Unit - 1
DC

○ **BASIC ELEMENTS**

Active Elements

↳ Those Elements which supply/ deliver Electrical Energy

<u>for ex</u>: Battery, Generator, Operational Amplifier, Transistor, current source, voltage source, etc.

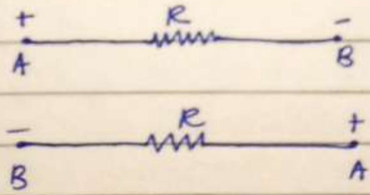
Passive Elements

↳ These elements can only store/ recieve energy, which it can either dissipate or absorb.

<u>For ex</u>: Resistor, Inductor, Capacitor, Transformer, Switch, etc.

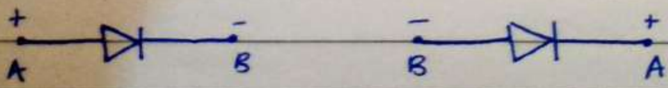
• <u>Bilateral Elements</u> : The elements in which magnitude of current remains same regardless of the direction.

<u>for ex</u> : Resistor



• <u>Unilateral Elements</u> : The elements in which there is a change in functioning when direction of current changes.

<u>for ex</u> : Diode



(Forward Bias) (Reverse Bias)

- **Electric Current (I)**: Rate of flow of Electrical Charge

$$\boxed{I = \frac{dq}{dt}}$$ (Unit → Ampere (A))

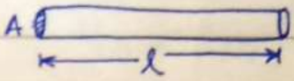
{ 1 Coulomb = 6.25×10^{18} e^{-}s (A) }   { Electric Charge (q^{-}) = 1.602×10^{-19} C }

- **Ohm's law**

The voltage across a conductor is directly proportional to the current flowing through it, provided all physical conditions & temperature remains constant.

$$\boxed{\begin{array}{c} V \propto I \\ \Rightarrow V = IR \end{array}}$$

- **Laws of Resistance**



$\boxed{1^{st}}$: $R \propto l$

$\boxed{2^{nd}}$: $R \propto \frac{1}{A}$

$\Rightarrow R \propto \frac{l}{A}$ → $\boxed{R = \frac{\rho l}{A}}$

[ρ → resistivity (unit : Ω m (rho))]

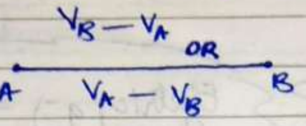
- **Conductance**: Reciprocal of Resistance. It offers the flow of current.

$$\boxed{G = \frac{1}{R}}$$ (unit → mho)

- **Conductivity** (σ): Reciprocal of Resistivity.

$$\boxed{\sigma = \frac{1}{\rho}}$$ (unit → mho/m OR siemens/m)

- **Potential Energy Difference**: The potential diff. b/w two points is the amount of Electrical Energy required to move a unit charge b/w two points.



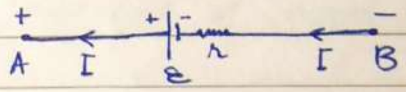
[unit → volt (V)]

- **Electromotive force (emf)**: emf is equal to the terminal voltage when no current flows. It is the force that causes an electric current to flow in an electric circuit.

[unit → volt (V)]

- **Terminal Voltage**: The potential difference across the terminals of a load when current flows through the circuit.

$$\boxed{V_{AB} = \varepsilon - Ir}$$



Sources

Independent Sources

→ value does not depend upon any other voltage & current.

(i) Voltage Source (constant voltage across two terminals)

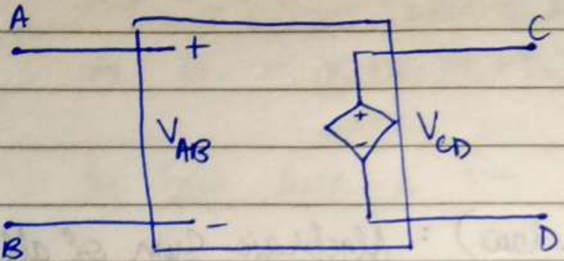
(ii) Current Source (maintains constant current).

Dependent Sources

→ Value depends upon some voltage or current.

(i) VDVS (voltage depended voltage source)
(ii) CDCS (current depended current source)
(iii) VDCS (voltage depended current source)
(iv) CDVS (current depended voltage source)

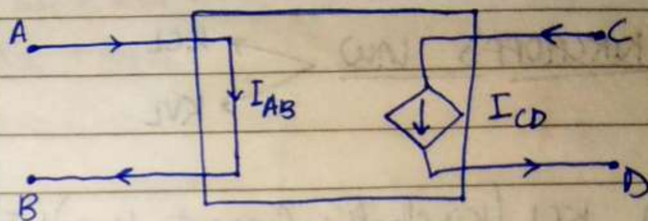
(i) Voltage depended Voltage Source (VDVS)



$V_{CD} \propto V_{AB}$

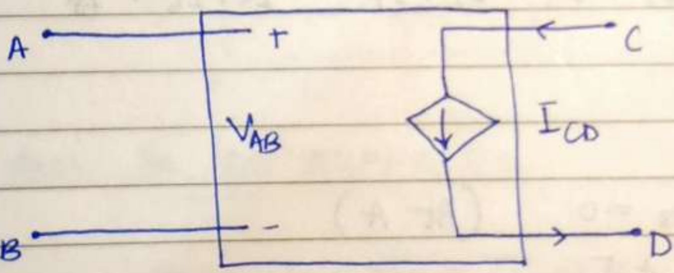
$\Rightarrow \boxed{V_{CD} = \mu V_{AB}}$

(ii) Current depended Current Source (CDCS)



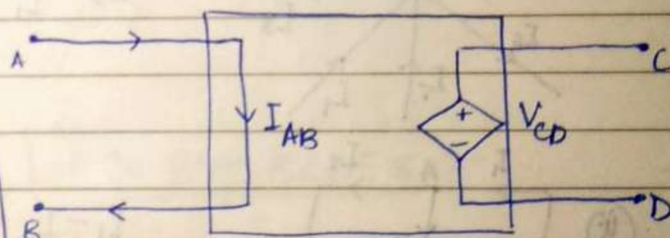
$I_{CD} \propto I_{AB}$

(iii) Voltage depended Current Source (VDCS)



$I_{CD} \propto V_{AB}$

(iv) Current depended voltage Source (CDVS)



$V_{CD} \propto I_{AB}$

Unit – 1 DC

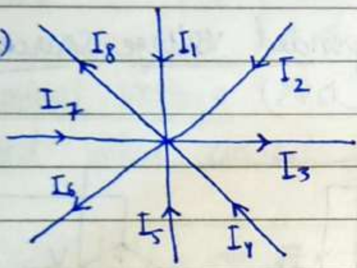
KIRCHOFF'S LAW → KCL, KVL

1) **KCL (Kirchoff's Current law) (Junction law)**: Algebraic sum of all currents meeting at a junction/point is zero.

OR

Sum of incoming current on a junction is equal to sum of outgoing current.

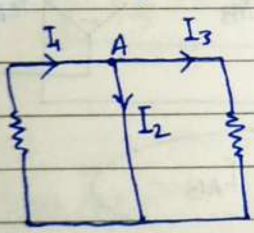
(i)



$$I_1 + I_2 - I_3 + I_4 + I_5 - I_6 + I_7 - I_8 = 0$$

$$\Rightarrow I_1 + I_2 + I_4 + I_5 + I_7 = I_3 + I_6 + I_8$$

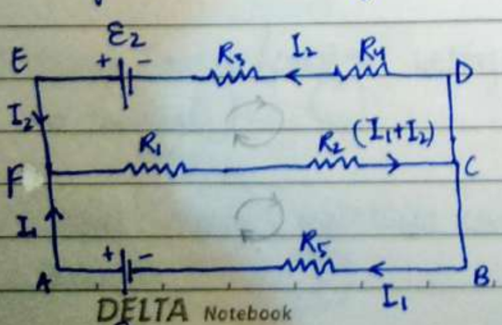
(ii)



$$I_1 - I_2 - I_3 = 0 \quad \text{(At A)}$$

$$\Rightarrow I_1 = I_2 + I_3$$

2) **KVL (Kirchoff's Voltage law) (loop law)**: The algebraic sum of emfs acting in a circuit is equal to the algebraic sum of products of current & resistance



In loop ABCFA:

$$\varepsilon_1 - R_1(I_1+I_2) - R_2(I_1+I_2) - I_1R_5 = 0$$

$$\Rightarrow \varepsilon_1 = (R_1+R_2)(I_1+I_2) + I_1R_5$$

In loop EDCFE :—

$$-\varepsilon_2 + I_2R_3 + I_2R_4 + R_1(I_1+I_2) + R_2(I_1+I_2) = 0$$

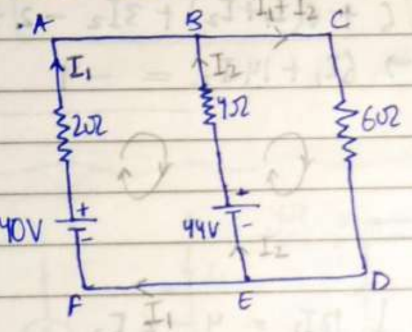
$$\Rightarrow \varepsilon_2 = (R_1+R_2)(I_1+I_2) + I_2(R_3+R_4)$$

In loop ABDEA :—

$$\varepsilon_1 - \varepsilon_2 + I_2R_3 + I_2R_4 - I_1R_5 = 0$$

$$\Rightarrow \varepsilon_1 - \varepsilon_2 = I_1R_5 - I_2(R_3+R_4)$$

Ques.)



Calculate current through each battery & the load.

Ans.) In loop ABEFA :—

$$40 - 2I_1 + 4I_2 - 44 = 0$$

$$\Rightarrow 4I_2 - 2I_1 = 4$$

$$\Rightarrow 2I_2 - I_1 = 2 \quad \text{——— (I)}$$

In loop BCDEB :—

$$44 - 4I_2 - 6(I_1+I_2) = 0$$

$$\Rightarrow 6I_1 + 10I_2 = 44$$

$$\Rightarrow 3I_1 + 5I_2 = 22 \quad \text{——— (II)}$$

Solving eqn. (I) × 3 & eqn. (II) :—

$$-\cancel{3I_1} + 6I_2 = 6$$

$$\cancel{3I_1} + 5I_2 = 22$$

$$11I_2 = 28$$

$$\Rightarrow I_2 = \frac{28}{11}\text{ A}$$

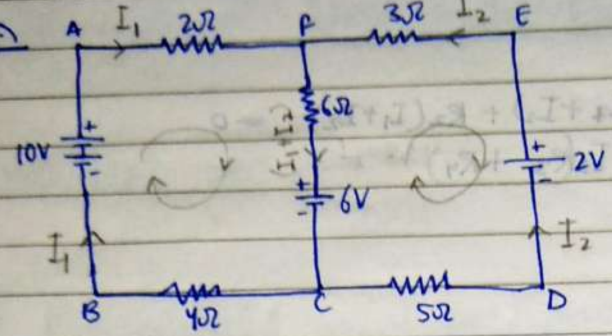
& $I_1 = 2I_2 - 2$

$$\Rightarrow I_1 = \frac{2\times 28}{11} - 2$$

$$\Rightarrow I_1 = \frac{34}{11}\text{ A}$$

load current $= I_1 + I_2 = \frac{62}{11}\text{ A}$

Ques.)



Find current through each battery.

Ans.) In loop AFCBA :—

$$10 - 2I_1 - 6(I_1+I_2) - 6 - 4I_1 = 0$$
$$\Rightarrow 12I_1 + 6I_2 = 4 \quad \text{——— (I)}$$

In loop FEDCF :—

$$6 + 6(I_1+I_2) + 3I_2 - 2 + 5I_2 = 0$$
$$\Rightarrow 6I_1 + 14I_2 = -4 \quad \text{——— (II)}$$

Solving eqn. (I) & (II) × 2 :—

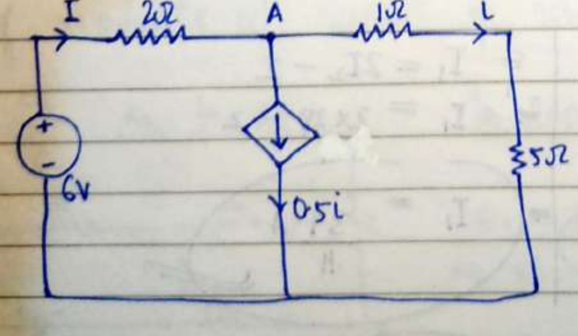
$$\cancel{12I_1} + 28I_2 = -8$$
$$\underset{(-)}{}\cancel{12I_1} \underset{(-)}{+} 6I_2 = \underset{(-)}{4}$$
$$22I_2 = -12$$
$$\Rightarrow I_2 = -\frac{6}{11}\text{ A}$$

$$12I_1 = 4 - 6I_2$$
$$\Rightarrow 12I_1 = 4 + \frac{36}{11}$$
$$\Rightarrow I_1 = \frac{20}{33}\text{ A}$$

and,

$$(I_1+I_2) = \frac{20}{33} - \frac{6}{11} = \frac{2}{33}\text{ A}$$

Ques.)

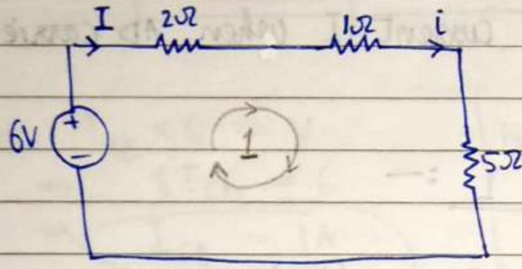


Determine current (i) in 5Ω resistor.

Ans.) KCL at A node :—

$I = 0.5i + i$
$\;\;= 1.5i$

(Now, let's neglect dependent source)



In loop 1 :

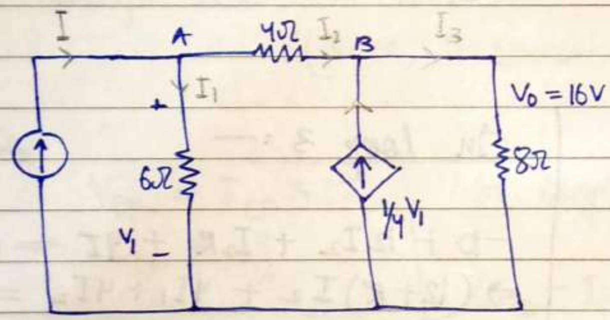
$6 - 2I - i - 5i = 0$

$\Rightarrow 2I + 6i = 6$

$\Rightarrow 2(1.5i) + 6i = 6$

$\Rightarrow i = \frac{6}{9} = \frac{2}{3}\text{ A}$

Ques.)



Calculate the value of V_1, I_1, I_2, I_3.

Ans.) $I_3 = \frac{V_0}{R} = \frac{16}{8} = 2\text{A}$

Now,

KCL at point B :—

$\frac{1}{4}V_1 = I_2 + I_3$

$V_{AB} = I_2 \times 4$

$\Rightarrow V_B - V_A = 4I_2$

$\Rightarrow 16 - V_1 = 4I_2$

$\Rightarrow 16 - 4I_2 - 4I_3 = 4I_2$

$\Rightarrow 8I_2 + 8 = 16$

$\Rightarrow I_2 = 1\text{A}$

So, $V_1 = 4I_2 + 4I_3$

$\Rightarrow V_1 = 4(1+2)$

$\Rightarrow V_1 = 12\text{ V}$

Delta

so, $V_1 = I_1 \times 6$

$\Rightarrow 12 = 6I_1$

$\Rightarrow I_1 = 2A$

and, $I + I_2 - I_1 = 0$ (KCL at A)

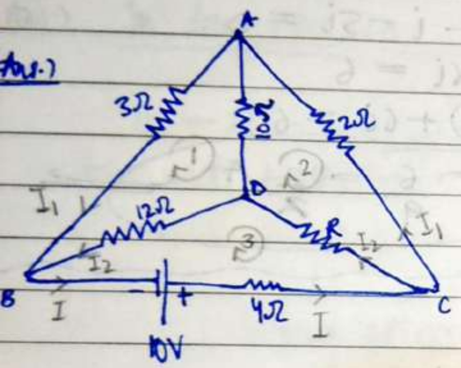
$\Rightarrow I = I_1 - I_2$

$\Rightarrow I = 2 - 1$

$\Rightarrow I = 1A$

Ques.) find value of resistance R & current I when AD carries no current.

Ans.)



In loop 1 :—

$3I_1 - 12I_2 + 0(10\Omega) = 0$

$\Rightarrow 12I_2 = 3I_1$

$\Rightarrow I_1 = 4I_2$

In loop 2 :—

$2I_1 - RI_2 + 0(10) = 0$

$\Rightarrow RI_2 = 2I_1$

$\Rightarrow R = \frac{2I_1}{I_2}$

$\Rightarrow R = \frac{2(4\cancel{I_2})}{\cancel{I_2}}$

$\Rightarrow R = 8\Omega$

In loop 3 :—

$-10 + 12I_2 + I_2R + 4I = 0$

$\Rightarrow (12+R)I_2 + 4I_1 + 4I_2 = 10$

$\Rightarrow 4I_1 + (16+R)I_2 = 10$

$\Rightarrow 16I_2 + 16I_2 + 8I_2 = 10$

$\Rightarrow I_2 = \frac{1}{4} A$

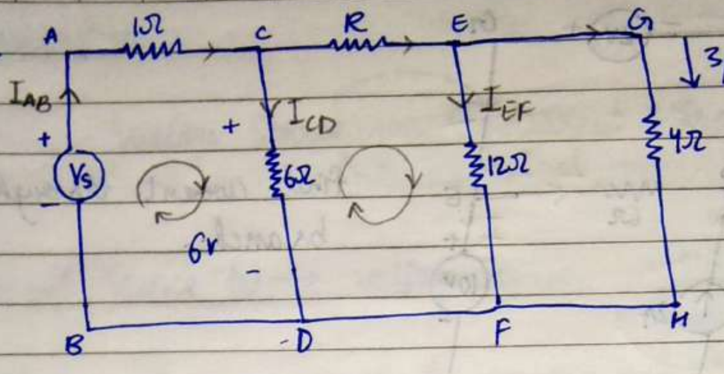
so, $I_1 = 4I_2$

$= 1A$

so, $I = I_1 + I_2$

$\Rightarrow I = \frac{5}{4} A$

Ques.)



Calculate value of R and V_s ?

Ans.)

$$I_{CD} \times 6 = V$$
$$\Rightarrow 6 I_{CD} = 6$$
$$\Rightarrow I_{CD} = 1A$$

Now, Voltage across GH :—

$$V_{GH} = \frac{3}{4} \times 4$$
$$= 3V$$

Now, voltage across EF will be = voltage across GH (since, ∥ connection)

So,

$$V_{EF} = I_{EF} \times 12$$
$$\Rightarrow I_{EF} = \frac{3}{12}$$
$$\Rightarrow I_{EF} = \frac{1}{4} A$$

In loop CEFDC :—

$$6I_{CD} - I_{CE} R - 12 I_{EF} = 0$$
$$\Rightarrow 6 \times 1 - 1 \times R - 12 \times \frac{1}{4} = 0$$
$$\Rightarrow R = 3\Omega$$

$$\left(I_{CE} = I_{EF} + I_{GH} = \frac{1}{4} + \frac{3}{4} = 1A \right)$$

Now,

In loop ACDBA :—

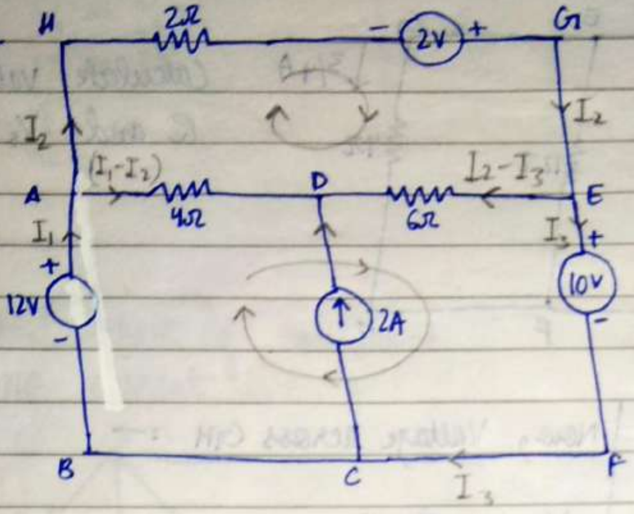
$$V_s - I_{AB} \times 1 - 6 I_{CD} = 0$$
$$\Rightarrow V_s - 2 \times 1 - 6 \times 1 = 0$$
$$\Rightarrow V_s = 8V.$$

$$\left(\because I_{AB} = I_{CD} + I_{CE} = 1 + 1 = 2A \right)$$

Delta

Dt.:
Pg.:

Ques.)



find current through each branch.

Ans.) KCL at point D :—

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

$$\Rightarrow I_3 - I_1 = 2 \quad \text{——— (I)}$$

KVL in loop AEFBA :—

$$12 - 4(I_1 - I_2) + 6(I_2 - I_3) - 10 = 0$$

$$\Rightarrow 12 - 4I_1 + 4I_2 + 6I_2 - 6I_3 - 10 = 0$$

$$\Rightarrow 4I_1 - 10I_2 + 6I_3 = 2 \quad \text{——— (II)}$$

KVL in loop HGEAH :—

$$2 - 6(I_2 - I_3) + 4(I_1 - I_2) - 2I_2 = 0$$

$$\Rightarrow 6I_2 - 6I_3 - 4I_1 + 4I_2 + 2I_2 = 2$$

$$\Rightarrow -4I_1 + 12I_2 - 6I_3 = 2 \quad \text{——— (III)}$$

Adding eq^n. (II) & (III) :—

$$\cancel{4I_1} - 10I_2 + \cancel{6I_3} = 2$$
$$\cancel{-4I_1} + 12I_2 \cancel{- 6I_3} = 2$$
$$2I_2 = 4$$
$$\Rightarrow I_2 = 2A$$

eq^n. (II) :

$$4I_1 - 10I_2 + 6I_3 = 2$$
$$4I_1 - 20 + 6I_3 = 2$$
$$2I_1 + 3I_3 = 11 \quad \text{——— (IV)}$$

Solving eq^n (I) × 2 & (IV)

$$\cancel{2I_1} + 3I_3 = 11$$
$$\cancel{-2I_1} + 2I_3 = 4$$
$$I_3 = 15/5$$
$$\Rightarrow I_3 = 3A$$

So, $I_1 = 1A$

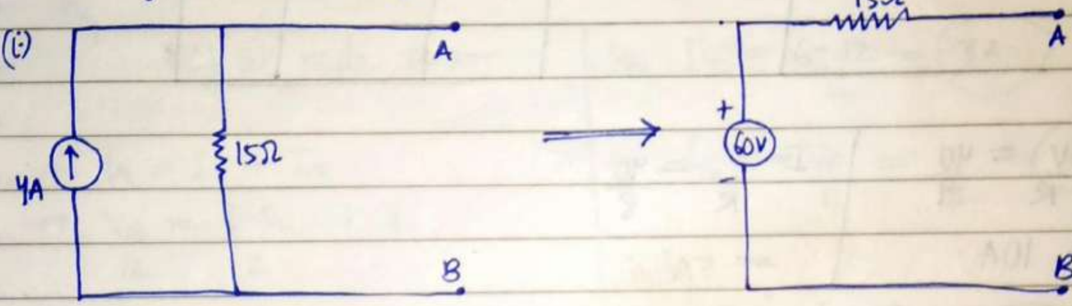
- Conversions

Voltage Source ⇄ Current Source

1) Current Source to → voltage Source.

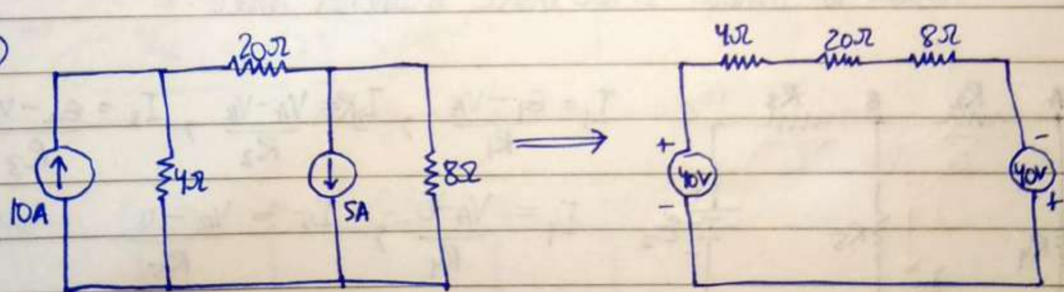
→ If current source is to be converted to voltage source, then join the voltage source with resistor in series.

(i)



$V = IR$
$= 4 \times 15$
$= 60\,V$

(ii)

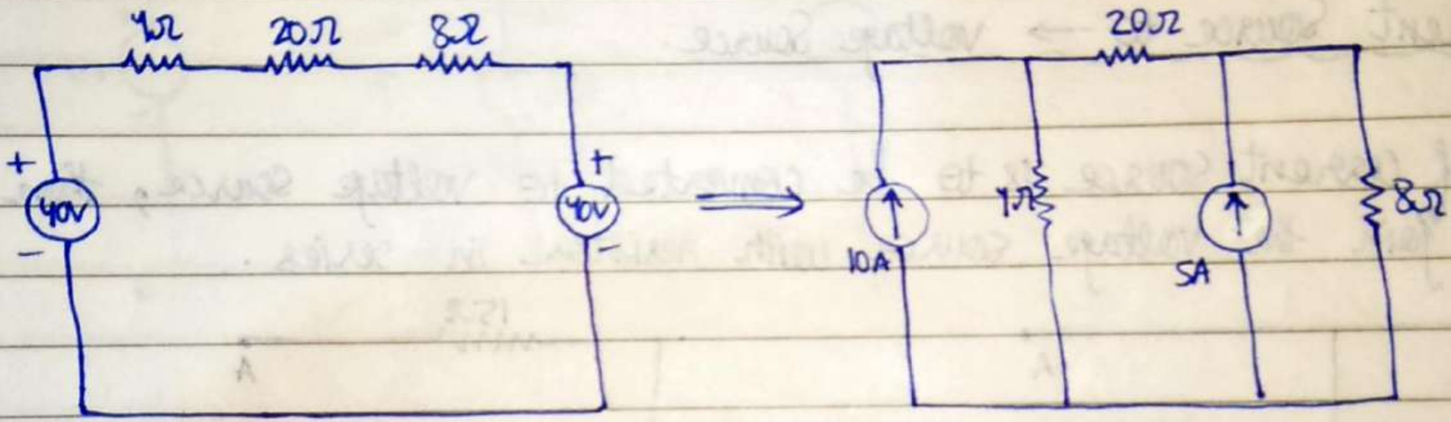


$V = IR$	$V = IR$
$= 10 \times 4$	$= 5 \times 8$
$= 40V$	$= 40V$

Pg.:

2.) Voltage Source → to → Current Source

→ If we have to convert voltage source to current source, then join the current source with resistor/load in parallel.



$$I = \frac{V}{R} = \frac{40}{4}$$

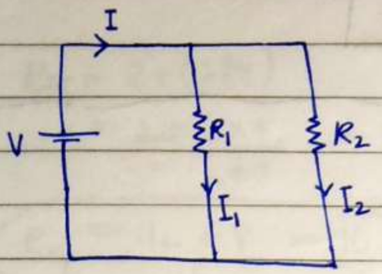
$$= 10A$$

$$I = \frac{V}{R} = \frac{40}{8}$$

$$= 5A.$$

Unit – 1

Current Division Rule



we know: In Parallel combination :—

voltage remains same in all resistor and current is different.

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} \xrightarrow{so,} \boxed{\begin{aligned} V &= I R_{eq} \\ &= I\left(\frac{R_1 R_2}{R_1 + R_2}\right) \end{aligned}}$$

so,

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

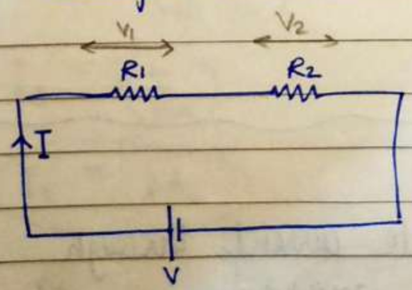
$$\Rightarrow I_1 = I\left(\frac{\cancel{R_1} R_2}{R_1 + R_2}\right)\frac{1}{\cancel{R_1}}$$

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

Similarly,

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

Voltage Distribution Rule



we know: In series combination :—

current remains same and voltage is different in all resistor

so,

$$R_{eq} = R_1 + R_2 \xrightarrow{so,} \boxed{\begin{aligned} V &= I R_{eq} \\ \Rightarrow I &= \frac{V}{R_1 + R_2} \end{aligned}}$$

Dt.:
Pg.:

Sol

$$V_1 = IR_1$$

$$\Rightarrow V_1 = \left(\frac{V}{R_1+R_2}\right)R_1$$

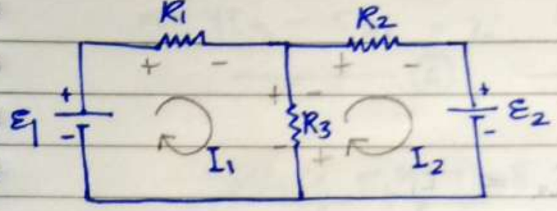
similarly,

$$\Rightarrow \boxed{V_1 = \frac{VR_1}{R_1+R_2}}$$

$$\boxed{V_2 = \frac{VR_2}{R_1+R_2}}$$

Unit – 1
DC Circuits

□ **MESH ANALYSIS** → In this method we use KVL in a different method and develop a technique which makes analysing circuits easier than KVL.



Step 1 : To consider mesh currents in either clockwise or anti-clockwise.

→ Step 2 : Write the mesh equations to all meshes using KVL and then use Ohm's law.

In mesh 1 :–

$$\varepsilon_1 - I_1R_1 - I_1R_3 + I_2R_3 = 0$$
$$\Rightarrow I_1(R_1+R_3) - I_2R_3 = \varepsilon_1 \quad \text{—— (I)}$$

In mesh 2 :

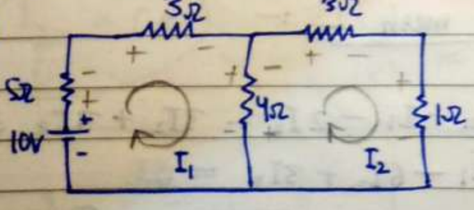
$$-I_2R_3 + I_1R_3 - I_2R_2 - \varepsilon_2 = 0$$
$$\Rightarrow I_1R_3 - I_2(R_2+R_3) = \varepsilon_2 \quad \text{—— (II)}$$

Then solve for eqn. (I) & (II) :

and get :–

I_1 & I_2 value.

Ques 1.)



Find current across 1Ω resistor.

Ans 1.)

$$10 - 5I_1 - 3I_1 - 4I_1 + 4I_2 = 0$$
$$\rightarrow 12I_1 - 4I_2 = 10$$
$$\rightarrow 6I_1 - 2I_2 = 5 \quad \text{—— (1)}$$

and, In mesh 2 :—

$$-4I_2 + 4I_1 - 3I_2 - I_2 = 0$$
$$\Rightarrow 4I_1 - 8I_2 = 0$$
$$\Rightarrow I_1 - 2I_2 = 0 \quad \text{—— (II)}$$

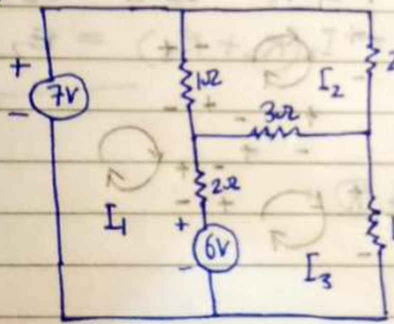
Subtracting (I) — (II) :—

$$6I_1 - 2\cancel{I_2} = 5$$
$$(-)I_1 \; \overline{(+)}\cancel{2I_2} = 0$$
$$5I_1 = 5$$
$$\Rightarrow I_1 = 1A$$

$$I_2 = \frac{I_1}{2}$$
$$\Rightarrow I_2 = 0.5A$$

so, Current across 1Ω resistor = 0.5A

Ques 2:)



Calculate current in each branch.

Ans.) In mesh 1 :-

$$-6 + 7 - I_1 + I_2 - 2I_1 + 2I_3 = 0$$
$$\Rightarrow 3I_1 - I_2 - 2I_3 = 1 \quad \text{—— (I)}$$

In mesh 2 :-

$$-I_2 + I_1 - 2I_2 - 3I_2 + 3I_3 = 0$$
$$\Rightarrow I_1 - 6I_2 + 3I_3 = 0 \quad \text{—— (II)}$$

In mesh 3 :-

$$6 - 2I_3 + 2I_1 - 3I_3 + 3I_2 - I_3 = 0$$
$$-2I_1 - 3I_2 + 6I_3 = 6 \quad \text{—— (III)}$$

Solving eqn. (II)×2 & (III):–

$$\cancel{2I_1} - 12I_2 + 6I_3 = 0$$
$$\underset{(-)}{}\cancel{2I_1} - 3I_2 + 6I_3 = 6$$
$$12I_3 - 15I_2 = 6$$
$$\Rightarrow 4I_3 - 5I_2 = 2 \quad \text{—— (a)}$$

Solving eqn. (II)×3 & (I):–

$$\cancel{3I_1} - 18I_2 + 9I_3 = 0$$
$$\underset{(-)}{}3I_1 \underset{(+)}{-} I_2 \underset{(+)}{-} 2I_3 = \underset{(-)}{1}$$
$$11I_3 - 17I_2 = -1 \quad \text{—— (b)}$$

Solving eqn. (a)×11 & (b)×4 :–

$$\cancel{44I_3} - 55I_2 = 22$$
$$\underset{(-)}{}\cancel{44I_3} \underset{(+)}{-} 68I_2 = \underset{(+)}{-}4$$
$$13I_2 = 26$$
$$I_2 = 2A$$

$$I_3 = \frac{5(2) + 2}{4}$$
$$\Rightarrow I_3 = 3A$$

So,
$$I_1 = 6I_2 - 3I_3$$
$$\Rightarrow I_1 = 6\times2 - 3\times3$$
$$\Rightarrow I_1 = 3A$$

So,
$$\underset{(i)}{I_{1\Omega}} = I_1 - I_2 = 3 - 2 = 1A$$

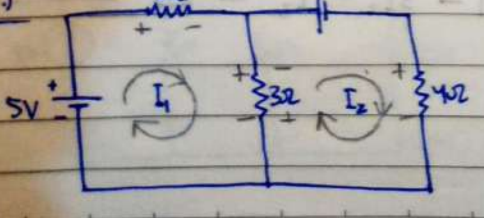
$$\underset{(ii)}{I_{1\Omega}} = I_3 = 3A$$

$$I_{3\Omega} = I_3 - I_2 = 1A$$

$$\underset{(i)}{I_{2\Omega}} = 0A$$

$$\underset{(ii)}{I_{2\Omega}} = I_2 = 2A.$$

Que:



Calculate current across 3Ω resistor.

Ans.) **In Mesh 1:**

$$5 - 2I_1 - 3I_1 + 3I_2 = 0$$
$$\Rightarrow 5I_1 - 3I_2 = 5 \quad \text{——— (I)}$$

In mesh 2:

$$-2 - 4I_2 - 3I_2 + 3I_1 = 0$$
$$\rightarrow 3I_1 - 7I_2 = 2 \quad \text{——— (II)}$$

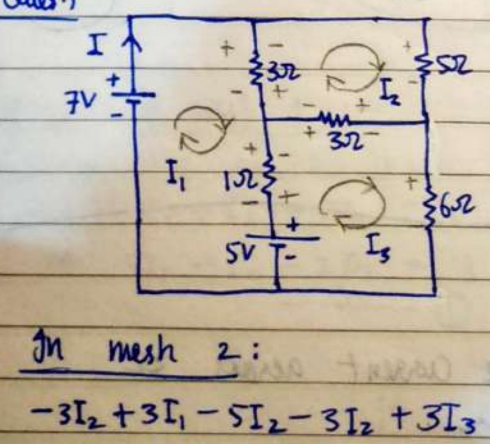
Solving eq^n. (I) × 3 & (II) × 5 :—

$$\Rightarrow \cancel{15I_1} - 35I_2 = 10$$
$$\underline{\cancel{-15I_1} \mp 9I_2 = -15}$$
$$-26I_2 = -5$$
$$\Rightarrow I_2 = \frac{5}{26}\,A$$

$$I_1 = \frac{5 + 3 \times 5/26}{5}$$
$$= \frac{\cancel{145}\ 29}{\cancel{5} \times 26} = \frac{29}{26}\,A$$

So,
current across 3Ω resistor $= I_1 - I_2$
$$= \frac{29}{26} - \frac{5}{26}$$
$$= \frac{\cancel{24}\ 12}{\cancel{26}\ 13}$$
$$= \frac{12}{13}\,A$$

Ques.)



Find current I :

Ans.) **In mesh 1 :**

$$7 - 3I_1 + 3I_2 - I_1 + I_3 - 5 = 0$$
$$\Rightarrow 4I_1 - 3I_2 - I_3 = 2 \quad \text{——— (I)}$$

In mesh 2 :

$$-3I_2 + 3I_1 - 5I_2 - 3I_2 + 3I_3 = 0$$
$$\Rightarrow 3I_1 - 11I_2 + 3I_3 = 0 \quad \text{——— (II)}$$

In mesh 3 :

$$5 - I_3 + I_1 - 3I_3 + 3I_2 - 6I_3 = 0$$
$$\Rightarrow -I_1 - 3I_2 + 10I_3 = 5 \qquad \text{——— (iii)}$$

Solving eqn. (iii) × 3 & eqn. (ii) :—

$$-3\cancel{I_1} - 9I_2 + 30I_3 = 15$$
$$\cancel{3I_1} - 11I_2 + 3I_3 = 0$$
$$33I_3 - 20I_2 = 15 \qquad \text{——— (a)}$$

Solving eqn. (iii) × 4 + eqn. (i) :—

$$-4\cancel{I_1} - 12I_2 + 40I_3 = 20$$
$$\cancel{4I_1} - 3I_2 - I_3 = 2$$
$$39I_3 - 15I_2 = 22 \qquad \text{——— (b)}$$

Solving eqn. (b) × 4 & eqn. (a) × 3 :—

$$156I_3 - \cancel{60I_2} = 88$$
$$\underset{(-)}{}99I_3 \underset{(+)}{-} \cancel{60I_2} \underset{(-)}{=} 45$$
$$57I_3 = 43$$
$$\Rightarrow I_3 = 0.754\ A$$

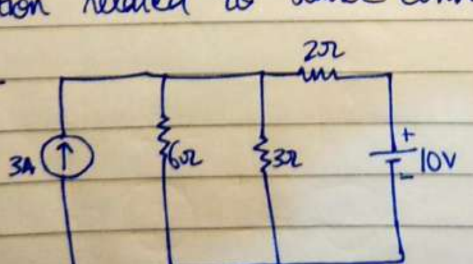
$$I_2 = \frac{39 \times 0.754 - 22}{15}$$
$$\Rightarrow I_2 = 0.493\ A$$

So,
$$I_1 = -5 - 3 \times 0.493 + 10 \times 0.754$$
$$\Rightarrow I_1 = 1.061\ A$$

So, $I = I_1 = 1.061\ A$

(Question related to Source Conversion)

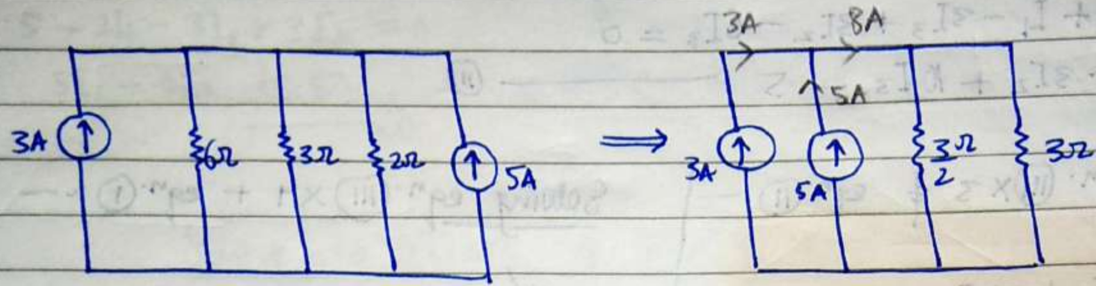
Ques.)



Calculate current across 3Ω resistor.

Dt.:
Pg.:

Ans.) can be redrawn as :—



Using current division Rule :—

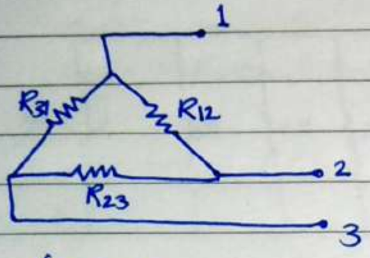
$$I_{3\Omega} = 8 \times \frac{3/2}{3 + 3/2}$$

$$\Rightarrow I_{3\Omega} = 8 \times \frac{3}{9}$$

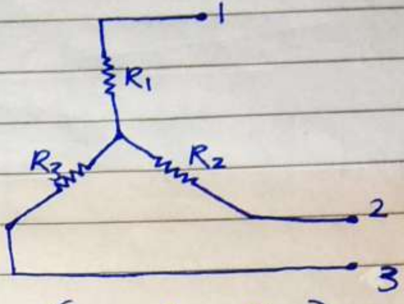
$$\Rightarrow I_{3\Omega} = \frac{8}{3} A$$

(This question can be done using KVL/ mesh / or any other method.)

TRANSFORMATIONS (Star & Delta).



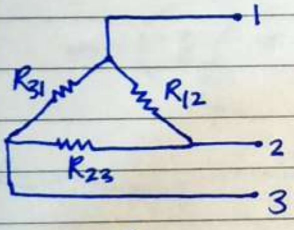
(equivalent)



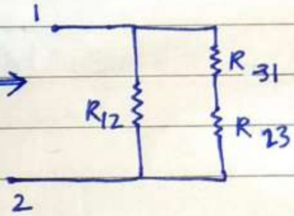
(Delta)

(equivalent Star)

1. Delta $\xrightarrow{\text{to}}$ Star Transformation



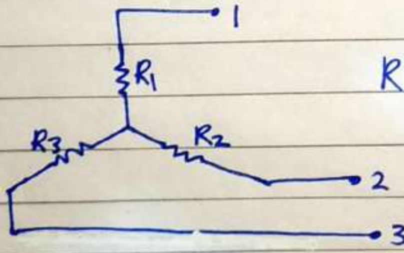
$\Longrightarrow$



so, $$\frac{1}{R_{eq(12)}} = \frac{1}{R_{12}} + \frac{1}{(R_{23}+R_{31})}$$

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

but, In star :



$$R_{eq(12)} = R_1 + R_2$$

$$\Rightarrow R_1 + R_2 = \frac{R_{12}(R_{23}+R_{31})}{R_{12}+R_{23}+R_{31}} \quad \text{——— (a)}$$

Similarly, In case of terminal 2 & 3 :

$$R_2 + R_3 = \frac{R_{23}(R_{12}+R_{31})}{R_{12}+R_{23}+R_{31}} \quad \text{——— (b)}$$

In case of terminal 3 & 1 :

$$R_3 + R_1 = \frac{R_{31}(R_{12}+R_{23})}{R_{12}+R_{23}+R_{31}} \quad \text{------} \ (c)$$

Now,

Subtracting (c) − (b) :

$$R_1 + \cancel{R_3} - R_2 - \cancel{R_3} = \frac{R_{12}R_{31} - R_{12}R_{23}}{R_{12}+R_{23}+R_{31}}$$

$$R_1 - R_2 = \frac{R_{12}R_{31} - R_{12}R_{23}}{R_{12}+R_{23}+R_{31}}$$

Now, adding this eqn. & (1) :

$$\cancel{2}R_1 = \frac{\cancel{2}(R_{12}\cdot R_{31})}{R_{12}+R_{23}+R_{31}}$$

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

similarly,

we can find values of R_2 & R_3 .

$$\boxed{\begin{aligned} R_1 &= \frac{R_{12}\cdot R_{31}}{R_{12}+R_{23}+R_{31}} \quad \text{------} \ (e) \\ R_2 &= \frac{R_{12}\cdot R_{23}}{R_{12}+R_{23}+R_{31}} \quad \text{------} \ (f) \\ R_3 &= \frac{R_{23}\cdot R_{31}}{R_{12}+R_{23}+R_{31}} \quad \text{------} \ (g) \end{aligned}}$$

2. Star-to ⟶ Delta Transformation

eqn. (e)×(f) :-

$$R_1R_2 = \frac{R_{12}^2 R_{23} R_{31}}{(R_{12}+R_{23}+R_{31})^2} \quad \text{------} \ (1)$$

eqn. (f)×(g) :-

$$R_2R_3 = \frac{R_{12} R_{23}^2 R_{31}}{(R_{12}+R_{23}+R_{31})^2} \quad \text{------} \ (2)$$

eqn. (e)×(g) :-

$$R_3R_1 = \frac{R_{12} R_{23} R_{31}^2}{(R_{12}+R_{23}+R_{31})^2} \quad \text{------} \ (iii)$$

Now, Adding eqn. (1), (2) & (3) :—

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

$$\Rightarrow R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12}.R_{23}.R_{31}}{R_{12}+R_{23}+R_{31}} \quad \text{———} (4)$$

Now, putting eqn. (9) in eqn. (4) :—

$$R_1R_2 + R_2R_3 + R_3R_1 = R_{12}\left(\frac{R_{23}R_{31}}{R_{12}+R_{23}+R_{31}}\right)$$

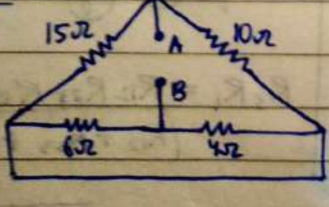
$$\Rightarrow R_{12}\cdot R_3 = R_1R_2 + R_2R_3 + R_3R_1$$

$$\Rightarrow R_{12} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

Similarly, we can find R_{23} & R_{31} :—

$$\boxed{\begin{aligned} R_{12} &= \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} \\ R_{23} &= \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} \\ R_{31} &= \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} \end{aligned}}$$

Ques 1)



find the equivalent resistance between points A — B.

Ans.) $R_{eq(AB)} = (15+6) \parallel (10+4)$

$\Rightarrow \quad " \quad = 21 \parallel 14$

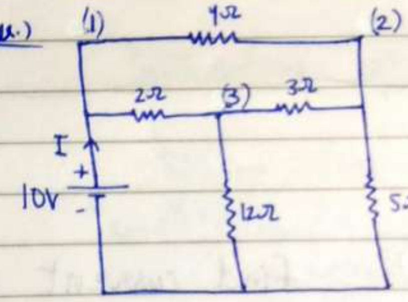
$\Rightarrow \quad " \quad = \dfrac{21 \times 14}{21 + 14}$

$\Rightarrow \quad " \quad = \dfrac{\overset{3}{\cancel{21}} \times 14}{\underset{5}{\cancel{35}}}$

$\Rightarrow \quad " \quad = \dfrac{42}{5}$

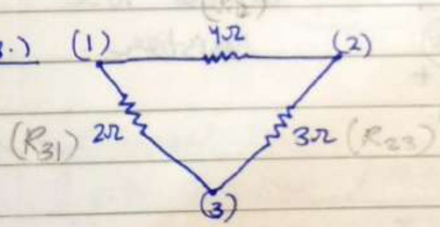
$\Rightarrow \quad R_{eq(AB)} = 8.4\,\Omega$

Ques.)

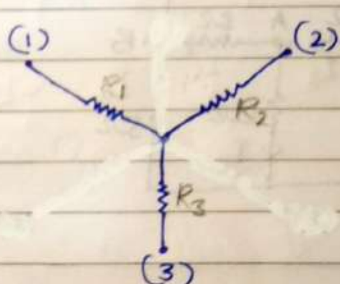


find current I.

Ans.)



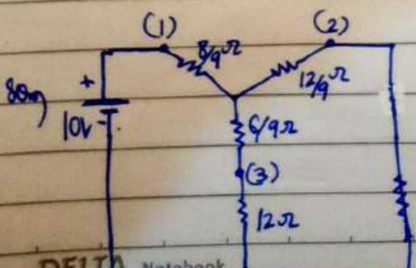
$\Longrightarrow$



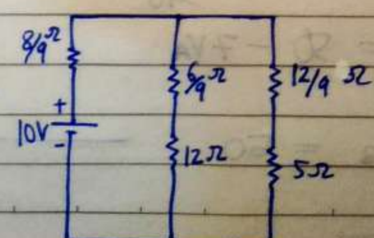
$R_1 = \dfrac{R_{12} \cdot R_{31}}{R_{12} + R_{23} + R_{31}} = \dfrac{4 \times 2}{2+3+4} = \dfrac{8}{9}\,\Omega$

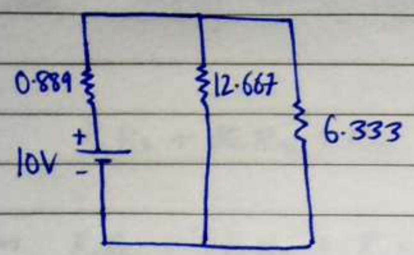
$R_2 = \dfrac{4 \times 3}{2+3+4} = \dfrac{12}{9}\,\Omega$

$R_3 = \dfrac{3 \times 2}{2+3+4} = \dfrac{6}{9}\,\Omega$



$\Longrightarrow$



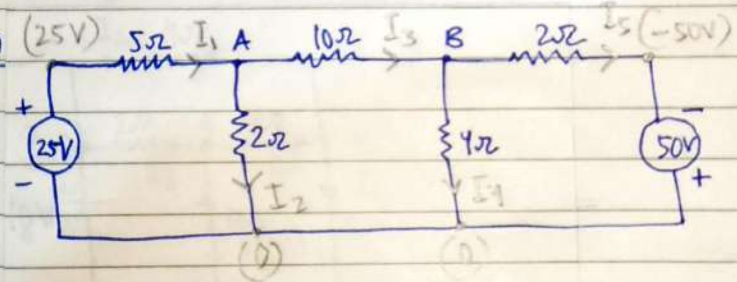


$$R_{eq} = 0.889 + (12.667 \parallel 6.333)$$
$$= 0.889 + \frac{12.667 \times 6.333}{12.667 + 6.333}$$
$$= 0.889 + \frac{80.220}{19}$$
$$= 5.111\ \Omega$$

So,
$$I = \frac{V}{R_{eq}} = \frac{10}{5.111}$$
$$\Rightarrow I = 1.956\ A$$

(Question of Nodal Analysis)

Ques.) find current across 10 Ω resistor.



Ans.)

KCL at node A :—

$$I_1 = I_2 + I_3$$
$$\Rightarrow \frac{25 - V_A}{5} = \frac{V_A - 0}{2} + \frac{V_A - V_B}{10}$$
$$\Rightarrow \frac{V_A - V_B}{\cancel{10}} = \frac{2(25 - V_A) - 5V_A}{\cancel{10}}$$
$$\Rightarrow V_A - V_B = 50 - 7V_A$$
$$\Rightarrow 8V_A - V_B = 50 \quad \text{——— (1)}$$

Dt.:
Pg.:

Now, KCL at Node B :-

$$I_3 = I_4 + I_5$$

$$\Rightarrow \frac{V_A - V_B}{10} = \frac{V_B - 0}{4} + \frac{V_B - (-50)}{2}$$

$$\Rightarrow \frac{V_A - V_B}{\cancel{10}\,5} = \frac{V_B + 2V_B + 100}{\cancel{4}\,2}$$

$$\Rightarrow 2V_A - 2V_B = 5V_B + 10V_B + 500$$

$$\Rightarrow 2V_A - 17V_B = 500 \quad \text{———} \quad (II)$$

Subtracting eq^n (I) & eq^n (II) × 4 :—

$$\cancel{8V_A} - 68V_B = 2000$$
$$\cancel{8V_A} \mp V_B = -50$$
$$-67V_B = 1950$$
$$\Rightarrow V_B = -29.10\text{ V}$$

$$V_A = \frac{50 + V_B}{8}$$

$$\Rightarrow V_A = \frac{50 - 29.10}{8}$$

$$\Rightarrow V_A = 2.61\text{ V}$$

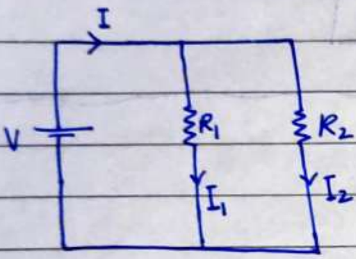
So, (current across 10Ω resistor) $I_3 = \frac{V_A - V_B}{10}$

$$\Rightarrow I_3 = \frac{2.61 - (-29.10)}{10}$$

$$\Rightarrow I_3 = 3.17165\text{ A}$$

Unit – 1

Current Division Rule



we know: In Parallel combination :—

voltage remains same in all resistor and current is different.

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} \xrightarrow{so} \boxed{V = I R_{eq} = I\left(\frac{R_1 R_2}{R_1 + R_2}\right)}$$

so

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

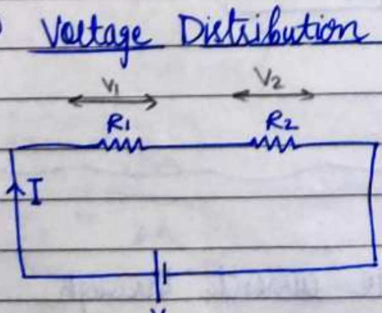
$$\Rightarrow I_1 = I\left(\frac{\cancel{R_1} R_2}{R_1 + R_2}\right)\frac{1}{\cancel{R_1}}$$

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

Similarly,

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

Voltage Distribution Rule



we know: In series combination :-

current remains same and voltage is different in all resistor

so

$$R_{eq} = R_1 + R_2 \xrightarrow{so} \boxed{V = I R_{eq} \Rightarrow I = \frac{V}{R_1 + R_2}}$$

Sol

$V_1 = IR_1$

$\Rightarrow V_1 = \left(\frac{V}{R_1 + R_2}\right) R_1$

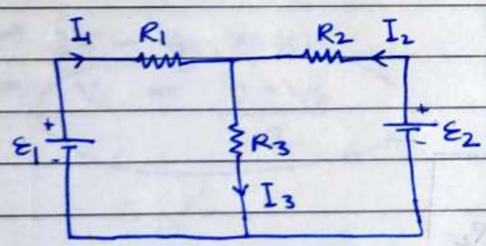
$\Rightarrow \boxed{V_1 = \frac{VR_1}{R_1 + R_2}}$

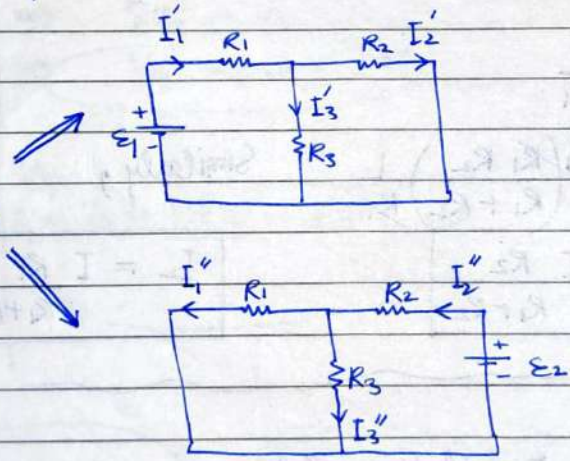
similarly,

$\boxed{V_2 = \frac{VR_2}{R_1 + R_2}}$

SUPERPOSITION THEOREM

→ If more than one source acts simultaneously in an Electric circuit, then the current through any one of the branches of the circuit is the summation of currents which would flow through the branch of each source, keeping all the other sources short circuited/dead.

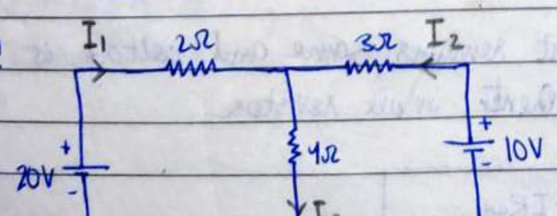




Sol

$$\boxed{\begin{aligned} I_1 &= I_1' - I_1'' \\ I_2 &= -I_2' + I_2'' \\ I_3 &= I_3' + I_3'' \end{aligned}}$$

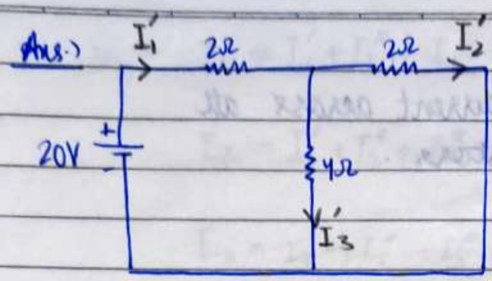
Ques.)

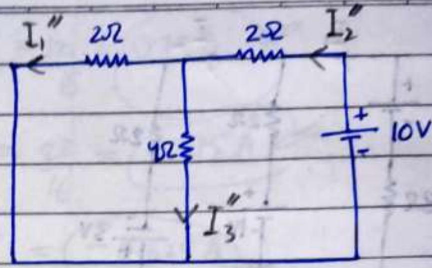


Calculate current through each resistor.

Dt.:
Pg.:

Ans.)





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

$\Rightarrow \quad " = 2 + \frac{2 \times 4}{2+4}$

$\Rightarrow R_{eq} = \frac{12+8}{6} = \frac{10}{3}\Omega$

so,

$I_1' = \frac{V}{R_{eq}} = \frac{20}{10/3}$

$\Rightarrow I_1' = 6A$

so,

$I_2' = I_1'\left(\frac{R_3}{R_2+R_3}\right)$

$\Rightarrow I_2' = \cancel{6}\left(\frac{4}{\cancel{2+4}}\right)$

$\Rightarrow I_2' = 4A$

and,

$I_3' = I_1'\left(\frac{R_2}{R_2+R_3}\right)$

$\Rightarrow I_3' = \cancel{6}\left(\frac{2}{\cancel{2+4}}\right)$

$\Rightarrow I_3' = 2A$

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

$\Rightarrow R_{eq} = \frac{10}{3}\Omega$

so,

$I_1'' = \frac{V}{R_{eq}} = \frac{10}{10/3}$

$\Rightarrow I_2'' = 3A$

so,

$I_1'' = I_2''\left(\frac{R_3}{R_1+R_3}\right)$

$\Rightarrow I_1'' = \cancel{3}\left(\frac{4}{\cancel{2+4}_2}\right)$

$\Rightarrow I_1'' = 2A$

and,

$I_3'' = I_2''\left(\frac{R_1}{R_1+R_3}\right)$

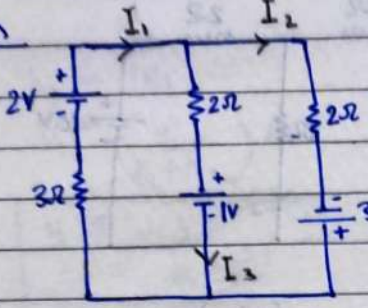
$\Rightarrow I_3'' = 3\left(\frac{2}{2+4}\right)$

$\Rightarrow I_3'' = 1A$

so,

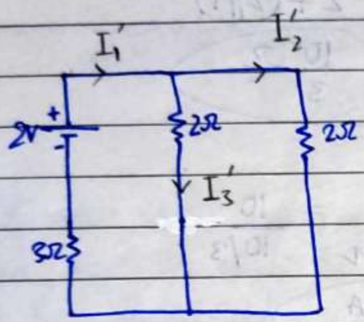
$$\boxed{\begin{aligned} I_1 &= I_1' - I_1'' = 4A \\ I_2 &= -I_2' + I_2'' = -1A \\ I_3 &= I_3' + I_3'' = 3A \end{aligned}}$$

Ques.)



Calculate current across all resistors.

Ans.)



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

so, $I_1' = \frac{V}{R_{eq}} = \frac{2}{4} = \frac{1}{2}\,A$

so,

$I_2' = I_1'\left(\frac{2}{4}\right)$

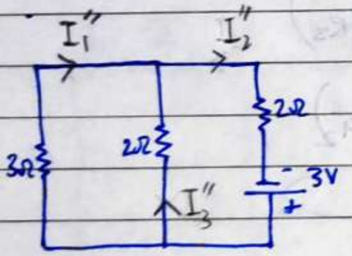
$\Rightarrow I_2' = \frac{1}{2} \times \frac{2}{4}$

$\Rightarrow I_2' = \frac{1}{4}\,A$

$I_3' = I'\left(\frac{2}{4}\right)$

$\Rightarrow I_3' = \frac{1}{2} \times \frac{2}{4}$

$\Rightarrow I_3' = \frac{1}{4}\,A$



$$R_{eq} = 2 + (2 \| 3) = 2 + \frac{6}{5} = \frac{16}{5}\,\Omega$$

so, $I_2'' = \frac{V}{R_{eq}} = \frac{3}{16/5} = \frac{15}{16}\,A$

and, $I_1'' = I_2''\left(\frac{2}{5}\right)$

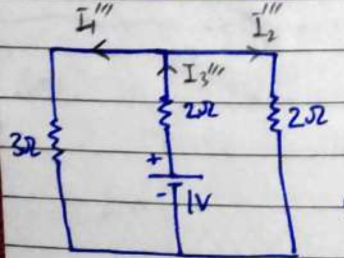
$\Rightarrow I_1'' = \frac{15}{16} \times \frac{2}{5}$

$\Rightarrow I_1'' = \frac{6}{16}\,A$

$I_3'' = I_2''\left(\frac{3}{5}\right)$

$\Rightarrow I_3'' = \frac{15}{16} \times \frac{3}{5}$

$\Rightarrow I_3'' = \frac{9}{16}\,A$



$$R_{eq} = 2 + (2 \| 3) = \frac{16}{5}\,\Omega$$

$I_3''' = \frac{V}{R_{eq}} = \frac{1}{16/5} = \frac{5}{16}\,A$

so, $I_1''' = \frac{5}{16} \times \frac{2}{5} = \frac{2}{16}\,A$

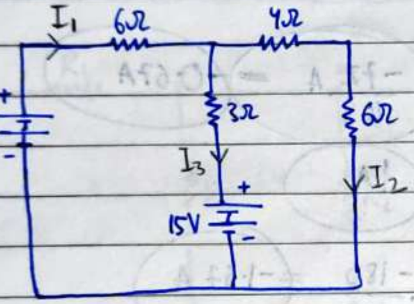
$I_2''' = \frac{5}{16} \times \frac{3}{5} = \frac{3}{16}\,A$

sol $I_1 = I_1' + I_1'' - I_1''' = \frac{8}{16} + \frac{6}{16} - \frac{2}{16} = \frac{12}{16} = 0.75\,A$

$I_2 = I_2' + I_2'' + I_2''' = \frac{4}{16} + \frac{15}{16} + \frac{3}{16} = \frac{22}{16} = 1.375\,A$

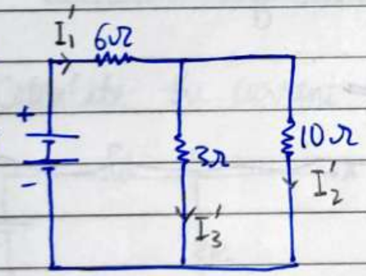
$I_3 = I_3' - I_3'' - I_3''' = \frac{4}{16} - \frac{9}{16} - \frac{5}{16} = -0.625\,A$

Ques.)



Calculate current across 3Ω?

Ans.)



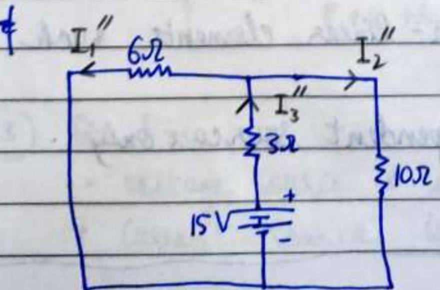
$R_{eq} = 6 + (3 \| 10)$
$= 6 + \frac{30}{13}$
$= \frac{108}{13}\,\Omega$

sol $I_1' = \frac{V}{R_{eq}}$
$= \frac{6}{108/13}$
$= \frac{78}{108}\,A$

and, $I_2' = I_1'\left(\frac{3}{13}\right)$
$= \frac{\cancel{78}^{6}}{108} \times \frac{3}{\cancel{13}}$
$= \frac{18}{108}\,A$

$I_3' = I_1'\left(\frac{10}{13}\right)$
$= \frac{\cancel{78}^{6}}{108} \times \frac{10}{\cancel{13}}$
$= \frac{60}{108}$

&



$R_{eq} = 3 + (6 \| 10)$
$= 3 + \frac{60}{16}$
$= \frac{108}{16}$

sol $I_3'' = \frac{V}{R_{eq}}$
$= \frac{15}{108/16}$
$= \frac{240}{108}\,A$

$$I_1'' = I_3''\left(\frac{10}{16}\right) = \frac{\overset{15}{\cancel{240}}}{108} \times \frac{10}{\cancel{16}} = \frac{150\,A}{108}$$

$$I_2'' = I_3''\left(\frac{6}{16}\right) = \frac{\overset{15}{\cancel{240}}}{108} \times \frac{6}{\cancel{16}} = \frac{90}{108}\,A$$

so,

$$I_1 = I_1' - I_1'' = \frac{78}{108} - \frac{150}{108} = \frac{-72}{108}\,A = -0.67\,A$$

$$I_2 = I_2' + I_2'' = \frac{18}{108} + \frac{90}{108} = 1\,A$$

$$I_3 = I_3' - I_3'' = \frac{60}{108} - \frac{240}{108} = \frac{-180}{108} = -1.67\,A$$

Answer → −1.67 A

○ Applications of Superposition Theorem

→ Useful in circuit analysis, when the circuit has a large no. of independent sources.

→ Used in AC as well as DC network.

○ Drawbacks :

→ Not applicable to circuit consisting of non-linear elements such as diode.

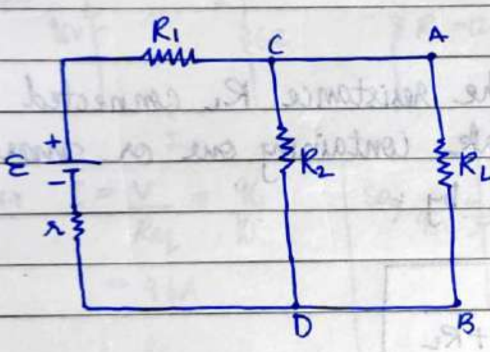
→ Cannot be applied to circuit having dependent sources only.

→ Used for calculating power.

THEVENIN'S THEOREM

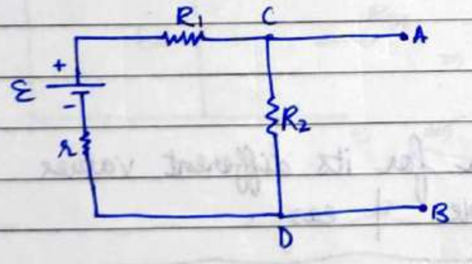
→ This theorem provides a mathematical technique for replacing a two terminal network by a voltage Source V_{TH} & resistance R_{TH} connected in series.

Steps to calculate I_L, V_{TH} & R_{TH} :—



(1) Remove or disconnect the load resistance (R_L) to get a open circuit.

(2) Calculate the current flowing through the circuit



$$I = \frac{\varepsilon}{R_{eq}}$$

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

then, Open Circuit Voltage or Thevenin's Voltage (V_{TH}) is given by :

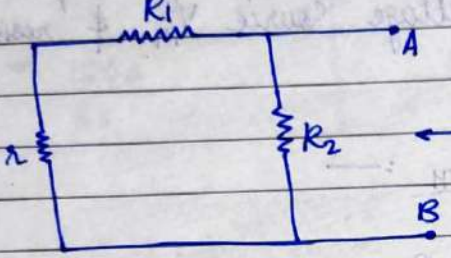
$$\boxed{\begin{aligned} V_{TH} &= IR_2 \\ \Rightarrow V_{TH} &= \frac{\varepsilon}{R_1+R_2+r} \cdot R_2 \end{aligned}}$$

(V_{TH} is the voltage across AB terminal which is same as voltage drop across R_2 resistor)

(3) for R_{TH} :—

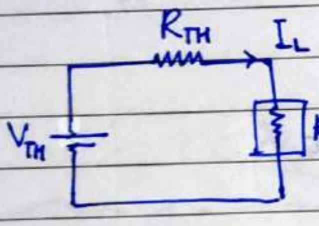
- voltage source is short circuited.
- Current source is open circuited.

sol Remove the voltage source from circuit leaving behind the internal resistance.



$$\boxed{\begin{aligned} R_{TH} &= (R_1 + r) \parallel R_2 \\ \Rightarrow R_{TH} &= \frac{(R_1 + r) R_2}{R_1 + R_2 + r} \end{aligned}}$$

(4) The current (I_L) flowing through the resistance R_L connected across any two terminals of network containing one or more sources of current / voltage is given by:



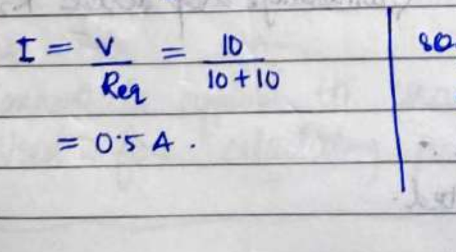
$$\boxed{I_L = \frac{V_{TH}}{R_{TH} + R_L}}$$

Advantages :-

→ We can find current in any resistor for its different values

→ Makes electronic network very simple & easy.

Ques.) Determine the Thevenin's Voltage & Thevenin's Resistance (AB)?

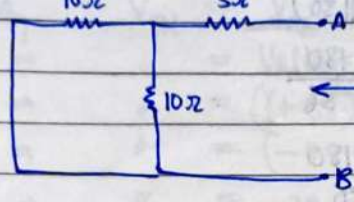


Ans.) $I = \frac{V}{R_{eq}} = \frac{10}{10+10}$

$= 0.5\,A$.

sol $V_{TH} = 0.5 \times 10$

$\Rightarrow V_{TH} = 5\,V$

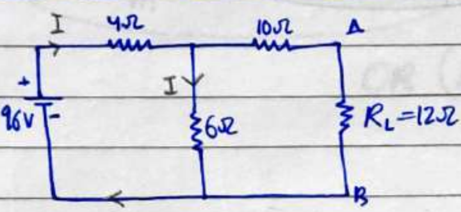


$R_{TH} = 5 + (10 \| 10)$

$\Rightarrow R_{TH} = 5 + \frac{100}{20}$ (5)

$\Rightarrow R_{TH} = 10\Omega$

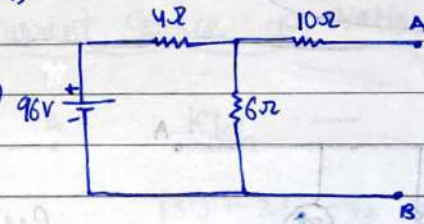
Ques.) Find the current in 12Ω resistance using Thevenin's Theorem.



Ans.) $I = \frac{V}{R_{eq}} = \frac{96}{10}$

$= 9.6A$

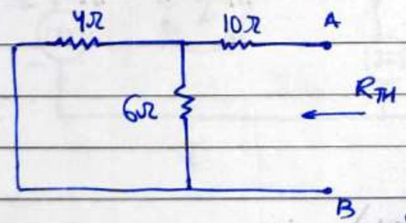
Sol:



$V_{TH} = I \times 6$

$\Rightarrow V_{TH} = 9.6 \times 6$

$\Rightarrow V_{TH} = 57.6\ V$



$R_{TH} = 10 + (4 \| 6)$

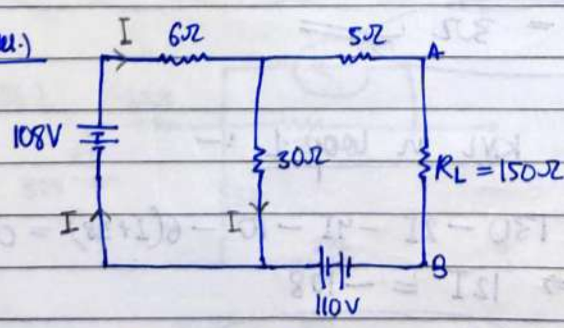
$\Rightarrow R_{TH} = 10 + \frac{24}{10}$

$\Rightarrow R_{TH} = 12.4\ \Omega$

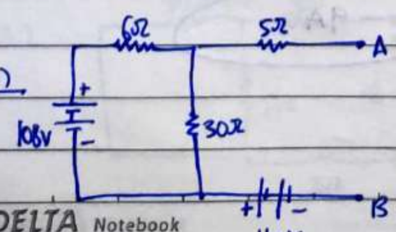
Sol: $I_L = \frac{V_{TH}}{R_{TH} + R_L} = \frac{57.6}{12.4 + 12}$

$\Rightarrow I_L = \frac{57.6}{24.4} = 2.36\ A$

Ques.) By Thevenin's Theorem calculate the load current in load resistance.



Ans.)



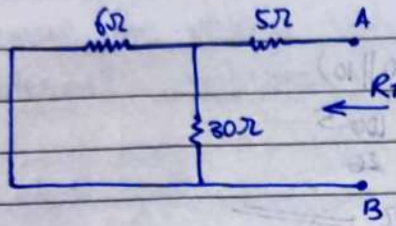
$I = \frac{V}{R_{eq}} = \frac{108}{36}$

$\Rightarrow I = 3A$

$V_{TH} = 3 \times 30 + 110V$

$\Rightarrow V_{TH} = 200V$

Now,



So, $R_{TH} = 5 + (6 \| 30)$

$\Rightarrow$ " $= 5 + \frac{180}{36}$

$\Rightarrow$ " $= \frac{180 + 180}{36}$

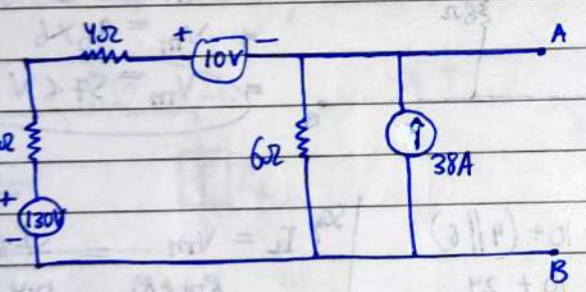
$\Rightarrow$ $R_{TH} = 10\,\Omega$

So,

$I_L = \frac{V_{TH}}{R_{TH} + R_L} = \frac{200}{10 + 150}$

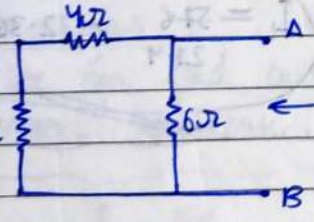
$\Rightarrow$ $I_L = \frac{200}{160} = 1.25\,A$

Ques.)



Calculate V_{TH} & R_{TH}.

Ans.)

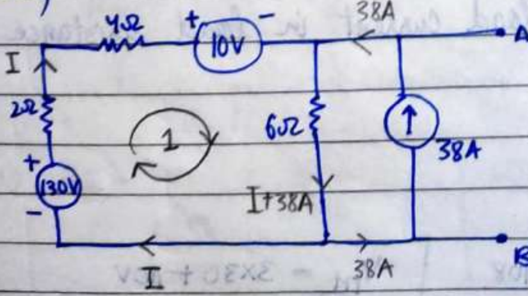


$R_{TH} = 6 \| (2+4)$

$\Rightarrow R_{TH} = \frac{6 \times 6}{6+6}$

$\Rightarrow$ $R_{TH} = 3\,\Omega$

Now,



KVL in loop 1 :-

$130 - 2I - 4I - 10 - 6(I + 38) = 0$

$\Rightarrow 12I = -108$

$\Rightarrow$ $I = -9A$

Sol $V_{TH} = V_{AB}$

$\Rightarrow$ " = Voltage across 6Ω resistor

$\Rightarrow$ " $= (I + 38) \times 6$

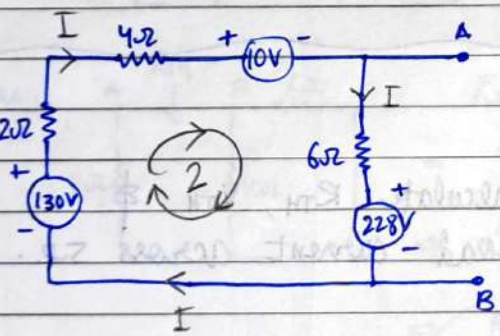
$\Rightarrow$ " $= (-9 + 38) \times 6$

$\Rightarrow$ " $= 29 \times 6$

$\Rightarrow$ $V_{TH} = 174\ V$

OR (Alternate method to find V_{TH})

- Using Conversion of current Source to voltage Source :-



KVL :-

$130 - 2I - 4I - 10 - 6I - 228 = 0$

$\Rightarrow I = -9A$

Sol

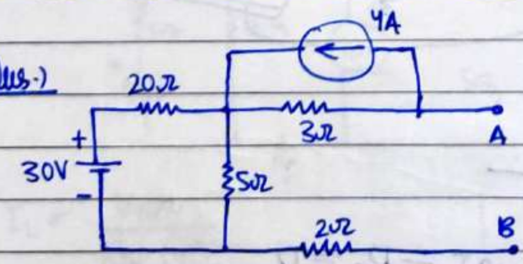
$V_{TH} = V_{AB}$

$\Rightarrow V_{TH} = 228 + 6I$

$\Rightarrow V_{TH} = 228 + 6 \times -9$

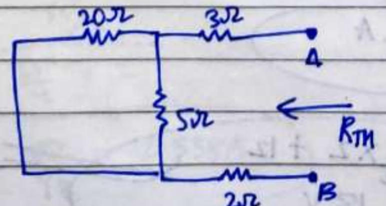
$\Rightarrow V_{TH} = 174\ V$

Ques.)



Calculate V_{TH} & R_{TH}.

Ans.)

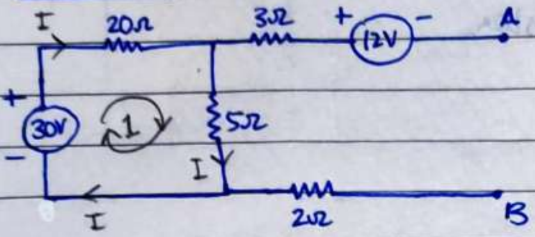


$R_{TH} = 3 + (20 \| 5) + 2$

$\Rightarrow R_{TH} = 3 + \frac{100}{25} + 2$

$\Rightarrow R_{TH} = 9\Omega$

for V_{TH} :—



KVL in loop 1 :—

$$30 - 20I - 5I = 0$$

$$\Rightarrow I = \frac{30}{25} = \frac{6}{5} \text{ A}$$

So,

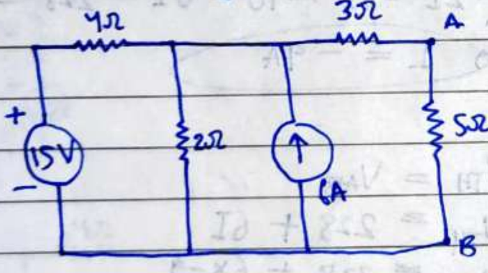
$$V_{TH} = V_{AB}$$

$$\Rightarrow V_{TH} = 5I - 12$$

$$\Rightarrow V_{TH} = 5 \times \frac{6}{5} - 12$$

$$\Rightarrow V_{TH} = -6V$$

Ques.)

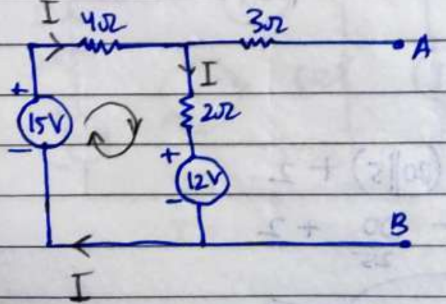


Calculate R_{TH}, V_{TH} & Load current across 5Ω.

Ans.)

$$R_{TH} = 3 + (2 \| 4)$$

$$\Rightarrow R_{TH} = \frac{13}{3} \Omega$$



KVL :—

$$15 - 4I - 2I - 12 = 0$$

$$\Rightarrow I = \frac{1}{2} \text{ A}$$

So,

$$V_{TH} = \frac{1}{2} \times 2 + 12$$

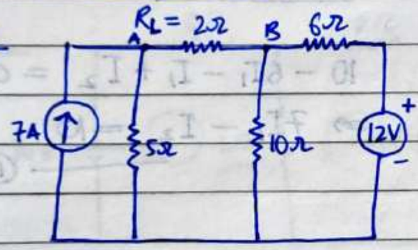
$$= 13 V$$

So, $I_L = \dfrac{V_{TH}}{R_{TH} + R_L}$

$\Rightarrow I_L = \dfrac{13}{\frac{13}{3} + 5}$

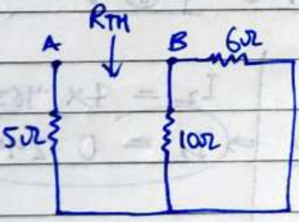
$\Rightarrow I_L = \dfrac{39}{28} A$

Ques.)



Calculate V_{TH}, R_{TH} & load current (I_L).

Ans.)



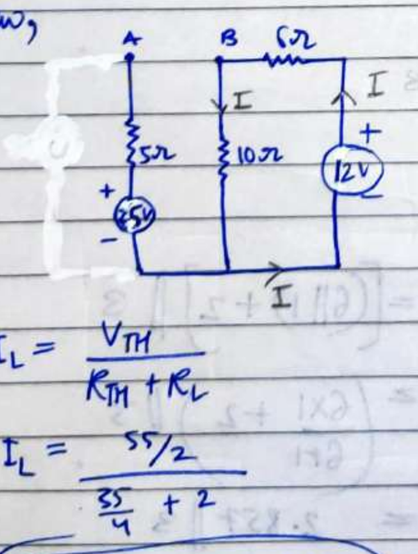
$R_{TH} = (6 \| 10) + 5$

$\Rightarrow R_{TH} = \dfrac{60}{16} + 5$

$\Rightarrow R_{TH} = \dfrac{15}{4} + 5$

$\Rightarrow R_{TH} = \dfrac{35}{4} \Omega$

Now,



$I = \dfrac{12}{6+10} = \dfrac{3}{4} A$

So, $V_{TH} = -\frac{3}{4} \times 10 + 35$ $\quad (V_{TH} = V_A - V_B)$

$V_{TH} = 35 - \dfrac{15}{2}$

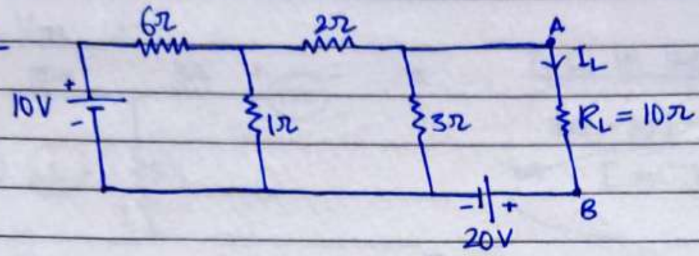
$V_{TH} = \dfrac{55}{2} V$

So, $I_L = \dfrac{V_{TH}}{R_{TH} + R_L}$

$\Rightarrow I_L = \dfrac{55/2}{\frac{35}{4} + 2}$

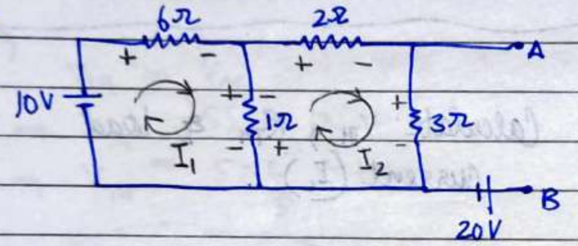
$\Rightarrow I_L = \dfrac{110}{43} = 2.558 A$

Ques.)



Find current I_L.

Ans.)



In mesh 1 :

$$10 - 6I_1 - I_1 + I_2 = 0$$
$$\Rightarrow 7I_1 - I_2 = 10 \quad \text{——— (I)}$$

In mesh 2 :

$$-I_2 + I_1 - 2I_2 - 3I_2 = 0$$
$$\Rightarrow I_1 - 6I_2 = 0 \quad \text{——— (II)}$$

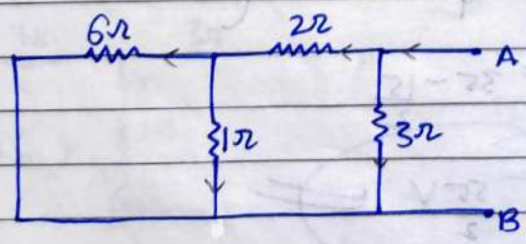
Subtracting eq^n (I)×6 & (II) :-

$$42I_1 - \cancel{6I_2} = 60$$
$$\underline{(-)I_1 \; \cancel{(+)6I_2} = 0}$$
$$41I_1 = 60$$
$$\Rightarrow I_1 = 1.463\text{ A}$$

$$I_2 = 7 \times 1.463 - 10$$
$$\Rightarrow I_2 = 0.244\text{ A}$$

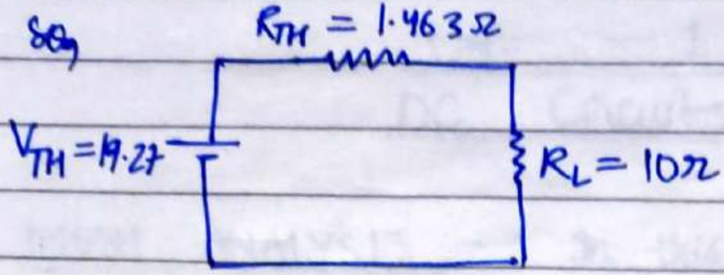
So,

$$V_{TH} = V_{AB}$$
$$\Rightarrow \quad '' = 3I_2 - 20$$
$$\Rightarrow \quad '' = 3 \times 0.244 - 20$$
$$\Rightarrow V_{TH} = -19.268\text{ V}$$



$$R_{TH} = [(6 \| 1) + 2] \| 3$$
$$\Rightarrow \quad '' = \left(\frac{6 \times 1}{6+1} + 2\right) \| 3$$
$$\Rightarrow \quad '' = 2.857 \| 3$$
$$\Rightarrow \quad '' = \frac{2.857 \times 3}{5.857}$$
$$\Rightarrow R_{TH} = 1.4634\ \Omega$$

Sol



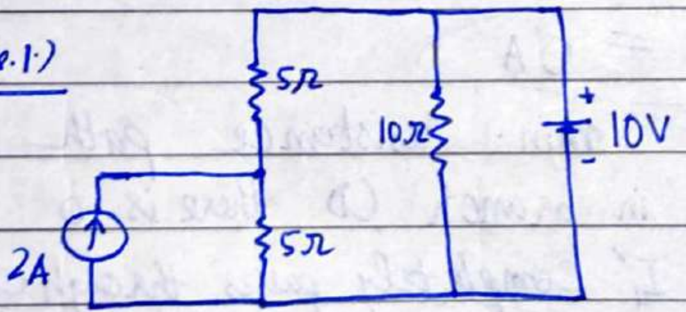
Sol $\dfrac{V_{TH}}{R_{TH}+R_L} = I_L$

$$\Rightarrow I_L = \frac{-19.27}{1.4634 + 10}$$

$$\Rightarrow I_L = -1.681\ A$$

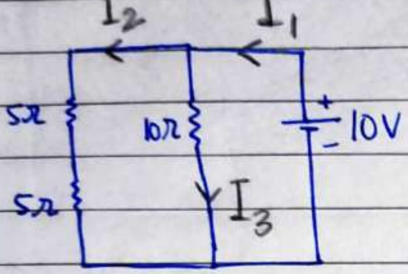
(Question of Superposition theorem.)

(Ques. 1.)



find current across 10Ω resistor.

Ans.) • Considering 10V battery :



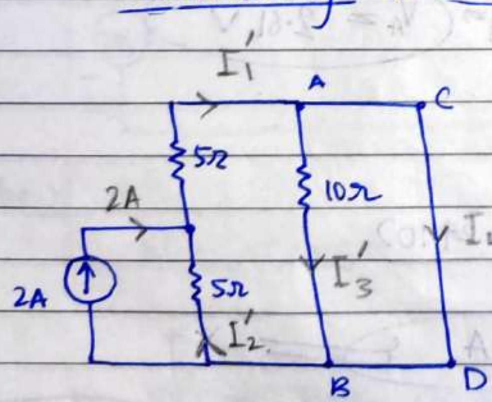
$$R_{eq} = (5+5) \| 10$$
$$\Rightarrow \;\; '' = 10 \| 10$$
$$\Rightarrow \;\; '' = \frac{10 \times 10}{10+10}$$
$$\Rightarrow R_{eq} = 5\Omega$$

so, $I_1 = V/R_{eq}$
$$\Rightarrow I_1 = 10/5$$
$$\Rightarrow I_1 = 2\,A$$

so, Using current divider Rule :—

$$I_3 = \frac{(5+5)}{(5+5)+10} \times I_1$$
$$\Rightarrow I_3 = 2 \times \frac{10}{20}$$
$$\Rightarrow I_3 = 1\,A$$

• Considering 2A current source :



In ideal conditions : we know :—

Resistance of a branch / connecting wire (CD in this case) $= 0$

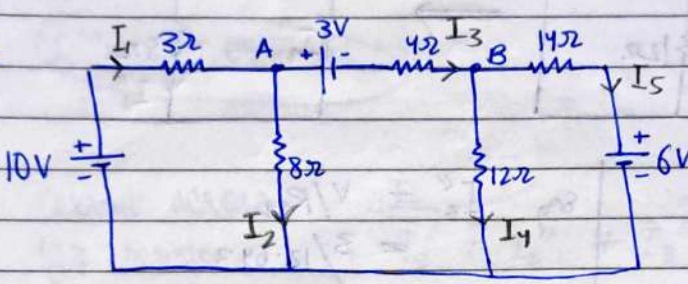
so, Using current divider rule :

$$I_3' = I_1' \times \frac{0}{10+0}$$
$$I_3' = 0\,A$$

Note :— Current always follow the min. resistance path. (And here in this case since, in branch CD there is 0 resistance, so, the current I_1' completely passes through CD & not in AB. so, $I_4' = I_1'$ & $I_3' = 0$)

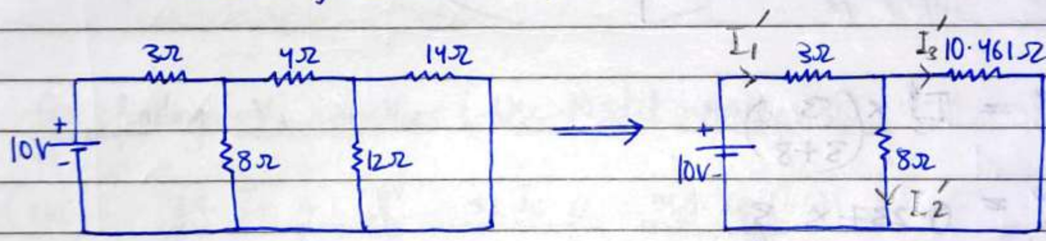
so, current through 10 Ω resistor = 1A

Ques.



Find current across 8 Ω resistor.

Ans. 2.) • Considering 10V battery :



$4 + (14 \| 12)$
$4 + 6.461$
$10.461\ \Omega$

$$R_{eq} = 3 + (8 \| 10.461)$$
$$= 3 + \frac{8 \times 10.461}{8 + 10.461}$$
$$= 3 + 4.533$$
$$= 7.533\ \Omega$$

so, $I_1' = V/R_{eq}$

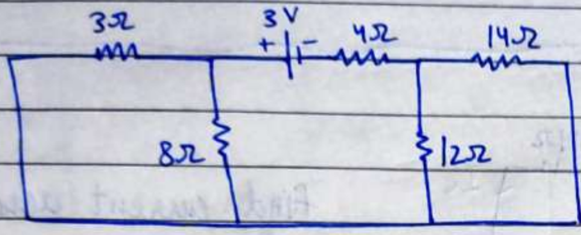
$\Rightarrow I_1' = 10/7.533$

$\Rightarrow I_1' = 1.327\ A$

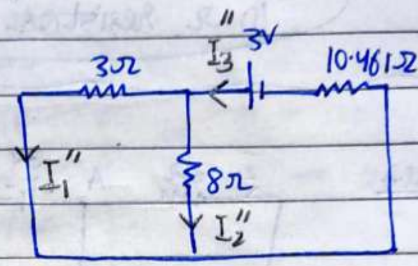
so,
$$I_2' = I_1' \left(\frac{10.461}{8 + 10.461} \right)$$
$$\Rightarrow I_2' = \frac{1.327 \times 10.461}{18.461}$$
$$\Rightarrow I_2' = 0.751\ A$$

Now,

- **Considering 3V battery :—**



$\Longrightarrow$

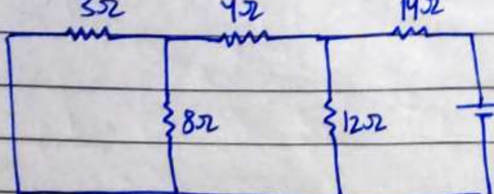


$$R_{eq} = (3\|8) + 10.461$$
$$= \frac{3\times 8}{3+8} + 10.461$$
$$= 12.643\ \Omega$$

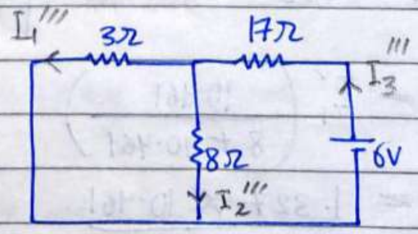
so, $I_3'' = V/R_{eq}$
$= 3/12.643$
$= 0.237\ A$

so,
$$I_2'' = I_3'' \times \left(\frac{3}{3+8}\right)$$
$$\Rightarrow I_2'' = 0.237 \times \frac{3}{11}$$
$$\Rightarrow I_2'' = 0.064\ A$$

- **Considering 6V battery :—**



$\Longrightarrow$



$(14 + (12\|4)$
$\Rightarrow 14 + 3$
$\Rightarrow 17\Omega)$

$$R_{eq} = 17 + (3\|8)$$
$$= 17 + \frac{3\times 8}{3+8}$$
$$= 19.182\ \Omega$$

so, $I_3''' = V/R_{eq}$
$= 6/19.182$
$= 0.312\ A$

Sol

$$I_2''' = I_3''' \times \left(\frac{3}{3+8}\right)$$

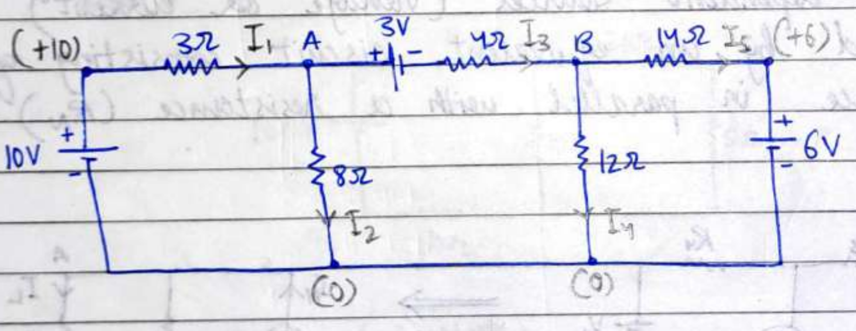
$$\Rightarrow I_2''' = \frac{0.312 \times 3}{11}$$

$$\Rightarrow I_2''' = 0.085\ A$$

Sol

$$\begin{aligned} \text{current across } 18\Omega \text{ resistor} &= I_2 \\ &= I_2' + I_2'' + I_3''' \\ &= 0.751 + 0.064 + 0.085 \\ &= 0.900\ A \end{aligned}$$

<u>For finding V_A & V_B</u> (<u>Use Nodal Analysis</u>) :-



<u>KCL at node A :</u>

$$I_1 = I_2 + I_3$$

$$\Rightarrow \frac{10-V_A}{3} = \frac{V_A}{8} + \frac{V_A-3-V_B}{4}$$

$$\Rightarrow \frac{10-V_A}{3} = \frac{V_A + 2V_A - 6 - 2V_B}{8}$$

$$\Rightarrow 80 - 8V_A = 3V_A + 6V_A - 18 - 6V_B$$

$$\Rightarrow 17V_A - 6V_B = 98 \quad \text{--- (I)}$$

<u>KCL at node B :</u>

$$I_3 = I_4 + I_5$$

$$\Rightarrow \frac{V_A-3-V_B}{4} = \frac{V_B}{12} + \frac{V_B-6}{14}$$

$$\Rightarrow \frac{V_B-6}{\cancel{14}\ 7} = \frac{3V_A - 9 - 3V_B - V_B}{\cancel{12}\ 6}$$

$$\Rightarrow 6V_B - 36 = 21V_A - 63 - 28V_B$$

$$\Rightarrow 21V_A - 34V_B = 27 \quad \text{--- (II)}$$

Solving eqn. (I) & (II) :-

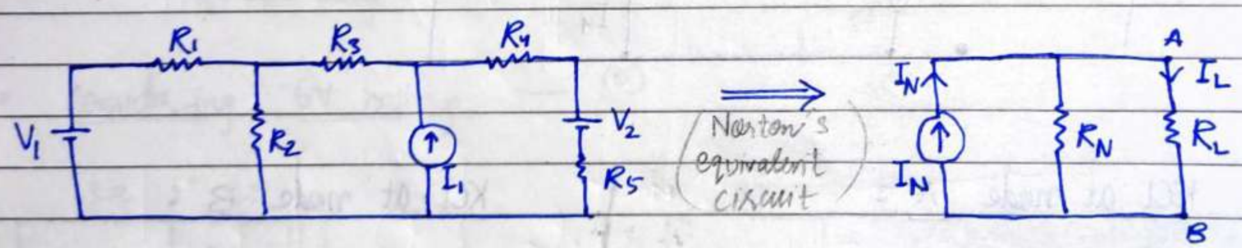
Subtracting eqn. (I) × 34 & eqn. (II) × 6 :-

$$578 V_A - 204 V_B = 3332$$
$$\underline{\overset{(-)}{}126 V_A \overset{(+)}{-} 204 V_B = \overset{(-)}{}162}$$
$$452 V_A = 3170$$
$$\Rightarrow V_A = 7.013 \text{ V}$$

$$V_B = \frac{17 \times 7.013 - 98}{6}$$
$$\Rightarrow V_B = 3.536 \text{ V}$$

▫ NORTON'S THEOREM

→ It states that any linear bilateral circuit consisting of independent or dependent sources (voltage or current) can be replaced by an equivalent circuit consisting of a current source (I_N) in parallel with a resistance (R_N).



Step 1 : Remove R_L and short circuit the branch through which current is to be calculated.

Step 2 : Obtain current through the short circuited branch using any simplification method. And this current is Norton's current (I_N).

Step 3 : Calculate R_N by open circuiting R_L (load resistance) and

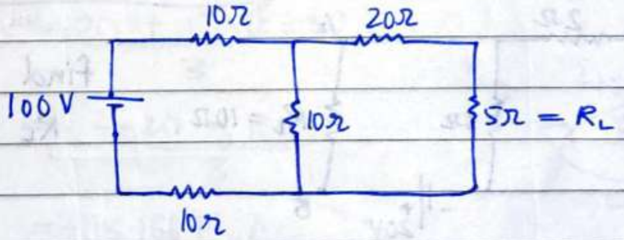
and replacing the active sources with their internal resistances. (If no internal resistance, then short ckt. voltage sources and open ckt. current sources.)

Step 4: Draw Norton's equivalent circuit across the terminals of interest.

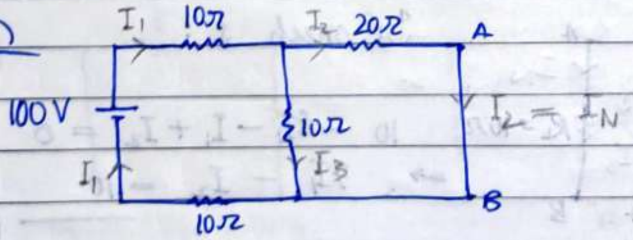
Step 5: find I_L.

$$\boxed{I_L = I_N \times \frac{R_N}{R_N + R_L}}$$ (Using current divider Rule.)

Ques.) Calculate the value of current in 5Ω resistance using Norton's Theorem.



Ans.)



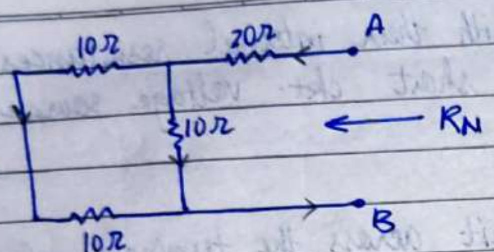
$$R_{eq} = 10 + 10 + (10 \| 20)$$
$$= 20 + \frac{200}{30}$$
$$= 80/3 \,\Omega$$

Sol.

$$I_1 = \frac{V}{R_{eq}} = \frac{100}{80/3}$$
$$= \frac{30}{8} \text{ A}$$

Sol.

$$I_2 = I_N = I_1 \times \frac{10}{10+20}$$
$$\Rightarrow I_N = \frac{30}{8} \times \frac{1}{3} = \frac{10}{8}$$
$$\Rightarrow I_N = 1.25 \text{ A}$$



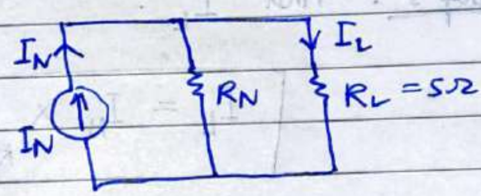
$$R_N = [(10+10) \,\|\, 10] + 20$$

$$\Rightarrow \text{"} = (20\|10) + 20$$

$$\Rightarrow R_N = \frac{200}{30} + 20$$

$$\Rightarrow R_N = \frac{80}{3}\,\Omega$$

Sol^n



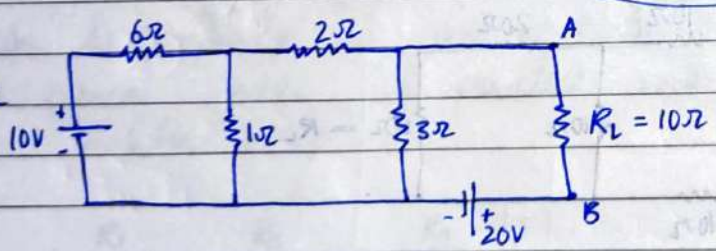
$$I_L = I_N \times \frac{R_N}{R_N + R_L}$$

$$\Rightarrow \text{"} = \frac{10}{8} \times \frac{80/3}{80/3 + 5}$$

$$\Rightarrow \text{"} = \frac{10}{\cancel{8}} \times \frac{\cancel{80}\,10}{95}$$

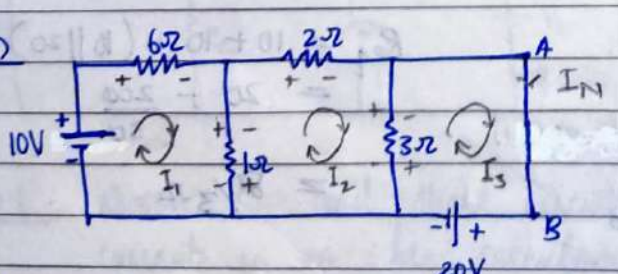
$$\Rightarrow I_L = 1.052\text{ A}$$

Ques.)



find I_L through $R_L = 10\Omega$.

Ans.)



In mesh 1 :

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

$$\Rightarrow 7I_1 - I_2 = 10 \quad \text{(i)}$$

In mesh 2 :

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

$$\Rightarrow I_1 - 6I_2 + 3I_3 = 0 \quad \text{(ii)}$$

In mech 3 :

$$-20 - 3I_3 + 3I_2 = 0$$

$$\Rightarrow 3I_2 - 3I_3 = 20 \quad \text{(iii)}$$

Subtracting eqn. (III) − eqn. (I) :

$$3I_2 - 3I_3 = 20$$
$$\underline{-7I_1 \; (+)\; I_2 = (-)\, 10}$$
$$-7I_1 + 4I_2 - 3I_3 = 10 \quad \text{——— (a)}$$

Adding eqn. (a) & (II) :—

$$I_1 - 6I_2 + \cancel{3I_3} = 0$$
$$\underline{-7I_1 + 4I_2 - \cancel{3I_3} = 10}$$
$$-6I_1 - 2I_2 = 10 \quad \text{——— (b)}$$

Subtracting eqn. (I) × 2 − eqn. (b) :—

$$14I_1 - \cancel{2I_2} = 20$$
$$\underline{(+)\,6I_1 \; (+)\, \cancel{2I_2} = (-)\, 10}$$
$$20I_1 = 10$$
$$\Rightarrow I_1 = 0.5\text{ A}$$

So, $I_2 = 7 \times 0.5 - 10$

$\Rightarrow I_2 = -6.5\text{ A}$

So,

$$I_3 = \frac{-20 + 3\times(-6.5)}{3}$$

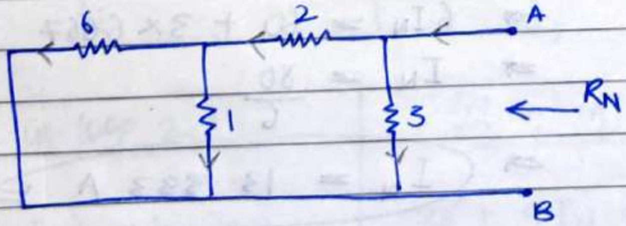
$$\Rightarrow I_3 = \frac{-20 - 19.5}{3}$$

$$\Rightarrow I_3 = -13.1667\text{ A}$$

So, $I_N = I_3$

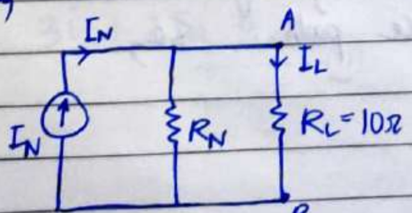
$\Rightarrow I_N = -13.1667\text{ A}$

So,



$$R_N = [(6 \| 1) + 2] \| 3$$
$$\Rightarrow \text{"} = \left(\frac{6}{7} + 2\right) \| 3$$
$$\Rightarrow \text{"} = \frac{20}{7} \| 3$$
$$\Rightarrow R_N = 1.4634\ \Omega$$

So,

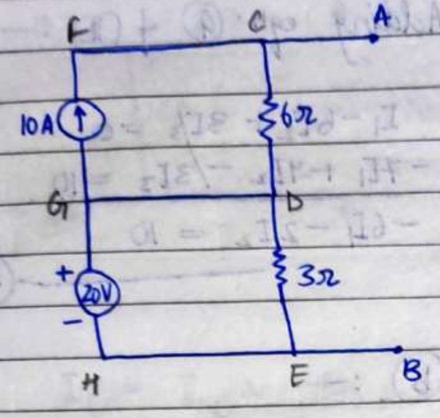


$$I_L = I_N \times \frac{R_N}{R_N + R_L} = -13.2 \times \frac{1.4634}{1.4634 + 10}$$

$$\Rightarrow I_L = 1.685\text{ A}$$

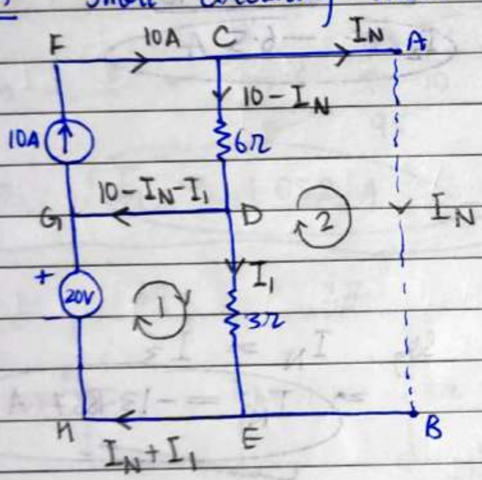
Dt.:
Pg.:

Ques.)



Replace the given circuit by Norton's Equivalent circuit across A & B.

Ans.) Short circuiting AB :



KVL in loop 1 :

$20 - 3I_1 = 0$

$\Rightarrow I_1 = \frac{20}{3}$

$\Rightarrow I_1 = 6.667$ A

KVL in loop 2 :

$6(10 - I_N) + 3I_1 = 0$

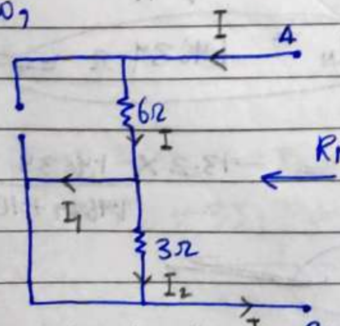
$\Rightarrow 60 - 6I_N + 3I_1 = 0$

$\Rightarrow 6I_N = 60 + 3 \times 6.667$

$\Rightarrow I_N = \frac{80}{6}$

$\Rightarrow I_N = 13.333$ A

Now,



we know: current always follow min. resistance path. So,

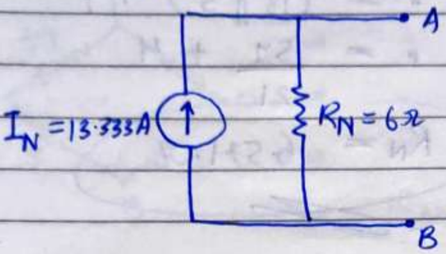
$I_2 = 0$

$I_1 = I$

So,

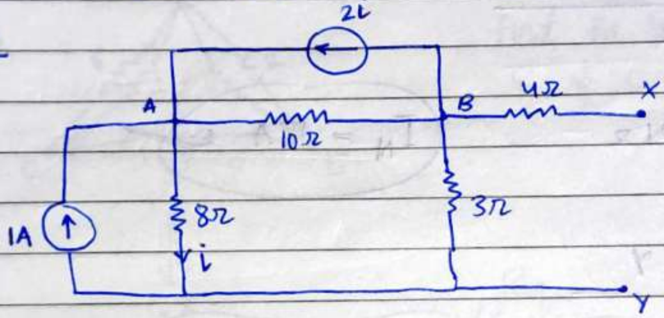
$R_N = 6\Omega$

So, <u>Norton's equivalent circuit</u> :—



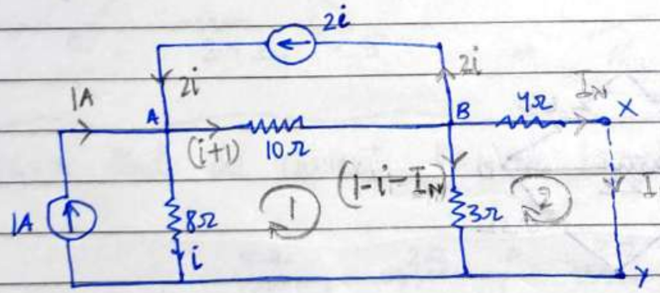
Ans

Ques.:



Determine the values of I_N, R_N & i.

Ans.: <u>Short circuiting XY</u> :—



<u>KVL in loop 1</u> :—

$8i - 10(i+1) - 3(1-i-I_N) = 0$

$\Rightarrow 8i - 10i - 10 - 3 + 3i + 3I_N = 0$

$\Rightarrow i + 3I_N = 13$ —— (I)

<u>KVL in loop 2</u> :

$3(1-i-I_N) - 4I_N = 0$

$\Rightarrow 3 - 3i - 3I_N - 4I_N = 0$

$\Rightarrow 3i + 7I_N = 3$ —— (II)

<u>Solving eqn. (I)×3 − (II)</u> :—

$\cancel{3i} + 9I_N = 39$

$\underset{(-)}{\cancel{3i}} \underset{(-)}{+} 7I_N = \underset{(-)}{3}$

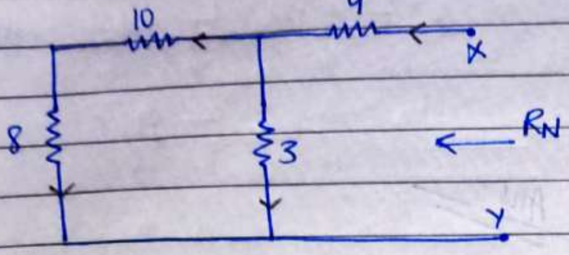
$2I_N = 36$

$\Rightarrow I_N = 18\ A$

So, $i = 13 - 3I_N$

$i = 13 - 54$

$\Rightarrow i = -41\ A$



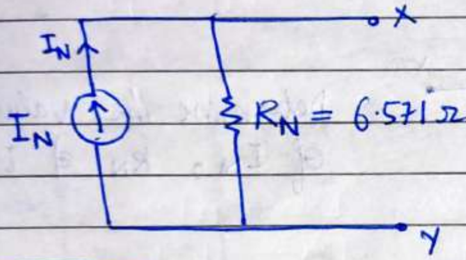
$R_N = ((10+8) \parallel 3) + 4$

$\Rightarrow R_N = (18 \parallel 3) + 4$

$\Rightarrow R_N = \frac{54}{21} + 4$

$\Rightarrow R_N = 6.571\ \Omega$

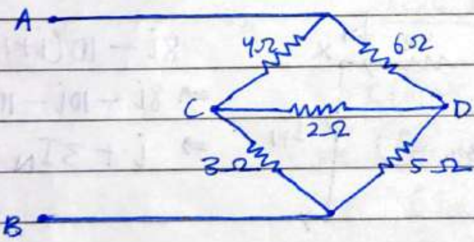
So, Norton's equivalent circuit :—



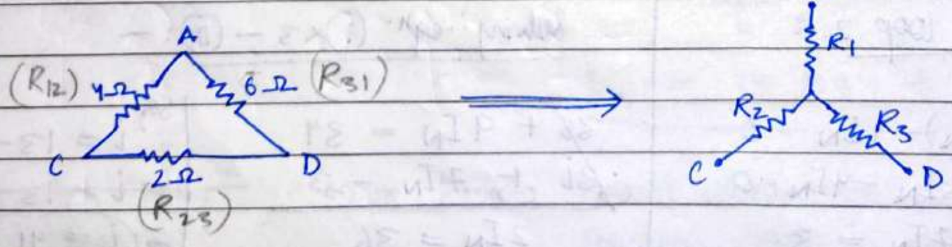
$I_N = 18A$

Extra Questions

Ques.1.) find the resistance between A - B using star delta transform-ation.



Ans.)



$R_1 = \frac{R_{12} \cdot R_{31}}{R_{12}+R_{23}+R_{31}} = \frac{4 \times 6}{4+2+6}$

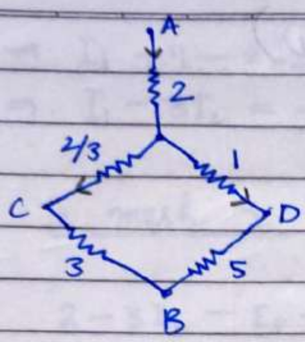
$\Rightarrow R_1 = 2\ \Omega$

$R_2 = \frac{2 \times 4}{4+2+6}$

$\Rightarrow R_2 = \frac{2}{3}\ \Omega$

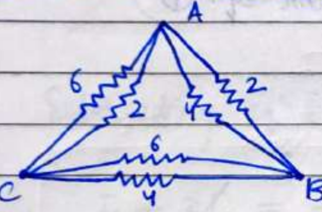
$R_3 = \frac{2 \times 6}{4+2+6}$

$\Rightarrow R_3 = 1\ \Omega$

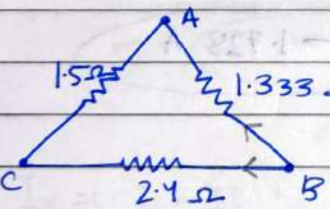


$$R_{eq\,(AB)} = 2 + \left[\left(\tfrac{2}{3}+3\right) \| (1+5)\right]$$
$$= 2 + (3.667 \| 6)$$
$$\Rightarrow \quad = 2 + \frac{3.667 \times 6}{3.667 + 6}$$
$$\Rightarrow \quad = 2 + 2.275$$
$$\Rightarrow \quad R_{AB} = 4.275\ \Omega$$

Que. 2) Find the resistance b/w terminals B & C.

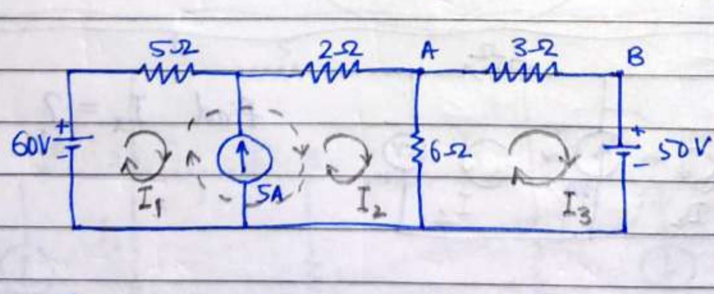


Ans.)



$$R_{eq\,(B \to C)} = (1.5 + 1.333) \| 2.4$$
$$= 2.833 \| 2.4$$
$$\Rightarrow \quad R_{BC} = \frac{6.7992}{5.233}$$
$$\Rightarrow \quad R_{BC} = 1.3\ \Omega$$

Que. 3) find the current through branch A-B using mesh analysis.



Ans. 3.) $I_2 - I_1 = 5A$ ——— (1)

In supermesh (1 & 2) :—

$$60 - 5I_1 - 2I_2 - 6I_2 + 6I_3 = 0$$
$$\rightarrow 5I_1 + 8I_2 - 6I_3 = 60$$

$\Rightarrow 5I_1 + 8(I_1+5) - 6I_3 = 60$ (from eq^n. 1)

$\Rightarrow 5I_1 + 8I_1 + 40 - 6I_3 = 60$

$\Rightarrow 13I_1 - 6I_3 = 20$ ——— (II)

In mesh 3 :-

$-50 - 6I_3 + 6I_2 - 3I_3 = 0$

$\Rightarrow 6(I_1+5) - 9I_3 = 50$ (from eq^n. 1)

$\Rightarrow 6I_1 - 9I_3 = 20$ ——— (III)

Now, Subtracting eq^n (II) × 3 − eq^n. (III) × 2 :

$39I_1 - 18I_3 = 60$

$\underset{(-)}{}12I_1 \underset{(+)}{-} 18I_3 = \underset{(-)}{}40$

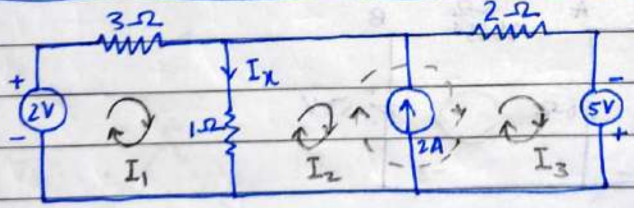
$27I_1 = 20$

$\Rightarrow I_1 = 0.740\text{ A}$

$I_3 = \frac{13 \times 0.740 - 20}{6}$

$\Rightarrow I_3 = -1.728\text{ A}$

So, current through branch AB $= I_3 = -1.728\text{ A}$

Ques 4) 

find $I_x = ?$

Ans:) $I_3 - I_2 = 2$ ——— 1

In supermesh (2 & 3) :

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

$\Rightarrow I_1 - 2(2+I_2) - I_2 = -5$ (from eq^n. 1)

$\Rightarrow I_1 - 4 - 2I_2 - I_2 = -5$

$\Rightarrow I_1 - 3I_2 = -1$ ——— (II)

In mesh 1 :

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

$\Rightarrow 4I_1 - I_2 = 2$ ——— (III)

Subtracting eqn. (II) − eqn. (III)×3 :-

$$\begin{aligned} I_1 - \cancel{3I_2} &= -1 \\ (-)12I_1 \; \cancel{(+)3I_2} &= (-)6 \\ \hline -11I_1 &= -7 \end{aligned}$$

$\Rightarrow I_1 = 0.6363\ A$

$I_2 = 4 \times 0.6363 - 2$

$\Rightarrow I_2 = 0.5454\ A$

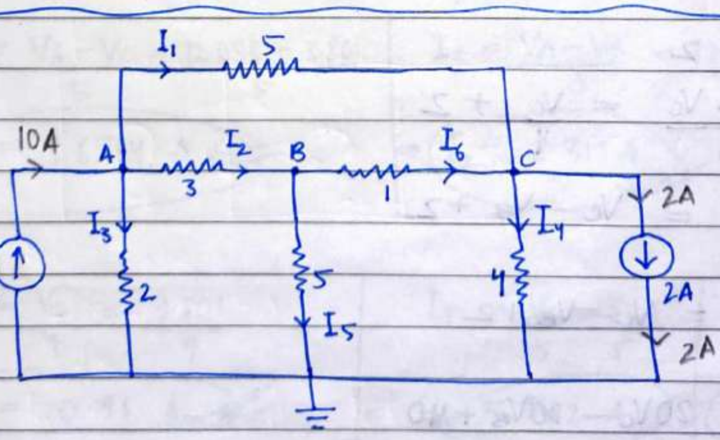
So,

$I_x = I_1 - I_2$

$\Rightarrow I_x = 0.6363 - 0.5454$

$\Rightarrow I_x = 0.0909\ A \downarrow$

(Ques. 5.)



Find the currents in the various resistors using nodal analysis.

Ans.)

Applying KCL at node A :

$I_1 + I_2 + I_3 = 10$

$\Rightarrow \dfrac{V_A - V_C}{5} + \dfrac{V_A - V_B}{3} + \dfrac{V_A}{2} = 10$

$\Rightarrow \dfrac{6V_A - 6V_C + 10V_A - 10V_B + 15V_A}{30} = 10$

$\Rightarrow 31V_A - 10V_B - 6V_C = 300$ ——— (I)

KCL at node B :

$I_5 + I_6 = I_2$

$\Rightarrow \dfrac{V_B}{5} + \dfrac{V_B - V_C}{1} = \dfrac{V_A - V_B}{3}$

$\Rightarrow \dfrac{V_A - V_B}{3} - \dfrac{V_B}{5} = \dfrac{V_B - V_C}{1}$

$\Rightarrow \dfrac{5V_A - 5V_B - 3V_B}{15} = V_B - V_C$

$\Rightarrow 5V_A - 8V_B = 15V_B - 15V_C$

$\Rightarrow 5V_A - 23V_B + 15V_C = 0$ ——— (II)

KCL at Node C :

$I_1 + I_6 = I_4 + 2$

$\Rightarrow \dfrac{V_A - V_C}{5} + \dfrac{V_B - V_C}{1} = \dfrac{V_C}{4} + 2$

$\Rightarrow \dfrac{V_A - V_C}{5} - \dfrac{V_C}{4} = V_C - V_B + 2$

$\Rightarrow \dfrac{4V_A - 4V_C - 5V_C}{20} = V_C - V_B + 2$

$\Rightarrow 4V_A - 9V_C = 20V_C - 20V_B + 40$

$\Rightarrow 4V_A + 20V_B - 29V_C = 40$ ——— (III)

$$D = \begin{vmatrix} 31 & -10 & -6 \\ 5 & -23 & 15 \\ 4 & 20 & -29 \end{vmatrix} = 31(667-300) + 10(-145-60) - 6(100+92)$$
$$= 11377 - 2050 - 1152$$
$$= 8175$$

and,

$$D_x = \begin{vmatrix} 300 & -10 & -6 \\ 0 & -23 & 15 \\ 40 & 20 & -29 \end{vmatrix} = 300(667-300) + 40(-150-138)$$
$$= 110100 - 11520$$
$$= 98580$$

$$D_y = \begin{vmatrix} 31 & 300 & -6 \\ 5 & 0 & 15 \\ 4 & 40 & -29 \end{vmatrix} = -300(-145-60) - 40(465+30)$$
$$= 61500 - 19800$$
$$= 41700$$

$$D_z = \begin{vmatrix} 31 & -10 & 300 \\ 5 & -23 & 0 \\ 4 & 20 & 40 \end{vmatrix} = 300(100+92) + 40(-713+50)$$
$$= 57600 - 26520$$
$$= 31080$$

so,

$V_A = \dfrac{D_x}{D} = \dfrac{98580}{8175}$ $\Rightarrow$ $V_A = 12.058\ V$

$V_B = \dfrac{D_y}{D} = \dfrac{41700}{8175}$ $\Rightarrow$ $V_B = 5.1\ V$

$V_C = \dfrac{D_z}{D} = \dfrac{31080}{8175}$ $\Rightarrow$ $V_C = 3.801\ V$

so,

$I_1 = \dfrac{V_A - V_C}{5} = \dfrac{12.058 - 3.801}{5}$ $\Rightarrow$ $I_1 = 1.6514\ A$

$I_2 = \dfrac{V_A - V_B}{3} = \dfrac{12.058 - 5.1}{3}$ $\Rightarrow$ $I_2 = 2.319\ A$

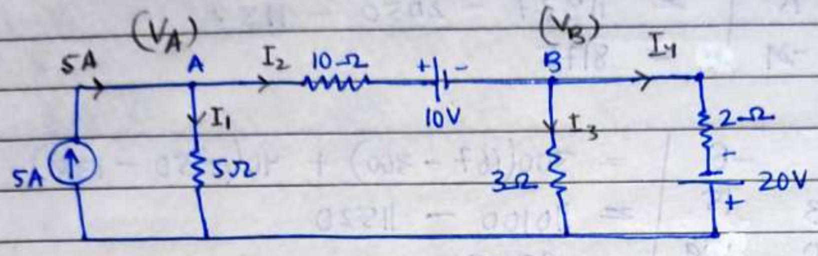
$I_3 = \dfrac{V_A}{2} = \dfrac{12.058}{2}$ $\Rightarrow$ $I_3 = 6.029\ A$

$I_4 = \dfrac{V_C}{4} = \dfrac{3.801}{4}$ $\Rightarrow$ $I_4 = 0.95\ A$

$I_5 = \dfrac{V_B}{5} = \dfrac{5.1}{5}$ $\Rightarrow$ $I_5 = 1.02\ A$

$I_6 = \dfrac{V_B - V_C}{1} = 5.1 - 3.801$ $\Rightarrow$ $I_6 = 1.299\ A$

Ques.6) find current and voltage across 2-Ω resistor.



Ans.) KCL at node A :-

$I_1 + I_2 = 5$

$\Rightarrow \dfrac{V_A}{5} + \dfrac{V_A - V_B - 10}{10} = 5$

$\Rightarrow 2V_A + V_A - V_B - 10 = 50$

$\Rightarrow 3V_A - V_B = 60$ ——— (1)

KCL at node B :-

$I_2 = I_3 + I_4$

$\Rightarrow \dfrac{V_A - V_B - 10}{10} = \dfrac{V_B}{3} + \dfrac{V_B - (-20)}{2}$

$\Rightarrow \dfrac{V_A - V_B - 10 - 5V_B - 100}{10} = \dfrac{V_B}{3}$

$\Rightarrow 3V_A - 28V_B = 330$ ——— (11)

eqn. (1) — eqn. (11) :

$\cancel{3V_A} - V_B = 60$

$\underset{(-)}{\cancel{3V_A}} \underset{(+)}{-} 28V_B = \underset{(-)}{330}$

$27V_B = -270$

$\Rightarrow V_B = -10\ V$

$V_A = \dfrac{60 + (-10)}{3}$

$\Rightarrow V_A = 16.667\ V$

So,

$I_4 = \dfrac{V_B + 20}{2} = \dfrac{-10+20}{2}$

$\Rightarrow I_4 = 5A$

Voltage across 2-Ω resistor :

$V_{2\Omega} = IR$

$\Rightarrow V_{2\Omega} = 5 \times 2$

$\Rightarrow V_{2\Omega} = 10\ V$

Same Ques can be done by mesh analysis by firstly converting (5A) current source to voltage source (±)25V