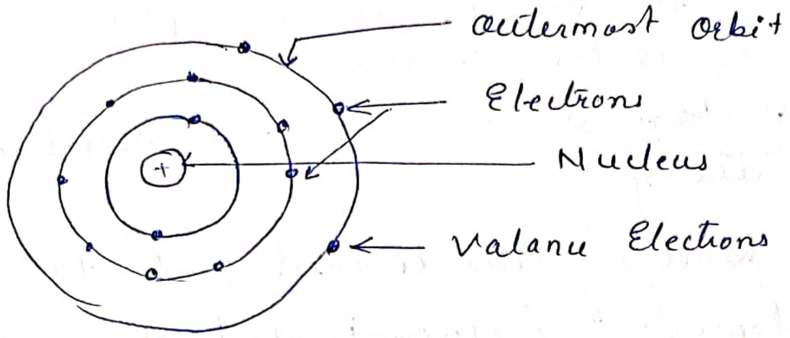
STRUCTURE OF ATOM



CONCEPT OF EMF

The Electrical force or pressure that causes the Electrons to move in a particular direction is called as Electromotive force i.e. EMF.

It is also called as voltage or potential difference.

unit = volts and denoted by "V"

CONCEPT OF CURRENT

Electron current : The current due to flow of Electrons is called Electron current.

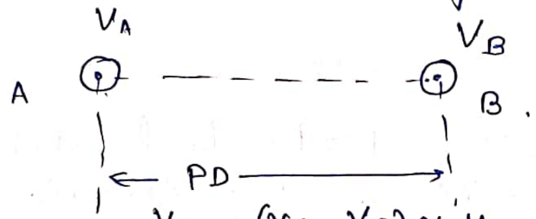
Conventional current :

Convential current is said to be flowing from higher potential to lower potential.

The direction of flow of convential current is always opposite to that of flow of Electrons or Electron current.

* Potential difference

Potential difference between any two points is defined as the difference between the Electric potentials at those points.



$V_{AB} = (V_A - V_B)$ Volts.

* Power.

It is defined as the product of voltage & Current.

Power (P) $= V \times I$.

Limits : watts.

* Energy.

Electrical Energy is defined as the product of Power and time.

$\therefore$ Energy = Power (P) x time (t).

Unit : watts x seconds or Joules.

———x———

2

Electrical Network

It is interconnection of various active & Passive Elements

Active Source

The source which gives out Energy is Called as active source.

Eg: Voltage source, current source, generator, Battery

Active sources are divided into two Types.

1. Independent / uncontrolled source.
2. Dependent / controlled source.

① Independent / uncontrolled source

The source whose Magnitude is not dependent or cannot be controlled by any other parameter of given Network then it is called as independent or uncontrolled source.

They are classified as.

I] Independent voltage source. (symbol)

II] Independent current source. (symbol)

(I) Independent voltage source.

(a) Ideal voltage source

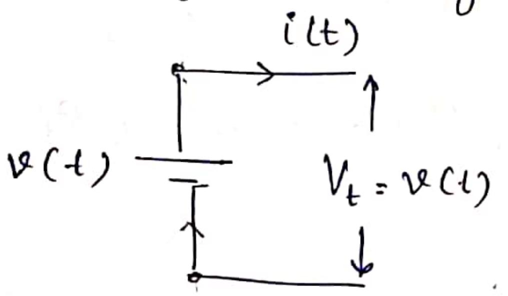
Ideal voltage source is that source when terminal voltage remains Constant irrespective of change in current flowing through it.

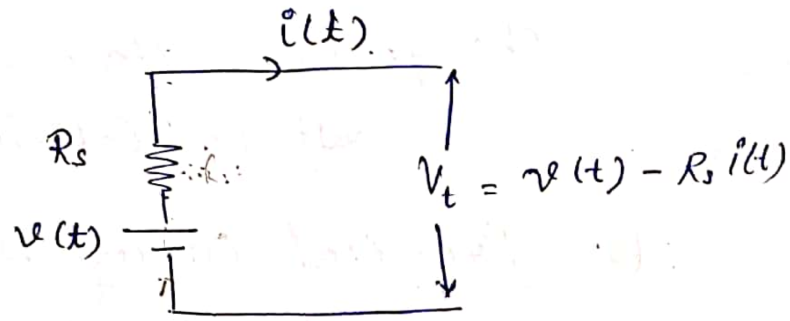
The source resistance of an Ideal voltage source is zero. [Therefore Terminal voltage remains Const without load or with load]

(b) Practical voltage source

In practice the ideal voltage source discussed earlier does not exist.

The Practical voltage source has some internal resistance connected in series with source, due to which terminal voltage across it goes on decreasing for increasing value of current coming out of it.





Ideal voltage source.

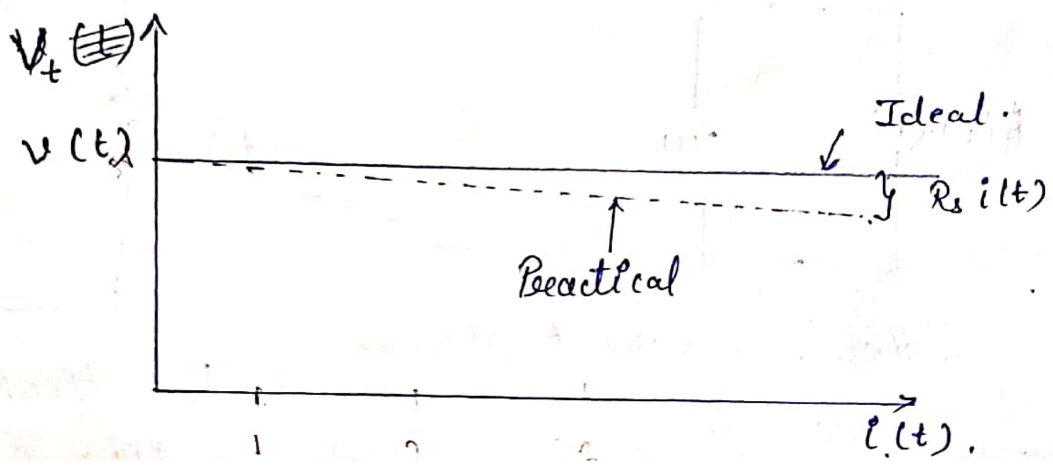
$$V_t' = v(t)$$

$$R_s = 0$$

Practical voltage source

$$V_t = v(t) - R_s\, i(t).$$

Characteristics of Ideal and Practical voltage source.



4 II Independent current sources

They are further classified as.

(a) Ideal current source.
(b) Practical current source.

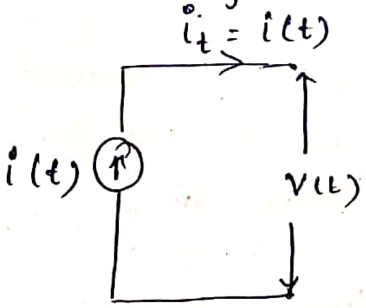
(a) Ideal current source

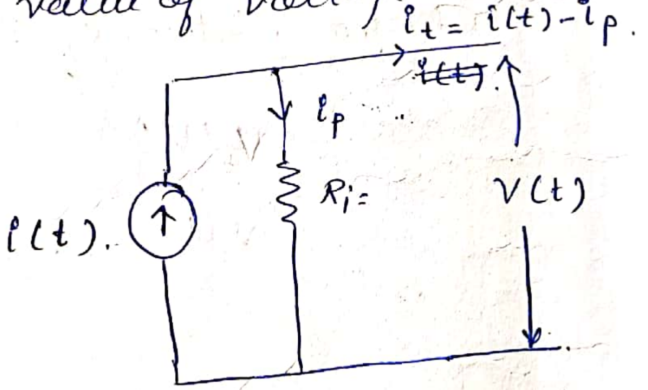
Ideal current source is that source whose terminal current remains constant irrespective of any change in voltage across it.

It has infinite internal Resistance ($R_i = \infty$).

(b) Practical current source

The Practical current source ~~has~~ will have a finite shunt resistance (internal). which is assumed to be parallel with source. Because of these resistance, the output current goes on decreasing for increasing value of voltage across it.





Ideal current source

$R_i = \infty$

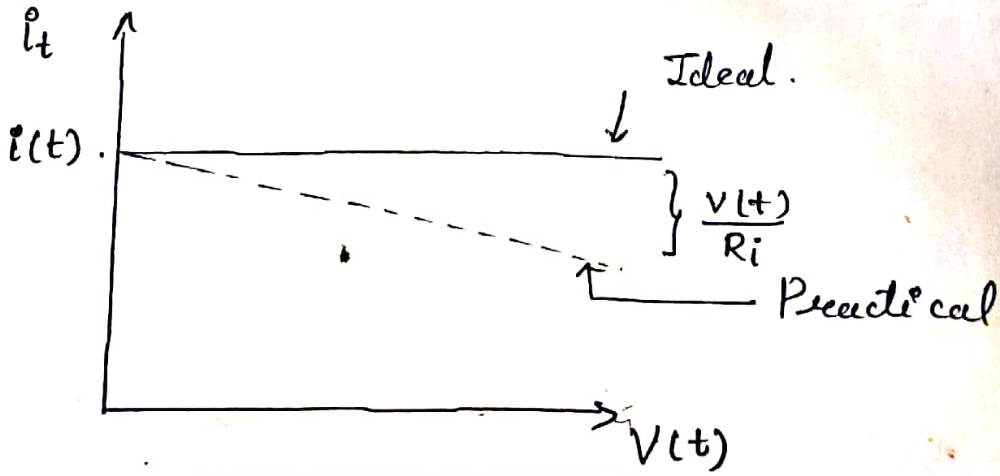
$i_t = i(t)$.

Practical current source

$i(t) = i_t + i_p$.

$i_t = i(t) - i_p$

Characteristics of ideal & Practical current source



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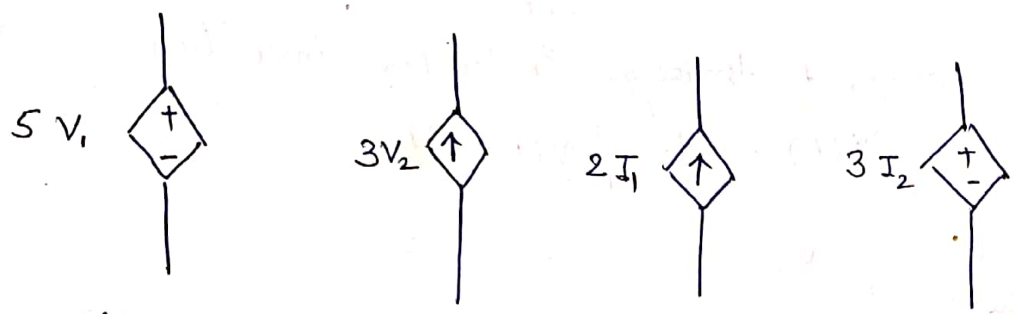
② **Dependent or controlled source**

The source whose Magnitude is depend upon or can be controlled by any other parameter of the given Network.

They are classified as.

1] Voltage Controlled voltage source. (VCVS)
2] Voltage Controlled current source (VCCS)
3] Current Controlled current source (CCCS)
4] Current Controlled voltage source (CCVS).



VCVS   VCCS   CCCS   CCVS

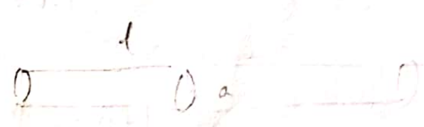
Passive Elements.

The Elements which Consumes Energy is called as Passive Element.

i] **Resistor** (R)

Resistance of a material is defined as the opposition to flow of current. It is measured in ohms (Ω). The symbol is R.

$$R = \rho \frac{l}{a}.$$



$R \rightarrow$ Resistance. (Ω)
$\rho \rightarrow$ Resistivity of the material. (Ω-m)
$l \rightarrow$ length of the Conductor. (m)
$a =$ Cross section area. (m^2)

ii) # Inductance (L)

Inductance is defined as the property of the coil by which an EMF is induced when is the current passing through it changes with respect to time.

$$V_L(t) \propto \frac{d}{dt} i_L(t).$$

$$V_L(t) = L \frac{d}{dt} i_L(t) \rightarrow \text{Voltage across Inductor.}$$

current through inductor:

Integrated w.r.t 't'

$$\int V_L(t) \, . \, dt = L \, i_L(t).$$

$$i_L(t) = \frac{1}{L} \int V_L(t) \, . \, dt$$

The unit of Inductance is ~~Henkey~~ Henry (H).

iii) # Capacitance (C)

Capacitance is defined as the property of a device by which it carries current when its voltage is changed with respect to time.

Or.

Charge developed between plates of capacitor is directly proportional to the potential difference between the plates, the constant of proportionality is called Capacitance.

$$Q = C V_c$$

Differentiate w.r.t 't'

$$\frac{dq}{dt} = C \frac{dV_c}{dt}.$$

Current through capacitance.

$$i_c(t) = C \frac{d}{dt} V_c(t)$$

Integrate w.r.t. time.

$$\int i_c(t).dt = C . \times V_c(t).$$

$$\boxed{V_c(t) = \frac{1}{C} \int i_c(t).dt}$$ → Voltage across Capacitor.

The unit of Capacitance is farad.

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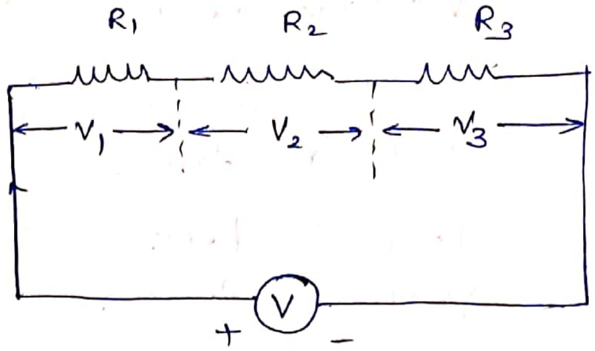
(I) Resistances in series.

Consider three resistances R_1, R_2, R_3 are connected in series across a voltage source 'V' volts.



In series circuit current through all Resistances is same but the voltage across Each resistance is different.

Let $V_1 \rightarrow$ voltage across $R_1 = IR_1$

$V_2 \rightarrow$ voltage across $R_2 = IR_2$

$V_3 \rightarrow$ voltage across $R_3 = IR_3$

The applied voltage 'V' is algebric sum of voltage across each Element.

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

$$= IR_1 + IR_2 + IR_3.$$

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

But $V = IR_T$.

$$\cancel{I}R_T = \cancel{I}(R_1 + R_2 + R_3).$$

$$R_T = R_1 + R_2 + R_3.$$

where R_T is Total or Equivalent resistance

when 'n' no. of Resistances are connected in series, Total Resistance is given by.

$$\boxed{R_T = R_1 + R_2 + R_3 + \cdots R_n}.$$

Voltage division Rule

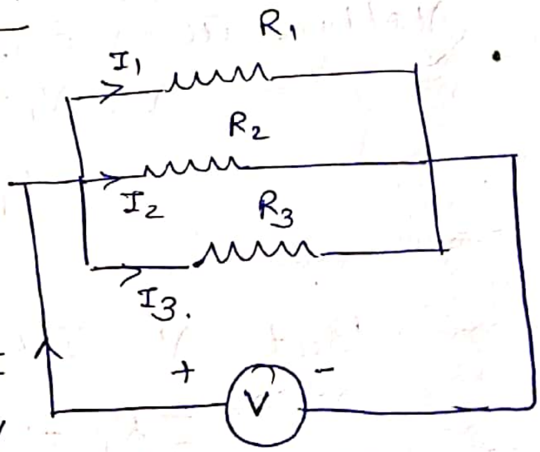
In series combination. Current flowing in each Resistances is same. but voltage is divided. To calculate Individual voltage, we use Voltage division Rule,

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

$$V_2 = \left(\frac{R_2}{R_1+R_2+R_3}\right) \times V.$$

$$V_3 = \left(\frac{R_3}{R_1+R_2+R_3}\right) \times V.$$

Resistances in Parallel



The resistances are said to be connected in parallel when one ~~one~~ end of each resistances ~~are~~ is connected to one common point & Remaining end of each Resistance is connected to another common point.

Consider the three resistances R_1, R_2, R_3 are connected in parallel across a source voltage 'V' volts. The voltage across each Resistance is same but current is divided ~~given by~~.

~~$I_1 = V$~~ Total current,

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

Also

$$I_1 = \frac{V}{R_1} \; ; \quad I_2 = \frac{V}{R_2} \; ; \quad I_3 = \frac{V}{R_3}.$$

But $I = \frac{V}{R_T}$

$$\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}.$$

$$\Rightarrow \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

When 'n' no. of Resistances are connected in parallel, then the Equivalent resistance is given by

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

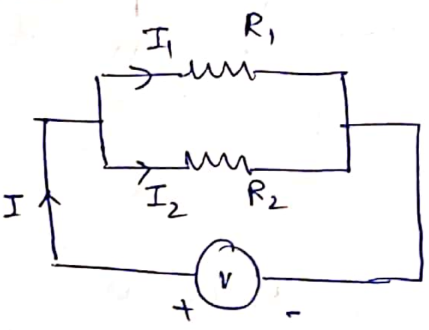
Current Division Rule

In parallel Connection, voltage across each Resistance is same but current divides. And to Calculate current through Each Branch can be done by using current division Rule.

For Two Resistance in Parallel

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

$$I_2 = \left(\frac{R_1}{R_1+R_2}\right) \times I.$$

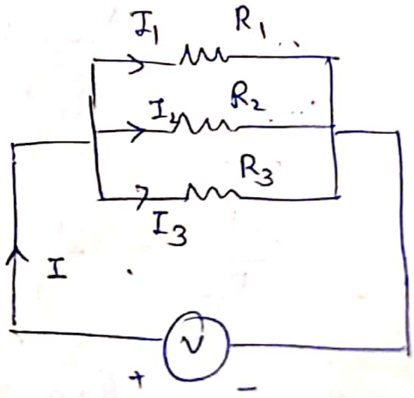


When Three Resistances are in parallel.

$$I_1 = \left(\frac{R_2 \cdot R_3}{R_1R_2 + R_2R_3 + R_3R_1}\right) \times I.$$

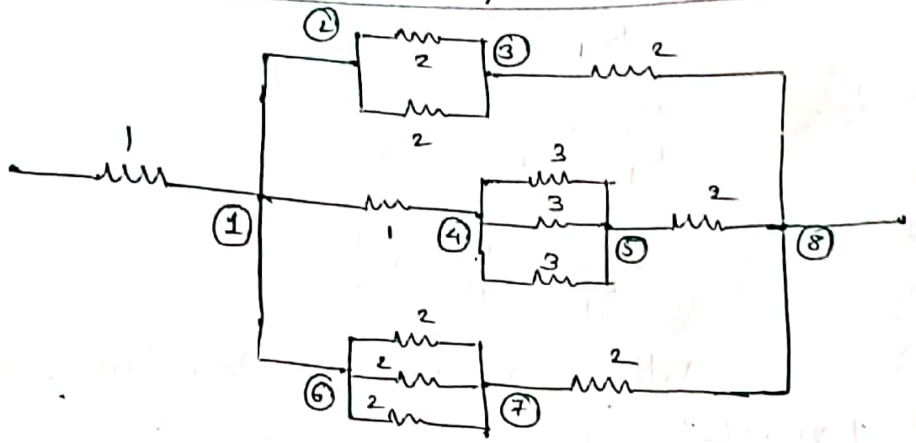
$$I_2 = \left(\frac{R_1 \cdot R_3}{R_1R_2 + R_2R_3 + R_3R_1}\right) \times I.$$

$$I_3 = \left(\frac{R_1 \cdot R_2}{R_1R_2 + R_2R_3 + R_1R_3}\right) \times I.$$



Numericals on series, parallel and ohms law

Ts-1



Calculate R_{AB}.

⇒

$$\frac{1}{R_{23}} = \frac{1}{2} + \frac{1}{2}$$

$$\boxed{R_{23} = 1\,\Omega}$$

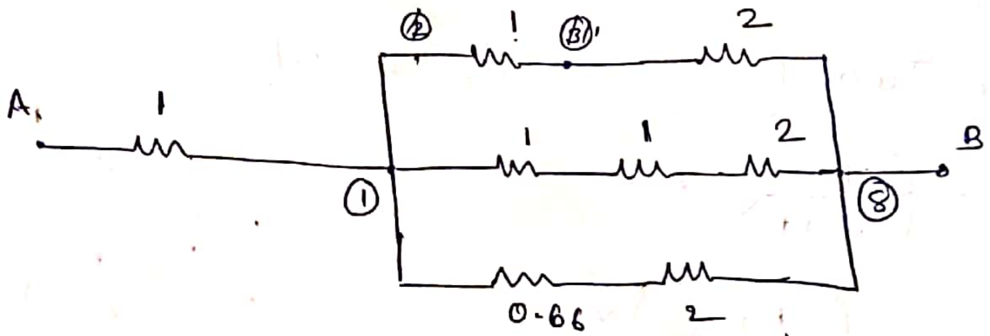
$$\frac{1}{R_{45}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$$

$$\frac{1}{R_{45}} = \frac{3}{3}$$

$$\boxed{R_{45} = 1\,\Omega}$$

$$\frac{1}{R_{67}} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = \frac{3}{2}.$$

$$\boxed{R_{67} = 0.66\,\Omega}$$



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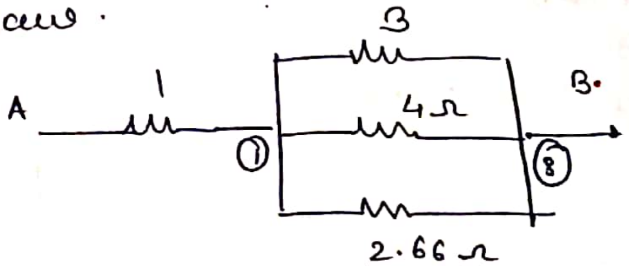


1 & 2 in series

$$R'_{18} = 1+2 = 3\,\Omega.$$

1 & 1 & 2 in series

$$R''_{18} = 1+1+2 = 4\,\Omega$$

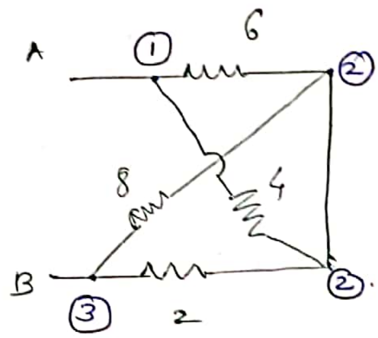
0.66 & 2 in series

$$R'''_{18} = 2.66\,\Omega$$

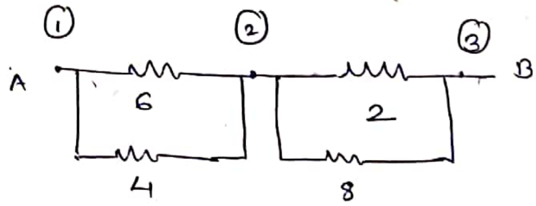
$$\frac{1}{R_{18}} = \frac{1}{3} + \frac{1}{4} + \frac{1}{2.66} = 1.04\,\Omega$$

$$R_{AB} = 1 + 1.04 = 2.04\,\Omega.$$

Calculate Equivalent Resistance Across AB.



Sol^n ⇒ Redraw.



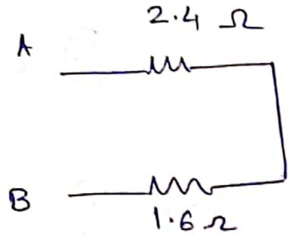
⇒ 6 & 4 are in parallel.

$$\frac{1}{R_{12}} = \frac{1}{6} + \frac{1}{4} = \boxed{2.4\,\Omega = R_{12}}$$

⇒ 8 & 2 are in parallel.

$$\frac{1}{R_{23}} = \frac{1}{8} + \frac{1}{2} = \frac{10}{16}$$

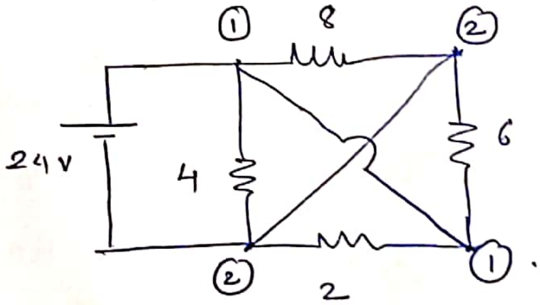
$$\boxed{R_{23} = 1.6\,\Omega}$$



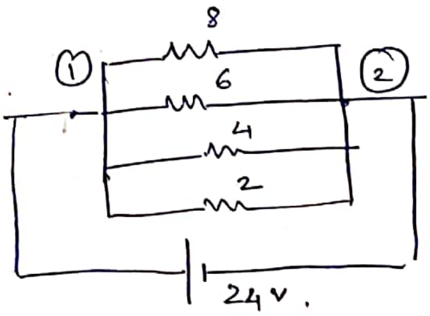
Now, 2.4 Ω & 1.6 Ω are in series

$\therefore$ $R_{AB} = 2.4 + 1.6 = 4\,\Omega$

Q Calculate I



⇒



$\therefore$ All Resistances are in parallel.

$$\frac{1}{R_{12}} = \frac{1}{8} + \frac{1}{6} + \frac{1}{4} + \frac{1}{2}$$

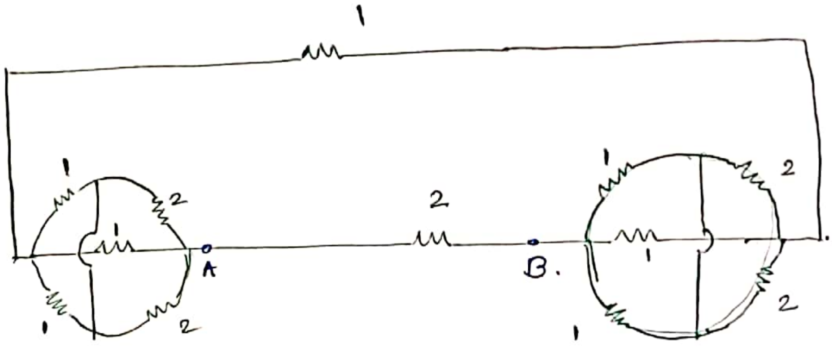
$$= \frac{6+12+8+24}{48} = \frac{50}{48}.$$

$$\boxed{R_{12} = 0.96\,\Omega}$$

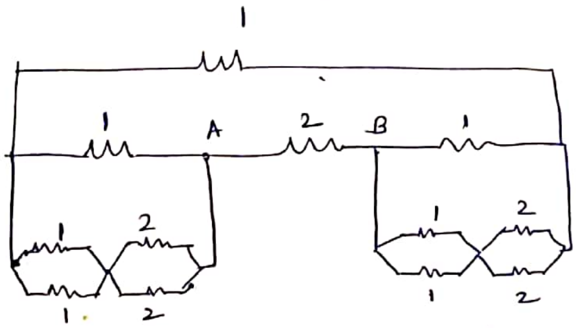
$$I = \frac{24}{0.96} = 25 \text{ Amp}.$$

Calculate R_{AB}.

★



⇒ Circuit can be simplified as follows.



1 & 1 are in parallel

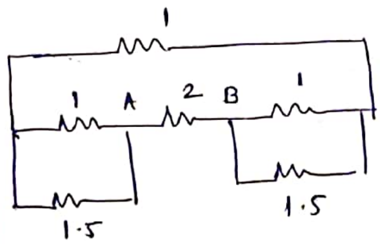
$$R_{1\|1} = \frac{1\times1}{1+1} = 0.5$$

2 & 2 are in parallel

$$R_{2\|2} = \frac{2\times2}{2+2} = 1\,\Omega.$$

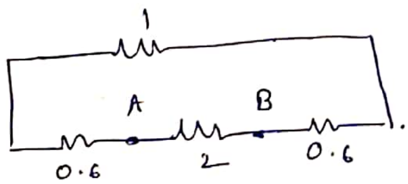
Then 1 & 0.5 are in series.

$$R = 1+0.5 = 1.5\,\Omega.$$



Now, 1 & 1.5 are in Parallel.

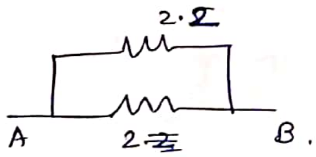
$$R_{1\|1.5} = \frac{1.5\times1}{1+1.5} = \frac{1.5}{2.5} = 0.6\,\Omega$$



⇒ Now, 0.6, 0.6 & 1 are in series

$$: 0.6+0.6+1 = 2.2\,\Omega.$$

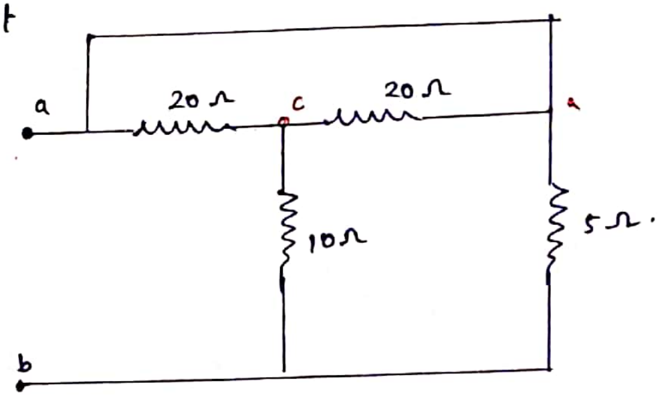
Now 2.2 is in parallel 2.



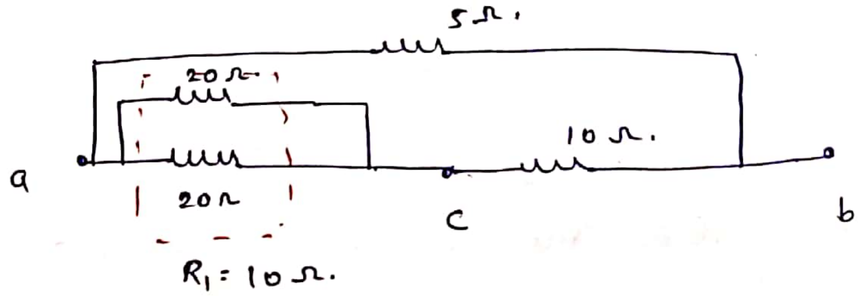
$$R_{AB} = \frac{2.2\times2}{2+2.2} = 1.047\,\Omega.$$

M-17.

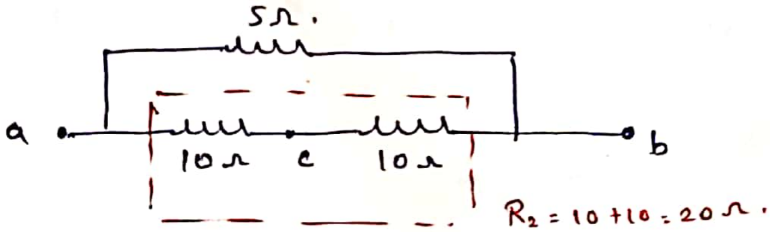
Q. Find R_{eq} between the terminals a - b for the circuit



⇒.



$$R_1 = 20 \parallel 20 = \frac{20 \times 20}{20 + 20} = 10\Omega.$$



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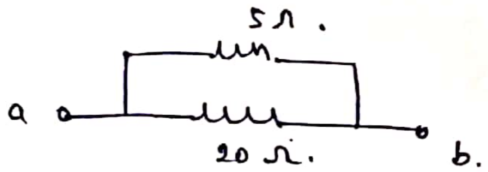

$$R_{ab} = 20 \parallel 5 = \frac{20 \times 5}{20 + 5} = \frac{100}{25}$$

$$\boxed{R_{ab} = 4\Omega.}$$

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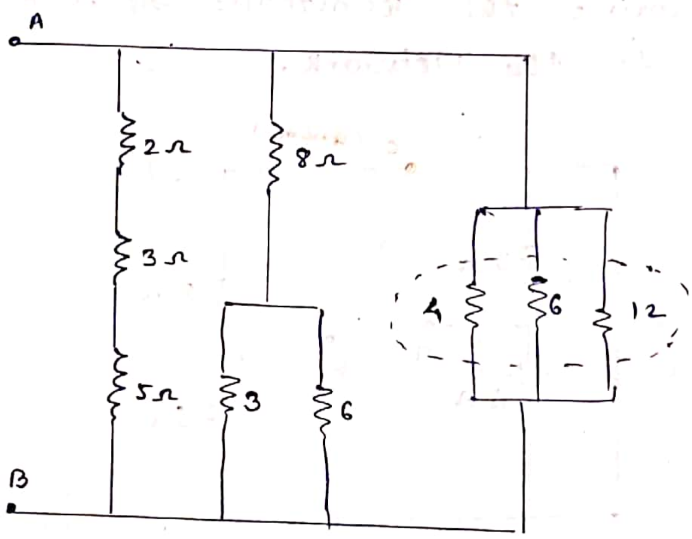
Q. $R_{AB} = ?$ Calculate Equivalent Resistance between terminals A & B ?



⇒ 2Ω, 3Ω & 5Ω are in series

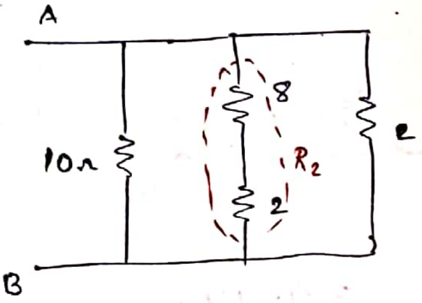
∴ 3Ω is in parallel with 6Ω.

$$3 \| 6 = \frac{3 \times 6}{3+6} = 2\,\Omega.$$

4Ω, 6Ω & 12Ω are in parallel.

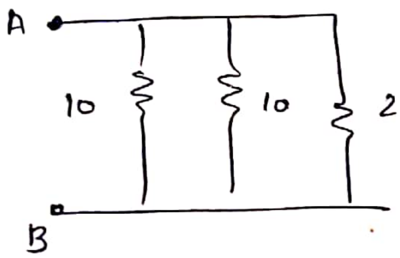
$$4 \| 6 \| 12 : \quad \frac{1}{R_1} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12}$$

$$R_1 = 2\,\Omega.$$



8Ω & 2Ω are in series

$$R_2 = 8 + 2 = 10\,\Omega.$$

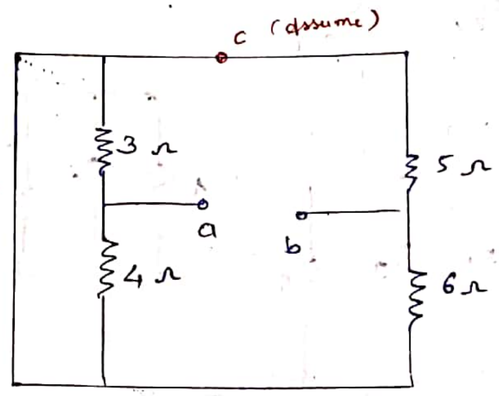


$$10 \| 10 \| 2$$

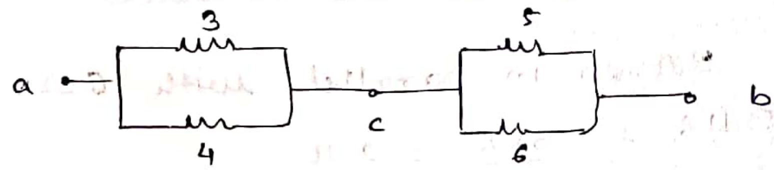
$$\frac{1}{R_{AB}} = \frac{1}{10} + \frac{1}{10} + \frac{1}{2}$$

$$R_{AB} = \frac{10}{7}\,\Omega = 1.4285\,\Omega$$

Q. Determine the resistance between the terminals a-b in the Network.



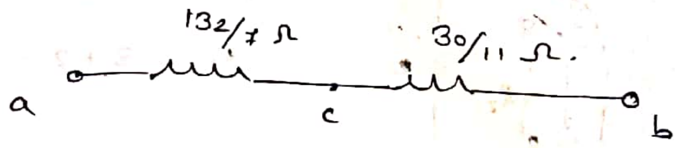
⇒



$R_{ac} = 3 \parallel 4 = \dfrac{3 \times 4}{3+4} = \dfrac{132}{7}\ \Omega$

$R_{bc} = 5 \parallel 6 = \dfrac{5 \times 6}{5+6} = \dfrac{30}{11}\ \Omega.$

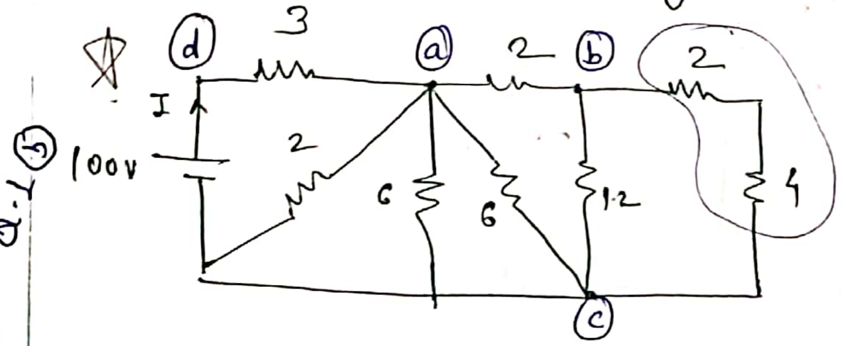
$R_{ab} =$



$R_{ab} = \dfrac{132}{7} + \dfrac{30}{11} = 4.44\ \Omega.$

Imp!

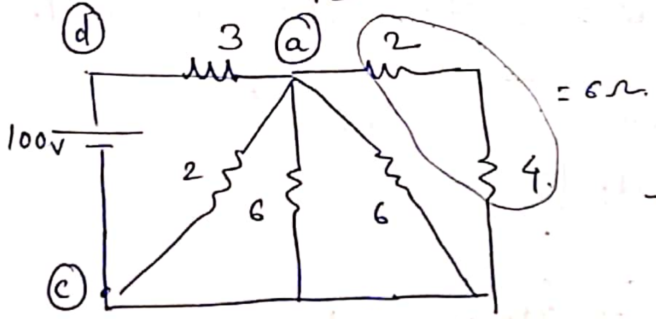
Q. Find the current I for given Network.



Sol^n

2 & 4 are in series in parallel with 12

$$\frac{1}{R_{bc}} = \frac{1}{12} + \frac{1}{6} \Rightarrow \boxed{R_{bc} = 4\,\Omega}$$

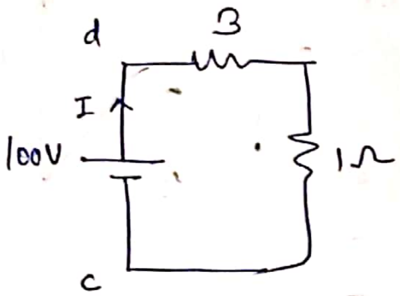


$$\frac{1}{R_{ac}} = \frac{1}{6} + \frac{1}{6} + \frac{1}{6} + \frac{1}{2}$$

$$\frac{1}{R_{ac}} = \frac{1}{2} + \frac{1}{2} = 1$$

$$\boxed{R_{ac} = 1\,\Omega}$$

Redraw



$$\Rightarrow \boxed{R_{dc} = 4\,\Omega}$$

$$\therefore I = \frac{100}{4}$$

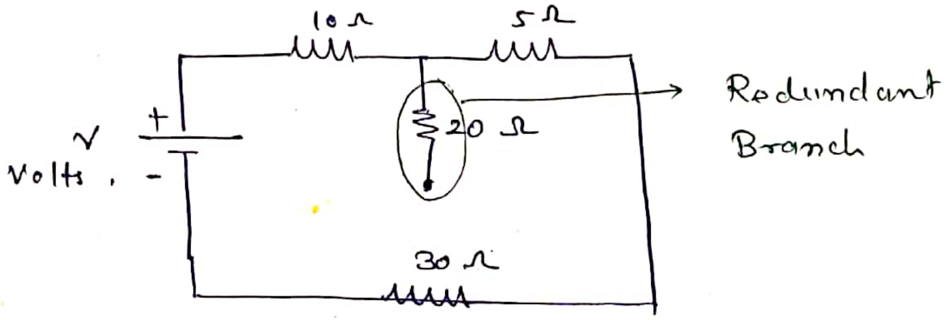
$$\boxed{I = 25\,Amps}$$

Scanned with CamScanner

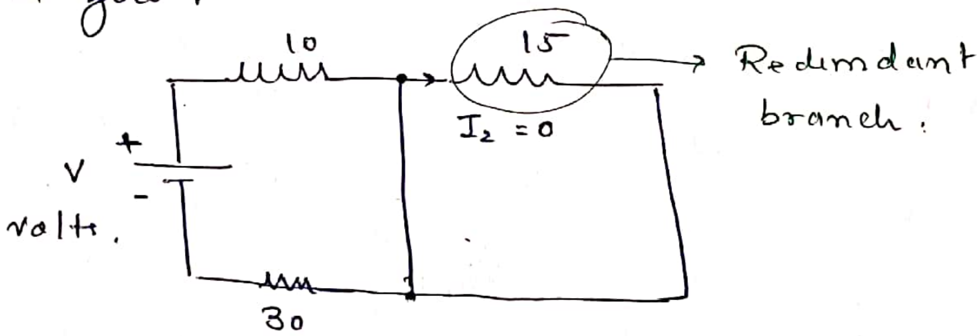
Removal of Redundant Branches

A redundant branch (or group of branches) is the one which can be removed from the circuit without affecting the circuit.

CASE I : Any branch that does not carry current is redundant and hence can be removed.



CASE II : Any branch which has both terminals short circuited will also be a redundant branch because current flowing through such branch will be zero.

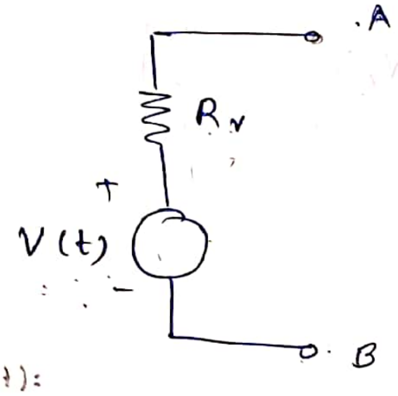


Source Transformation

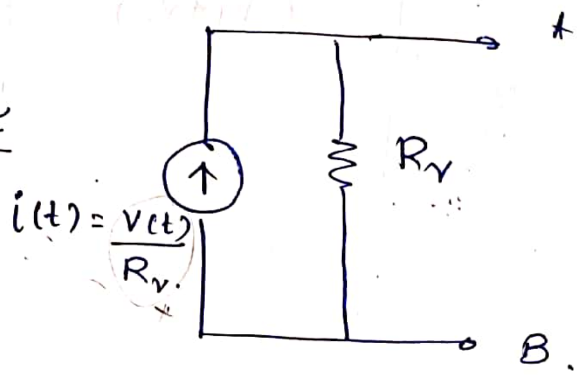
V = (I)R

I = V/R

From voltage source, to current source.



≃

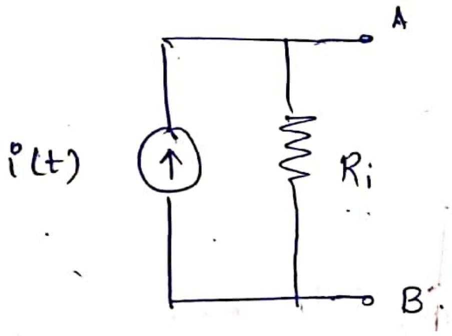


V(t) =

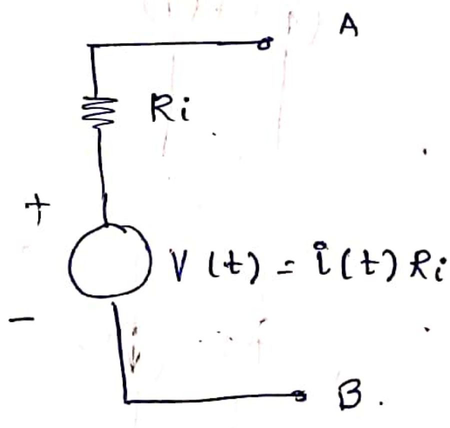
Voltage source

Equivalent current source.

From known current source to voltage source.



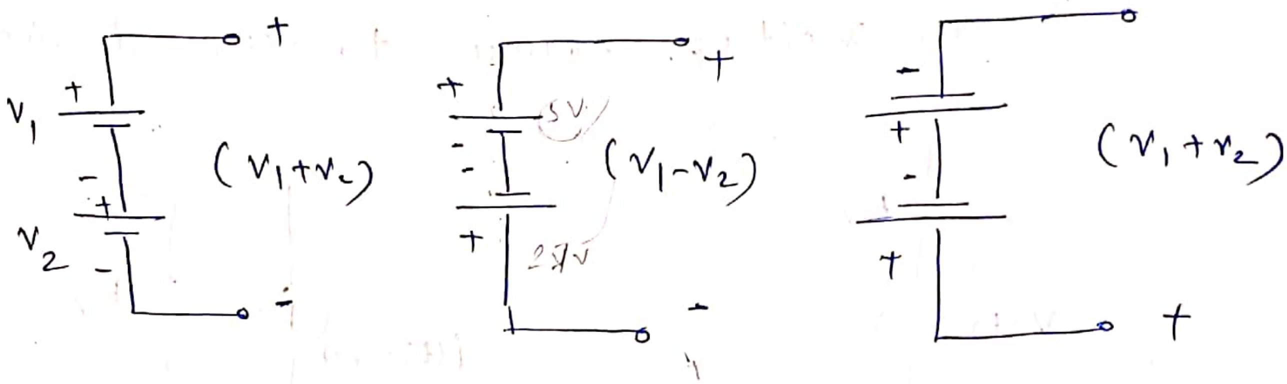
⇒



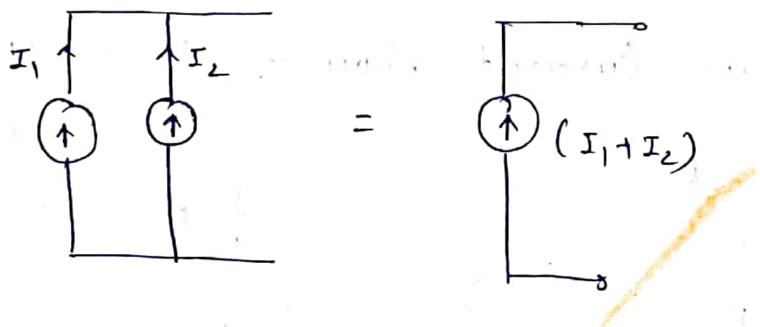
Current source.

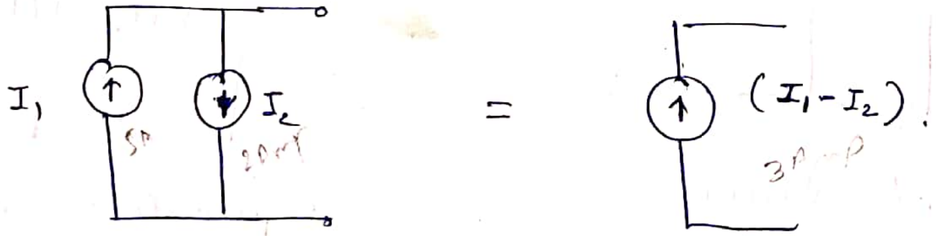
Equivalent voltage source

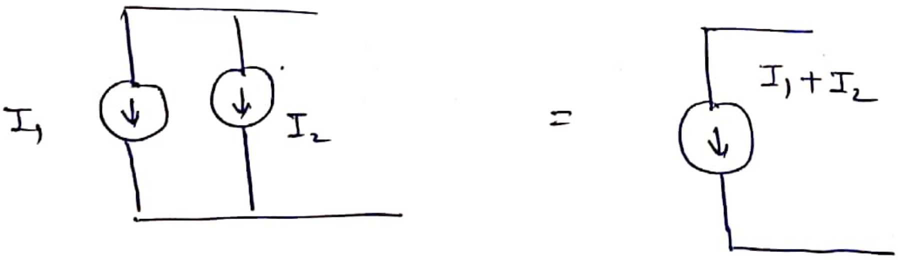
Voltage Sources in Series



Current Sources in Parallel







Note :

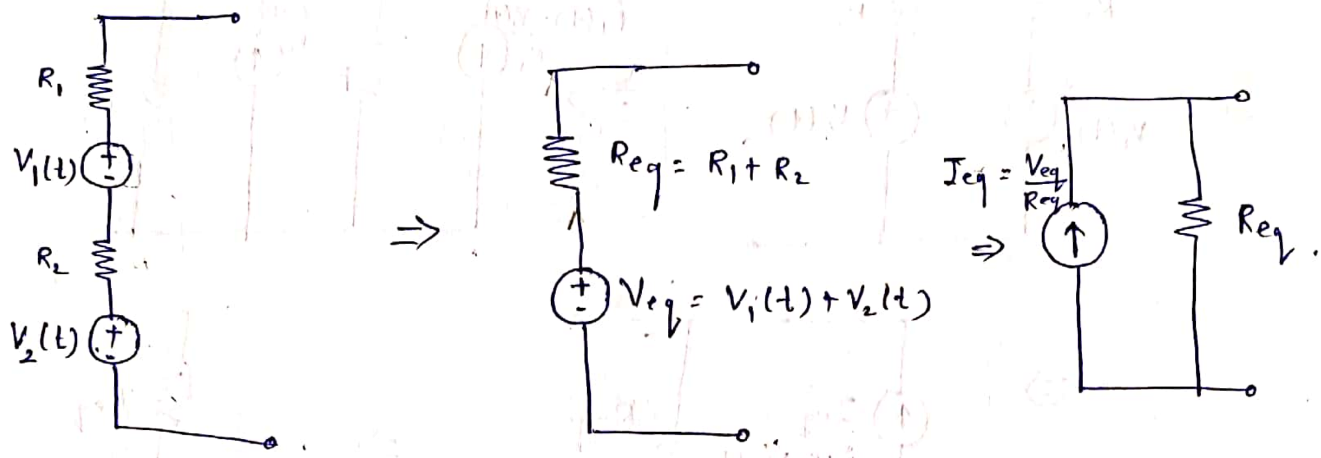
1) No two Ideal current source of different magnitude are connected in series

2) Ideal voltage source of different magnitude are never connected in parallel.

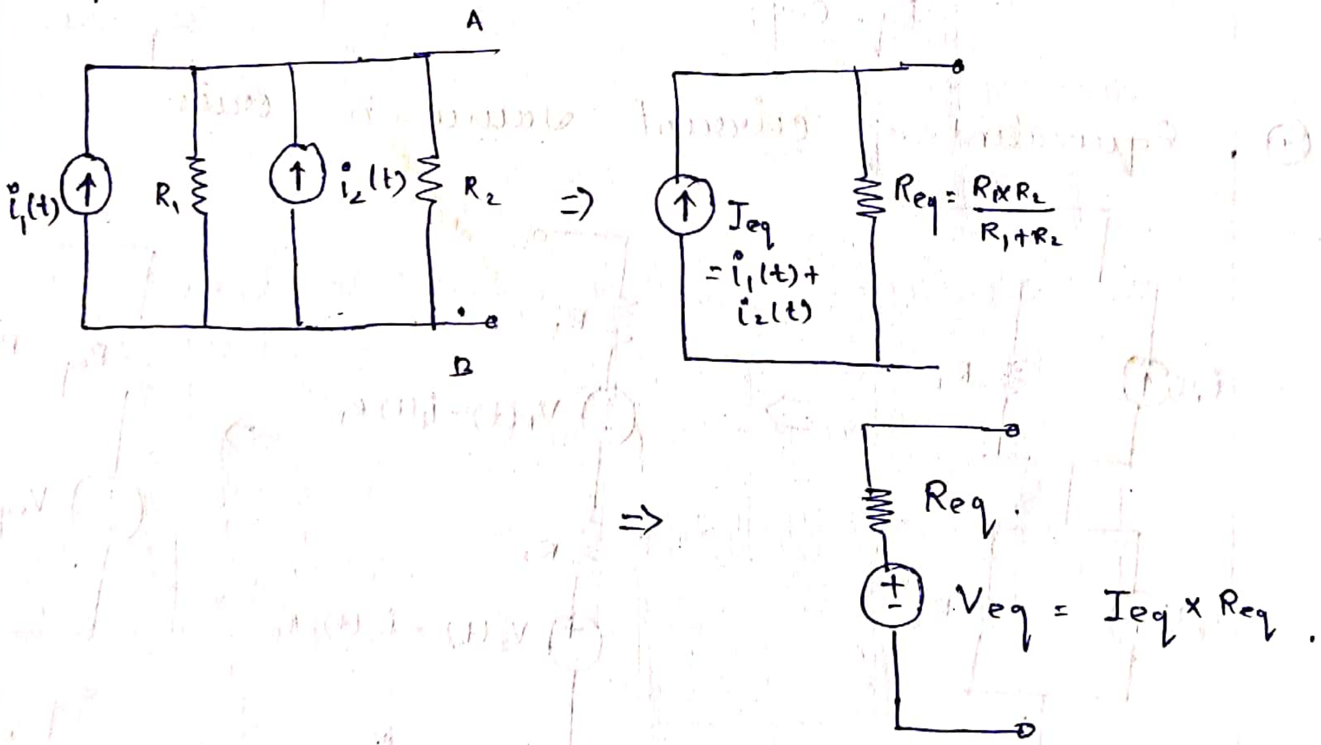
$V = IR$
$I = \frac{V}{R}$

Various combination of sources.

① Equivalent voltage source in series.

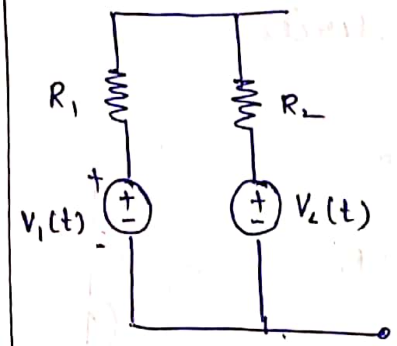


② Equivalent of current source in parallel.

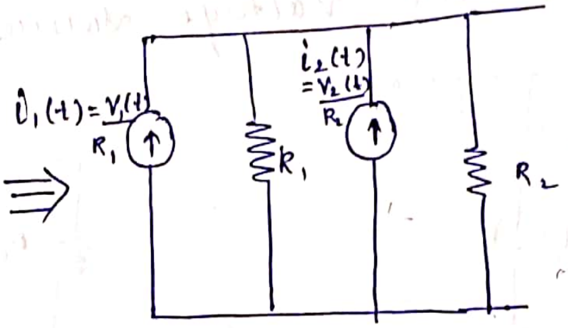


28

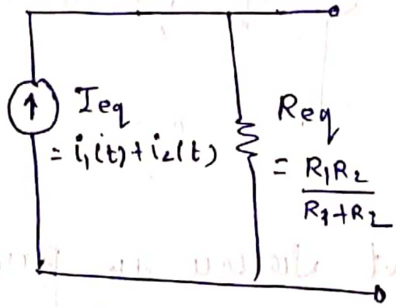
③ Equivalent of voltage source in parallel.



⇒

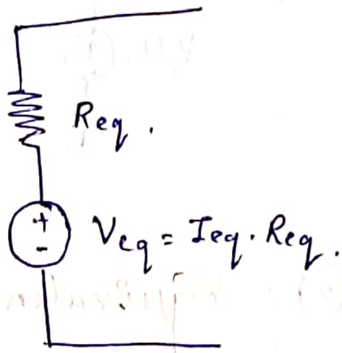


⇒



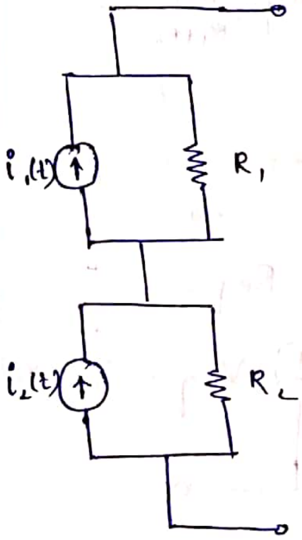
Eq. C.S.

⇒

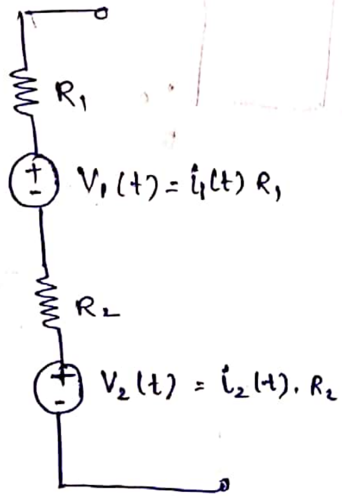


Eq. V.S.

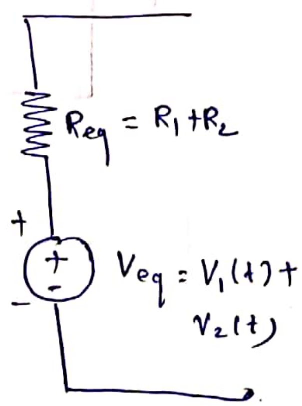
④ Equivalent of current source in series



⇒

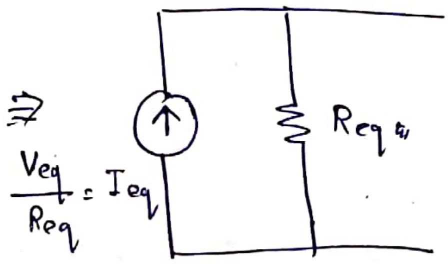


⇒

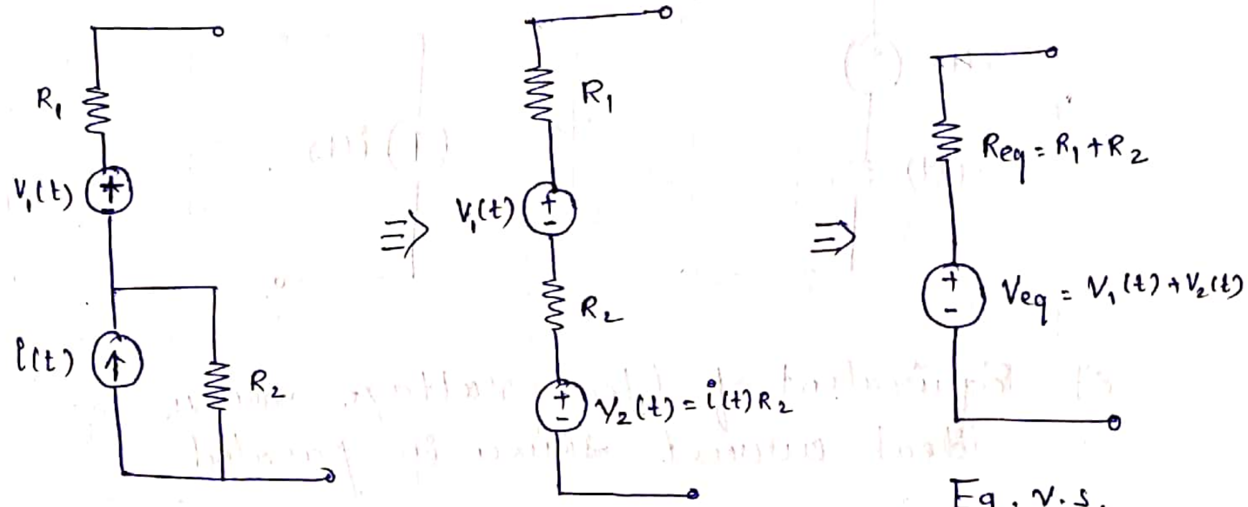


Eq. V.S.

⇒

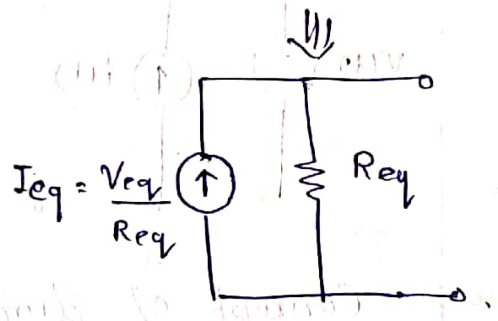


⑤ Equivalent of voltage source & current source in series.

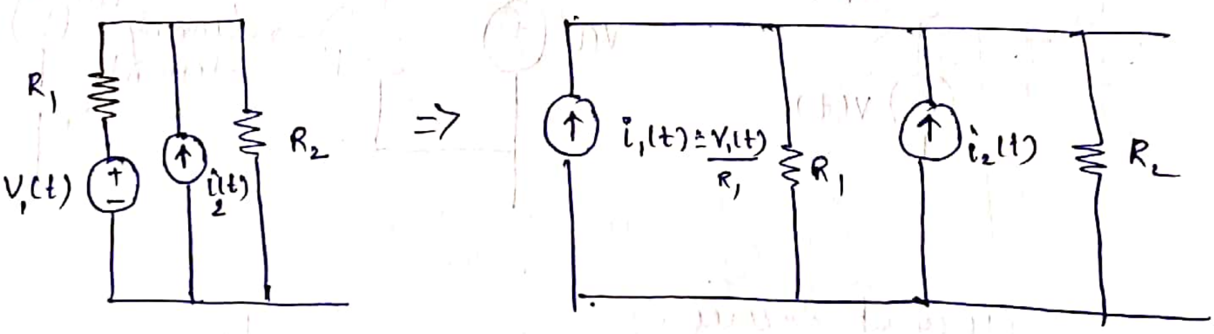


Eq. v.s.

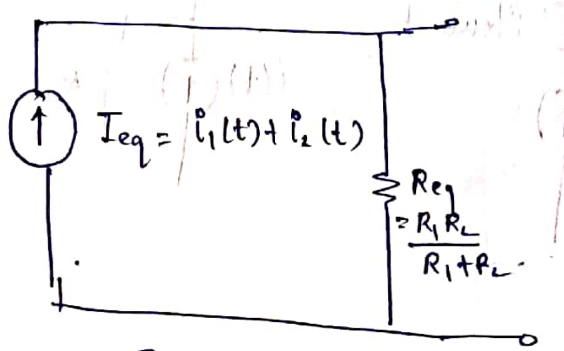
⇕



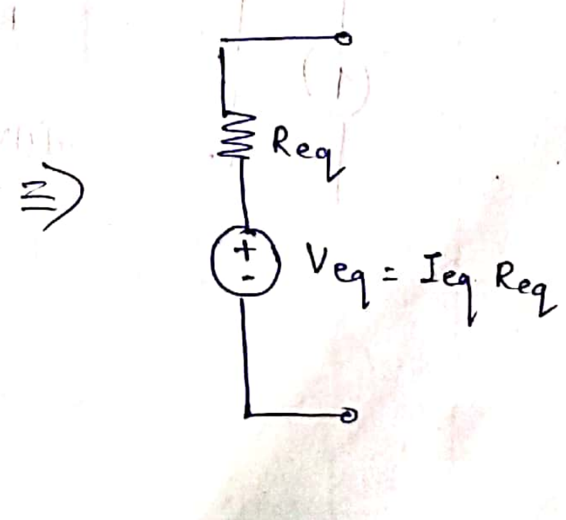
⑥ Equivalent of voltage source & current source in parallel.



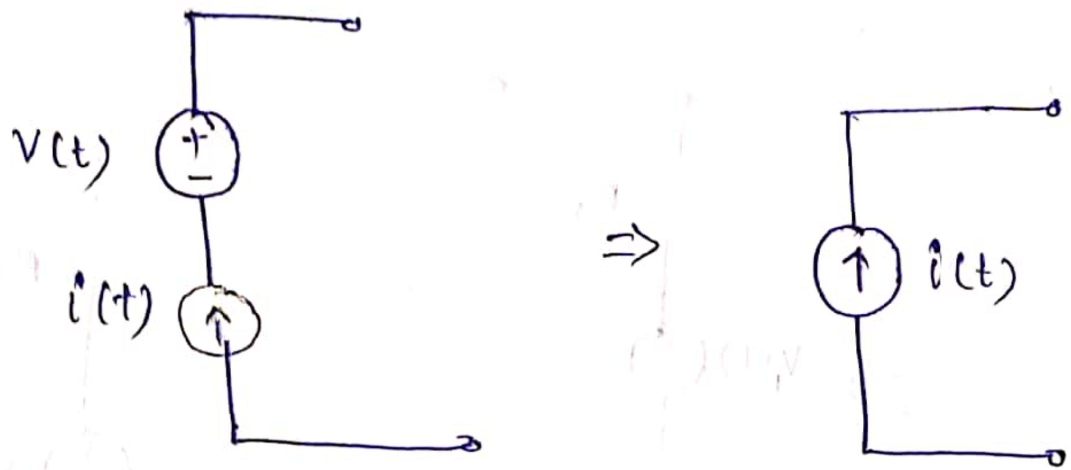
⇕



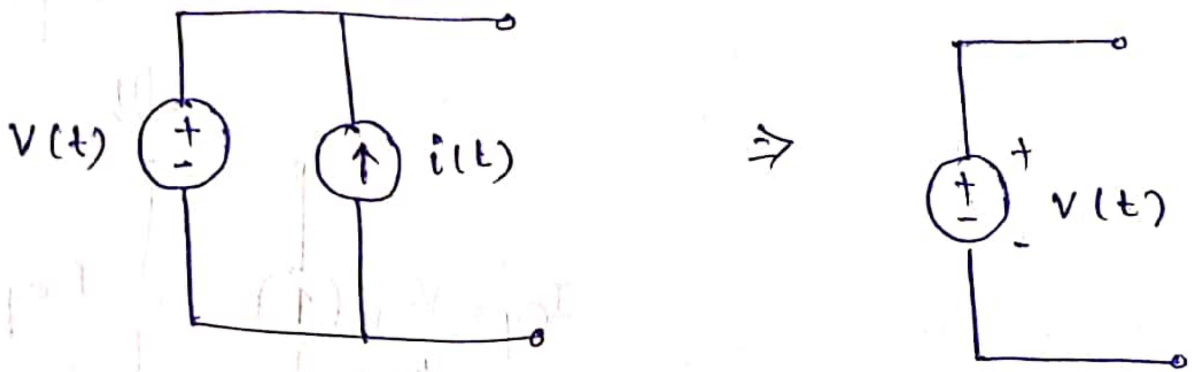
Eq c.s.



30 7. Equivalent of Ideal voltage source and Ideal current source in series.



8) Equivalent of ideal voltage source & ideal current source in parallel



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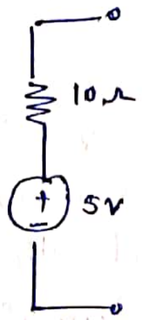
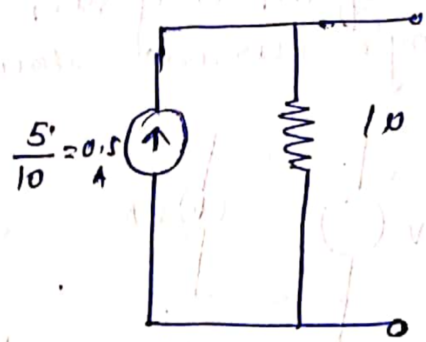
Numerical :

(1)

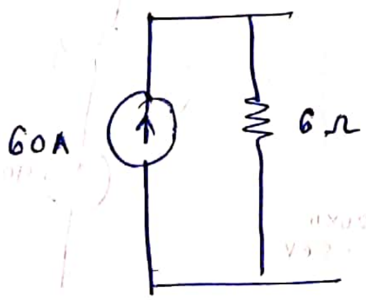


Transform into
Current source = ?

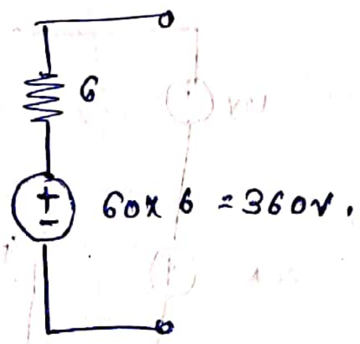


Eq. C.S.

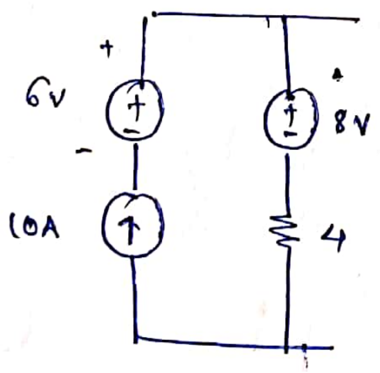
(2). Transform into voltage source



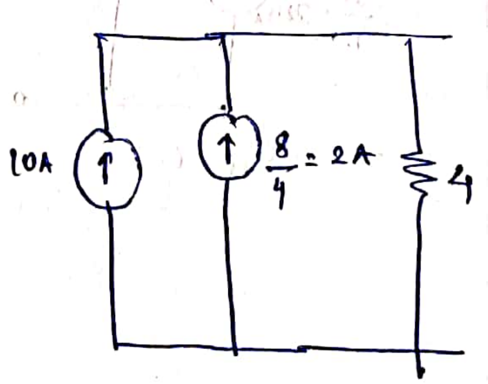
⇒



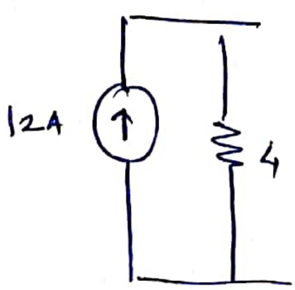
③ Convert the Network into a single voltage source.



⇒

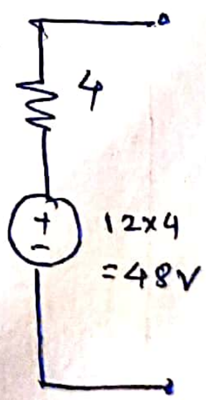


⇒



Eq. C.S.

⇒



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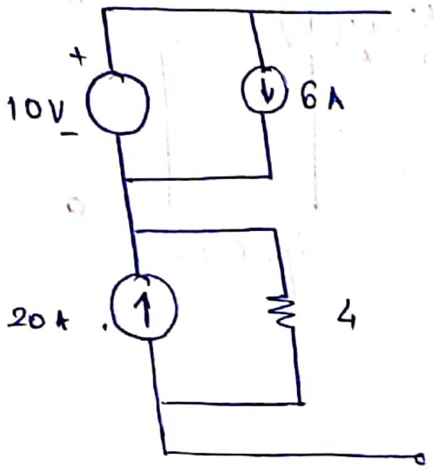
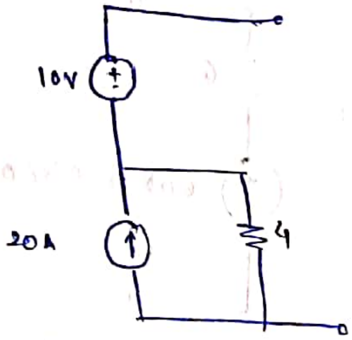
(4) Transform a given Network into a single current source.

⇒



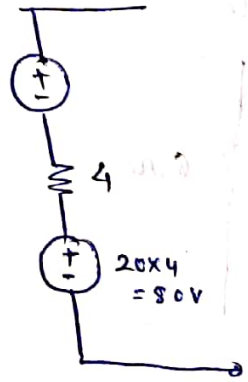
Ideal V.S. of 10V & Ideal C.S of 6A are connected only in parallel therefore only V.S. of 10V will remain in the circuit ~~only~~.

⇓

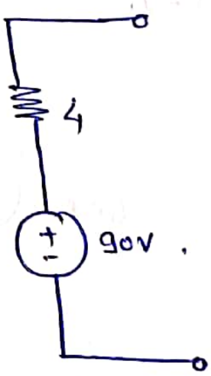


Convert C.S. into V.S

⇒

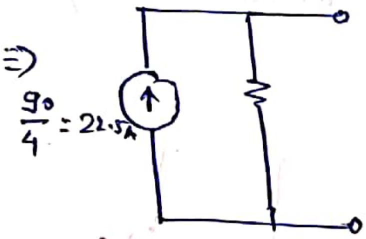


⇒



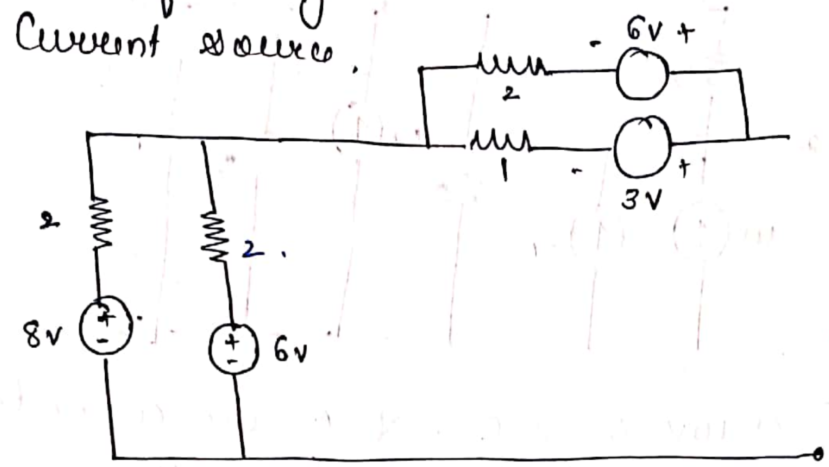
Eq V.S.

⇒

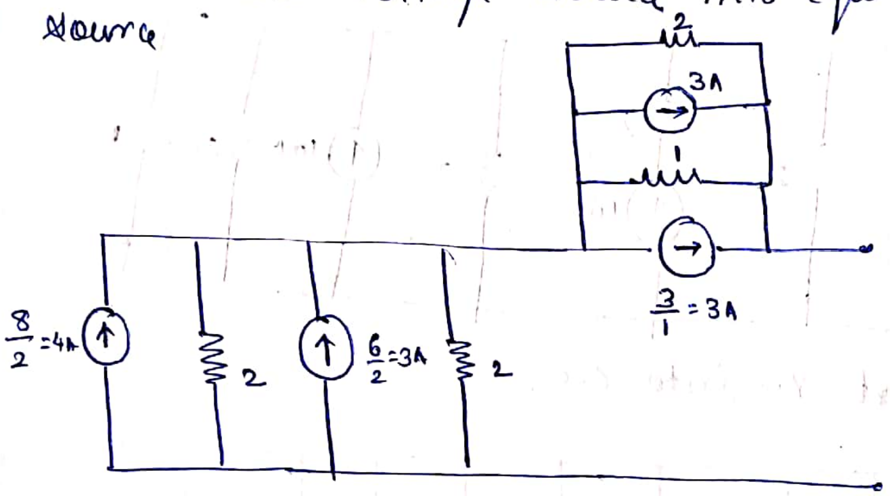


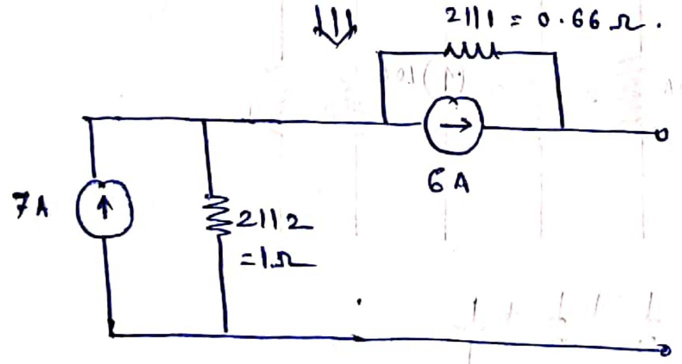
Eq. C.S.

Transform given Network into a Equivalent Current source.

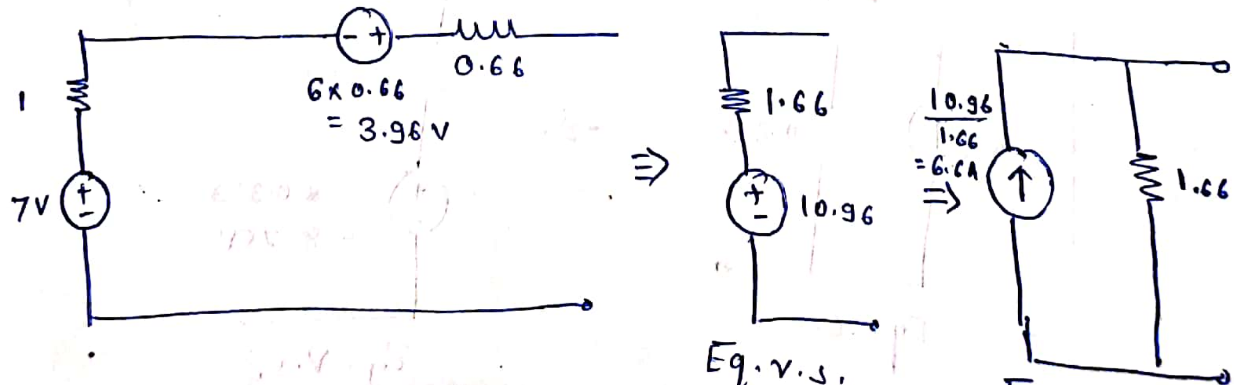


Convert all voltage source into Equivalent current source





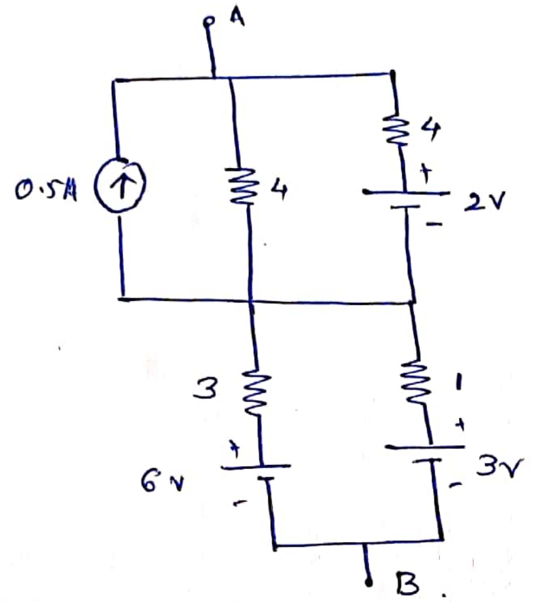
Convert current source into voltage source.



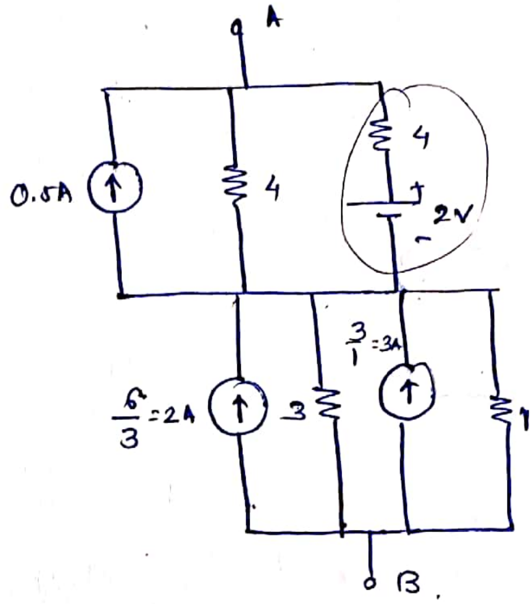
Eq. v.s.

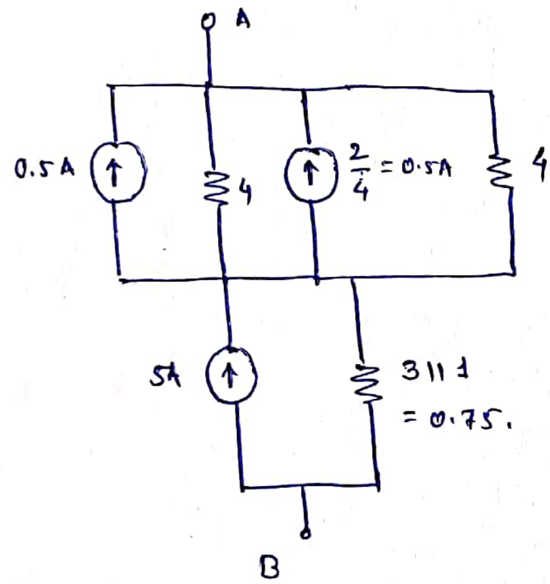
Eq. c.s.

7] Q. Convert all sources into single Equivalent source.

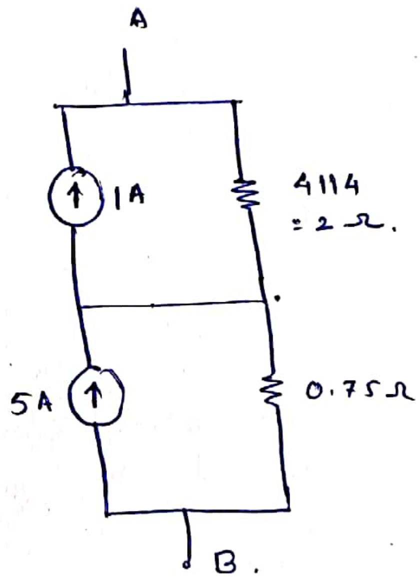


⇒

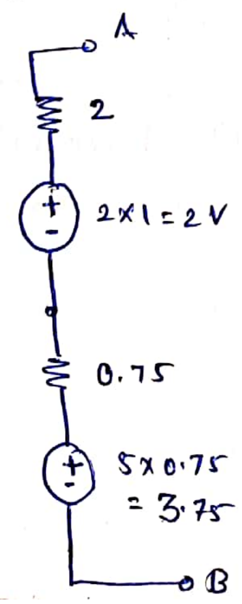




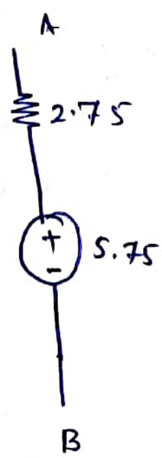
⇒



Convert current source into voltage source. TS-2(3)

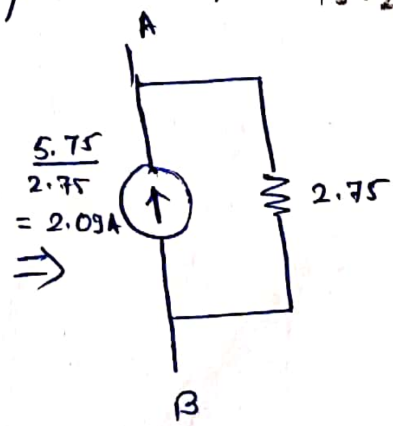


⇒



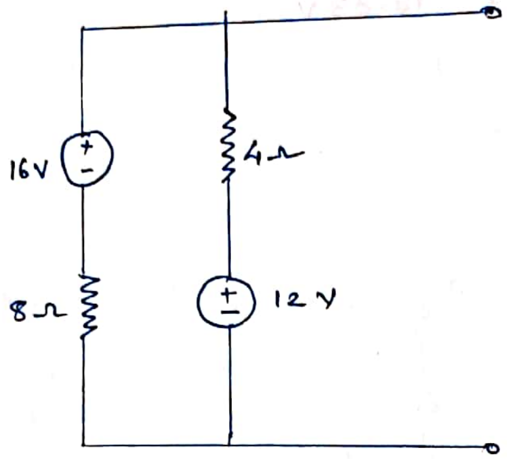
Eq. V.s.

⇒



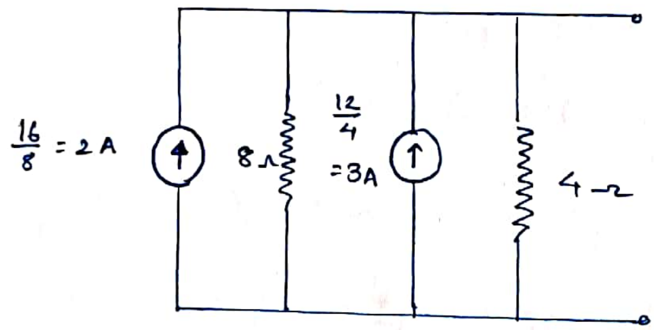
W-15

Q. using source Transformation, convert the circuit given below to a single voltage source in series with a resistor.

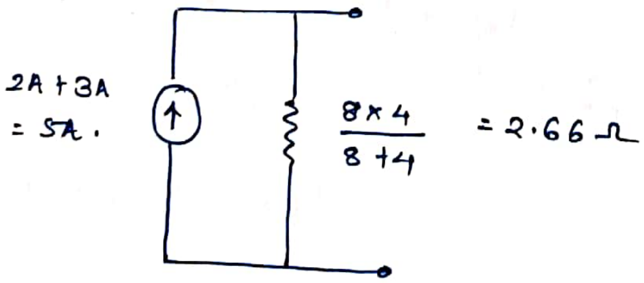


TS - 3 (1).

⇒ Converting both voltage source into its Equivalent current source.

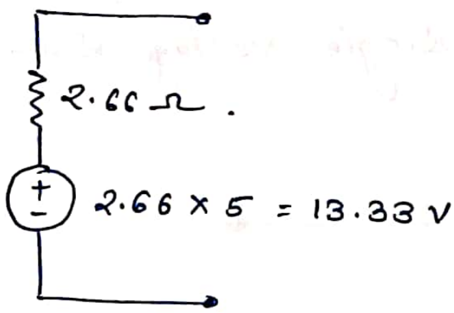


Combining current source to convert into single Equivalent source.



Now, Convert current source into its Equivalent Voltage source in series with Resistance.

⇒


2.66 Ω
2.66 × 5 = 13.33 V

Cramer's rule for solving simultaneous Equations

Suppose that the 'n' number of simultaneous Eqns are as follows.

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = c_1$$
$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = c_2$$
$$\vdots \qquad\qquad\qquad \vdots$$
$$a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = c_n$$

then By Cramer's rule,
the value of unknown variables are as follows. ($a_{11}, a_{12} \ldots a_{nn}$ & $c_1 \ldots c_n$ are constant)

$$x_1 = \frac{\Delta_1}{\Delta} \; ; \quad x_2 = \frac{\Delta_2}{\Delta} \; ; \ldots x_n = \frac{\Delta_n}{\Delta}$$

(Matrix form)

where

$$\Delta = \begin{vmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{vmatrix}$$

$$\Delta_1 = \begin{vmatrix} c_1 & a_{12} & \cdots & a_{1n} \\ c_2 & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \\ c_n & a_{n2} & \cdots & a_{nn} \end{vmatrix}.$$

$$\Delta_2 = \begin{vmatrix} a_{11} & c_1 & \cdots & a_{1n} \\ a_{21} & c_2 & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & c_n & & a_{nn} \end{vmatrix}$$

Kirchoff's laws :

Kirchoff discovered two basic laws that are used to calculate current in any branch & voltage across any branch.

1. Kirchoff's voltage law. (KVL)
2. Kirchoff's current law (KCL)

1. Kirchoff's voltage law (KVL)

Statement :

The algebric sum of product of current & resistance of various branches of closed mesh of the circuit & emd EMF in that closed mesh is equal to zero.

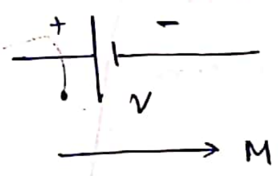
Or

The algebric sum of the voltage around a close loop in a circuit must be equal to zero.

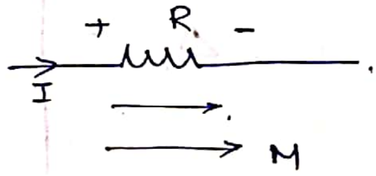
$$\Sigma IR + \Sigma EMF = 0$$

Rules Regarding KVL

1.

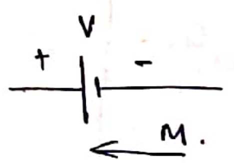


2. (-IR).

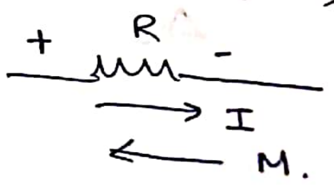


fall in potential

3.

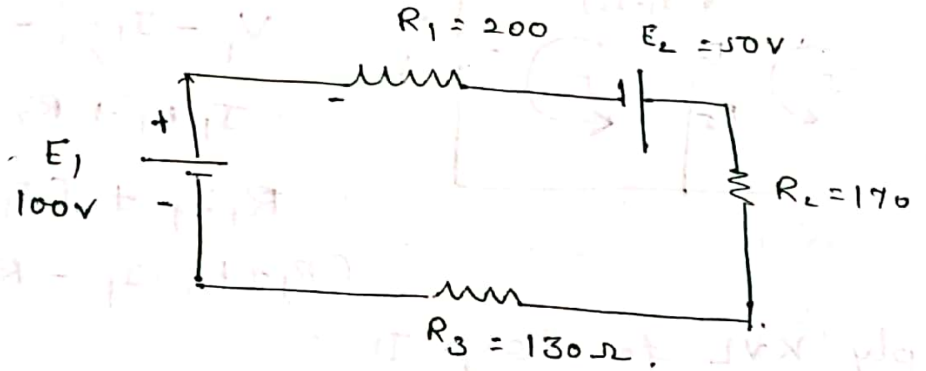


4. (IR).

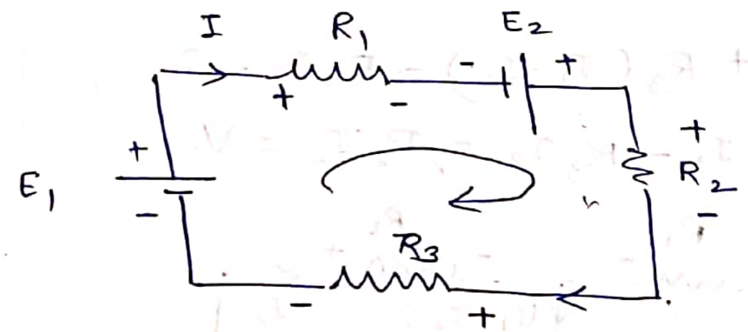


Rise in potential

Q. Write ~~kv.~~ loop Equation with help of KVL S1



⇒



$$E_1 - IR_1 + E_2 - IR_2 - IR_3 = 0$$

$$\therefore E_1 + E_2 = IR_1 + IR_2 + IR_3$$

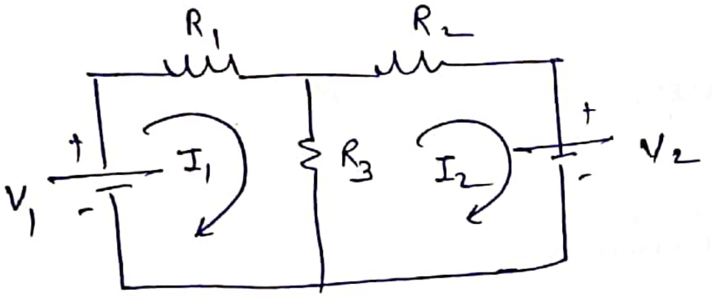
Rise in potential = fall in potential.

$$100 + 50 = I\,(200 + 170 + 130)$$

$$150 = I \times 500.$$

$$I = \frac{150}{500} = 0.3\text{ Amp}$$

Q. Apply KVL (mesh analysis) & write Equations.



$$V_1 - R_1 I_1 - R_3 (I_1 - I_2) = 0.$$

$$\cancel{R_1 I_1 =} \ (R_1 + R_3) I_1 - R_3 I_2 = V_1 \quad \text{——(1).}$$

KVL to loop 2.

$$- R_3 (I_2 - I_1) - R_2 I_2 - V_2 = 0$$

$$R_3 I_2 - R_3 I_1 + R_2 I_2 + V_2 = 0.$$

$$- R_3 I_1 + (R_2 + R_3) I_2 = - V_2 \quad \text{——(2).}$$

Matrix form.

$$\begin{bmatrix} R_1 + R_3 & -R_3 \\ -R_3 & R_2 + R_3 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ -V_2 \end{bmatrix}.$$

By Cramer's Rule.

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

where;

$$\Delta = \begin{vmatrix} R_1 + R_3 & -R_3 \\ -R_3 & R_2 + R_3 \end{vmatrix} \ ; \ \Delta_1 = \begin{vmatrix} V_1 & -R_3 \\ -V_2 & R_2 + R_3 \end{vmatrix}.$$

$$\Delta_2 = \begin{vmatrix} R_1 + R_3 & V_1 \\ -R_3 & -V_2 \end{vmatrix}.$$

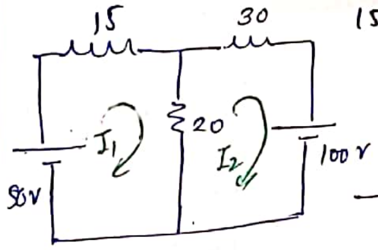
For cross check.

$$\Delta = \begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix}$$

$R_{ii} \rightarrow$ sum of all Resistances in mesh i

$R_{ij} \rightarrow$ sum of Resistances common to mesh i & j

Q. Find current in all Branches.



$$50 - 15 I_1 - 20(I_1 - I_2) = 0.$$

$$15 I_1 + 20(I_1 - I_2) = 50$$

$$35 I_1 - 20 I_2 = 50 \quad —(1).$$

$$-20(I_2 - I_1) - 30 I_2 - 100 = 0.$$

$$20 I_2 - 20 I_1 + 30 I_2 = -100 \quad —(2).$$

$$-20 I_1 + 50 I_2 = -100 \quad —(2).$$

$$\begin{bmatrix} 35 & -20 \\ -20 & 50 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 50 \\ -100 \end{bmatrix}$$

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

$$\Delta = \begin{bmatrix} 35 & -20 \\ -20 & 50 \end{bmatrix} = 1350.$$

$$\Delta_1 = \begin{bmatrix} 50 & -20 \\ -100 & 50 \end{bmatrix} = 500.$$

$$I_1 = \frac{500}{1350} = 0.37 \text{ Amp.}$$

$$\Delta_2 = \begin{vmatrix} 35 & 50 \\ -20 & -100 \end{vmatrix} = -2500. \Rightarrow I_2 = \frac{-2500}{1350}.$$

$$I_2 = -1.85 \text{ Amp.}$$

Current through Middle Branch.

$$= I_1 - I_2 \Rightarrow 0.37 - (-1.85).$$

$$\Rightarrow 2.22 \text{ Amp.}$$

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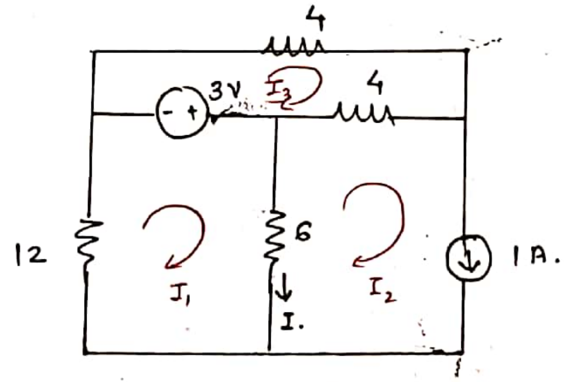
M-18.

Q In the given Circuit, use Mesh Analysis to obtain current I.



⇒ Apply KVL in Mesh ①

$$-12\,I_1 + 3 - 6(I_1 - I_2) = 0.$$

$$-12\,I_1 + 3 - 6\,I_1 + 6\,I_2 = 0.$$

$$-18\,I_1 + 6\,I_2 = -3$$

$$18\,I_1 - 6\,I_2 = 3 \quad -(1)$$

Apply KVL in mesh ③.

$$\cancel{-6(I_2 - I_1) - 6(I_2 - I_3)}$$

$$-4\,I_3 - 4(I_3 - I_2) - 3 = 0.$$

$$-4\,I_3 - 4\,I_3 + 4\,I_2 - 3 = 0.$$

$$4\,I_2 - 8\,I_3 = 3.$$

$$-4\,I_2 + 8\,I_3 = -3 \quad -(2).$$

we know. $I_2 = 1$ Amp.

① ⇒ $18\,I_1 - 6 = 3. \Rightarrow I_1 = \frac{9}{18} = 0.5$ Amp.

② ⇒ $-4(1) + 8\,I_3 = -3.$

$$8\,I_3 = 1.$$

$$I_3 = 0.125 \text{ Amp}.$$

Current through $6\,\Omega$. $\Rightarrow I = I_2 - I_1 = 1 - 0.5.$

$$\boxed{I = 0.5 \text{ Amp}}$$

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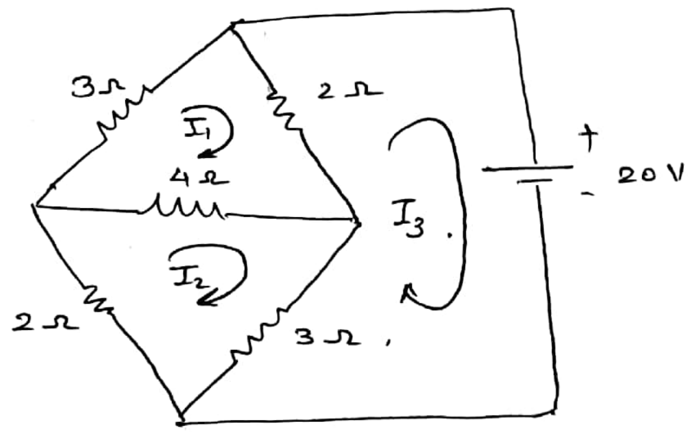
Q. Using kirchoff's law, find the current through 4Ω resistor



⇒ Apply KVL in loop I.

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

$$3I_1 + 2I_1 - 2I_3 + 4I_1 - 4I_2 = 0.$$

$$9I_1 - 4I_2 - 2I_3 = 0 \quad \text{— (1)}.$$

Apply KVL in loop II.

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

$$2I_2 + 4I_2 - 4I_1 + 3I_2 - 3I_3 = 0.$$

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

Apply KVL in loop III.

$$-20 - 3(I_3 - I_2) - 2(I_3 - I_1) = 0.$$

$$20 + 3I_3 - 3I_2 + 2I_3 - 2I_1 = 0.$$

$$-2I_1 - 3I_2 + 5I_3 = -20 \quad \text{— (3)}.$$

In Matrix form,

$$\begin{bmatrix} 9 & -4 & -2 \\ -4 & 9 & -3 \\ -2 & -3 & 5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -20 \end{bmatrix}$$

$I_1 = \frac{\Delta_1}{\Delta}$; $I_2 = \frac{\Delta_2}{\Delta}$.

$$\Delta = \begin{vmatrix} 9 & -4 & -2 \\ -4 & 9 & -3 \\ -2 & -3 & 5 \end{vmatrix} = 160$$

$$\Delta_1 = \begin{vmatrix} 0 & -4 & -2 \\ 0 & 9 & -3 \\ -20 & -3 & 5 \end{vmatrix} = -600$$

$$\Delta_2 = \begin{vmatrix} 9 & 0 & -2 \\ -4 & 0 & -3 \\ -2 & -20 & 5 \end{vmatrix} = -700$$

$I_1 = \frac{\Delta_1}{\Delta} = \frac{-600}{160} = -3.75$; $I_2 = \frac{\Delta_2}{\Delta} = \frac{-700}{160} = -4.375$

Current through 4Ω $\Rightarrow$ $I_2 - I_1$

$\Rightarrow$ $-4.375 - (-3.75)$.

$\Rightarrow$ $-4.375 + 3.75$

$\Rightarrow$ -0.625 Amp.

or.

Current through 4Ω $\Rightarrow$ $I_1 - I_2$

$\Rightarrow$ $-3.75 - (-4.375)$

$\Rightarrow$ $-3.75 + 4.375$

$\Rightarrow$ 0.625 Amp.

Example 2.13

Analyse the circuit of Fig. 2.25 (a) by the mesh method. From the results, calculate the current in the 5Ω resistance.

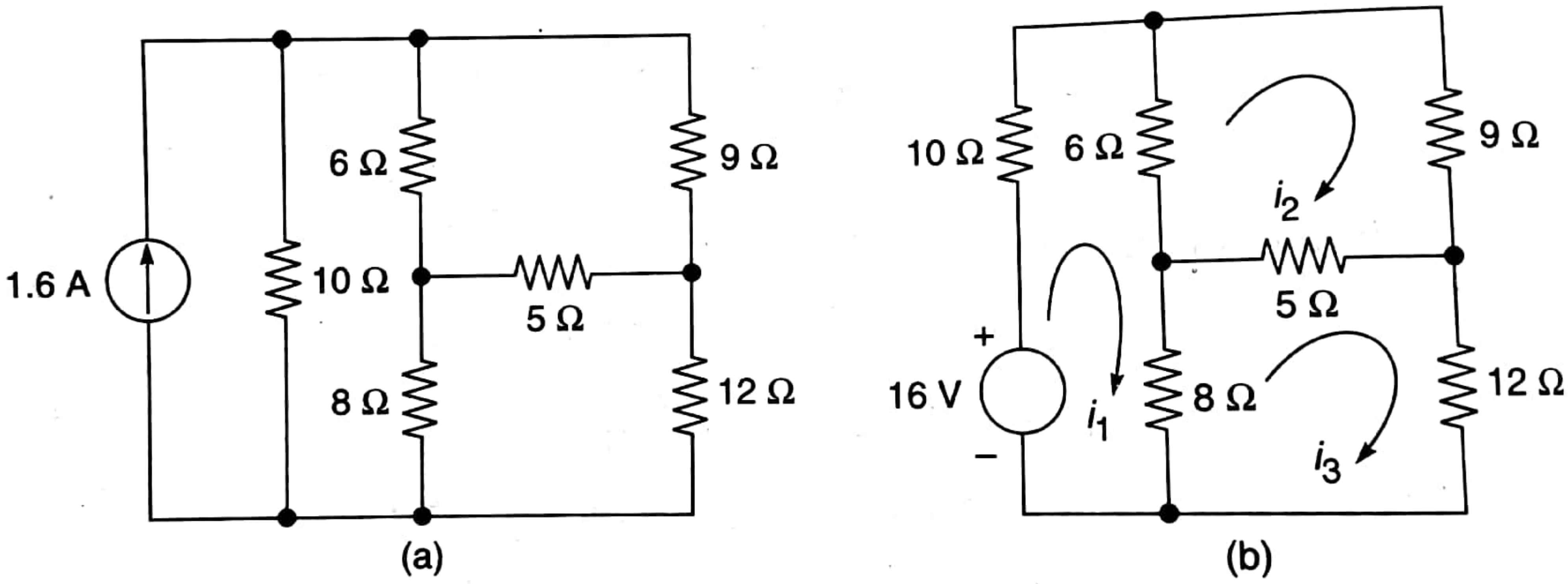


Fig. 2.25

Solution The practical current source of Fig. 2.25 (a) is first converted to voltage source as in Fig. 2.25 (b). Three meshes are immediately identified with associated currents i_1, i_2 and i_3. KVL equations for the three meshes are written as follows (directly in organized form).

Mesh 1: $$(10 + 6 + 8)i_1 - 6i_2 - 8i_3 = 16$$

or, $$24i_1 - 6i_2 - 8i_3 = 16 \qquad \text{(i)}$$

Mesh 2: $$-6i_2 + (6 + 9 + 5)i_2 - 5i_3 = 0$$

or, $$-6i_1 + 20i_2 - 5i_3 = 0 \qquad \text{(ii)}$$

Mesh 3: $$-8i_3 - 5i_2 + (8 + 5 + 12)\, i_3 = 0$$

or, $$-8i_1 - 5i_2 + 25i_3 = 0 \qquad \text{(iii)}$$

Solving Eqs (i), (ii) and (iii)

$$i_1 = 0.869 \text{ A}, i_2 = 0.348 \text{ A and } i_3 = 0.348 \text{ A}$$

$$\begin{aligned} \text{Current through } 5\ \Omega \text{ resistance} &= i_2 - i_3 \\ &= 0 \text{ A} \end{aligned}$$

Resistances 6Ω, 8Ω, 9Ω and 12Ω form a *bridge*. When any resistance is connected across a *balanced bridge*, it will not carry any current. Also observe,

$$\frac{6\ \Omega}{8\ \Omega} = \frac{2}{3} = \frac{9\ \Omega}{12\ \Omega} = \text{(equal bridge arms ratio)}$$

Example 2.14

For the circuit of Fig. 2.26 (a) determine the volt-age v across 20 Ω resistance using mesh analysis.

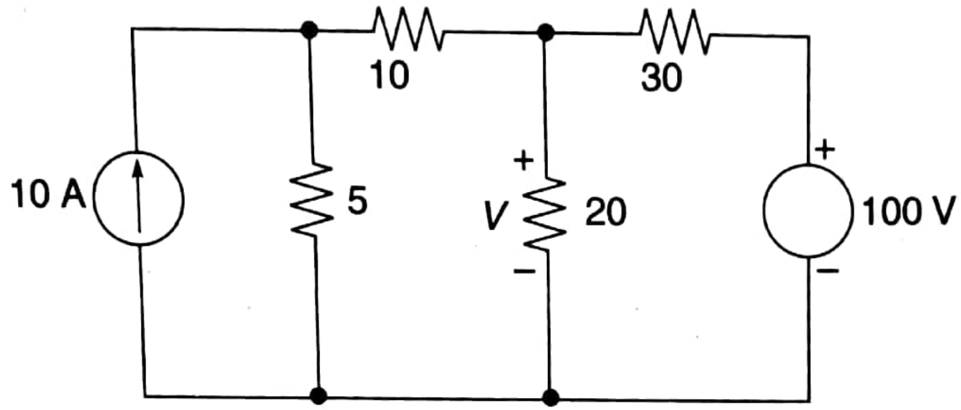


Fig. 2.26 (a)

Solution

Converting the practical current to a voltage source, we draw the circuit as in Fig. 2.26 (b). Writing the two mesh equations.

$$-50 + 15i_1 + 20(i_1 - i_2) = 0 \quad \text{(i)}$$

Or,

$$35i_1 - 20i_2 = 50 \quad \text{(ii)}$$

$$20(i_2 - i_1) + 30i_2 + 100 = 0 \quad \text{(iii)}$$

Or,

$$-20i_1 + 50i_2 = -100 \quad \text{(iv)}$$

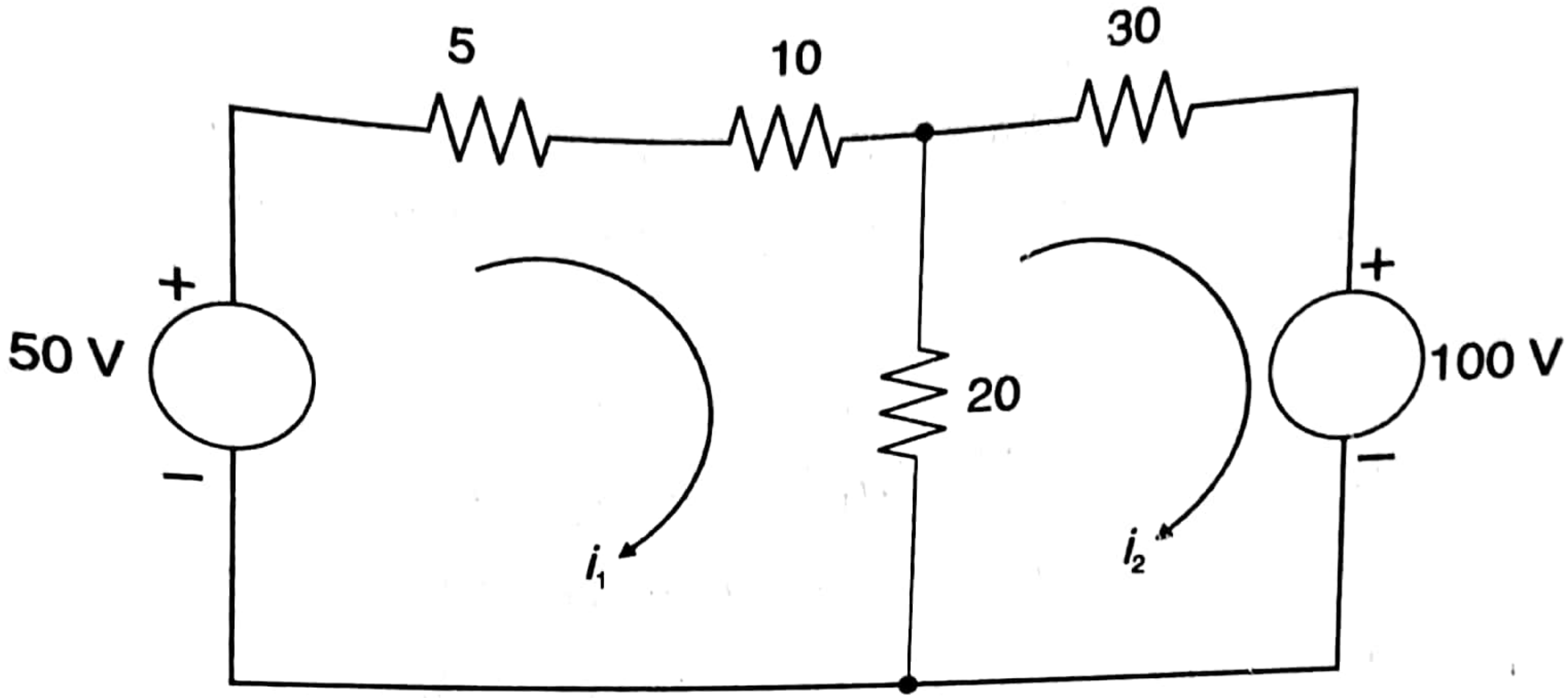


Fig. 2.26 (b)

Solving Eqs (ii) and (iv), we get

$$i_1 = 0.37\ A, \quad i_2 = -1.85\ \text{A}$$

Voltage across 20 Ω resistance

$$v = 20(i_1 - i_2) = 20 \times 2.22 = 44.4\ \text{V}$$

Example 2.10 *Find the current through the 2-Ω resistor.*

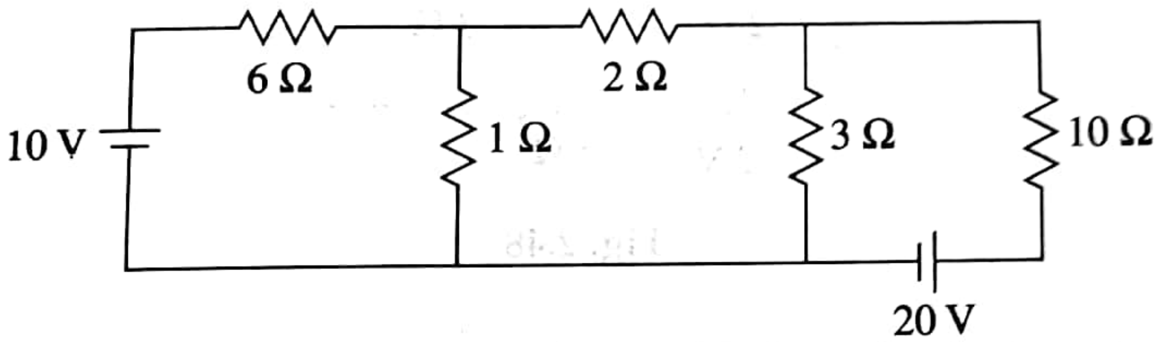


Fig. 2.46

Solution Assigning clockwise currents in three meshes,

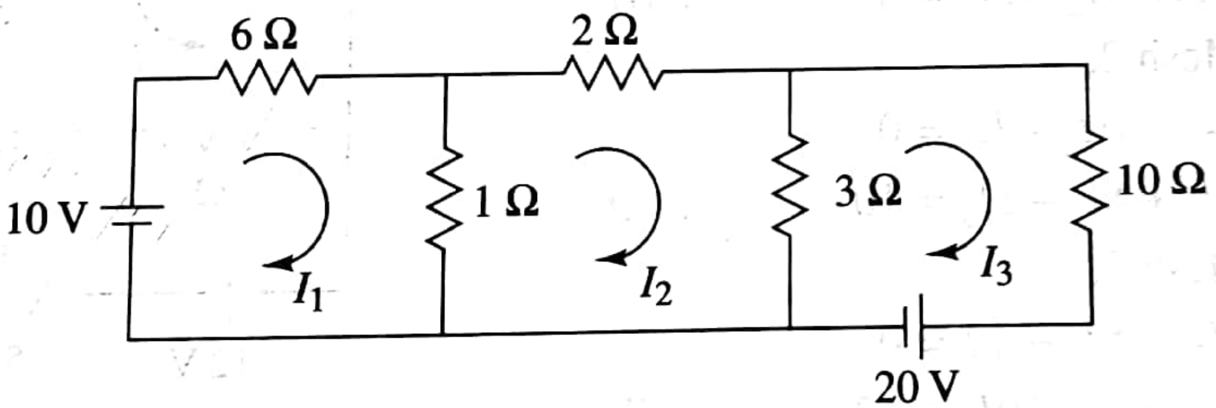


Fig. 2.47

Applying KVL to Mesh 1,

$$10 - 6I_1 - 1(I_1 - I_2) = 0$$

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

Applying KVL to Mesh 2,

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

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

Applying KVL to Mesh 3,

$$-3(I_3 - I_2) - 10I_3 - 20 = 0$$

$$-3I_2 + 13I_3 = -20 \quad \text{...(iii)}$$

Writing equations in matrix form,

$$\begin{bmatrix} 7 & -1 & 0 \\ -1 & 6 & -3 \\ 0 & -3 & 13 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ -20 \end{bmatrix}$$

Solving equations (i), (ii) and (iii),

$$I_1 = 1.34 \text{ A}$$

$$I_2 = -0.62 \text{ A}$$

$$I_3 = -1.68 \text{ A}$$

$$I_{2\,\Omega} = -0.62 \text{ A}$$

Example 2.11 *Determine the current through the 5-Ω resistor.*

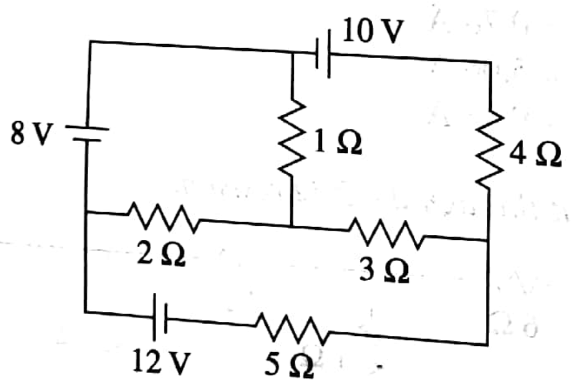


Fig. 2.48

Solution Assigning clockwise currents in three meshes,

Applying KVL to Mesh 1,

$$8 - 1(I_1 - I_2) - 2(I_1 - I_3) = 0$$

$$3I_1 - I_2 - 2I_3 = 8 \quad \text{...(i)}$$

Applying KVL to Mesh 2,

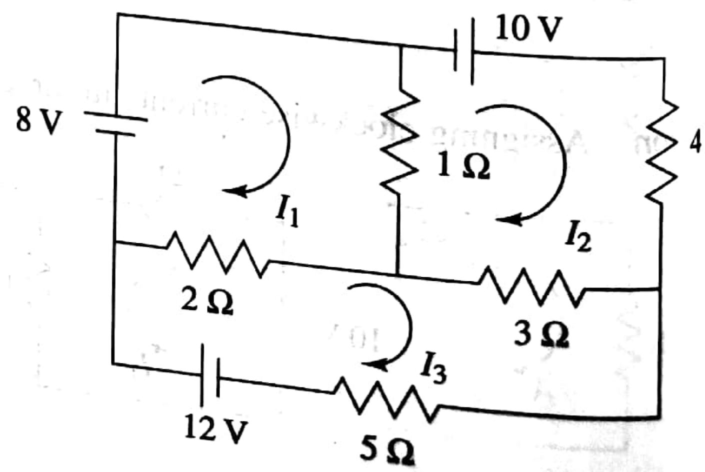
$$10 - 4I_2 - 3(I_2 - I_3) - 1(I_2 - I_1) = 0$$

$$-I_1 + 8I_2 - 3I_3 = 10 \quad \text{...(ii)}$$

Applying KVL to Mesh 3,

$$-2(I_3 - I_1) - 3(I_3 - I_2) - 5I_3 + 12 = 0$$

$$-2I_1 - 3I_2 + 10I_3 = 12 \quad \text{...(iii)}$$



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Writing equations in matrix form,

$$\begin{bmatrix} 3 & -1 & -2 \\ -1 & 8 & -3 \\ -2 & -3 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 8 \\ 10 \\ 12 \end{bmatrix}$$

Solving equations (i), (ii) and (iii),

$$I_1 = 6.01 \text{ A}$$
$$I_2 = 3.27 \text{ A}$$
$$I_3 = 3.38 \text{ A}$$
$$I_{5\,\Omega} = 3.38 \text{ A}$$

Example 2.12 *Find the current supplied by the battery.*

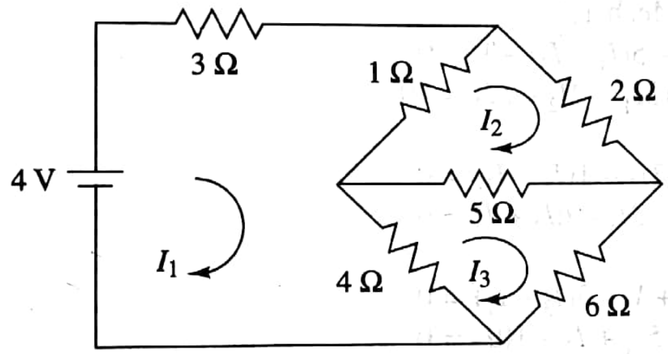


Fig. 2.50

Solution Applying KVL to Mesh 1,

$$4 - 3I_1 - 1(I_1 - I_2) - 4(I_1 - I_3) = 0$$
$$8I_1 - I_2 - 4I_3 = 4 \qquad \text{...(i)}$$

Applying KVL to Mesh 2,

$$-2I_2 - 5(I_2 - I_3) - 1(I_2 - I_1) = 0$$
$$-I_1 + 8I_2 - 5I_3 = 0 \qquad \text{...(ii)}$$

Applying KVL to Mesh 3,

$$-6I_3 - 4(I_3 - I_1) - 5(I_3 - I_2) = 0$$
$$-4I_1 - 5I_2 + 15I_3 = 0 \qquad \text{...(iii)}$$

Writing equations in matrix form,

$$\begin{bmatrix} 8 & -1 & -4 \\ -1 & 8 & -5 \\ -4 & -5 & 15 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 0 \\ 0 \end{bmatrix}$$

Solving equations (i), (ii) and (iii),

$$I_1 = 0.66 \text{ A}$$
$$I_2 = 0.24 \text{ A}$$
$$I_3 = 0.26 \text{ A}$$

Current supplied by the battery = 0.66 A.

Example 2.14 *Find the current through the 2-Ω resistor.*

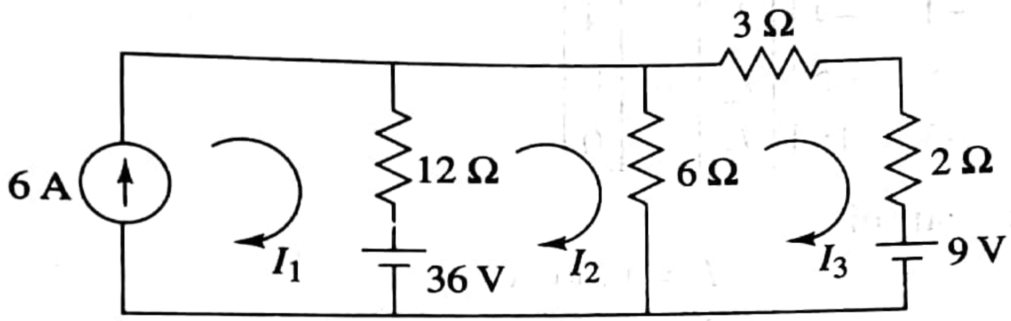


Fig. 2.52

Solution Mesh 1 contains a current source of 6 A. Hence, we cannot write KVL equation for Mesh 1. Since direction of current source and mesh current I_1 are same,

$$I_1 = 6\text{ A}$$

Applying KVL to Mesh 2,

$$36 - 12(I_2 - I_1) - 6(I_2 - I_3) = 0$$

$$36 - 12(I_2 - 6) - 6I_2 + 6I_3 = 0$$

$$18I_2 - 6I_3 = 108$$

Applying KVL to Mesh 3,

$$-6\,(I_3 - I_2) - 3I_3 - 2I_3 - 9 = 0$$

$$6I_2 - 11I_3 = 9$$

Solving equations (ii) and (iii),

$$I_3 = 3\text{ A}$$

$$I_{2\Omega} = 3\text{ A}$$

Kirchoff's current law:

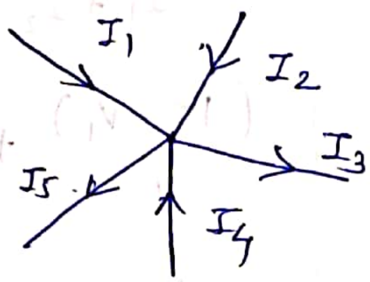
Statement :

Sum of currents flowing into any node in the circuit is equal to sum of current coming out of the same node.

In other words, "Summation of all currents entering or leaving a node must be equal to zero.

$$\therefore \Sigma I = 0.$$

Incoming current is considered as +ve.
Outgoing current is considered as -ve.

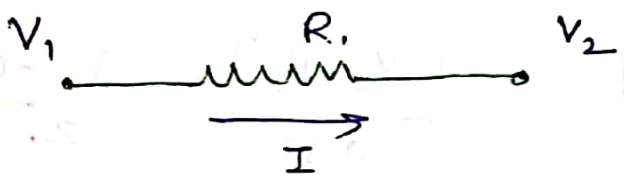


$$I_1 + I_2 + (-I_3) + (I_4) + (-I_5) = 0.$$

Or

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

Rules Regarding KCL



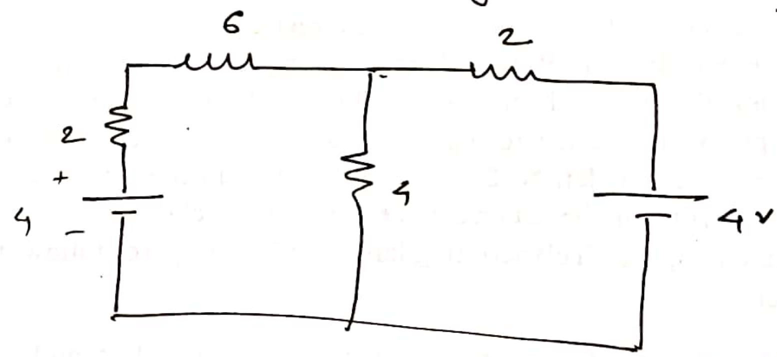
At Node 1

$$I = -\frac{(V_1 - V_2)}{R}.$$

At Node 2.

$$I = \frac{V_1 - V_2}{R}.$$

Q. Find current through 6 Ω resistor. By Nodal Analysis



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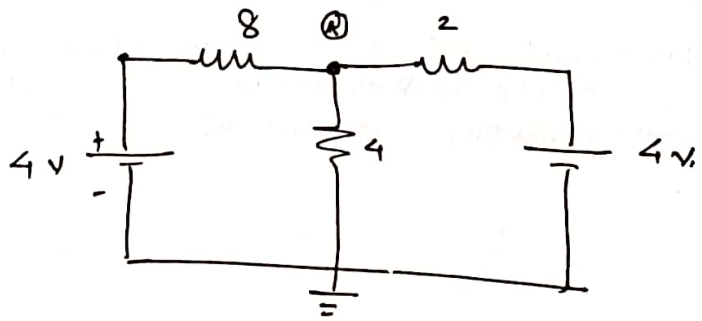


KCL at Node A

$$\frac{V_A - 4}{8} + \frac{V_A}{4} + \frac{V_A - 4}{2} = 0$$

$$\frac{V_A - 4}{8} + \frac{2V_A}{8} + \frac{4V_A - 16}{8} = 0$$

$$V_A - 4 + 2V_A + 4V_A - 16 = 0.$$

$$7V_A - 20 = 0.$$

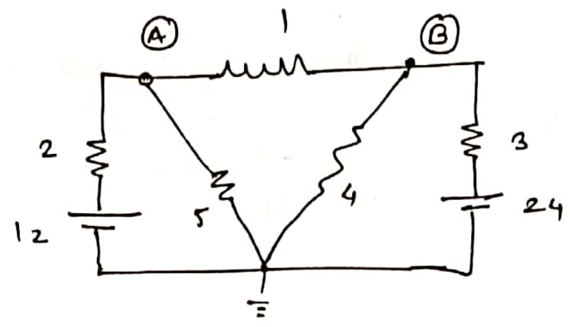
$$7V_A = 20 \Rightarrow V_A = 20/7 \text{ V.}$$

Current Through 6 Ω Resistor $(I_1) = \frac{V_A - 4}{8}$

$$= \frac{\frac{20}{7} - 4}{8} = \frac{\frac{20-28}{7}}{8}$$

$$= -\frac{8}{7} \times \frac{1}{8} = -\frac{1}{7} \text{ Amp.}$$

Q. Write the Node voltage Equation and determine current through 1 Ω resistor



⇒ Write KCL Equation for Node A

$$\frac{V_A - 12}{2} + \frac{V_A}{5} + \frac{V_A - V_B}{1} = 0$$

$$17V_A - 10V_B = 60 \quad -(1)$$

Write KCL Eqn for Node B.

$$\frac{V_B - V_A}{1} + \frac{V_B}{4} + \frac{V_B - 24}{3} = 0$$

$$12V_A - 19V_B = -96 \quad -(2)$$

$$\begin{bmatrix} 17 & -10 \\ 12 & -19 \end{bmatrix} \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 60 \\ -96 \end{bmatrix}$$

$$V_A' = \frac{\Delta_1}{\Delta} = \frac{\begin{bmatrix} 60 & -10 \\ -96 & -19 \end{bmatrix}}{\begin{bmatrix} 17 & -10 \\ 12 & -19 \end{bmatrix}} = \frac{-1140 - 960}{-323 + 120} = \frac{-2100}{-203}$$

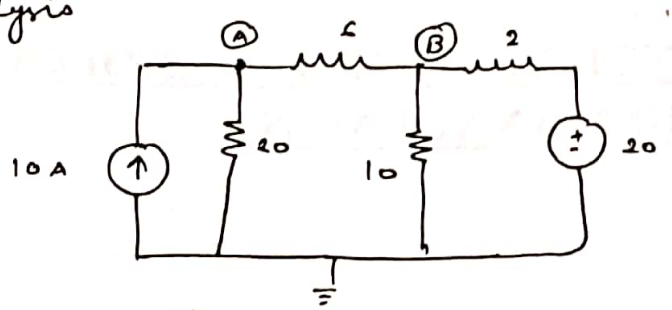
$$V_A = \frac{2100}{203} = 10.34 \text{ V}$$

$$V_B = \frac{\Delta_2}{\Delta} = \frac{\begin{bmatrix} 17 & 60 \\ 12 & -96 \end{bmatrix}}{203} = \frac{-1632 - 720}{-203} = \frac{-2352}{-203} = 11.58 \text{ V}$$

Current through 1 Ω resistor $= \frac{V_B - V_A}{1} = 11.58 - 10.34$

$= 1.24$ Amp (from Node B to A)

Q Determine current in Each Branch of Resistor using Nodal Analysis (10 Ω resistor)



⇒ Writing KCL at Node (A).

$$-10 + \frac{V_A - 0}{20} + \frac{V_A - V_B}{6} = 0.$$

$$13V_A - 10V_B = 600 \quad —(1).$$

Write KCL at Node (B)

$$\frac{V_B - V_A}{6} + \frac{V_B}{10} + \frac{V_B - 20}{2} = 0.$$

$$5V_A - 23V_B = -300 \quad — (2)$$

$V_A = 67.47$

$V_B = 27.71$.

Current Through 20 Ω resistor ⇒ $I_1 = \frac{V_A - }{20} = 3.373$

6 Ω resistor ⇒ $I_2 = \frac{V_A - V_B}{6} = \frac{67.47 - 27.71}{6}$

$I_2 = 6.627$

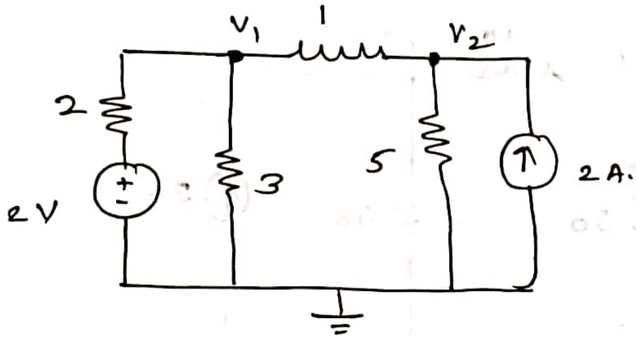
Current through 10 Ω resistor ⇒ $I_3 = \frac{V_B}{10} = 2.77\,A.$

Current through 2Ω resistor ⇒ $I_4 = \frac{V_B - 20}{2} = \frac{27.71 - 20}{2}$

$I_4 = 3.855$ Amp.

M-19

Q. Write only Nodal Equation of given circuit



⇒ Apply KCL at Node (1).

$$\frac{V_1-2}{2}+\frac{V_1}{3}+\frac{V_1-V_2}{1}=0.$$

Apply KCL at Node (2).

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

(1) ⇒ $3V_1-6+2V_1+6V_1-6V_2=0.$

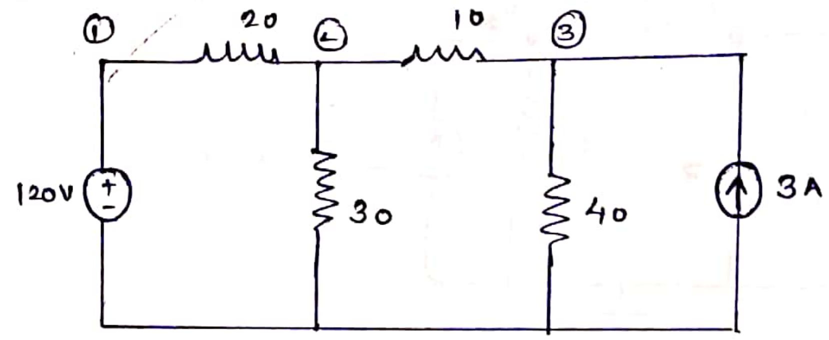
$$11V_1-6V_2=6 \quad -(1)$$

(2) ⇒ $5V_2-5V_1+V_2-10=0.$

$$-5V_1+6V_2=10 \quad -(2)$$

M-18.

Q. Obtain Nodal voltages of Node 1, 2 & 3 in the given Circuit.



⇒ from the given figure.;

$V_1 = 120\,V.$

Now, At Node (2) ; Apply KCL.

$$\frac{V_2 - 120}{20} + \frac{V_2}{30} + \frac{V_2 - V_3}{10} = 0.$$

$$3V_2 - 360 + 2V_2 + 6V_2 - 6V_3 = 0.$$

$$11V_2 - 6V_3 = 360 \quad -(1).$$

At Node (3) ; Apply KCL.

$$\frac{V_3 - V_2}{10} + \frac{V_3}{40} - 3 = 0.$$

$$4V_3 - 4V_2 + V_3 - 120 = 0.$$

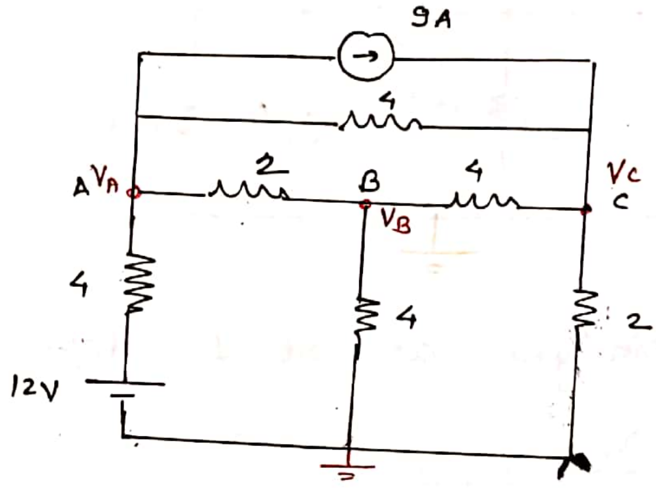
$$-4V_2 + 5V_3 = 120 \quad -(2)$$

Now; $V_2 = 81.29\,V.$

$V_3 = 89.03\,V.$

D-18

Q. Use Nodal Analysis to determine the voltage across BC and the current in the 12 V source



At Node A; KCL Eqn becomes.

$$\frac{V_A - 12}{4} + \frac{V_A - V_B}{2} + \frac{V_A - V_c}{4} + 9 = 0$$

$$V_A - 12 + 2V_A - 2V_B + V_A - V_c = -36$$

$$4V_A - 2V_B - V_c = -24 \quad \text{—(1)}$$

At Node B; KCL Eqn becomes.

$$\frac{V_B - V_A}{2} + \frac{V_B - V_c}{4} + \frac{V_B}{4} = 0$$

$$2V_B - 2V_A + V_B - V_c + V_B = 0$$

$$-2V_A + 4V_B - V_c = 0 \quad \text{—(2)}$$

At Node C; KCL Eqn becomes.

$$\frac{V_c - V_B}{4} + \frac{V_c - V_A}{4} + \frac{V_c}{2} - 9 = 0$$

$$V_c - V_B + V_c - V_A + 2V_c = \cancel{4}\,36$$

$$-V_A - V_B + 4V_c = \cancel{4}\,36 \quad \text{—(3)}$$

$V_A = -4\,V$

$V_B = 0\,V$

$V_c = 8\,V.$

$V_{BC} = V_B - V_c.$

$= 0 - 8$

$$\boxed{V_{BC} = -8\,V}$$

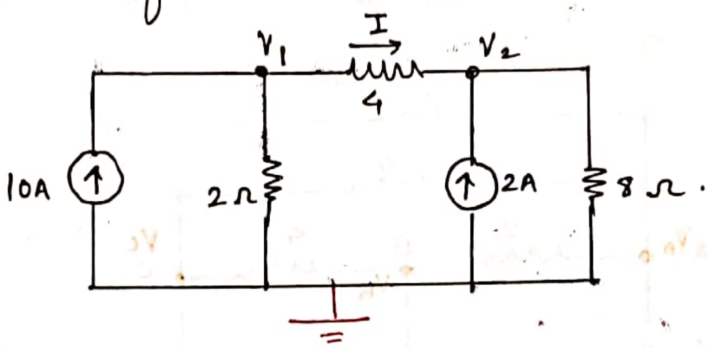
Current

$$I = \frac{12 - V_A}{4.} = \frac{12-(-4)}{4}$$

$$i = \frac{16}{4} = 4\,\text{Amp.}$$

D-16.

Q. User Nodal Analysis, determine node voltages V_1, V_2 & Current I for the Circuit Shown in figure.



⇒ By Nodal Analysis, at Node 1 ; Apply KCL.

$$-10 + \frac{V_1}{2} + \frac{V_1 - V_2}{4} = 0.$$

$$2V_1 + V_1 - V_2 = 20.$$

$$3V_1 - V_2 = 20 \quad -(1)$$

At Node ②, Apply KCL.

$$-\left(\frac{V_1 - V_2}{4}\right) + \frac{V_2}{8} - 2 = 0. \Rightarrow -2V_1 + 2V_2 + V_2 = 2 \times 8$$

$$-2V_1 + 3V_2 = 16$$

$$\cancel{2V_1 - 2V_2 + V_2 = 16}$$

$$\cancel{2V_1 - V_2 = 16 \quad -(2)}. \quad 2V_1 - 3V_2 = -16 \quad -(2)$$

$V_1 = \cancel{4V}.$ 19.42 V

$V_2 = \cancel{-8V}$ 18.28 V

Current through 4 Ω.,

$$I = \frac{V_1 - V_2}{4} = \frac{4 - (-8)}{4} = \frac{12}{4}$$

$\boxed{I = 3\text{ Amp}}$ $\boxed{I = 0.285\text{ Amp}}$

Superposition Theorem

→ The theorem is useful when a Network Contains more than one Energy sources. It is applicable to linear and bilateral N/w.

Linear N/w: A linear circuit is one whose Parameter is constant i.e. they do not change with voltage or current.

Bilateral N/w

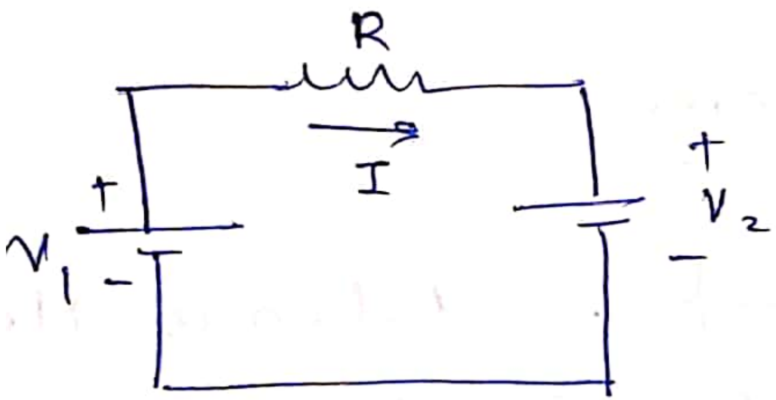
A bilateral N/w is one whose properties Or characteristics are same in either direction.

Statement

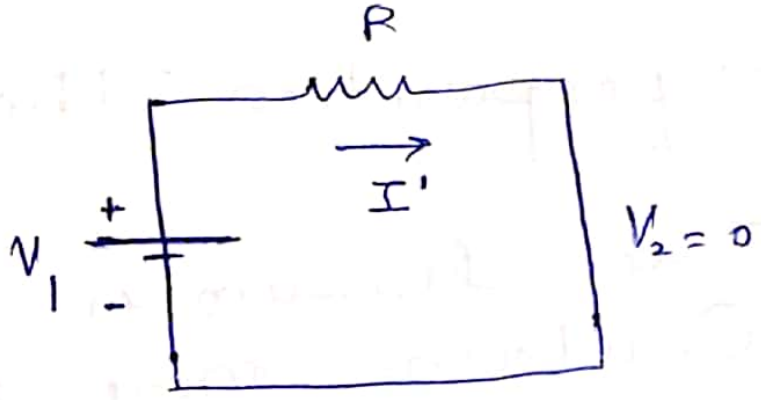
In a linear, bilateral Network, containing two or more sources, the response (current) in any Element is the algebric sum of current (response) Caused by Individual sources acting alone, while other sources are inoperative and are replaced by their internal resistances.

Note: In superposition theorem voltage sources is short circuited because it has zero internal resistances ($R_i = 0$).

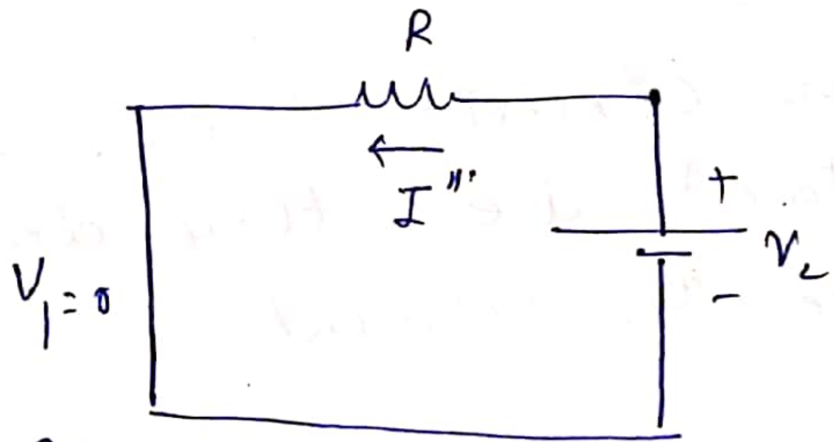
- Current source is open circuited because it has infinite internal Resistance ($R_i = \infty$).



(1) when V_1 & V_2 both acting



(2) V_2 is replaced by zero internal resistance, V_1 is acting alone.



$$I = I' + I''$$

(3). V_1 is short circuited & V_2 is acting alone.

Steps to Apply Superposition Theorem,

Step I: Select one Energy source.

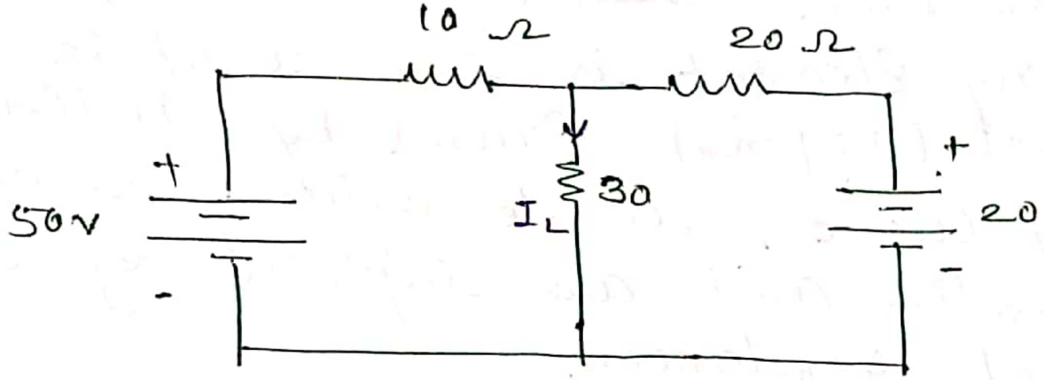
step 2: Replace all the other Energy source by their internal Resistance. (i.e. Voltage Source is short circuited & current source is open circuited).

Step 3 with only one Energy source solve the circuit.

step 4: Repeat 1, 2, 3 steps for each source individually.

step 5: (Take algebric sum of current) Add algebraically the currents obtained due to the individual source to obtain the combine effect of all sources.

Find I_L in circuit shown using superposition theorem.



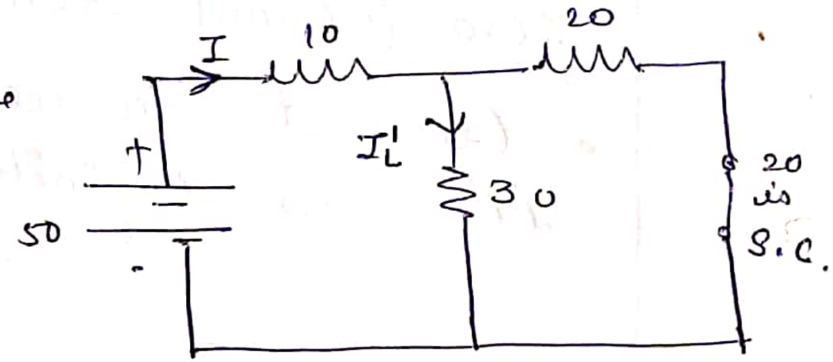
By Superposition Theorem,

a) Lets, Consider, 50 V Source is active & current through 30 Ω Resistor is I_L'

~~Total current~~

By current division Rule

$$I_L' = \frac{20}{20+30} \times I.$$



Now, Total current I.,

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

$$R_T = 10 + (20 \| 30) = 10 + \frac{30 \times 20}{20+30} = 10 + \frac{60\cancel{0}}{5\cancel{0}}$$

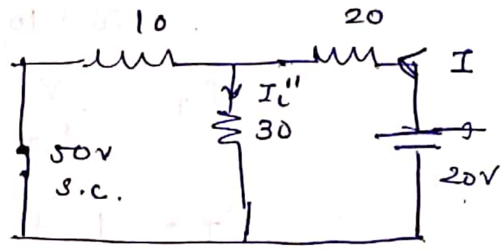
$$\boxed{R_T = 22\,\Omega}$$

Also,

$$I = \frac{50}{22} = 0.909 \text{ Amp} \downarrow$$

(b) Now, lets consider, 20 V source is active & current through 30 Ω resistor is I_L''

∴ By current division Rule



$$I_L'' = \frac{10}{10+30} \times I.$$

Also,

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

$$R_T = 20 + (10 \| 30) = 20 + \frac{10 \times 30}{10+30} = 20 + \frac{30\cancel{0}}{4\cancel{0}}$$

$$= 20 + 7.5 = 27.5$$

$$I = \frac{20}{27.5} = 0.73 \text{ Amp.}$$

$$I_L'' = \frac{10}{40} \times 0.73 = 0.181 \text{ A} \downarrow$$

Now, By Superposition theorem.

$$I_L = I_L' + I_L'' = 0.909 + 0.181$$

$$\boxed{I_L = 1.090 \text{ Amps}}$$

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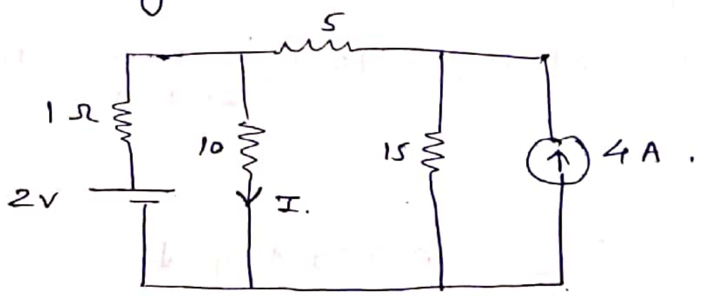
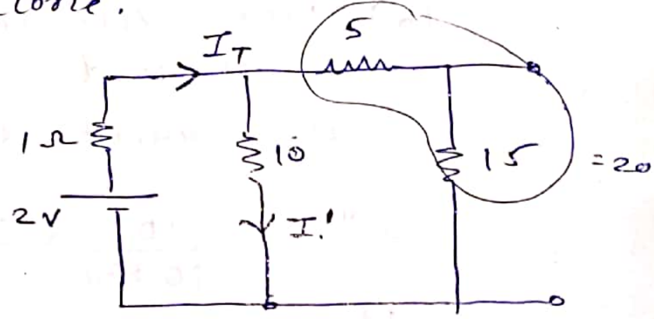
Q. Solve for Power delivered to $10\,\Omega$ by using SPT.



⇒ When 2V is acting alone.



$$I' = \frac{20}{20+10} \times I_T.$$

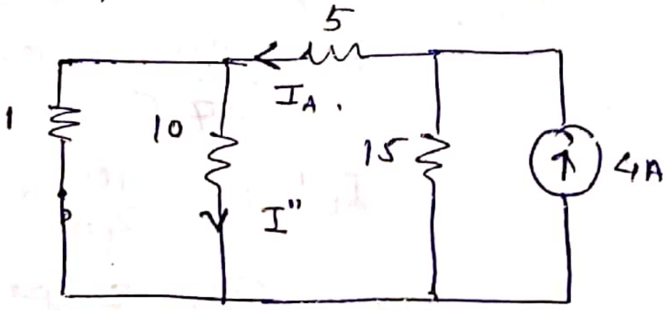
$$I_T = \frac{V}{R_T}.$$

$$R_T = 1 + (10 \parallel 20).$$

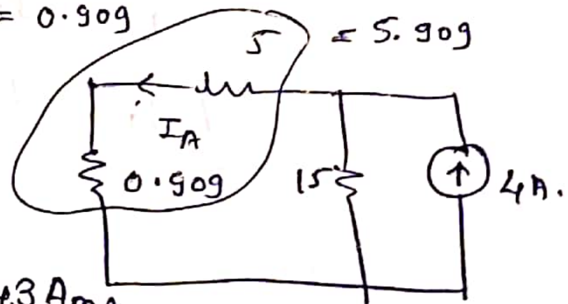
$$= 1 + \frac{10 \times 2\cancel{0}}{3\cancel{0}} = 1 + 6.67 = 7.67\,\Omega$$

$$I_T = \frac{2}{7.67} = 0.17 \text{ Amp } (\downarrow).$$

When 4A is acting alone.



$(10 \parallel 1)$ ⇓ $= 0.909$



$$I'' = \frac{1}{10+1} \times I_A.$$

$$I_A = \frac{15}{5.909 + 15} \times 4.$$

$$\underline{I_A = 2.87 \text{ Amp}}$$

$$I'' = \frac{1}{11} \times 2.87 = 0.26$$

$$I'' = 0.26 \text{ Amp} \downarrow$$

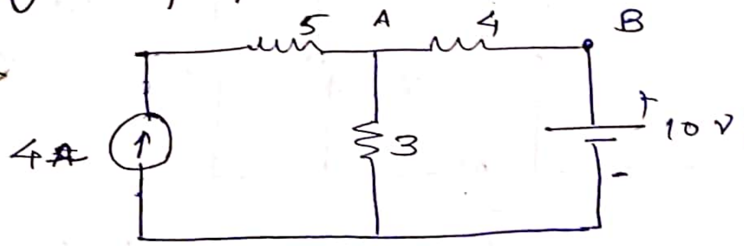
∴ Current through $10\,\Omega$ =

$$= 0.17 (\downarrow) + 0.26 (\downarrow) = 0.43 \text{ Amp}.$$

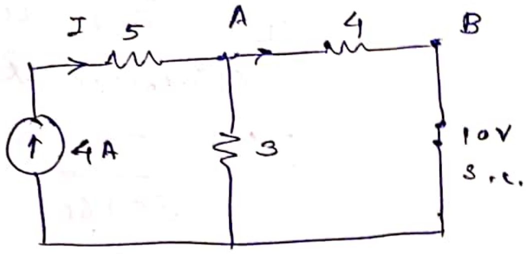
∴ Power delivered to $10\,\Omega$ $= I^2R = (0.43)^2 \times 10$

$$= 1.85 \text{ watts}.$$

Q. ~~sta~~ Find the voltage across Branch AB using superposition theorem.



⇒ When 4 A is acting alone

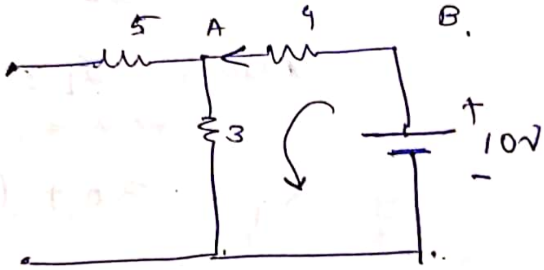


$$I'_{AB} = \frac{3}{3+4} \times I$$

$$I'_{AB} = \frac{3}{7} \times 4 = 1.714 \text{ Amp.}$$

$(\rightarrow)$

When 10V is acting alone.



$$I''_{AB} = \frac{10}{4+3} = 1.429 \text{ Amp.}$$

$(\leftarrow)$.

Total Current I_{AB} by Superposition Theorem.

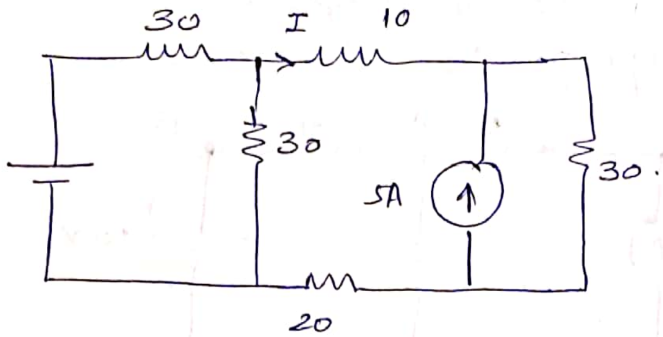
$$I_{AB} = I'_{AB} + I''_{AB} = 1.714 + (-1.429)$$

$$= 1.714 - 1.429 = 0.285 \text{ Amp.} (\rightarrow)$$

Direction of current is from A to B.

84

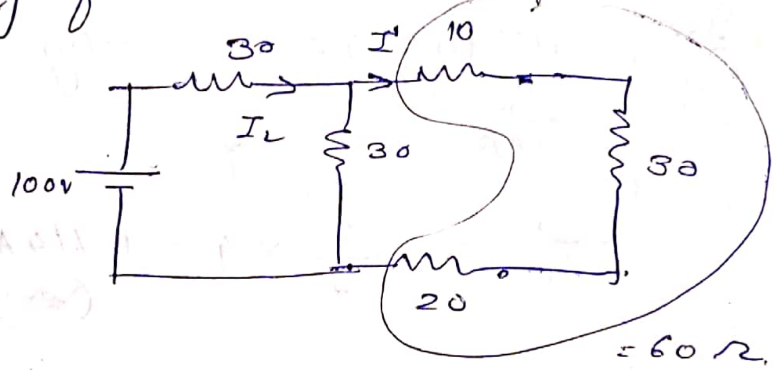
Q. W-17



Find current 'I' using SPT.

⇒ only 100V is acting find current I'

By current division Rule



$I' = \frac{30}{30+60} \times I_L$

$I' = \frac{\cancel{30}}{\cancel{90}_{3}} \times I_L$

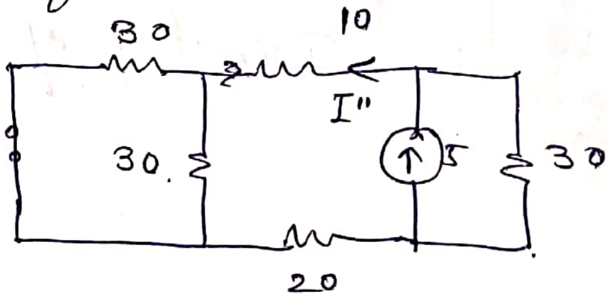
Also, $I_L = \frac{V}{R_T}$

$R_T = 30 + (30 \parallel 60) = 30 + \frac{\cancel{30}^{10} \times \cancel{60}^{2}}{\cancel{90}} = 50\,\Omega$

$I_L = \frac{100}{50} = 2\ \text{Amp}.$

$I' = \frac{2}{3} = 0.66\ \text{Amp}\ (\rightarrow).$

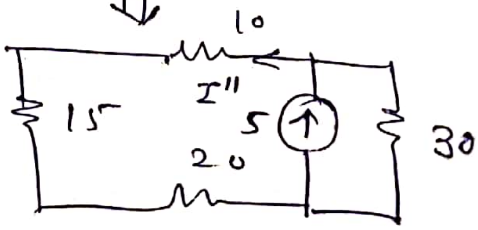
Only 5A is acting alone find I''



$I'' = \frac{30}{30+10+15+20} \times 5.$

$I'' = \frac{\cancel{30}\,2}{\cancel{75}\,\cancel{15}} \times \cancel{5}$

$I'' = 2\ \text{Amp}\ (\leftarrow).$



∴ Total current.

$I = I' + I''$

$= 0.66 + (-2)$

$I = -1.33\ \text{Amp}.$

$I = 1.33\ \text{Amp}\ (\leftarrow).$

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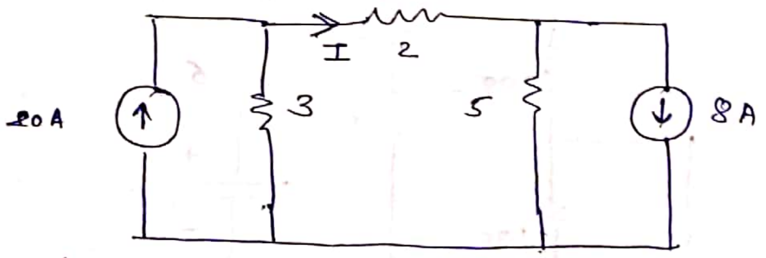
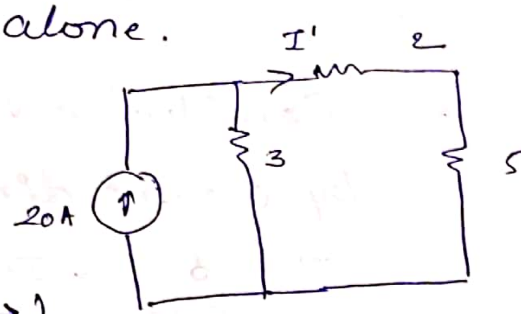
Q. Calculate value of current through 2Ω resistor. ~~to~~ using SPT.



$\Rightarrow$ Consider, 20A is acting alone.
Find I'

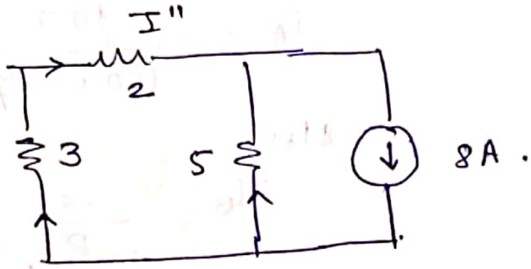


$$I' = \frac{3}{3+2+5} \times 20$$

(By current division Rule)

$$I' = \frac{3}{10} \times 20 = 6 \text{ Amp } (\rightarrow)$$

Consider 8 A is acting alone.
find I''



$$I'' = \frac{5}{3+2+5} \times 8$$

$$I'' = \frac{5}{10} \times 8 = 4 \text{ Amp } (\rightarrow)$$

Total current 'I' through 2Ω is

$$I = I' + I'' = 6 + 4 = 10 \text{ Amp } (\rightarrow)$$

$$\boxed{I = 10 \text{ Amp } (\rightarrow)}$$

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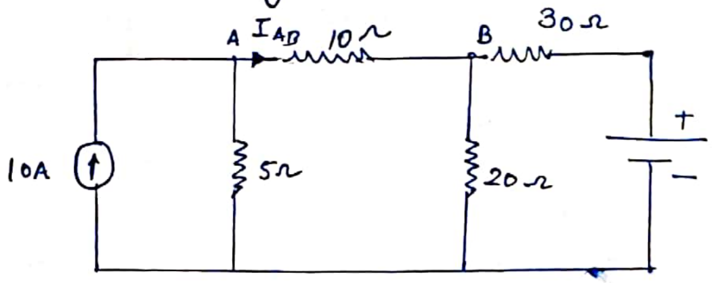
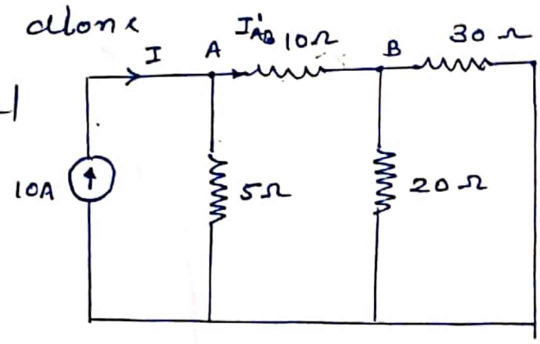
Q. Find current through branch AB as shown in fig.

S-15, S-17



Soln:

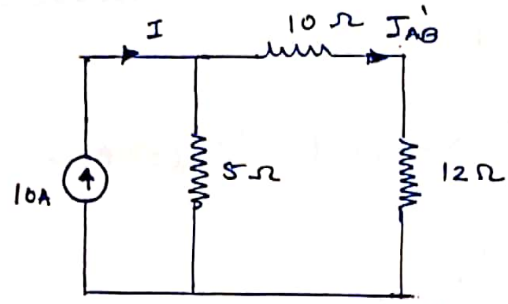
1] When only 10A is acting alone



30Ω & 20Ω are in parallel

$$30 \parallel 20 = \frac{30 \times 20}{30+20} = 12\,\Omega$$

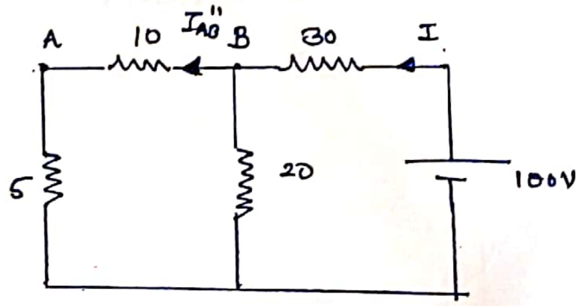
By current division Rule,



$$I'_{AB} = \frac{5 \times 10}{(5+10+12)}$$

$$\underline{I'_{AB} = 1.85\,A\,(\rightarrow)}$$

2] When 100V is acting alone



$$(10+5) \parallel 20$$

$$\therefore \; 15 \parallel 20 = \frac{15 \times 20}{15+20}$$

$$= 8.57\,\Omega$$

$$\therefore \; I = \frac{100}{30+8.75} = 2.59\,A.$$

$\therefore$ By current division Rule,

$$I''_{AB} = \left(\frac{20}{20+15}\right) \times 2.59 = \underline{1.48\,A\,(\leftarrow)}$$

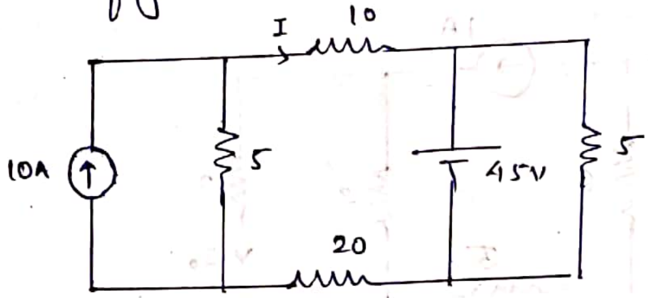
$\therefore$ Current through 10Ω $= I_{AB} = 1.85\,(\rightarrow) - 1.48\,(\leftarrow)$

$$I_{AB}\,(\rightarrow) = 1.85 - 1.48$$

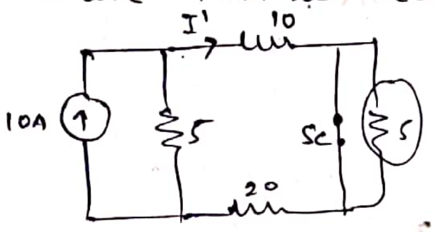
$$\boxed{I_{AB}\,(\rightarrow) = 0.37\,A}$$

D-16.

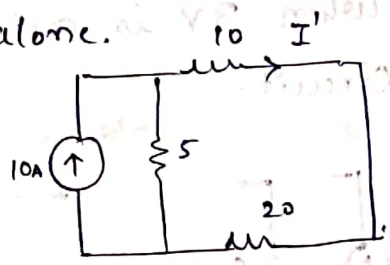
Q Using superposition Theorem, Find the current I in given figure.



Case 1: When 10 A is active alone.



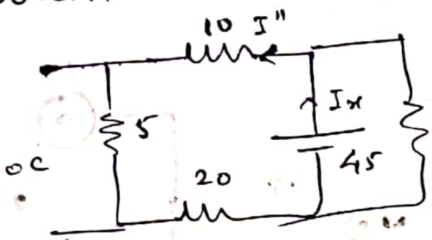
$\Rightarrow$



By current division Rule.

$$I' = \left(\frac{5}{5+30}\right) \times 10 = \frac{5}{35} \times 10 \Rightarrow I' = 1.42\,\text{Amp.} \ (\rightarrow)$$

Case 2: When 45V is active alone.

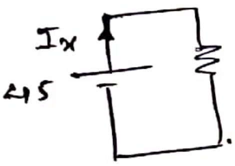


By current division Rule.;

$$I'' = \left(\frac{5}{5+35}\right) \times I_x \quad \text{— (1)}.$$

Now ; In above Circuit

$$5 \| 35 = \frac{35 \times 5}{5+35} \Rightarrow R_{eq} = 4.375\,\Omega.$$



$$\Rightarrow I_x = \frac{45}{4.375} = 10.285\,\text{Amp.}$$

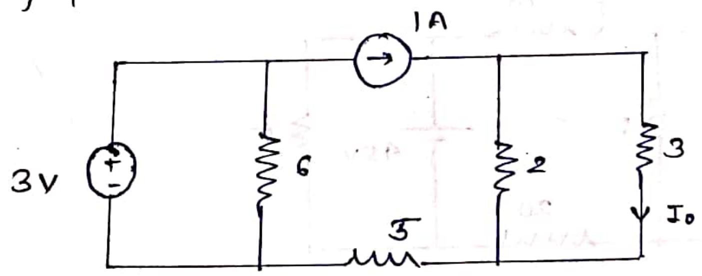
$$I'' = \frac{5}{40} \times 10.285 \Rightarrow I'' = 1.285\,\text{Amp} \ (\leftarrow)$$

By SPT $\Rightarrow$ $I = I' - I'' = 1.42 - 1.285$

$I = 0.135$ Amp.

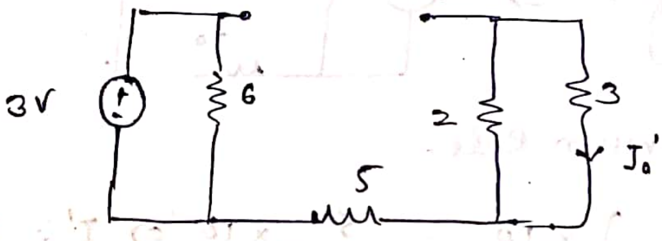
M-19.

Q. Find current I_o (current through 3Ω) using Superposition Theorem.



⇒ Case 1 : When 3V is active alone.

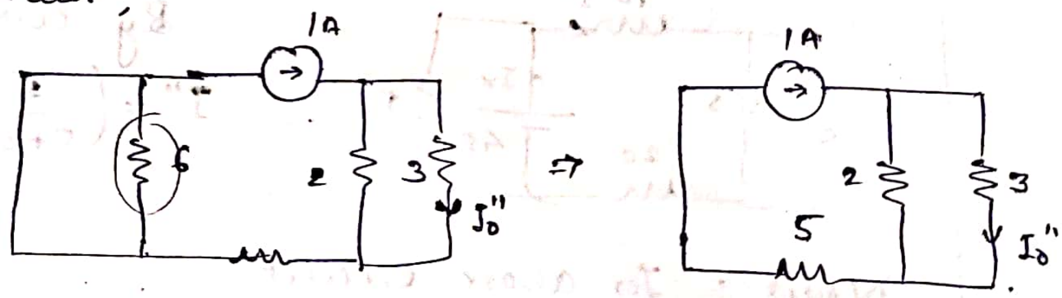
Redraw Circuit.



$I_o' = 0$ Amp.

Case 2 : When 1A is active alone.

Redraw Circuit ;



By current division Rule.

$$I_o'' = \left(\frac{2}{2+3}\right) \times 1 = \frac{2}{5} \times 1$$

$I_o'' = 0.4$ Amp (↓).

By SPT

$$I_o = I_o' + I_o'' = 0.4 \text{ Amp } (\downarrow).$$

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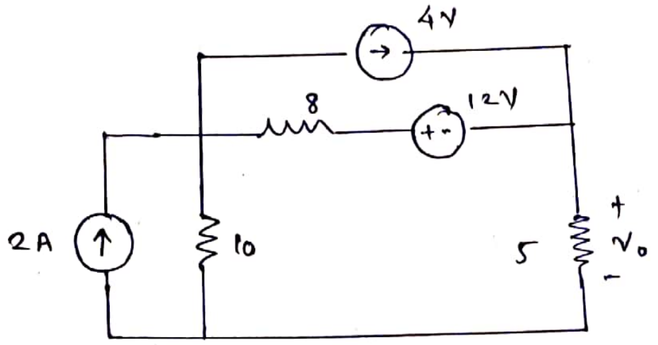
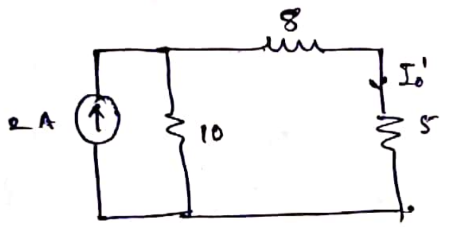
Q. Use superposition to find V_o in the circuit given below.



⇒ Case 1: only 2 A is active alone.

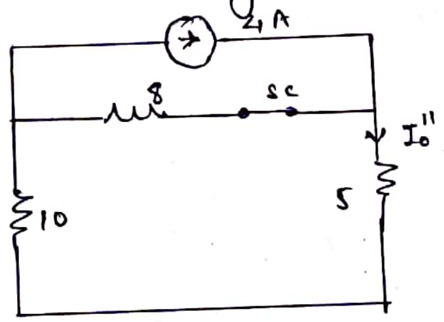


By current division Rule,

$$I_o' = \left(\frac{10}{10+13}\right) \times 2$$

$$I_o' = 1.538\ A\ (\downarrow).$$

Case 2: only 4 A is active alone

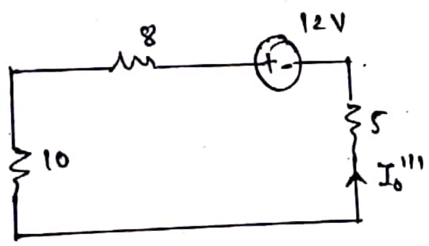


By current division Rule,

$$I_o'' = \left(\frac{8}{8+15}\right) \times 4$$

$$I_o'' = 2.133\ A\ (\downarrow)$$

Case 3: only 12 V is active alone.



Now; $I_o''' = \dfrac{12}{23}$

$$I_o''' = 0.521\ A\ (\uparrow).$$

Now; By SPT.

$$I_o = I_o' + I_o'' - I_o''' = 1.538 + 2.133 - 0.521$$

$$I_o = 3.15\ Amp\ (\downarrow).$$

Now; $V_o = I_o \times 5$ ⇒ $\boxed{V_o = 15.75\ V}$.

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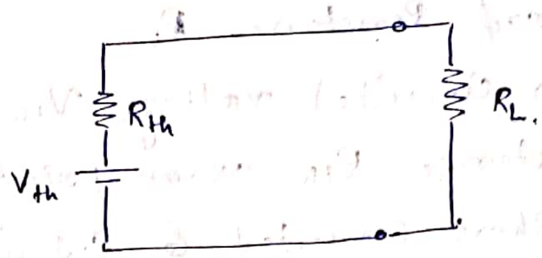
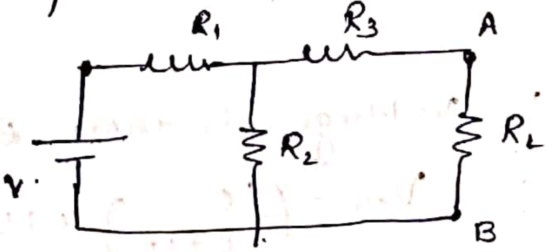
Thevenin's Theorem.

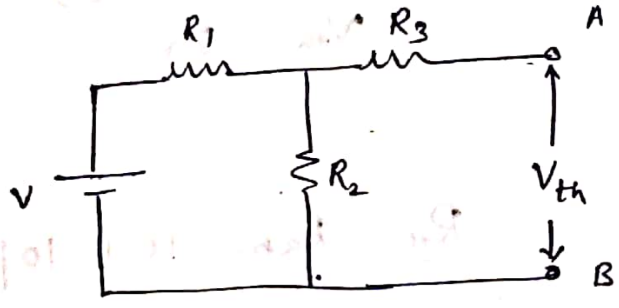


It states that current in any branch (may be R_L) in the network is same as would be obtained if R_L were supplied by voltage source V_{oc} or V_{Th} in series with Equivalent Resistance R_{th}; V_{th} or V_{oc} being the open-circuited voltage at the terminals from which R_L is Removed & R_{th} is the Resistance of Network measured between two terminals with R_L Removed & voltage source is replaced by its internal Resistance (S.C) & current source is replaced by Open Circuited.

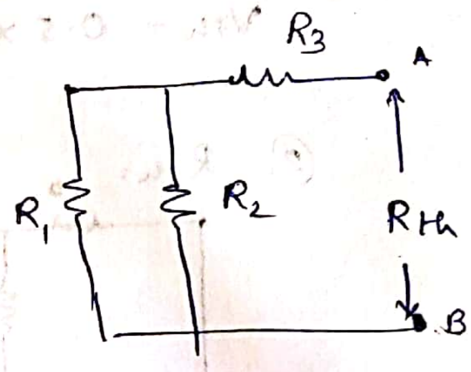
Eg.



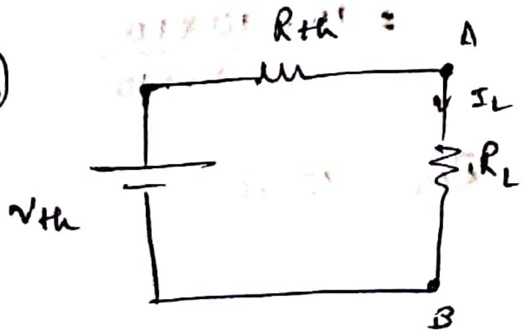
(1)



(2)



(3)



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

— (ohms law)

Steps to be followed in Thevenin's Theorem.

① Remove the load Resistance R_L

② Find the open circuited voltage V_{th} across points A & B

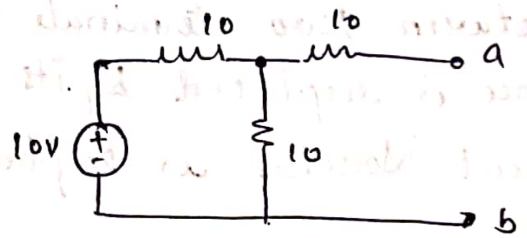
③ Find the Resistance R_{th} across points A & B.
also V.S is short circuited & C.S is open circuited

④. Replace Network by a voltage source V_{th} in series with Resistance R_{th}

⑤ Find the current through R_L using ohm's law

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

Q. Determine V_{th} & R_{th} across terminals AB.



① $V_{th} = V_{ab}$.

$$I = \frac{10}{10+10} = 0.5 \text{ Amp.}$$

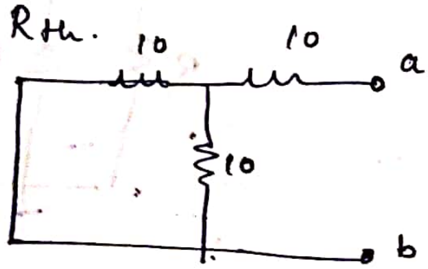
$$V_{th} = 0.5 \times 10 = 5V.$$

Voltage division Rule.

$$V_{th} = \left(\frac{10}{10+10}\right) \times 10$$

$$V_{th} = 5V.$$

② R_{th}.

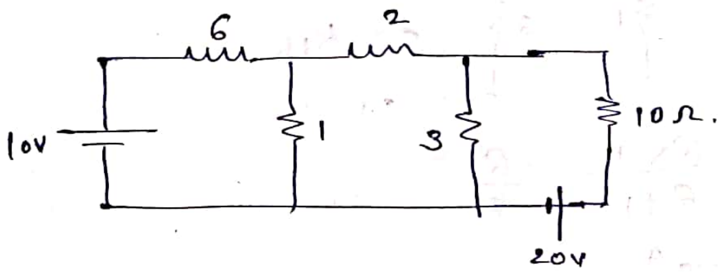


$$R_{th} = R_{ab} = 10 + 10 \| 10$$

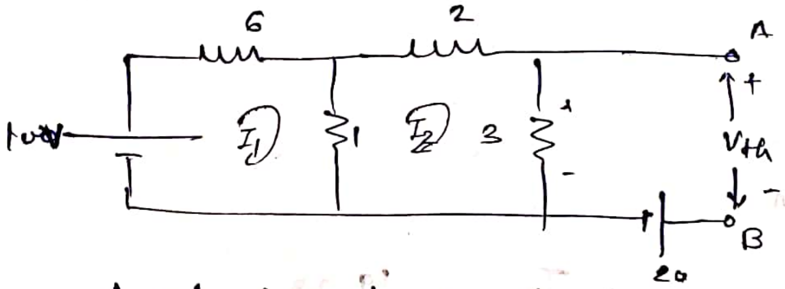
$$= 10 + \frac{10 \times 10}{10+10}$$

$$R_{th} = 15\,\Omega.$$

Q. Find the current through 10Ω Resistor using Thevenin's Theorem.



Step 1 : $V_{th} = ?$



Apply KVL in Mesh 1.

$$\cancel{10 - 6I_1 - 6} \quad 10 - 6I_1 - 1(I_1 - I_2) = 0.$$

$$7I_1 - I_2 = 10 \quad —(1).$$

Apply KVL in mesh 2.

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

$$I_1 - 6I_2 = 0. \quad —(2)$$

from (1) & (2) ; we get

$I_1 =$ $\qquad$ $I_2 = 0.24\,A.$

Writing V_{th} Eqn.

$$3I_2 - V_{th} - 20 = 0.$$

$$V_{th} = 3(0.24) - 20$$

$$V_{th} = -19.28\,V.$$

$V_{th} = 19.28\,V$ (B is at higher potential w.r.t A)

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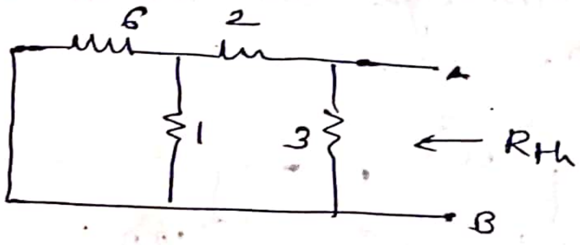
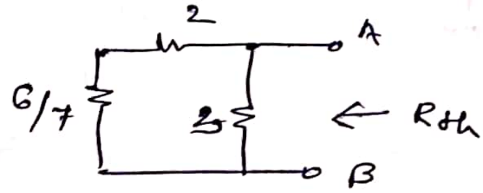
Step 2 : Calculation of R_{th}

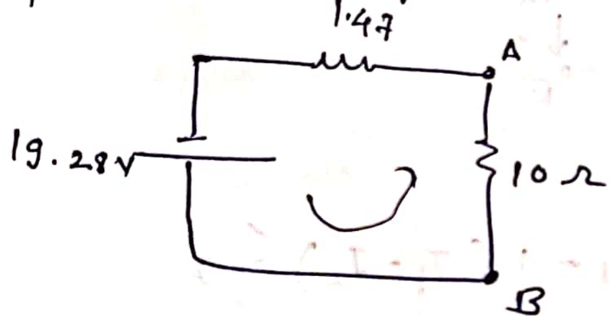


$$6 \parallel 1 = \frac{6 \times 1}{6+1} = \frac{6}{7}$$



$R_{th} = 1.47\ \Omega$.

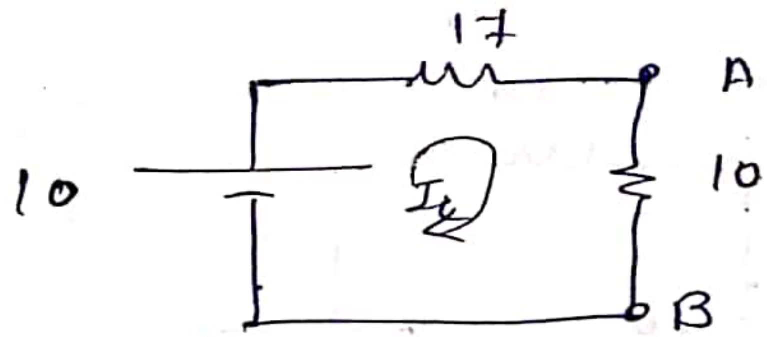
Step 3 : Cal^n of I_L.



$$I_L = \frac{19.28}{1.47+10}$$

$I_L = 1.68\ \text{Amp}\ (\uparrow)$

Step 3: Calculation of I_L



$$I_L = \frac{10}{17+10} = 0.37 \text{ Amp.}$$

Example 3.22 *Find the current through the 10-Ω resistor.*

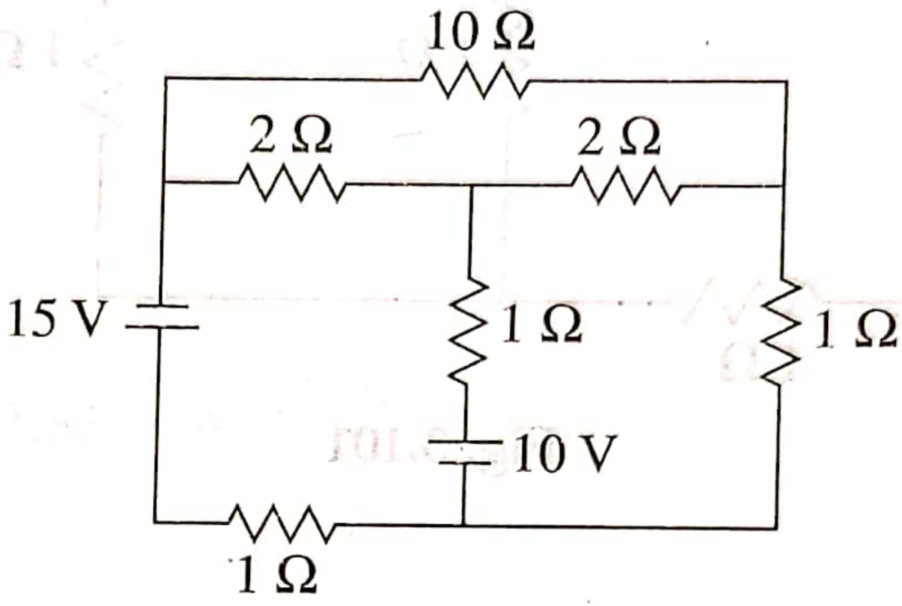


Fig. 3.99

Step I: *Calculation of V_{Th}*

Removing the 10-Ω resistor from the network,

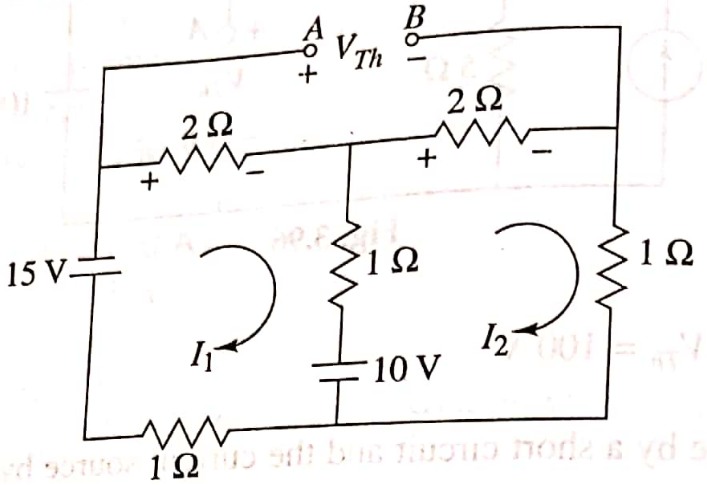


Fig. 3.100

Applying KVL to Mesh 1,

$$-15 - 2I_1 - 1\,(I_1 - I_2) - 10 - 1I_1 = 0$$

$$4I_1 - I_2 = -25$$

Applying KVL to Mesh 2,

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

$$-I_1 + 4I_2 = 10$$

Solving Eqs (1) and (2),

$$I_1 = -6 \text{ A}$$

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

Writing V_{Th} equation,

$$-V_{Th} + 2I_2 + 2I_1 = 0$$

$$V_{Th} = 2I_1 + 2I_2$$

$$= 2(-6) + 2\,(1) = -10 \text{ V}$$

$$= 10 \text{ V (the terminal } B \text{ is positive w.r.t. } A)$$

Step II: *Calculation of R_{Th}*

Replacing voltage sources by a short circuit,

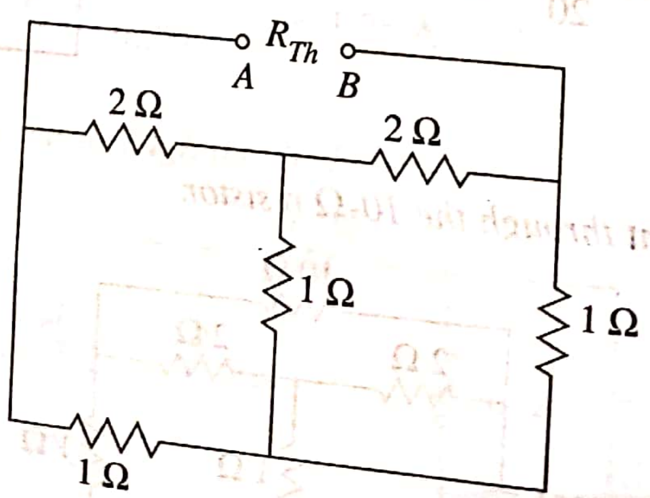


Fig. 3.101

Converting the star network formed by resistances of 2 Ω, 2 Ω and 1 Ω into an equivalent delta network.

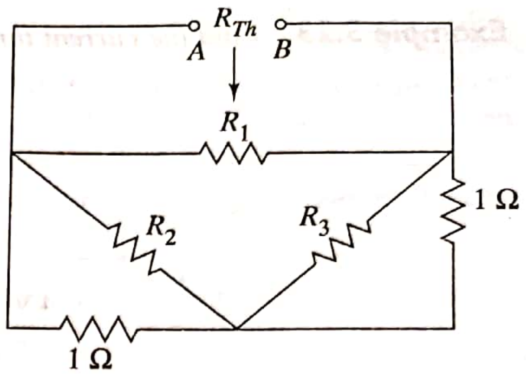


Fig. 3.102

$$R_1 = 2 + 2 + \frac{2 \times 2}{1} = 8\ \Omega$$

$$R_2 = 2 + 1 + \frac{2 \times 1}{2} = 4\ \Omega$$

$$R_3 = 2 + 1 + \frac{2 \times 1}{2} = 4\ \Omega$$

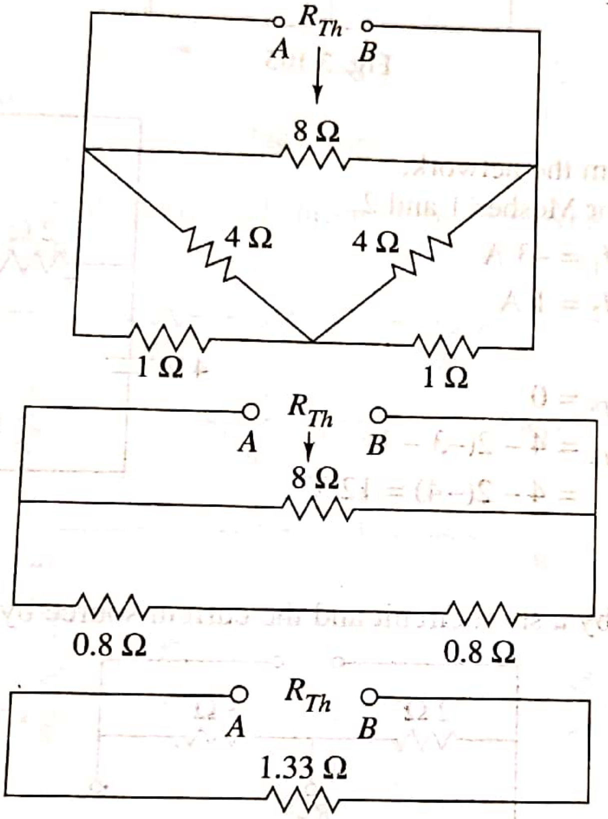


Fig. 3.103

Step III: *Calculation of* I_L

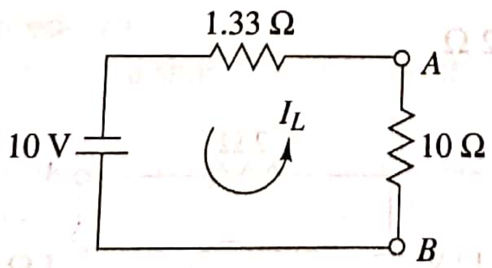


Fig. 3.104

$$I_L = \frac{10}{1.33 + 10} = 0.88\ \text{A}\ (\uparrow)$$

Example 3.23 *Find the current through the 1-Ω resistor.*

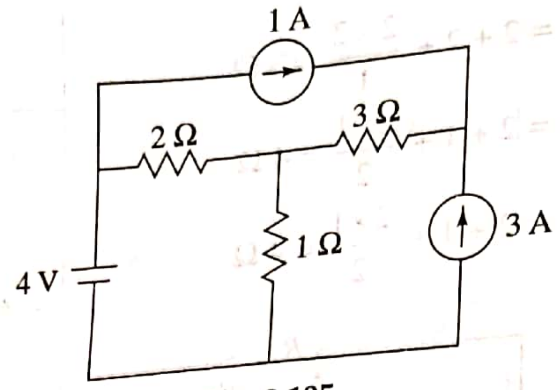


Fig. 3.105

Step I: *Calculation of V_{Th}*

Removing the 1-Ω resistor from the network,

Writing the current equation for Meshes 1 and 2,

$$I_1 = -3\text{ A}$$
$$I_2 = 1\text{ A}$$

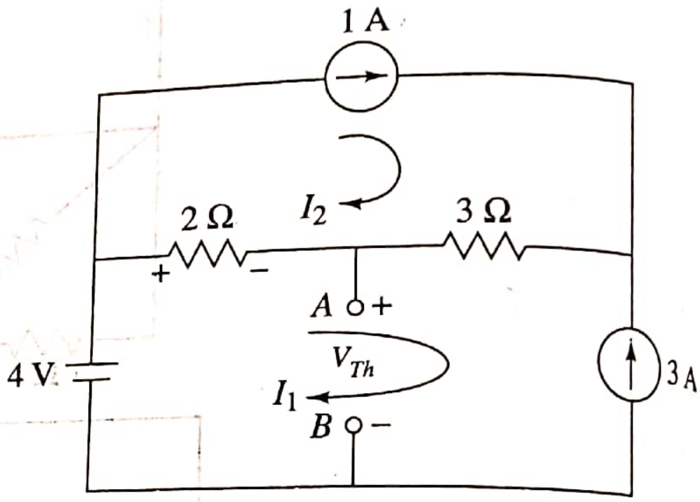


Fig. 3.106

Writing V_{Th} equation,

$$4 - 2(I_1 - I_2) - V_{Th} = 0$$
$$V_{Th} = 4 - 2(-3 - 1)$$
$$= 4 - 2(-4) = 12\text{ V}$$

Step II: *Calculation of R_{Th}*

Replacing the voltage source by a short circuit and the current source by an open circuit,

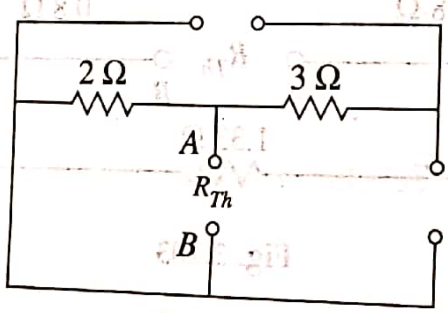


Fig. 3.107

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

Step III: *Calculation of I_L*

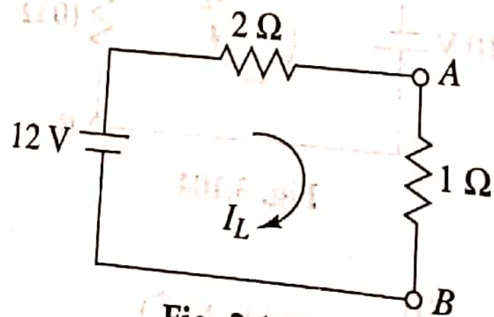


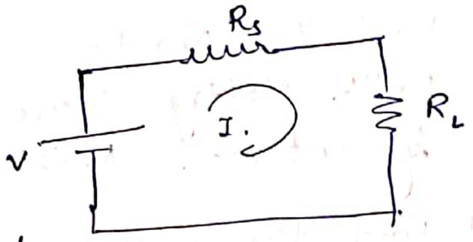
Fig. 3.108

$$I_L = \frac{12}{2+1} = 4\text{ A}$$

Maximum Power Transfer Theorem.

It states that the Maximum power is delivered from a source to a load when the load Resistance is equal to the source resistance.

$$I = \frac{V}{R_s + R_L}$$



Power delivered to the load

$$R_L \Rightarrow P = I^2 R_L = \frac{V^2 \; R_L}{(R_s + R_L)^2}$$

⇒ To determine the value of R_L for max. Power to be transferred to the load.

$$\frac{dP}{dR_L} = 0$$

$$\frac{dP}{dR_L} = \frac{d}{dR_L}\left\{\frac{V^2}{(R_s+R_L)^2} \; R_L\right\}$$

$$= \frac{V^2\left[(R_s+R_L)^2 - 2R_L(R_s+R_L)\right]}{(R_s+R_L)^4} = 0.$$

$$(R_s+R_L)^2 - 2R_L(R_s+R_L) = 0.$$

$$R_s^2 + 2\cancel{R_s R_L} + R_L^2 - \cancel{2R_L R_s} - 2R_L^2 = 0.$$

$$R_s^2 - R_L^2 = 0.$$

$$\boxed{R_s = R_L}$$

Hence, the max. Power will be transferred to the load resistance is equal to the source resistance.

I Imax

Steps to be followed in Maximum Power Transfer Theorem.

(1) Remove the variable load resistor 'R_L'.

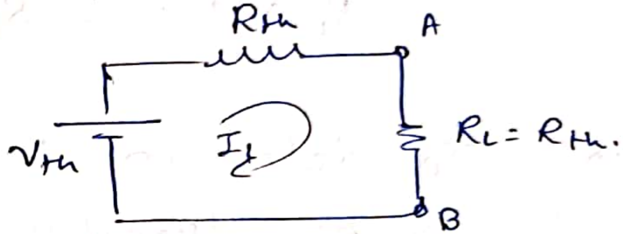
(2) Find the open circuit voltage 'V_{th}' across point A & B.

(3) Find the Resistance 'R_{th}' as seen from Point A & B with voltage source & current source replaced by internal Resistance.

(4) Find the resistance R_L for maximum power transfer.

$$(R_L = R_{th})$$

(5) Find the Max. Power.

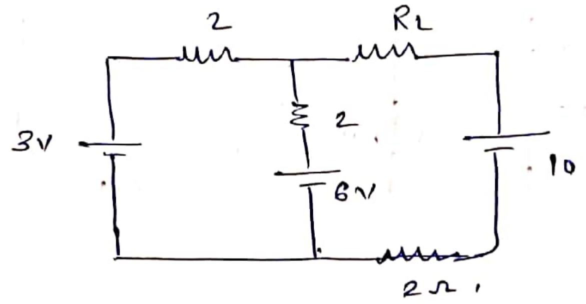


$$I_L = \frac{V_{th}}{R_{th} + R_L} = \frac{V_{th}}{2 R_{th}}$$

$$P_{max} = I_L^2 R_L$$

$$= \frac{V_{th}^2}{2 R_{th}^2} \times R_{th} \Rightarrow \boxed{P_{max} = \frac{V_{th}^2}{4 R_{th}}}$$

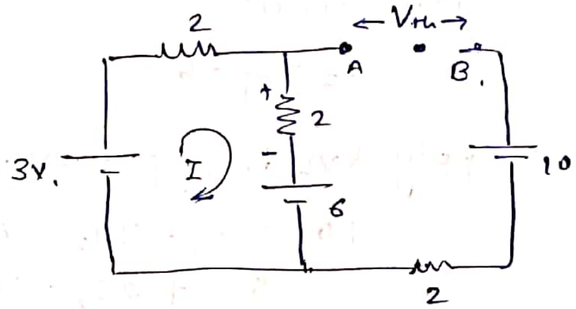
Q. Find value of Resistance 'R_L' for maximum Power & Calculate Maximum Power.



⇒ I V_{th} = ?

Remove R_L.

Apply KVL in mesh



$$3 - 2I - 2I - 6 = 0.$$

$$I = -0.75 \text{ Amp}$$

Writing V_{th} eqn.

$$6 + 2I - V_{th} - 10 = 0.$$

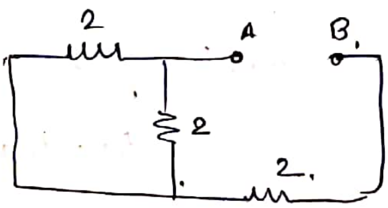
$$V_{th} = 6 + 2(-0.75) - 10.$$

$$V_{th} = -5.5 V.$$

V_{th} = 5.5 (terminal B is positive w.r.t A)

II R_{th} = ?

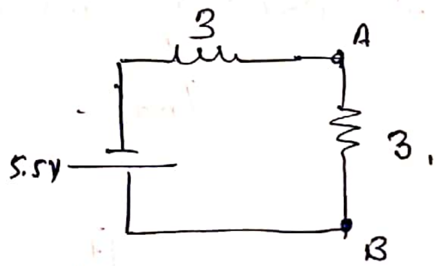
$$R_{th} = (2 \| 2) + 2 = 3 \Omega.$$



III Value of R_L.

Max. Power transfer

$$R_L = R_{th} = 3 \Omega.$$

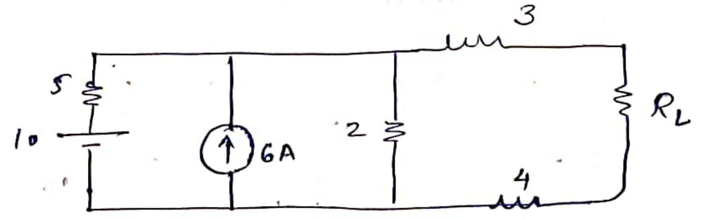


IV Cal^n of P_{max}.

$$P_{max} = \frac{V_{th}^2}{4 R_{th}} = \frac{5.5^2}{4 \times 3}$$

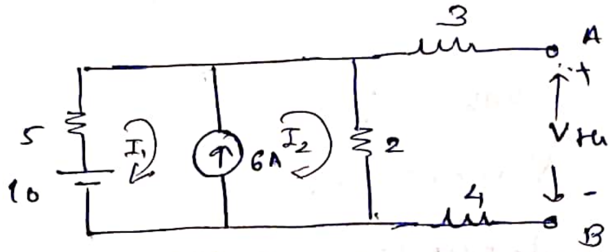
$$\boxed{P_{max} = 2.52 W.}$$

Q. Find value of Resistance R_L for max. Power & Calculate max. Power.



⇒ ① $V_{th} = ?$

Remove R_L from circuit.



From circuit

$$I_2 - I_1 = 6 ;$$

∴ Apply KVL in supermesh.

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

$$5I_1 + 2I_2 = 10.$$

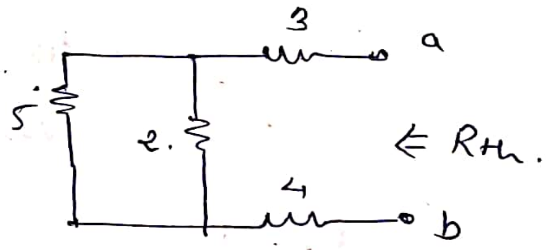
$$I_1 = -0.29\ A \quad ; \quad I_2 = 5.71\ A.$$

Writing V_{th} Eqⁿ;

$$V_{th} = 2I_2 = 11.42\ V.$$

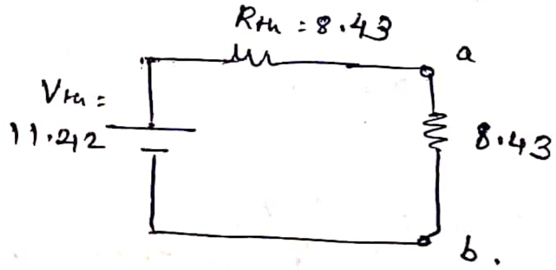
② $R_{th} = ?$

$$R_{th} = (5 \| 2) + 3 + 4 = 8.43\ \Omega.$$



③ Calⁿ of R_L

$$R_L = R_{th} = 8.43\ \Omega.$$

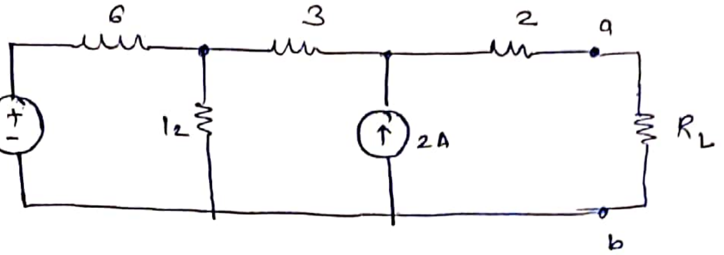


④ Calⁿ of P_{max}.

$$P_{max} = \frac{V_{th}^2}{4 \times R_{th}} = \frac{(11.42)^2}{4 \times 8.43}$$

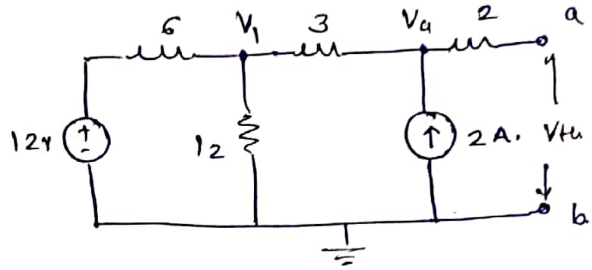
$$\boxed{P_{max} = 3.87\ W}$$

Q. Find the value of R_L for max. Power transfer in the circuit of. Find the max. Power.



$\Rightarrow$ ① $V_{th} = ?$

Apply KCL in Node ①.



$$\frac{V_1 - 12}{6} + \frac{V_1}{12} + \frac{V_1 - V_a}{3} = 0$$

$$2V_1 - 24 + V_1 + 4V_1 - 4V_a = 0.$$

$$7V_1 - 4V_a = 24 \quad —(1)$$

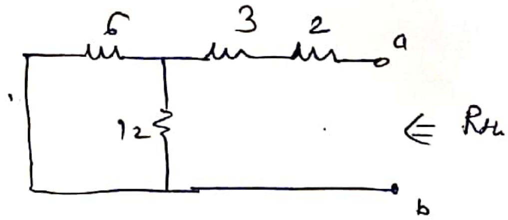
Apply KCL in Node ⓐ.

$$\frac{V_a - V_1}{3} - 2 = 0. \Rightarrow V_a - V_1 = 6 \quad —(2)$$

From Eqn ① & ②. ; $V_1 = 16V$; $V_a = 22V$.

$$V_a = V_{th} = 22V$$

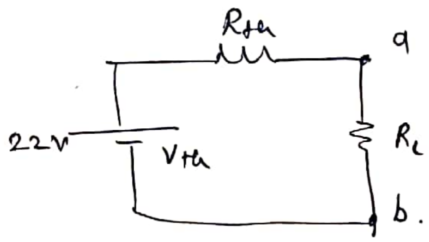
$\Rightarrow$ ② $R_{th} = ?$



$$R_{th} = (6 \| 12) + 3 + 2 = 4 + 3 + 2$$

$$\boxed{R_{th} = 9\,\Omega}$$

③. Value of R_L for max Power



$$R_L = R_{th} = 9\,\Omega$$

④. Caln of P_{max}.

$$P_{max} = \frac{V_{th}^2}{4R_{th}} = \frac{22^2}{4 \times 9} = \frac{484}{36}.$$

$$\boxed{P_{max} = 13.44 \text{ Watts}}$$

Example 3.42 *For the circuit shown, find the value of the resistance R_L for maximum power and calculate the maximum power.*

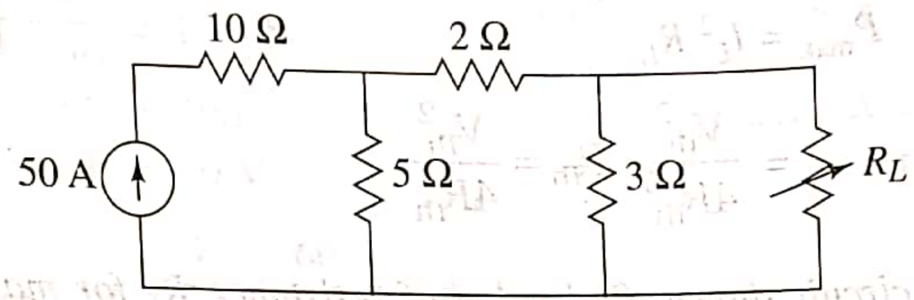


Fig. 3.182

Step I: *Calculation of V_{Th}*

Removing the variable resistor R_L from the circuit,

For Mesh 1,

$$I_1 = 50 \text{ A}$$

Applying KVL to Mesh 2,

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

$$5I_1 - 10I_2 = 0$$

$$I_1 = 2I_2$$

$$I_2 = 25 \text{ A}$$

$$V_{Th} = 3I_2 = 3(25) = 75 \text{ V}$$

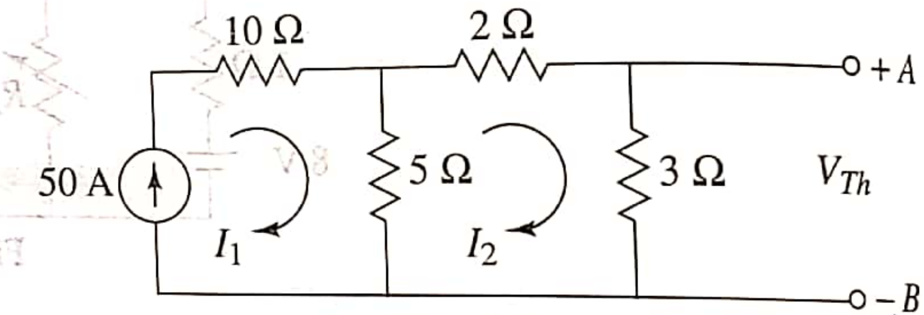


Fig. 3.183

Step II: *Calculation of R_{Th}*

Replacing the current source of 50 A with an open circuit,

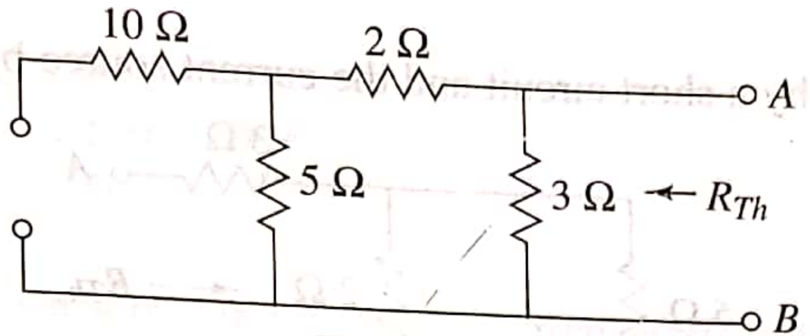


Fig. 3.184

$$R_{Th} = 7 \parallel 3 = 2.1\ \Omega$$

Step III: *Value of R_L*

For maximum power transfer,

$$R_L = R_{Th} = 2.1\ \Omega$$

Step IV: *Calculation of P_{max}*

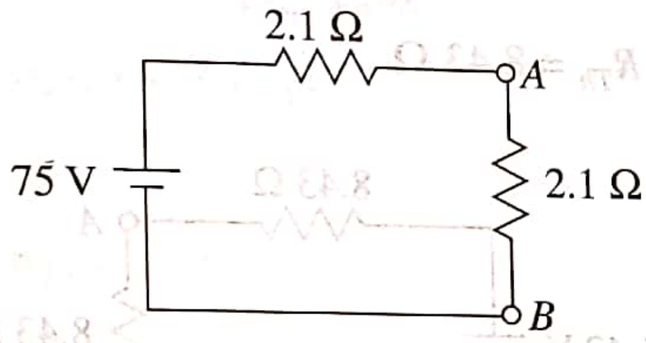


Fig. 3.185

$$P_{\max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{(75)^2}{4 \times 2.1} = 669.64\ \text{W}$$

Example 3.43 For the circuit shown ...

Example 3.44 *For the circuit shown, find the value of the resistance R_L for maximum power and calculate the maximum power.*

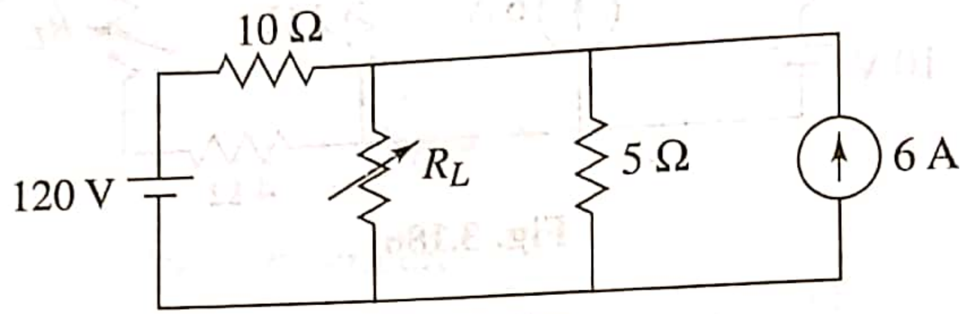


Fig. 3.190

Step I: *Calculation of V_{Th}*

Removing the variable resistor R_L from the circuit,

Applying KVL to Mesh 1,

$$120 - 10I_1 - 5(I_1 - I_2) = 0$$

$$15I_1 - 5I_2 = 120 \quad \text{...(1)}$$

Writing current equation for Mesh 2,

$$I_2 = -6\text{ A} \quad \text{...(2)}$$

Solving Eqs (1) and (2),

$$I_1 = 6\text{ A}$$

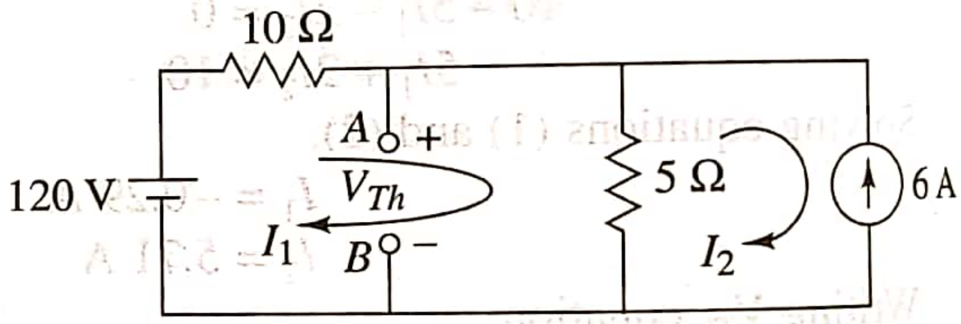


Fig. 3.191

Writing V_{Th} equation,

$$120 - 10I_1 - V_{Th} = 0$$

$$V_{Th} = 120 - 10\,(6)$$

$$= 60 \text{ V}$$

Step II: *Calculation of R_{Th}*

Replacing the voltage source by a short circuit and the current source by an open circuit,

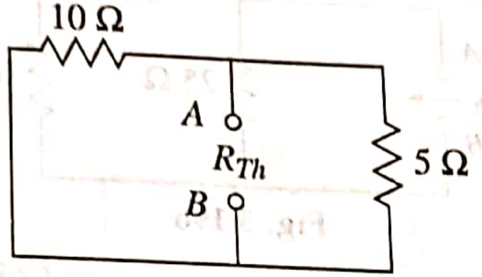


Fig. 3.192

$$R_{Th} = 10 \parallel 5 = 3.33\ \Omega$$

Step III: *Calculation of R_L*

For maximum power transfer

$$R_L = R_{Th} = 3.33\ \Omega$$

Step IV: *Calculation of P_{max}*

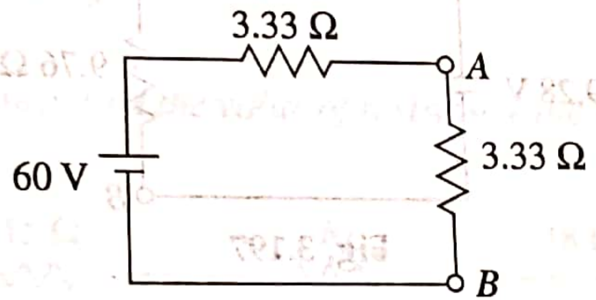


Fig. 3.193

$$P_{\max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{(60)^2}{4 \times 3.33} = 270.27 \text{ W}$$