terminals. R_{Th} is the resistance seen through the network across these two ~~#~~ terminal.



Thevenin's equivalent circuit

$$I_L = \frac{V_{TH}}{R_{TH} + R_L}$$

Steps to obtain Thevenin's equivalent circuit

1. Temporarily remove the load resistance (R_L) whose current is required.

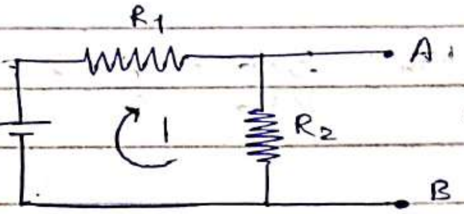
2. Find the open circuit voltage (V_{oc}) which appears across the two terminals from where the load resistance has been removed. It is also called as thevenin's voltage (V_{TH}).

3. Calculate the resistance of whole network from the terminals after all the voltage source are replaced by short circuit and all the current sources replaced by open circuit. It is also called R_{TH}.

4. Replace the entire network by a single thevenin's voltage source whose voltage is V_{TH} and ~~whose~~ whose

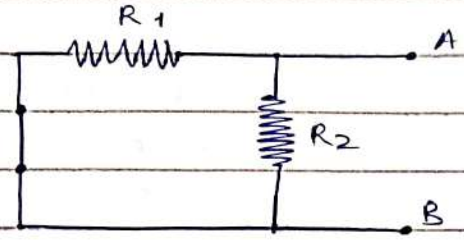
resistance is R_{TH} as shown in figure.

i.



$\Leftarrow V_{TH}$ or $V_{oc} = I \cdot R_2$

ii.



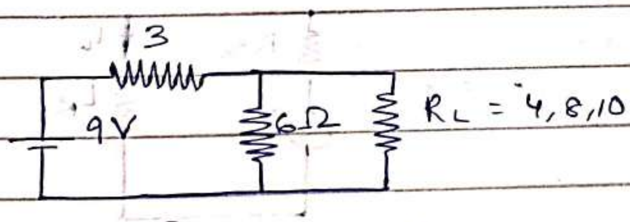
(series / parallel.)

$\Leftarrow R_{TH} = \dfrac{R_1 R_2}{R_1 + R_2}$

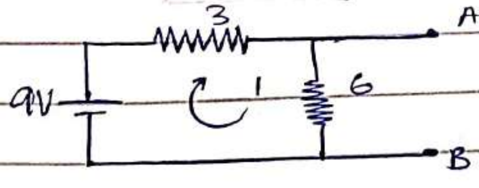
5. Connect the load resistance R_L back to its terminal from where it was previously removed.

6. Finally calculate the current flowing through load resistances by using eq^n $I_L = \dfrac{V_{TH}}{R_{TH} + R_L}$

Q. Consider a circuit shown in following figure and determine the thevenin's equivalent circuit for the load resistance R_L. Then determine I_L if $R_L = 4\Omega,\ 8\Omega,\ 10\Omega$
(i) (ii) (iii)



Ans.



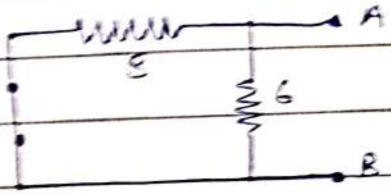
$\Leftarrow V_{TH}$

1) Calculation of V_{oc} / V_{TH}

$$I = \frac{V}{R} = \frac{9}{3+6} = \frac{9}{9} = 1$$

$$\boxed{\therefore V_{TH} = 6V}$$

2) Calculation for R_{TH}



$\Leftarrow \quad R_{TH} = \frac{3 \times 6}{3+6} = \frac{18}{9} = 2$

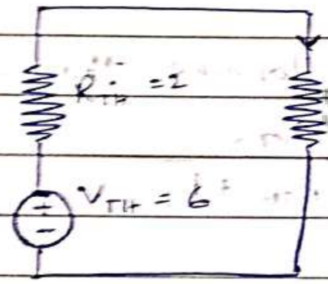
$\therefore I_L = \frac{V_{TH}}{R_{TH} + R_L}$

when $R_L = 4$

$I_L = \frac{6}{2+4} = \frac{6}{6} = 1$

$\boxed{\therefore I_2 = 1\ A}$

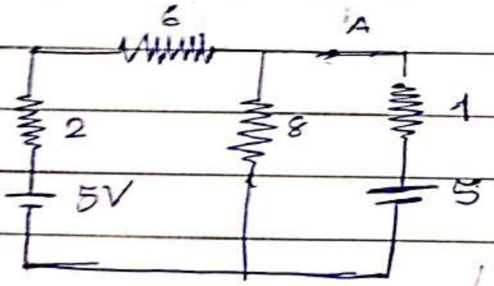
3) Thevenin's equivalent circuit :



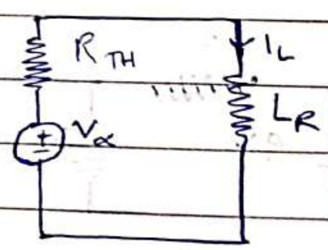
when $R_L = 8$

$I_L = \frac{2 \times 8}{2+8} = 0.6$

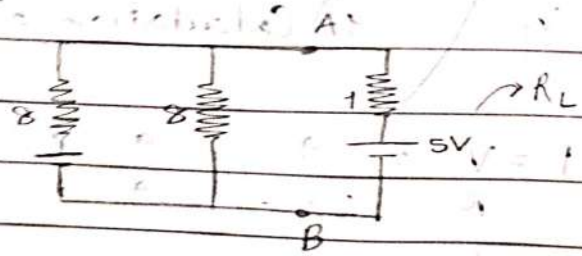
Q. Determine the thevenin's equivalent circuit between terminals A and B for the circuit shown below.

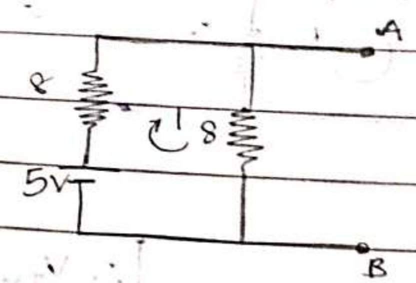


$\Longrightarrow$



Ans.





1) Calculation of V_{TH}

$$I = \frac{V}{R} = \frac{5}{4} = 1.25$$

$$V_{TH} = 8 \times I = 8 \times 1.25 = 10$$

$$\boxed{\therefore V_{TH} = 10}$$

2) Calculation's of R_{TH}

$$R_{TH} = \frac{8 \times 8}{8+8} = \frac{64}{16}$$

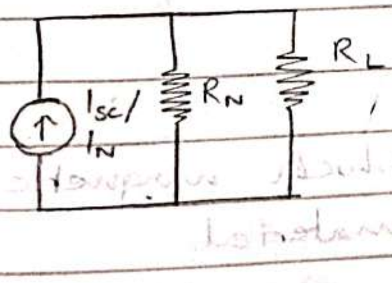
$$= 4$$

$$I_L = \frac{V_{TH}}{R_{TH} + R_L} = \frac{10}{4+1}$$

$$= 2$$

Norton's Theorem.

It states that any two terminals of an active resistance network may be represented by a parallel combination of current source and resistors. The value of the current source is a short circuit current at the terminals and the value of the equivalent resistance seen looking back into the network with all energy sources replaced by thier respective internal resistances.



Norton's equivalent circuit

Unit III: Magnetic Circuits

Magnetic Flux (ϕ)

Number of magnetic lines of force or the normal component of magnetic field passing through the surface of specified ~~one~~ area.

- more the lines of force, greater the flux and stronger the magnetic field. $\phi \propto B$
  - $\phi = B \cdot A$
  - → SI unit – Weber (Wb)
  - → $\phi = \vec{B} \cdot \vec{A}$
  - → B = magnetic flux density
  - → A = area of surface

- $\phi = BA\cos\theta$

Magnetic ~~flux~~ flux density (B)

- Amount of magnetic flux per unit area of surface taken perpendicular to the direction of magnetic flux
  - → SI unit – $Wb\,m^{-2}$

- B is a measure of the ~~strength~~ density of a magnetic field at a given point.
  - → $B = \dfrac{\phi}{A}$ $\left[T = \dfrac{Wb}{m^2} \right]$

Permeability (μ)

Measure of the ease with which magnetic lines of force passing through a given material.

- magnetic permeability $\propto$ conductivity of magnetic lines of force

- Definitions - Unit III & IV ✓
- Derivations - avg } Unit IV ✓
  - rms ✓
  - Unit III ✓
  - elect. circ. & mag. circ. ✓

(D)

Energy stored in mag. field.

Series mag. field

Assignment

- Notes sent for Unit IV
- Capacitor and all circuits derivation

• e.g.: soft iron has high permeability

• SI unit - Henry / meter (H/m)

$\mu = \frac{B}{H}$ [H = magnetic field strength, μ = permeability]

• μ of free space/vacuum = μ_0

$\mu_0 = 4\pi \times 10^{-7} \left(\frac{H}{m}\right)$

Relative μ

Measure of relative ease with which a given ~~core~~ material conducts magnetic flux compared with the conduction of flux in air.

• $\mu = 1$ for air / vacuum

Absolute permeability

μ of a non-magnetic material such as air, copper, wood, glass, etc. is usually equal to unity.

μ of magnetic materials such as Co, Ni, Fe, steel, and alloys ~~are~~ is greater than 1 and is not constant.

Magnetic field strength (H)

Ratio of the mmf (magneto-motive force) which is required to create a certain flux density within a certain material per unit length of that material.

• mmf = NI

- $H = \frac{NI}{l}$ $\left[H = \frac{A \cdot T}{m} \right]$ where A – ampere
  T – turns
  m – length

- H at any point within a magnetic field is numerically equal to the force experienced by a north pole of 1 Wb placed at that point.

- $B \propto H$

  $\frac{B}{H} = \text{constant} = \mu$

  $H = \frac{B}{\mu}$ [μ = absolute permeability of medium]

Reluctance

- Property of a material which opposes the magnetic flux in it.

- analogous to resistance

- reluctance (S) = $\frac{mmf}{flux} = \frac{AT}{Wb}$

- $S = \frac{l}{\mu_0 \mu_r a}$ [l = length
  μ_0 = μ of vacuum
  μ_r = relative μ
  a = area of ~~co~~ cross-section]

- SI unit – $AT \cdot Wb^{-1}$

Page

Permeance

Reciprocal of reluctance

- analogous to conductance

- property of a material which ~~carries~~ conducts the ϕ in it.

- permeance = $\dfrac{1}{\text{reluctance}} = \dfrac{\mu_0 \mu_r a}{l}$

- SI unit - $Wb \cdot A^{-1} T^{-1}$

Q. The area of the face of pole shoe is 1.5 cm² and the total flux is 0.18 mWb. Calculate the flux density in air gap.

Ans. $A = 1.5\ cm^2 = 1.5 \times 10^{-4}\ m^2$

$\phi = 0.18\ mWb = 0.18 \times 10^{-3}\ Wb$

$B = ?$

$B = \dfrac{\phi}{A} = \dfrac{0.18 \times 10^{-3}}{1.5 \times 10^{-4}} = 0.12 \times 10 = 1.2\ Wb\ m^{-2}$

Q. A coil of 100 turns is wound uniformly over an isolator ring with a mean circumference of 2m and a uniform sectional area of 0.025 cm². If the coil carries a current of 2A, calculate.

i. mmf of circuit

ii. ~~mean~~ H (magnetic field strength)

iii. B (magnetic field density)

iv. ϕ (magnetic flux)

Ans. $N = 100$

$a = 0.025 \text{ cm}^2 = 0.025 \times (10^{-2})^2 \text{ m}^2$

$= 0.025 \times 10^{-4} \text{ m}^2$

$I = 2A$

i. $\text{mmf} = NI$

$= 100 \times 2$

$= 200 \text{ AT}$

$\boxed{\therefore \text{The mmf is of } 200 \text{ AT.}}$

ii. $H = \frac{\text{mmf}}{l} = \frac{NI}{l} = \frac{200}{2} = 100 \text{ AT/m}$

iii. $B \propto H$

$B = \mu_0 H$

$B = 4\pi \times 10^{-7} \times 10^2$

$= 4\pi \times 10^{-5}$

$= 12.56 \times 10^{-5} \text{ Wb m}^{-2}$

$\boxed{\therefore \text{The magnetic field density is } 12.56 \times 10^{-5} \text{ Wb m}^{-2}}$

iv. $\phi = B \cdot A$

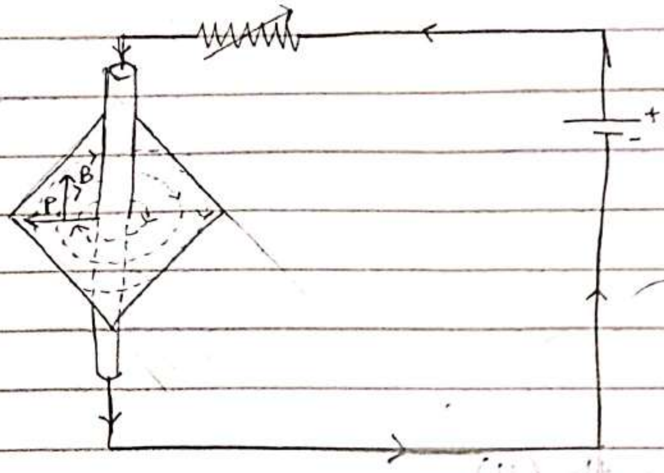
$= 12.56 \times 10^{-5} \times 0.025 \times 10^{-4}$

$\phi = 0.314 \times 10^{-9} \text{ Wb}$

$\boxed{\therefore \text{The magnetic flux is } 0.314 \times 10^{-9} \text{ Wb}}$

- How to take length?
- $\mu_0 = ?$ 1 OR 4π?
- Is length = circumference

Magnetic field of a straight conductor



"The magnetic field is in concentric circles around the straight conductor.

Let,

H = magnetic field strength at point P.

r = ⊥ distance of point P from the centre of the conductor.

I = current flowing through conductor

Work done = H × circumference

$= H \times 2\pi r$

$= 2\pi r H$ joules

W.D = flux cut by the conductor.

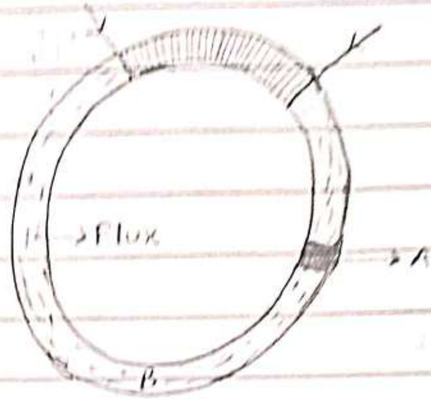
Direction of current in conductor (dot & cross convention)

o - conductor with no current

⊙ - conductor carrying current towards observer.

⊕ - conductor carrying current away from observer.

Magnetic Circuit



- Magnetic field strength (H)

$$H = \frac{mmf}{l} = \frac{NI}{l} \quad AT\,m^{-1}$$

- $$\phi = \frac{mmf}{reluctance} = B \times A \cos\theta = \frac{NI}{S}$$

But $B = \mu_0 \mu_r (H)$

$$\Rightarrow B = \mu_0 \mu_r \left(\frac{NI}{l}\right) \quad Wb\,m^{-2} \quad \text{—— (1)}$$

Total ϕ produced.

$$\phi = B \times A = \left(\frac{\mu_0 \mu_r NI}{l}\right)(A) \quad Wb \qquad [\text{From (1)}]$$

$$\therefore \phi = \frac{NI}{\frac{l}{\mu_0 \mu_r A}}$$

where NI = mmf

$\frac{l}{\mu_0 \mu_r A}$ = reluctance (S) of cir

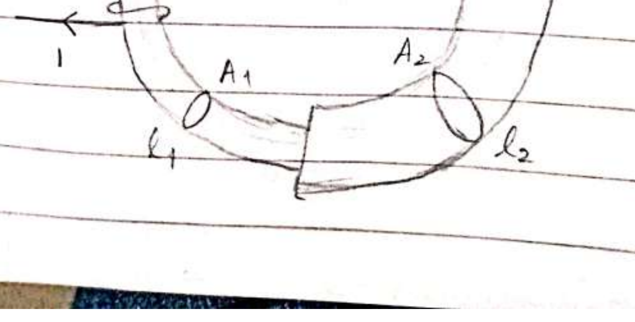
Similarities between magnetic circuits and electric circuits

Electric	Magnetic
a) closed path followed by current	closed path followed by magnetic flux.
b) current is flown thr- -ough a conductor $I = \frac{V}{R}$	flux is line of force through the medium from N to S pole. $\phi = \frac{mmf}{S}$
c) driving force for cur- -rent is called emf(V).	driving force for flux is mmf (AT)
d) R $\propto$ length of conductor $R = \frac{l\rho}{a}$	S $\propto$ length of magnetic path $S = \frac{l}{\mu_0 \mu_r a}$
e) current density is the rate of electric current flow- -ing per unit area. $S = \frac{I}{a}$ $A\,m^{-2}$	flux density is the amount of magnetic flux per unit area. $B = \frac{\phi}{A}$
f) the KCL and KVL are applicable to the electric circuit	the Kirchoff's flux and mmf laws are applicable to the magnetic circuit.

Differences between magnetic circuit and electric circuit

ELECTRIC	MAGNETIC
a) electric current flows in an electric circuit	ϕ does not flow but it is setup in the magnetic circuit.
b) value of resistivity varies very slightly with temp. hence resistance of an electric current is practically constant.	value of μ_r is not constant for a given material, hence the 'S' of the magnetic circuit is not constant. Rather, it depends on flux density (B_i)
c) energy needed as long as current flows through electric current	once a magnetic flux is set up in circuit. No energy needed.
d) electric field lines do not form a loop.	magnetic field lines form a loop.

Simple Series magnetic field (circuit)



• Total reluctance = S_T

$$S_T = \frac{l_1}{\mu_0 \mu_{r_1} A_1} + \frac{l_2}{\mu_0 \mu_{r_2} A_2} + \frac{l_3}{\mu_0 \mu_{r_3} A_3} + \frac{l_g}{\mu_0 A_g}$$

• Total mmf = mmf_T = (flux) · (reluctance)

$$mmf_T = \phi\left(\frac{l_1}{\mu_0 \mu_{r_1} A_1} + \frac{l_2}{\mu_0 \mu_{r_2} A_2} + \frac{l_3}{\mu_0 \mu_{r_3} A_3} + \frac{l_g}{\mu_0 A_g}\right)$$

$\because \phi = BA$

$\Rightarrow B = \frac{\phi}{A}$

$$mmf_T = \frac{B_1 l_1}{\mu_0 \mu_{r_1}} + \frac{B_2 l_2}{\mu_0 \mu_{r_2}} + \frac{B_3 l_3}{\mu_0 \mu_{r_3}} + \frac{B_g l_g}{\mu_0}$$

$\because H = \frac{B}{\mu_0 \mu_r}$

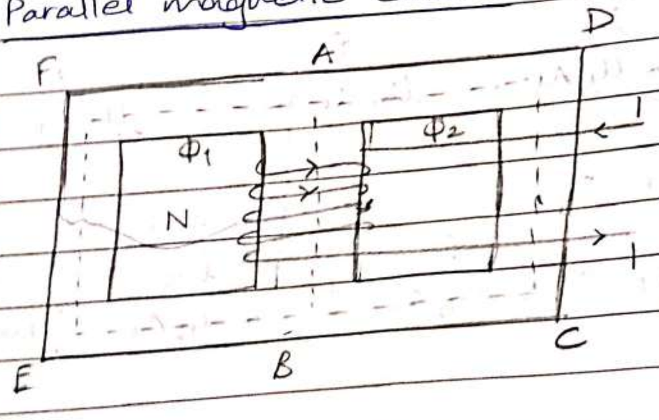
* $mmf_T = H_1 l_1 + H_2 l_2 + H_3 l_3 + H_g l_g$

• In series magnetic circuit, magnetic flux (ϕ) is the same in all the sections and all the equivalent reluctance of such magnetic circuit equals summation of the reluctance of an individual section.

• Consider a composite magnetic circuit of different magnetic material of different relative permeability along with an air gap as shown in fig.

• Therefore, the total ampere turns required for the entire series circuit in the sum of ampere turns of various parts.

Parallel magnetic circuit



$$\phi = \phi_1 + \phi_2$$

~~Total mmf required = mmf.~~

Total mmf required = (mmf required for path AB) + (mmf required for path AFEB)

OR

(mmf required for path ADCB)

Let S_c = reluctance of path AB

S_1 = reluctance of path AFEB

S_2 = reluctance of path ADCB

$\therefore NI = \phi S_c + (\phi_1 S_1 \text{ or } \phi_2 S_2)$

$\therefore$ Total mmf $= \phi S_c + \phi_1 S_1 = \phi S_c + \phi_1 S_2$

- a ‖ magnetic circuit has more than one path for magnetic flux.

- a coil of reluctance of N turns wound on central limb which carries a current of 1 ampere. The flux divides at A into two paths.

i. flux ϕ_1, along the path AFEB.

ii. flux ϕ_2, along the path ADCB,

Q. A coil of insulated wire of 500 turns and of resistance 4Ω is closely wound on an iron ring. The ring has mean diameter of 0.25 m and uniform cross-sectional area of $700 mm^2$. Calculate the total flux in the ring when a DC supply at 6V applied to the end of windings. Assume the $\mu_r = 550$.

Ans. <u>Given</u>

$N = 500$

$R = 4\Omega$

$D = 0.25$

$l = \pi \cdot D = 3.14 \times 0.25 = 0.785\ m$

$a = 700 \times 10^{-6} m^2 = 7 \times 10^{-4} m^2$

$V = 6V$

$\mu_r = 550$

$\Phi = ?$

<u>Sol^n</u>

We know that,

$\Phi = B \times A$

$I = \frac{V}{R} = \frac{6}{4} = 1.5$

$H = \frac{mmf}{l} = \frac{NI}{l} = \frac{500 \times 1.5}{\pi \times 0.25} = 955.41\ Am^{-1}$

$B = \mu H = \mu_0 \mu_r \cdot H = 4\pi \times 10^{-7} \times 550 \times 955$

$= 4\pi \times 55 \times 955 \times 10^{-6}$

$= 659714 \times 10^{-6}$

$= 0.659714$

≈ 0.66

$\phi = B \times A$
$= 0.66 \times 7 \times 10^{-4}$
$= 4.62 \times 10^{-4}$ Wb
$= 0.462 \times 10^{-3}$ Wb
~~0.462 × 10⁻³~~ $= 0.462$ mWb

Q. A ring shaped electromagnet has an air gap of 6 mm and cross-sectional area of 12 cm². The mean length of the core is 60 cm. Calculate the mmf required to produce flux density of 0.4 Wb m⁻² in the gap. Take μ_r =

Ans. Given

$l_g = 6mm = 6 \times 10^{-3}$ mm
$a = 12$ cm $= 12 \times 10^{-4}$ m²
$l_i = 60cm = 0.6$ m
$B = 0.4$ Wb m⁻²
mmf = ?

Flux $\Rightarrow \phi = B \times A$
$= 0.4 \times 12 \times 10^{-4}$
$\phi = 4.8 \times 10^{-4}$ Wb

$$\text{Total reluctance} = \frac{l_1}{\mu_0 \mu_r a} + \frac{l_g}{\mu_0 a}$$
$$= \frac{1}{\mu_0 a}\left(\frac{l_i}{\mu_r} + l_g\right)$$
$$= \frac{1}{4\pi \times 10^{-7} \times 12 \times 10^{-4}}\left(\frac{0.6}{400} + 6 \times 10^{-3}\right)$$
$$= \cancel{\frac{1}{48\pi \times 10^{-11}}}$$
$$= \left(1.5 \times 10^{-3} + 6 \times 10^{-3}\right)\frac{1}{150.79 \times 10^{-8}}$$

$$= \left(\frac{7.5\times10^{-3}}{150.79\times10^{-11}} + \frac{6\times10^{-3}}{150.79\times10^{-11}} \right)$$

$$= 9.94\times10^{-3}\times10^{8} + 0.039\times10^{8}$$

$$= 9.94\times10^{5} + 39\times10^{5}$$

$$= 48.94\times10^{5}$$

$$S = 489.4\times10^{4} \text{ AT Wb}^{-1}$$

$$mmf = S\times\phi$$

$$= 489.4\times10^{4}\times48\times10^{-4}$$

$$mmf = 2388.48 \text{ AT}$$

Q. An iron ring of 50cm mean length has an air gap of 1mm and winding of 200 turns. If permeability of iron is 500 then current of 1A close the coil, find the flux density. Assume $\mu_r = 500$

Ans. Given –

$l_i = 50\text{cm} = 0.5\text{m}$

$l_g = 1\text{mm} = 10^{-3}\text{m}$

$N = 200$

$I = 1\text{A}$

$B = ?$

Sol^n

$$\text{Total mmf} = H_i l_i + H_g l_g$$

$$\because H = \frac{B}{\mu_0 \mu_r}$$

$$\text{Total mmf} = \frac{B l_i}{\mu_0 \mu_r} + \frac{B l_g}{\mu_0 \mu_r}$$

$$\underset{(NI)}{\text{Total mmf}} = B\left[\frac{l_i}{\mu_0 \mu_r} + \frac{l_g}{\mu_0}\right]$$

$$200 \times 1 = B\left[\frac{0.5}{4\pi \times 10^{-7} \times 500} + \frac{10^{-3}}{4\pi \times 10^{-7}}\right]$$

$$200 = B\left[\frac{5 \times 10^{-1}}{4\pi \times 10^{-7} \times 500} + \frac{10^{-3}}{4\pi \times 10^{-7}}\right]$$

$$B = 0.1256 \ Wb\, m^{-2}$$

Q. A ring composed of 3 sections. The cross section area is $a = 0.001\ m^2$ for each section the mean arc length are $l_a = 0.3\,m$, $l_b = 0.2\,m$, $l_c = 0.1\,m$ and air gap length $l_g = 0.1\,mm$ cut in the ring. μ_r for section a, b, c are $\mu_{ra} = 5000$, $\mu_{rb} = 1000$ and $\mu_{rc} = 10000$. Flux in the air gap is $\phi = 7.5 \times 10^{-4}$ Wb. Find
i) mmf
ii) exciting current if coil has 100 turns

Ans. Given

$a = 0.001\ m^2$

$l_a = 0.3\,m$

$l_b = 0.2\,m$

$l_c = 0.1\,m$

$\mu_{ra} = 500$

$\mu_{rb} = 1000$

$\mu_{rc} = 10000$

$\phi = 7.5 \times 10^{-4}\,Wb$