# UNIT-1

# CIRCUIT THEOREMS

By

Ch. V. Krishna Reddy

EEE,CBIT

# Introduction

A large complex circuits

Simplify circuit analysis

Circuit Theorems

- Thevenin's theorem
- Circuit linearity
- source transformation
- Norton theorem
- Superposition
- max. power transfer

# Topics to be Discussed

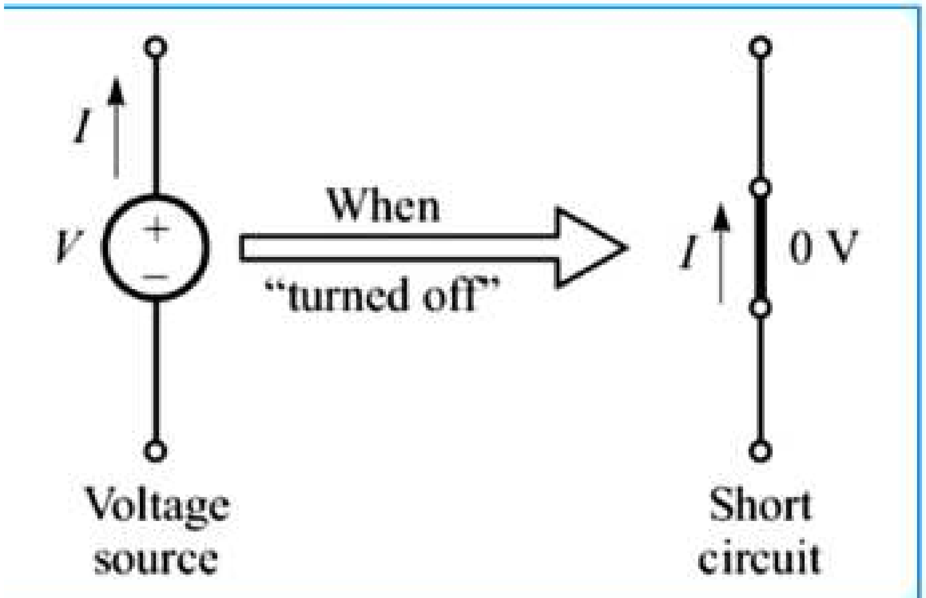
- Superposition Theorem.
- Thevenin's Theorem.
- Norton's Theorem.

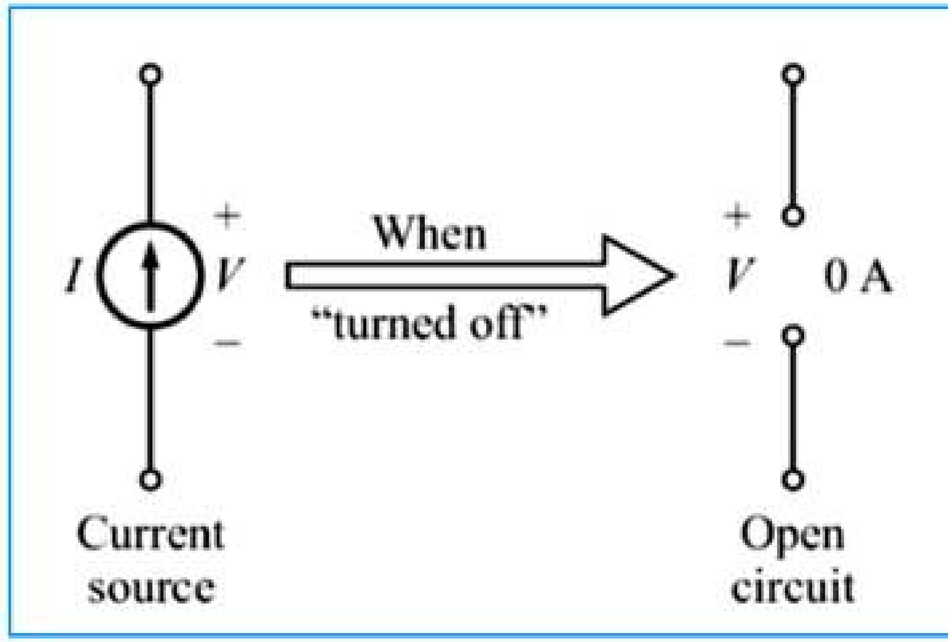
# Superposition Theorem

- The response (current or voltage) in a linear network at any point due to multiple sources (current and/or emf) can be calculated by summing the effects of each source considered separately,
- Turn off, killed, inactive source:
  - independent voltage source: 0 V (short circuit)
  - independent current source: 0 A (open circuit)
- Dependent sources are left intact.

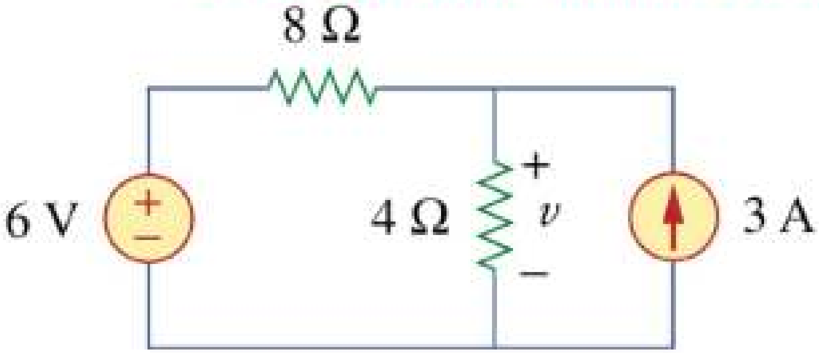
# Superposition Theorem

## How to "Turning off" sources

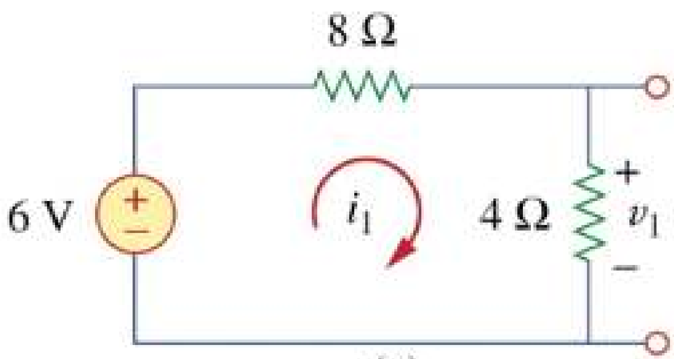


Ex:1 Use superposition theorem to find '*v*' in the circuit in Fig.




(i) consider voltage source of 6V alone

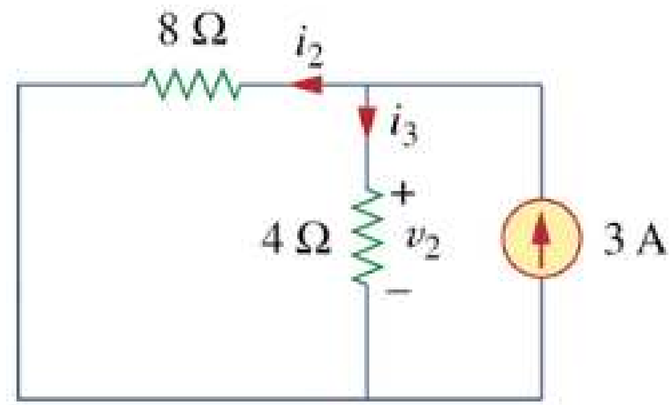



(a)

Apply VDR to get $V_1$

$$V_1 = \frac{4}{4+8}(6) = 2\text{V}$$

(ii) consider current source of 3 A alone




(b)

Apply CDR to get $i_3$

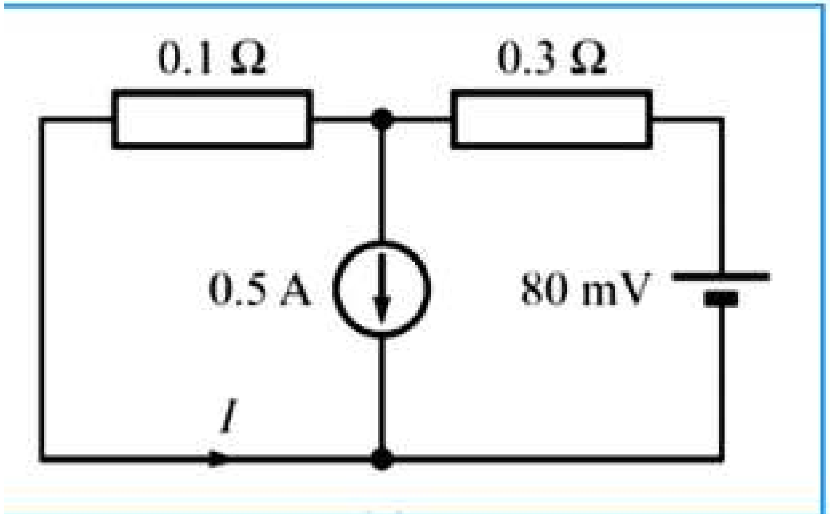
$$i_3 = \frac{8}{4+8}(3) = 2\text{A}$$

Hence $v_2 = 4i_3 = 8\text{V}$

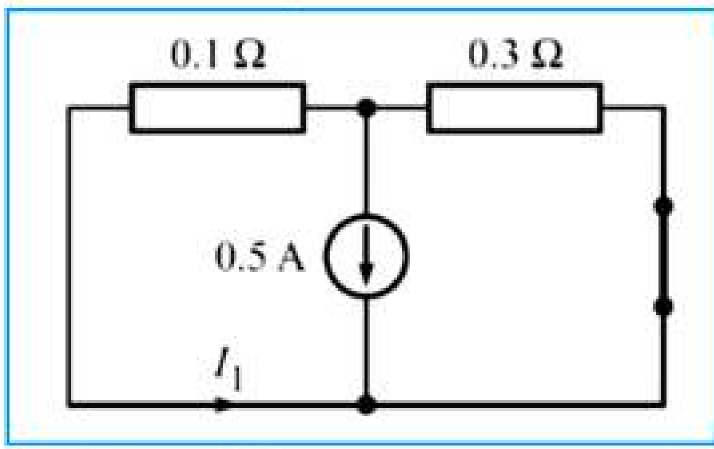
Finally find

$$v = v_1 + v_2 = 2 + 8 = 10\text{V}$$

**Ex: 2** Find the current $I$ in the circuit given, using superposition theorem.

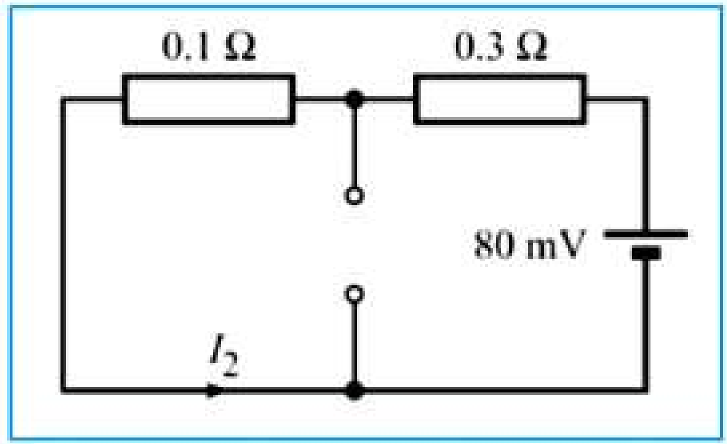



(i) First, consider the current source of 0.5 A alone,




$$I_1 = -\frac{0.5 \times 0.3}{0.1 + 0.3} = \frac{-0.15}{0.4} = \mathbf{-0.375\ A}$$

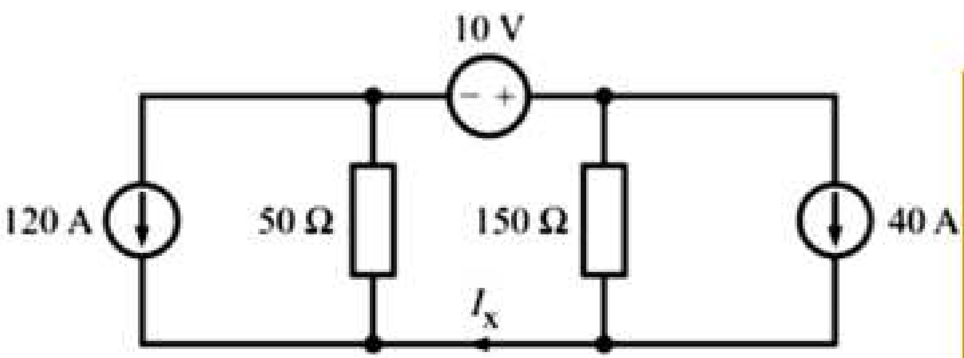
(ii) Next, consider the voltage source of 80mV alone,



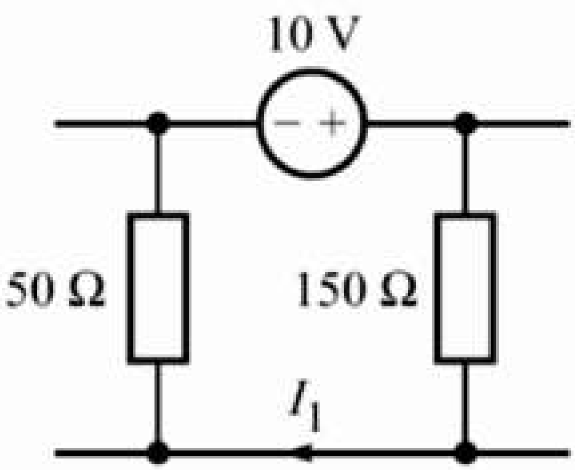

$$I_2 = \frac{80 \times 10^{-3}}{0.1 + 0.3} = \mathbf{0.2\ A}$$

$$\therefore\ \mathrm{I} = I_1 + I_2 = \mathbf{-0.175\ A}$$

**Ex:3** Using superposition theorem, find current $i_x$ in the network given.

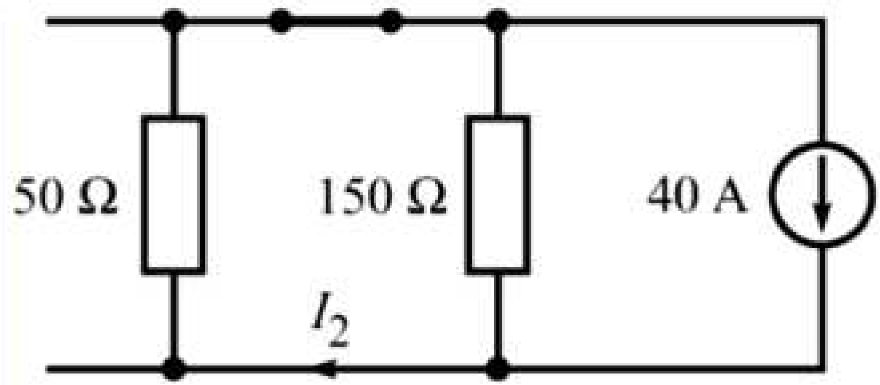



(i) Consider 10-V source alone



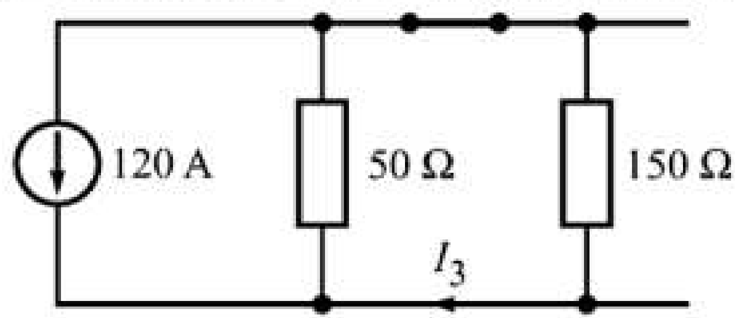

$$i_1 = \frac{10}{50+150} = 0.05\text{A}$$

(ii) Consider 40-A source alone




$$i_2 = 40 \times \frac{150}{50+150} = 30\text{ A}$$

(iii) Consider 120-A source alone




$$i_3 = -120 \times \frac{50}{50+150} = -30\text{ A}$$

**Ex:3** Using superposition theorem, find current $i_x$ in the network given.

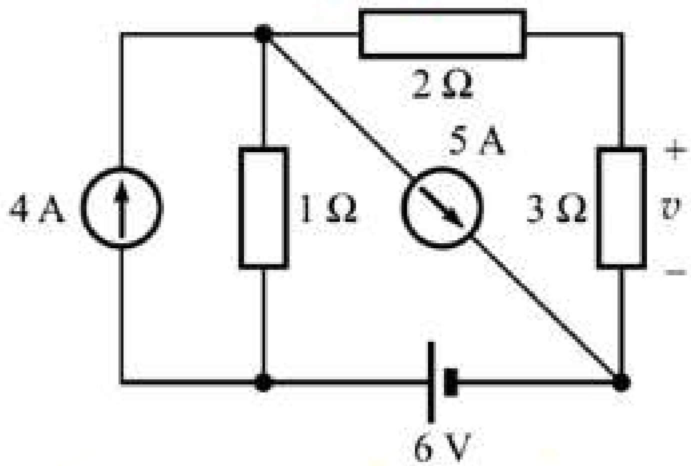
In the end, the total response due to all the sources working together is

$$i_x = i_1 + i_2 + i_3$$

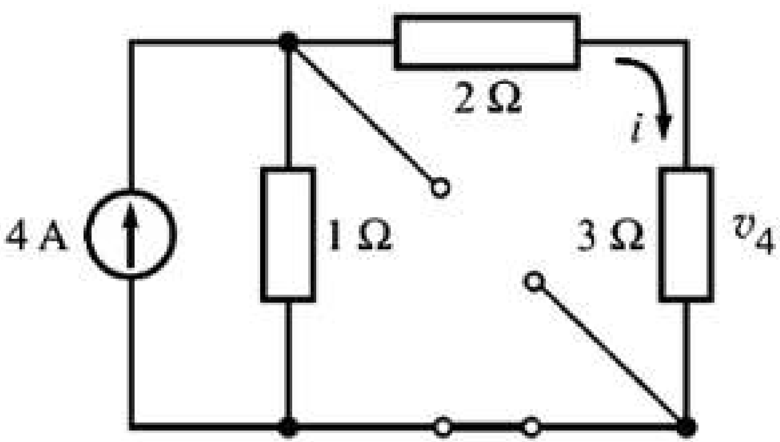
$$= 0.05 + 30 - 30$$

$$= \mathbf{0.05\ A}$$

## Ex:4 Find voltage $v$ across 3-Ω resistor by applying the principle of superposition.




(i) response due to 4-A source alone

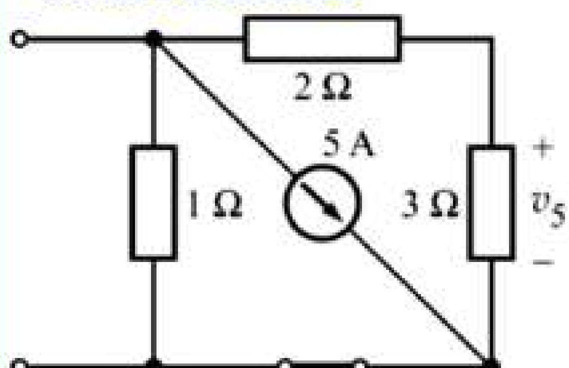



Using CDR

$$i = 4 \times \frac{1}{1+(2+3)} = \frac{2}{3}\text{ A}$$

$$\therefore v_4 = i \times R = (2/3\text{ A}) \times (3\ \Omega) = 2.0\text{ V}$$

(ii) Next, the response due to 5-A source alone

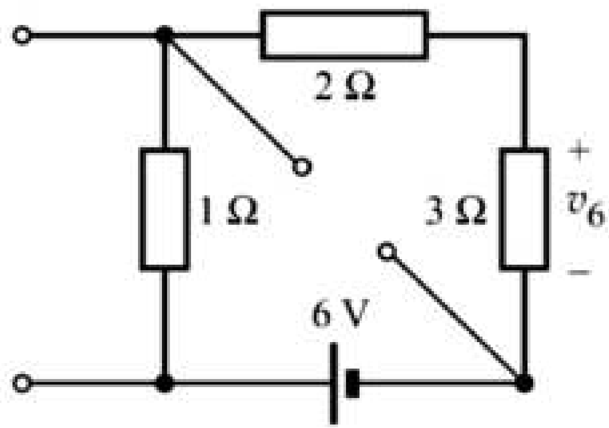



Using CDR, voltage $v_5$ across 3-Ω

$$v_5 = \left[-5 \times \frac{1}{1+(2+3)}\ \text{A}\right] \times (3\ \Omega) = -2.5\text{ V}$$

Ex:4 Find voltage $v$ across 3-Ω resistor by applying the principle of superposition.

(iii) response due to 6-V source alone

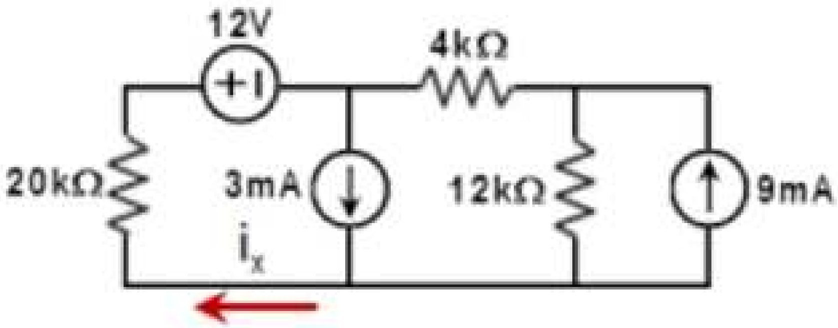



By voltage divider,

$$v_6 = 6 \times \frac{3}{1+2+3} = 3.0 \text{ V}$$

$$\therefore \quad v = +v_4 + v_5 + v_6 = +2.0 - 2.5 + 3.0 = +\mathbf{2.5\ V}$$

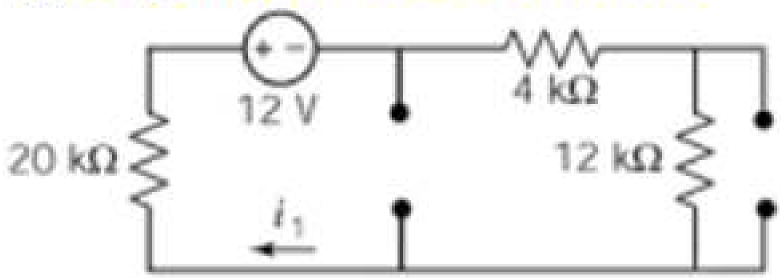
## Ex: 5 Use superposition to find the current $i_x$ through the 20 kΩ resistor ?




Superposition states that to calculate the current i20kΩ, this current is the sum of all of the individual currents produced by the 12V, 3mA and 9mA-sources:

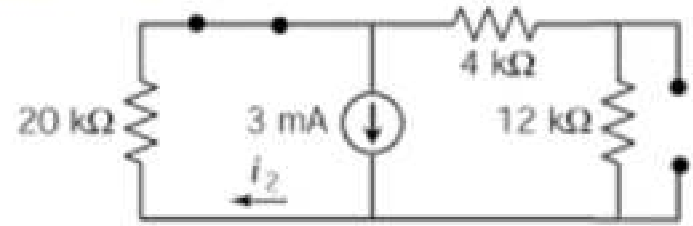
$$i_{20k} = i_{12V} + i_{3mA} + i_{9mA} \equiv i_1 + i_2 + i_3$$

### (i)Response of the 12V-source



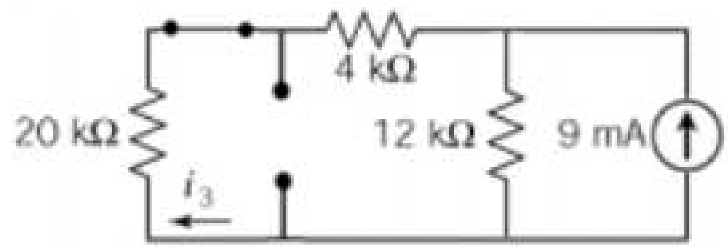

$$36 \cdot i_1 = -12 \longrightarrow \boxed{i_1 = -\tfrac{1}{3}\text{ mA}}$$

### (ii)Response of the 3mA-source




$$i_2 = \frac{16}{16+20}(3\text{mA}) = \boxed{\tfrac{4}{3}\text{ mA} = i_2}$$

### (iii) Response of the 9mA-source

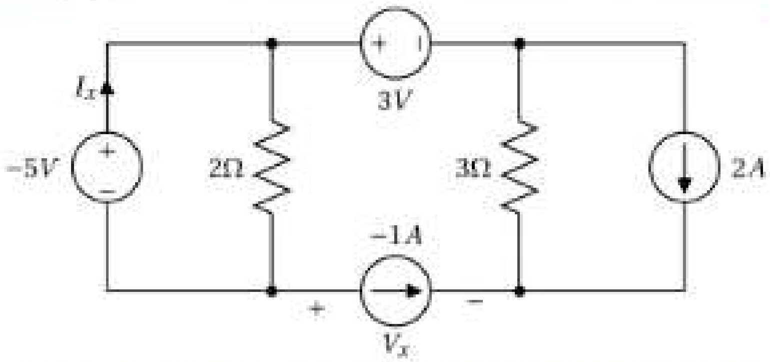



$$i_3 = \frac{12}{12+24}(9\text{A}) = \boxed{-3\text{ mA} = i_3}$$

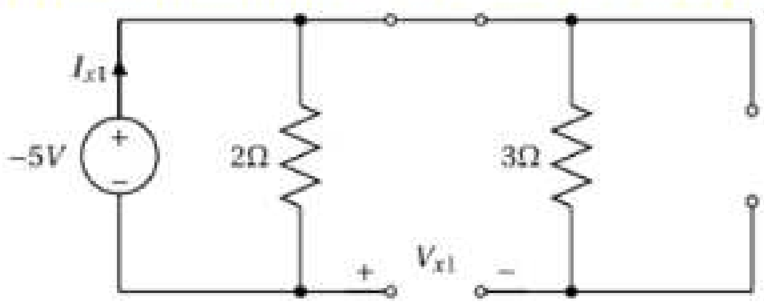
$$i_{20k\Omega} = i_1 + i_2 + i_3$$

$$= -\frac{1}{3} + \frac{4}{3} - 3 = \boxed{-2\text{ mA} = i_{20k\Omega}}$$

# Ex: 6 Determine Vx and Ix using the superposition method



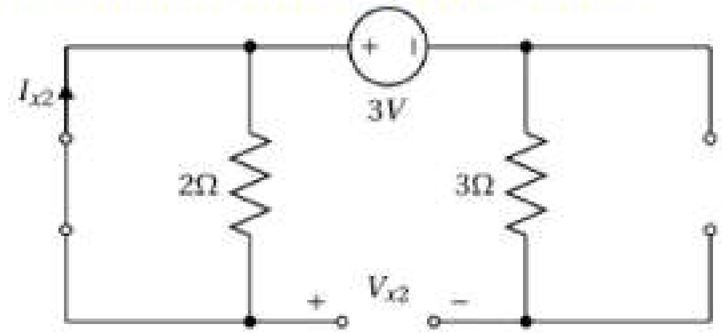

### (i) Contribution of −5V voltage source:




Using KVL, $-(-5V) + V_{3\Omega} - V_{x1} = 0$

$$V_{x1} = -(-5V) = 5V.$$

### (ii) Contribution of the 3V voltage source:

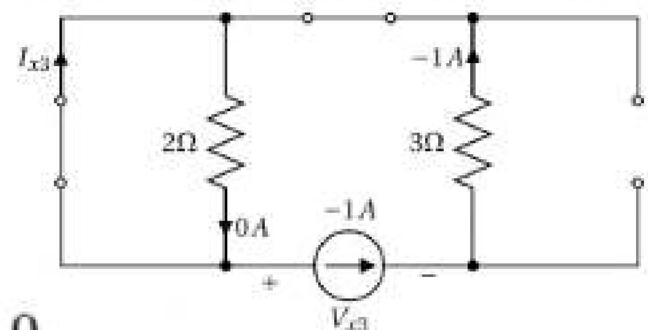



Using KVL

$$-(3V) + V_{2\Omega} + V_{x2} + V_{3\Omega} = 0$$

$$V_{x2} = 3V.$$

### (iii) Contribution of the −1A current source:



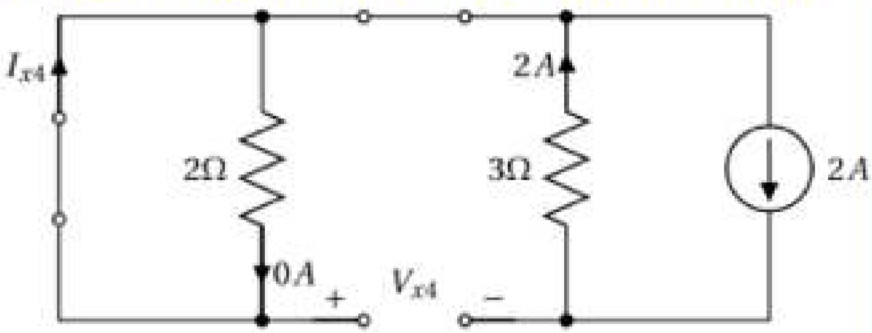

Using KVL

$$V_{x3} + V_{3\Omega} = 0$$

$$V_{x3} + (-1A) \times (3\Omega) = 0 \qquad V_{x3} = 3V$$

# Ex: 6 Determine Vx and Ix using the superposition method

**(iv) Contribution of the 2A current source:**




Using KVL

$$V_{x4} + V_{3\Omega} = 0$$

$$V_{x4} + (2A) \times (3\Omega) = 0$$

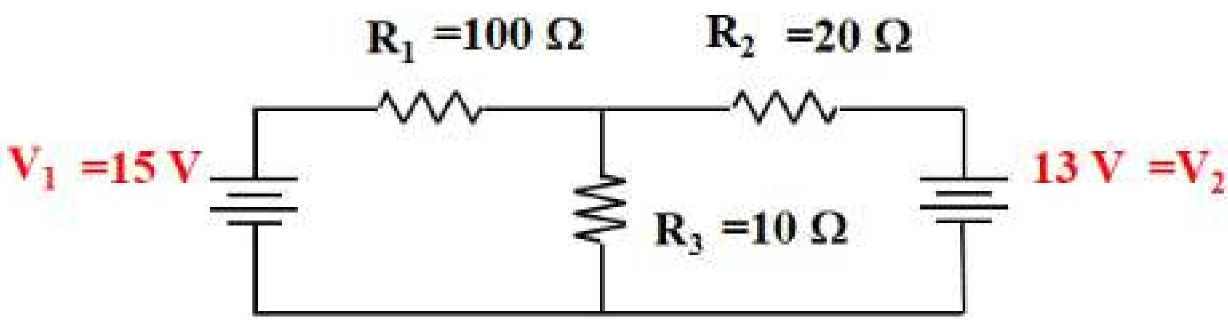
$$V_{x4} = -6V$$

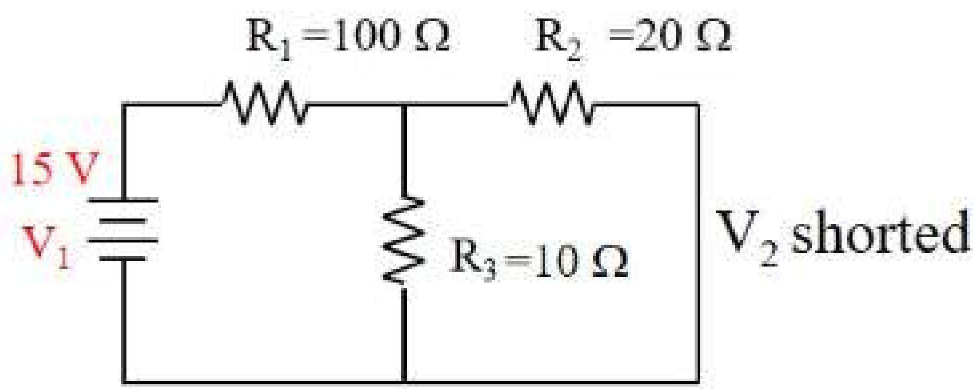
**V. Adding up the individual contributions algebraically:**

$$V_x = V_{x1} + V_{x2} + V_{x3} + V_{x4}$$
$$= 5V + 3V + 3V - 6V$$
$$V_x = 5V$$

$$I_x = I_{x1} + I_{x2} + I_{x3} + I_{x4}$$
$$= -2.5A + 1A + 0A - 0A$$
$$I_x = -1.5A$$

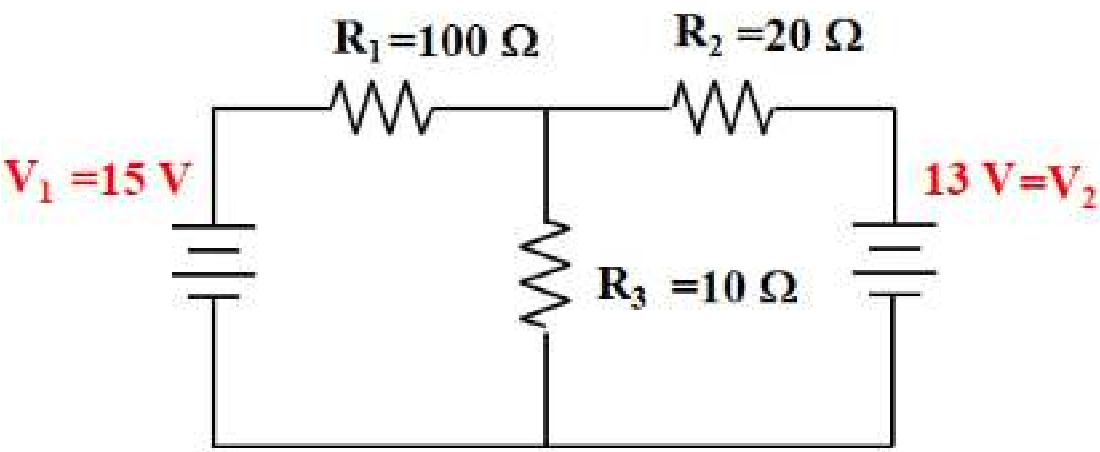
# Ex: 7 Using superposition theorem find current in $R_3$

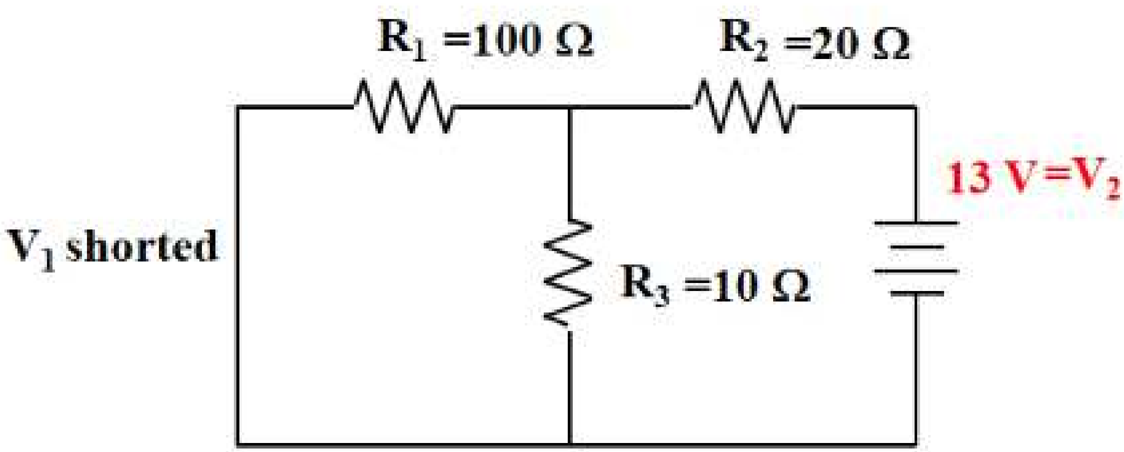



$R_{EQ}$ = 106.7 Ω, $I_T$ = 0.141 A and $I_{R_3}$ = 0.094 A

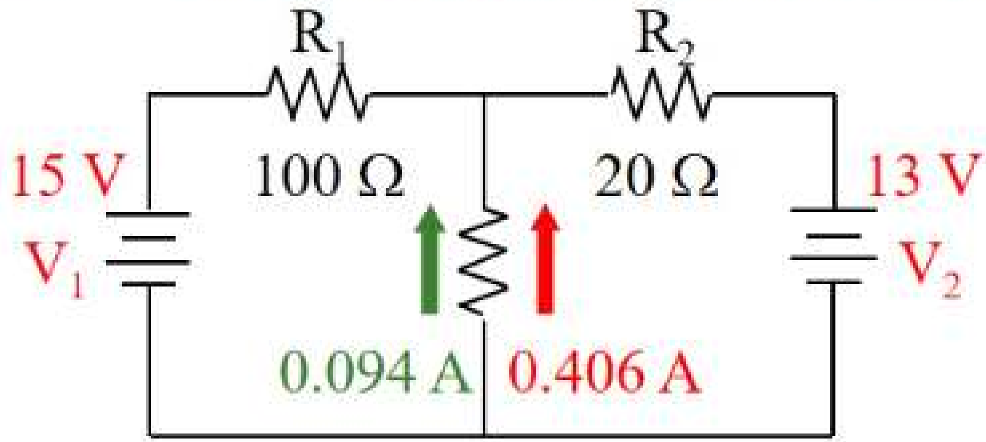
# Ex: 7 Using superposition theorem find current in $R_3$




$R_{EQ}$ = 29.09 Ω, $I_T$ = 0.447 A and $I_{R_3}$ = 0.406 A

# Ex: 7 Using superposition theorem find current in $R_3$




With $V_2$ shorted

$R_{EQ} = 106.7\ \Omega$, $I_T = 0.141$ A and $I_{R_3} = 0.094$ A

With $V_1$ shorted

$R_{EQ} = 29.09\ \Omega$, $I_T = 0.447$ A and $I_{R_3} = 0.406$ A

Adding the currents gives $I_{R_3} = 0.5$ A

# Thevenin's Theorem

- **Statement:** It states that a linear two-terminal circuit (Fig. a) composed of passive and active elements can be replaced by an equivalent circuit (Fig. b) consisting of a voltage source $V_{TH}$ in series with a resistor $R_{TH}$,
- where
- *VTH* is the open-circuit voltage at the load terminals.
- *RTH* is the input or equivalent resistance at the terminals when the independent sources are turned off.

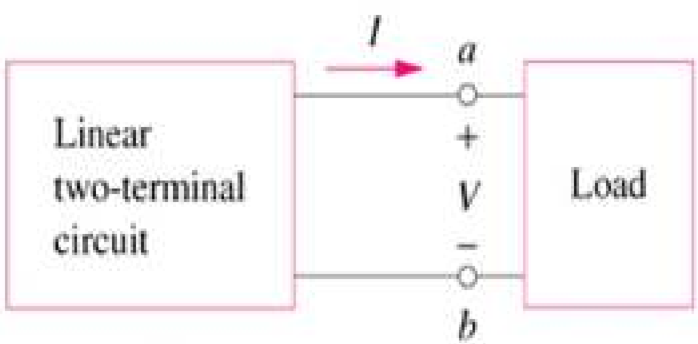



Fig. a

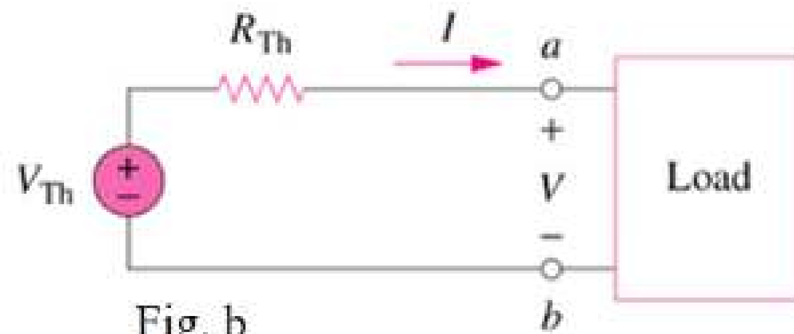


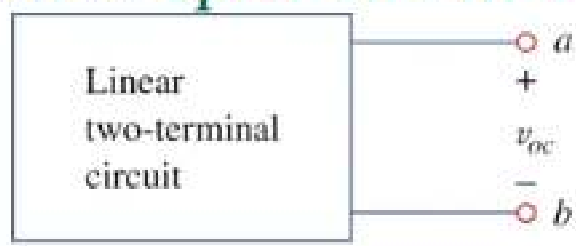

Fig. b

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

# Thevenin's Theorem

- Calculation of $V_{\mathrm{Th}}$

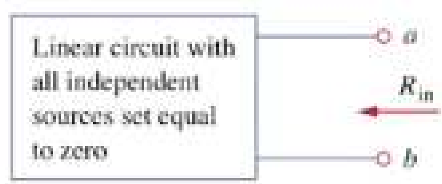
  The voltage $V_{\mathrm{Th}}$ is equal to the potential difference between the two terminals 'ab' caused by the active network with no external resistance (load) connected to these terminals. Hence, it is called open-circuit voltage, $V_{\mathrm{oc}}$.




$V_{\mathrm{Th}} = v_{oc}$

- Calculation of $R_{\mathrm{Th}}$

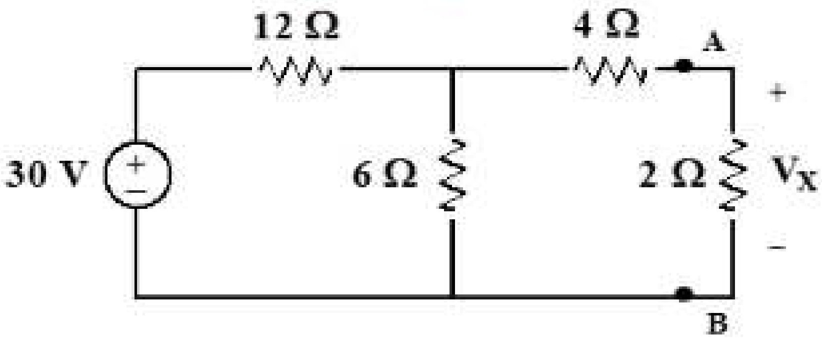
  The series resistance $R_{\mathrm{Th}}$ is the equivalent resistance looking back into the network at the terminals 'ab' with all the sources within the network made inactive, or dead.



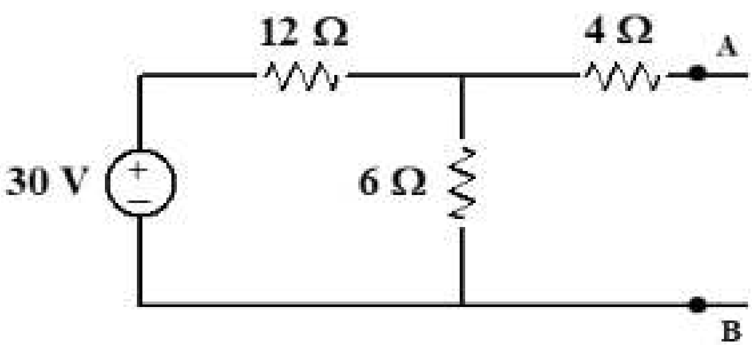

$R_{\mathrm{Th}} = R_{in}$

# Thevenin's Theorem

EX:1 Find $V_X$ using Thevenin theorem for the circuit shown in Fig.



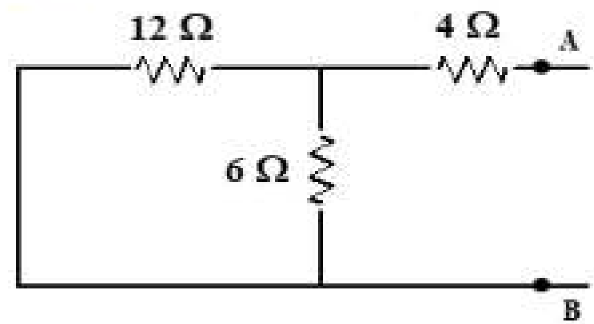

### (i) Find $V_{th}$




$$V_{AB} = \frac{(30)(6)}{6+12} = 10V$$

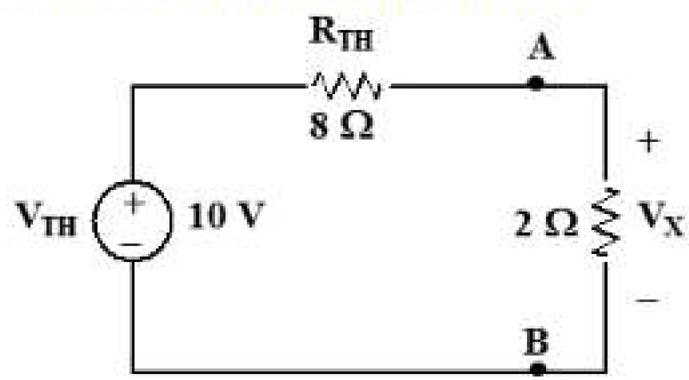
10

### (ii) Find $R_{th}$




$R_{TH} = 12||6 + 4 = 8\ \Omega$

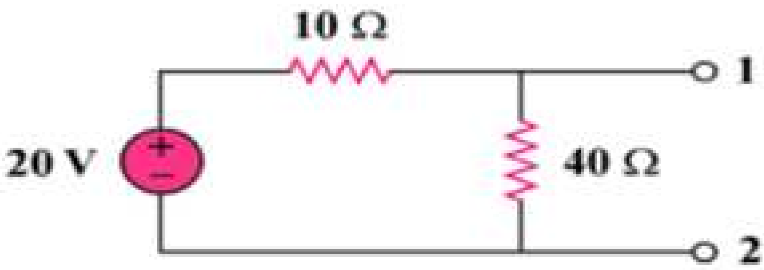
### (iii) Thevenin equivalent circuit




$$V_X = \frac{(10)(2)}{2+8} = 2V$$

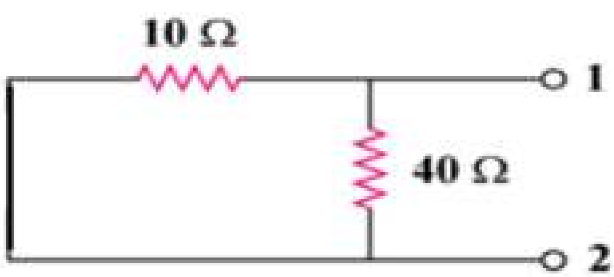
# Thevenin's Theorem

EX:2 Find $R_{th}$ and $V_{th}$ at terminals 1-2 of the given circit



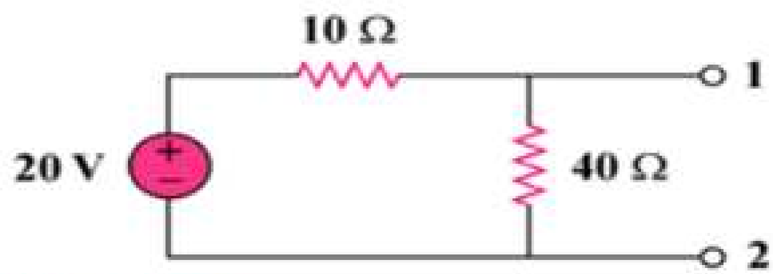

Solution:

(i) Find $R_{th}$




$$R_{Th} = 10\|40 = 400/50 = \underline{\mathbf{8\ ohms}}$$

(ii) Find $V_{th}$

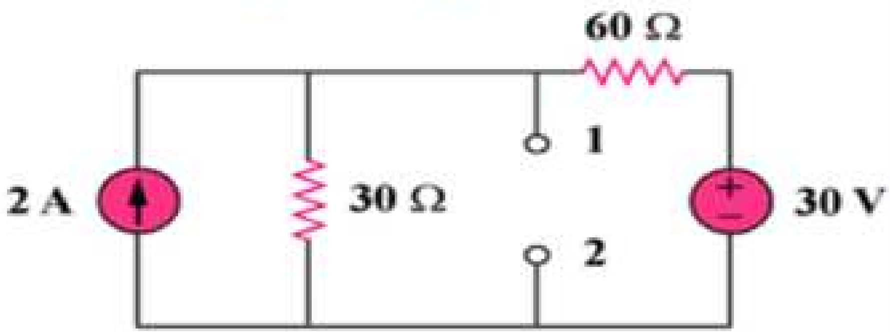



Use VDR

$$V_{Th} = (40/(40+10))20 = \underline{\mathbf{16\ V}}$$

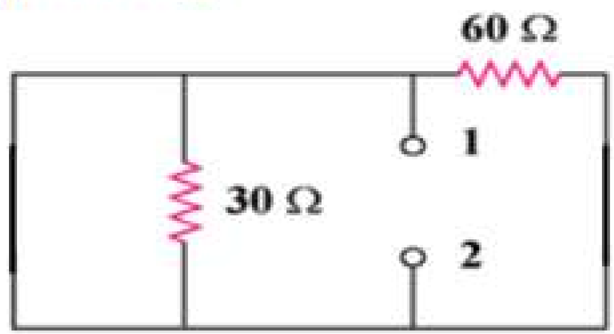
# Thevenin's Theorem

EX:3 Find $R_{th}$ and $V_{th}$ at terminals 1-2 of the given circit



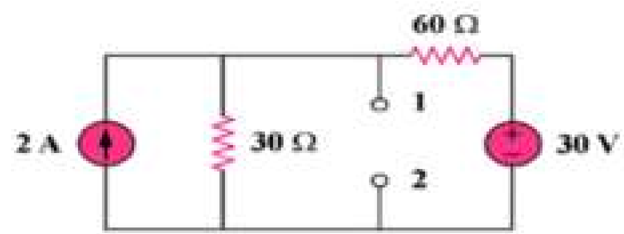

Solution:

(i) Find $R_{th}$




$$R_{Th} = 30||60 = 1800/90 = \underline{\mathbf{20\ ohms}}$$

(ii) Find $V_{th}$



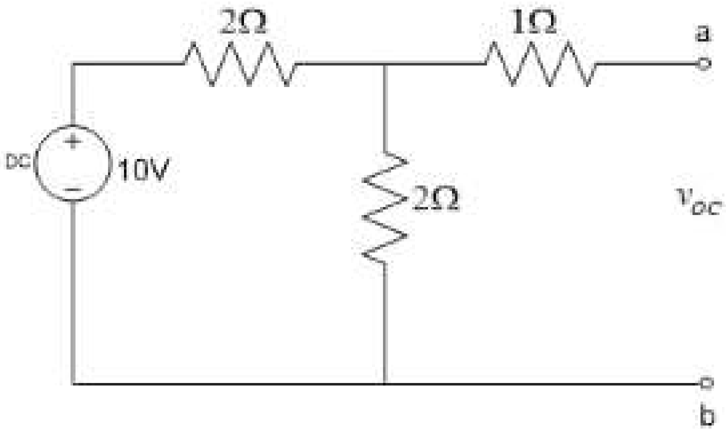

$$2 + (30 - v1)/60 = v_1/30, \text{ and } v_1 = V_{Th}$$

$$120 + 30 - v_1 = 2v_1, \text{ or } v_1 = 50\text{ V}$$

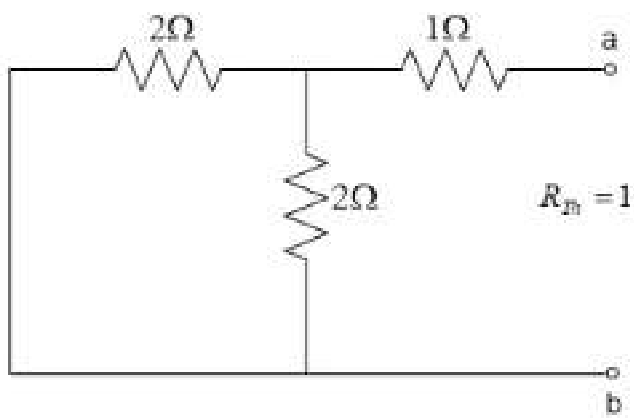
$$V_{Th} = \underline{\mathbf{50\ V}}$$

# Thevenin's Theorem

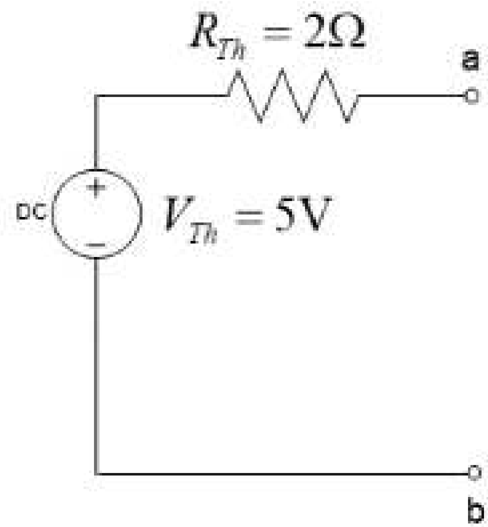
EX:4 Find the Thevenin equivalent circuit of the circuit shown in Fig.




$$v_{OC} = \frac{2}{2+2}10\text{V} = 5\text{V} = V_{Th}$$



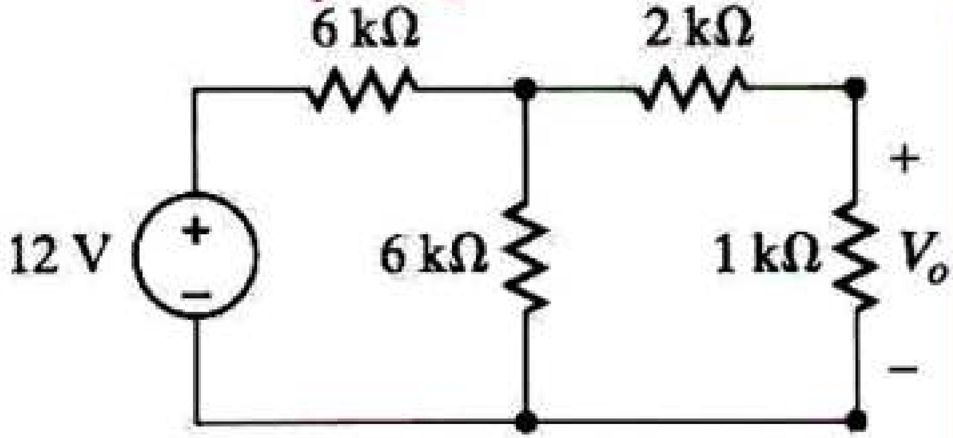

$$R_{Th} = 1 + \frac{2\times 2}{2+2} = 2\Omega$$

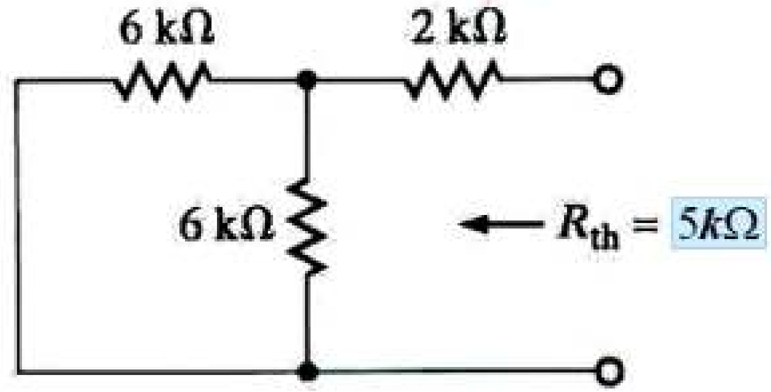


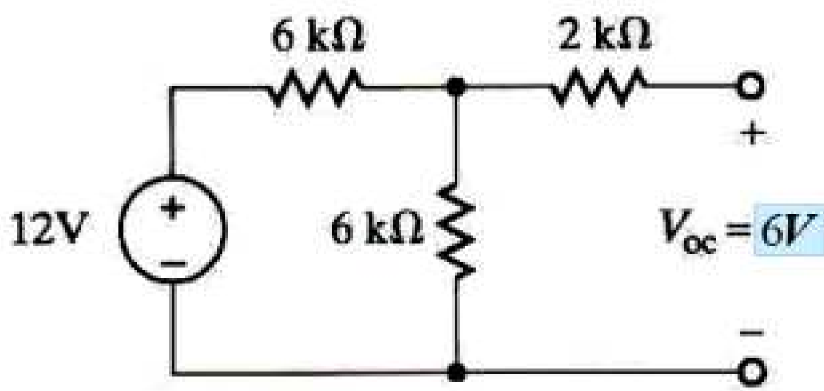

$$R_{Th} = \frac{V_{Th}}{i_{SC}} = \frac{5}{2.5} = 2\Omega$$

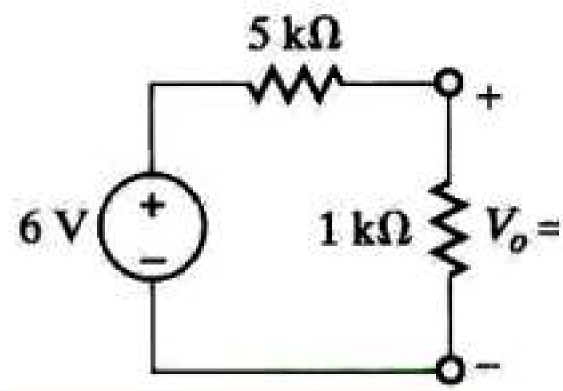
# Thevenin's Theorem

EX:5 Find $V_0$ using Thevenin theorem for the circuit shown in Fig.



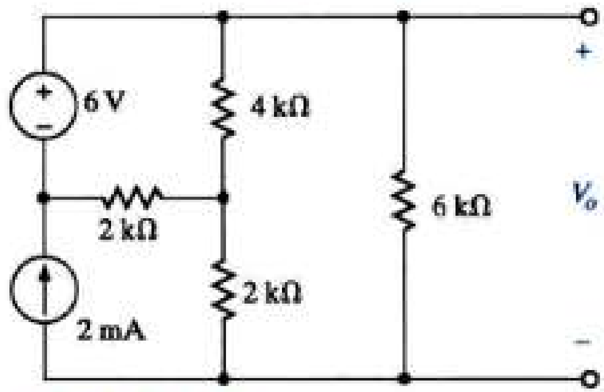




$$V_O = \frac{1k}{1k + 5k}(6V) = 1[V]$$

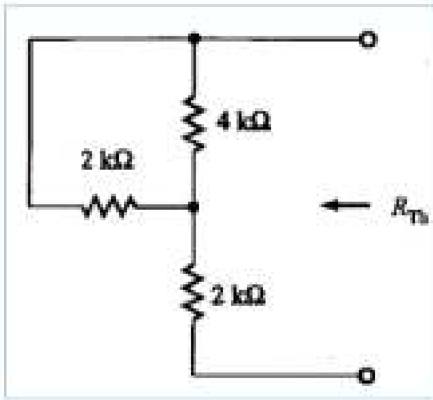
# Thevenin's Theorem

EX:6 Find $V_0$ using Thevenin theorem for the circuit shown in Fig.




**Solution:**

**(i) Find $R_{th}$**

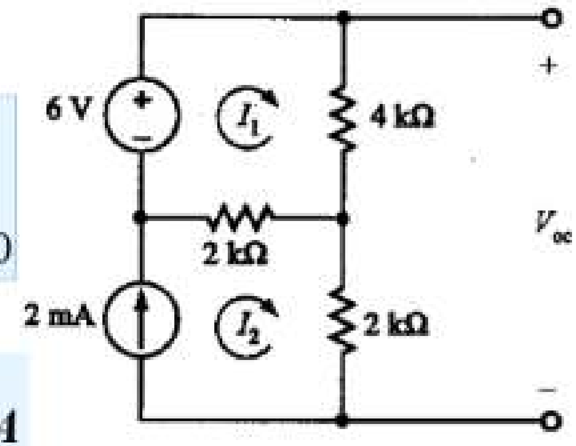



**(ii) Find $V_{th}$**

*Loop Analysis*

$I_2 = 2mA$

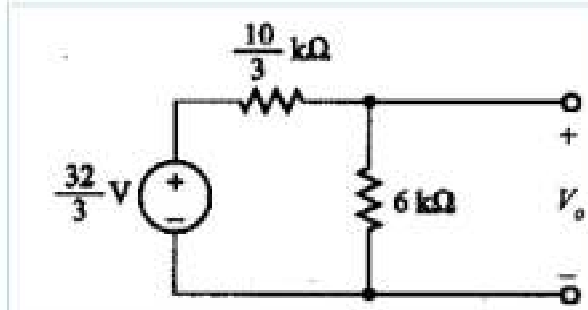
$-6V + 4kI_1 + 2k(I_1 - I_2) = 0$




$$I_1 = \frac{6 + 2I_2}{6} mA = \frac{5}{3} mA$$

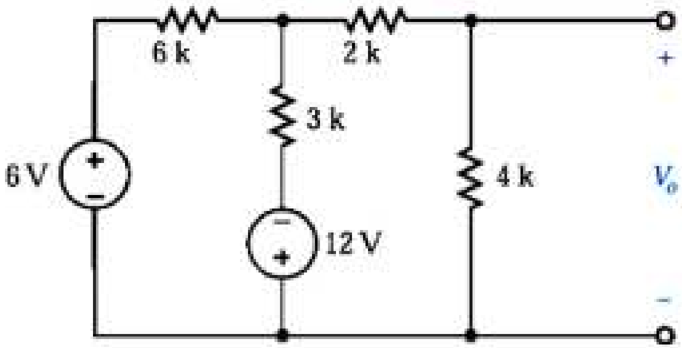
$$V_{OC} = 4k * I_1 + 2k * I_2 = 20/3 + 4V = 32/3[V]$$

**(iii) Thevenin equivalent circuit**



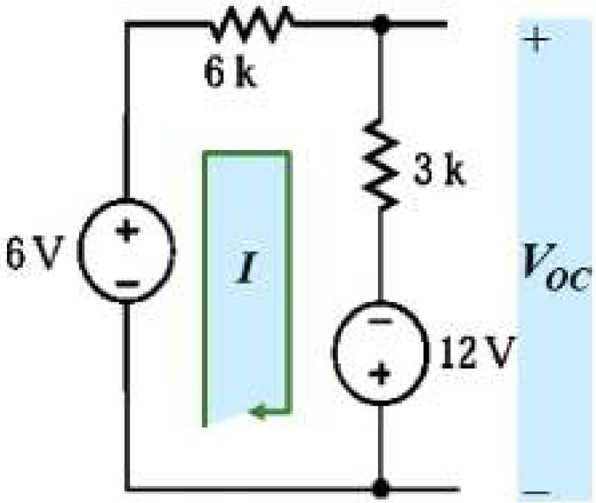
# Thevenin's Theorem

EX:7 Find $V_0$ using Thevenin theorem for the circuit shown in Fig.




**Solution:**

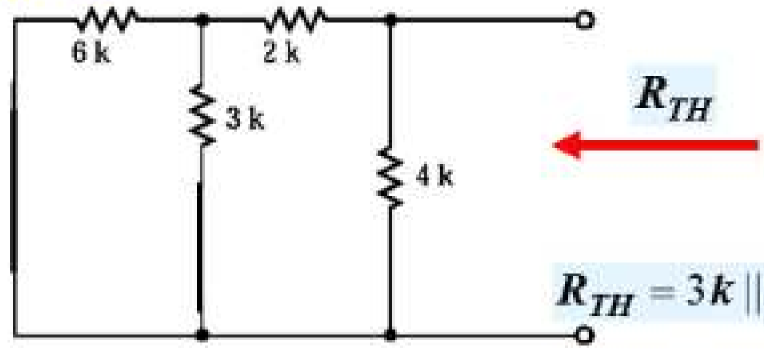
**(i) Find $V_{th}$**




$9kI = 18[V] \Rightarrow I = 2mA$

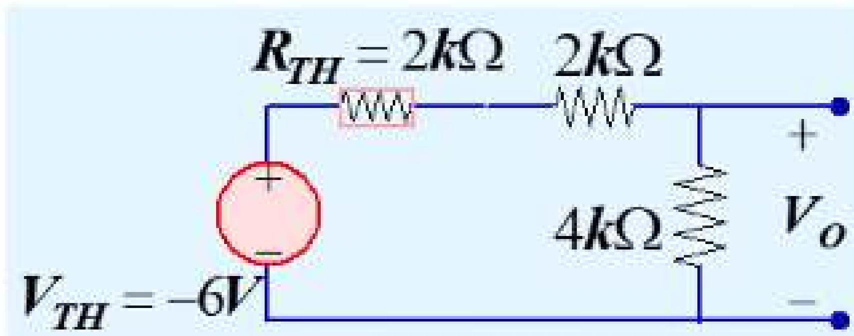
$V_{OC} = 3kI - 12 = -6[V]$

**(ii) Find $R_{th}$**




$R_{TH} = 3k \,||\, 6k = 2k$

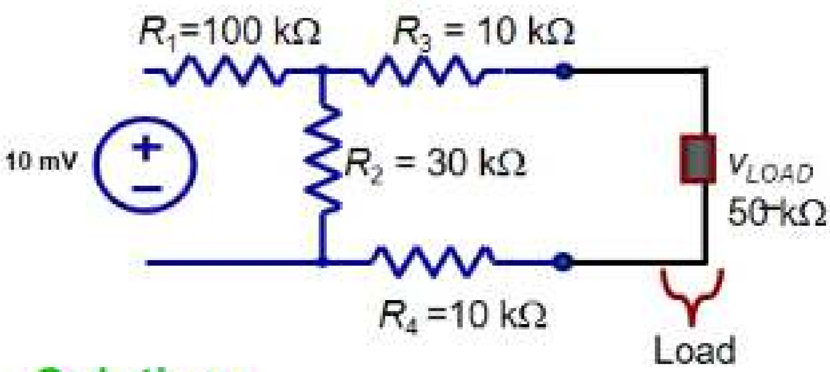
**(iii) Thevenin equivalent circuit**




$$V_O = \frac{4}{4+4}(-6V) = -3[V]$$

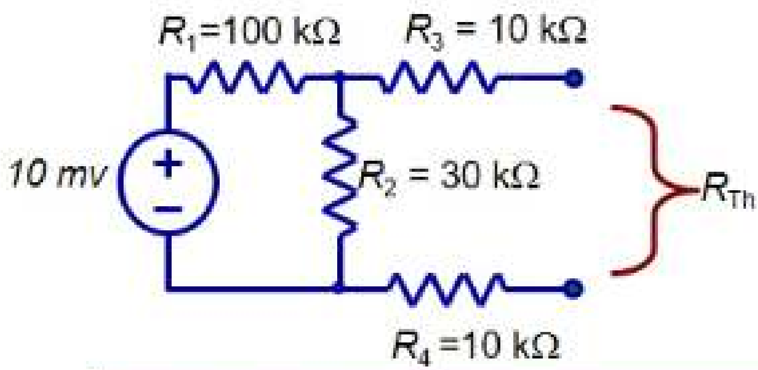
# Thevenin's Theorem

EX:8 Find voltage across 50 KΩ using Thevenin theorem in the given circuit



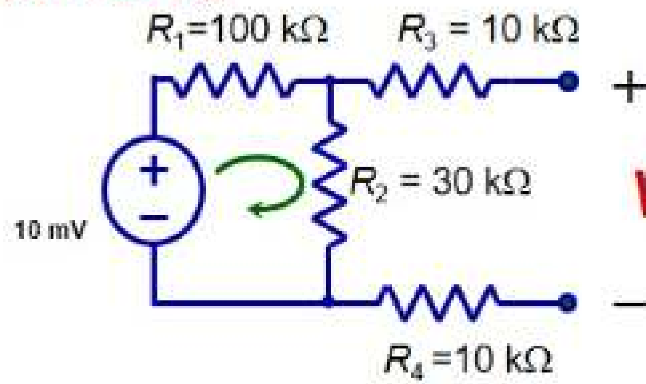

**Solution:**

(i) Find $R_{th}$




- $R_{Th} = R_3 + R_1||R_2 + R_4$
  $= 10\ k\Omega + 23\ k\Omega + 10\ k\Omega$
  $= 43\ k\Omega$

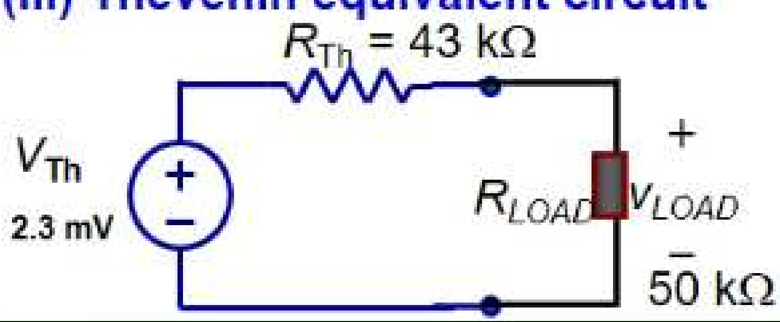
(ii) Find $V_{th}$




$V_{Th} = 2.3\ mV$

- From KVL around the inner loop
  $v_2 = 10 * R_2/(R_1 + R_2) = 2.3\ mV$

**(iii) Thevenin equivalent circuit**

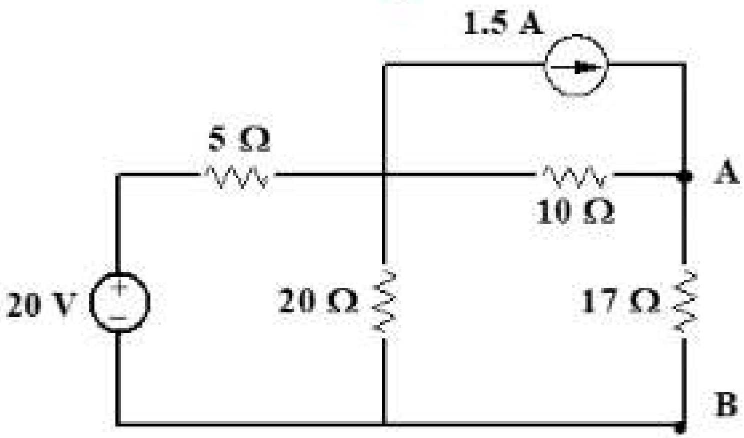



$v_{LOAD} = V_{Th}\ (R_{LOAD}/(R_{LOAD} + R_{Th}) = 2.3\ mV \times (50\ k\Omega)/(93\ k\Omega)$

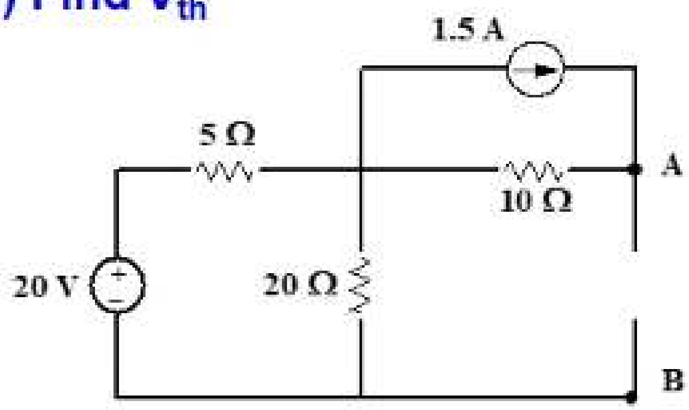
$=$ **0.54 mV**

# Thevenin's Theorem

EX:9 Find voltage across 17Ω using Thevenin theorem in the given circuit



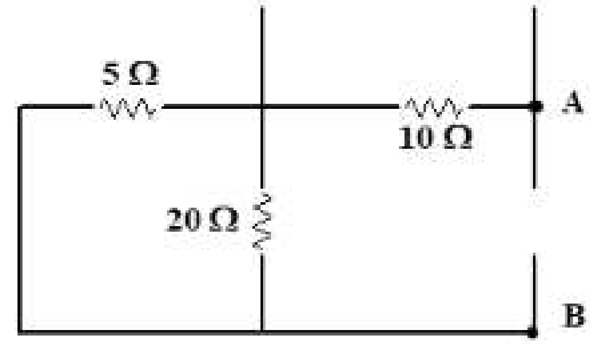

## (i) Find $V_{th}$




$$V_{OS} = V_{AB} = V_{TH} = (1.5)(10) + \frac{20(20)}{(20+5)}$$

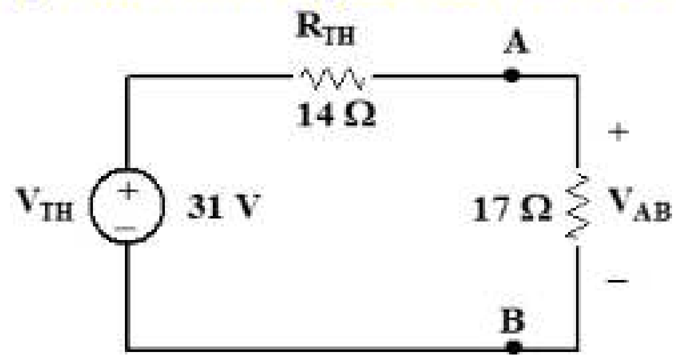
$$\therefore \quad V_{TH} = 31V$$

## (ii) Find $R_{th}$




$$R_{TH} = 10 + \frac{5(20)}{(5+20)} = 14\Omega$$

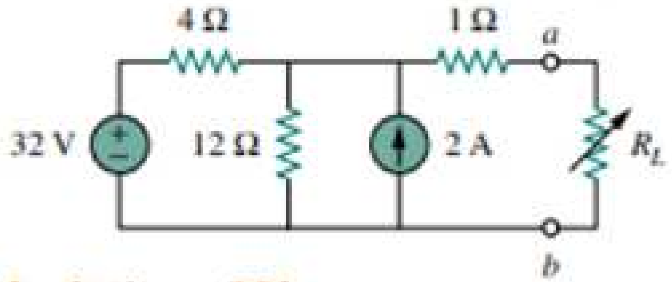
## (iii) Thevenin equivalent circuit




$$V_{AB} = 17V$$

# Thevenin's Theorem

EX:10 Find the Thevenin equivalent circuit of the circuit shown in Fig. Then find the current through $R_L$ = 6, 16, and 36 Ω



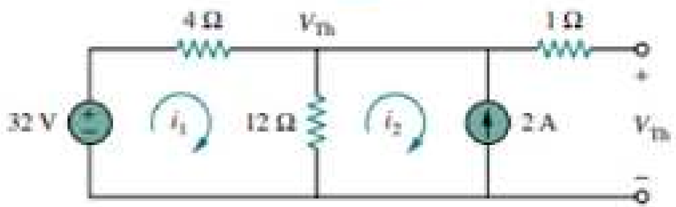

Using Nodal analysis

$$\frac{32 - V_{Th}}{4} + 2 = \frac{V_{Th}}{12}$$

$$96 - 3V_{Th} + 24 = V_{Th}$$

$$V_{Th} = 30 \text{ V}$$

**Calculation of $V_{Th}$**




Using mesh analysis

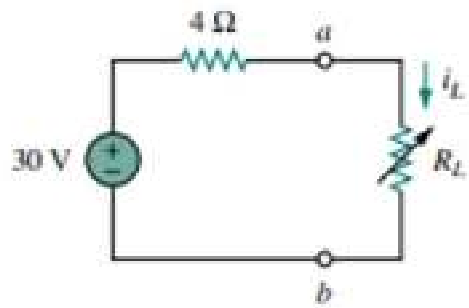
$$-32 + 4i_1 + 12(i_1 - i_2) = 0,$$

$$i_2 = -2 \text{ A}$$

Solving for $i_1$, we get $i_1 = 0.5$ A. Thus,

$$V_{Th} = 12(i_1 - i_2) = 12(0.5 + 2.0) = 30 \text{ V}$$

**Resultant circuit**




$$I_L = \frac{V_{Th}}{R_{Th} + R_L} = \frac{30}{4 + R_L}$$

When $R_L = 6$,

$$I_L = \frac{30}{10} = 3 \text{ A}$$

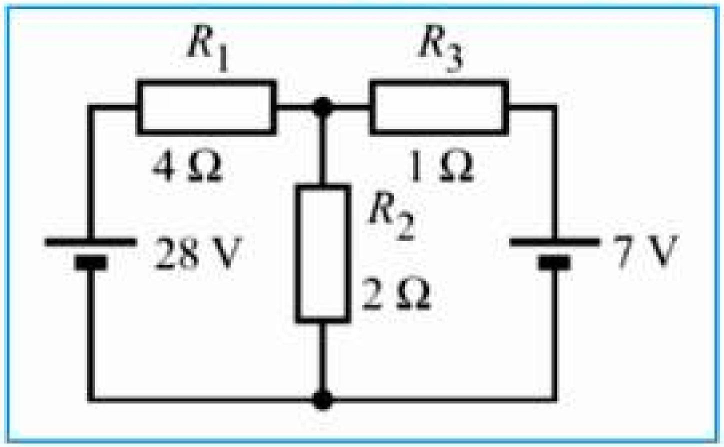
When $R_L = 16$,

$$I_L = \frac{30}{20} = 1.5 \text{ A}$$

When $R_L = 36$,

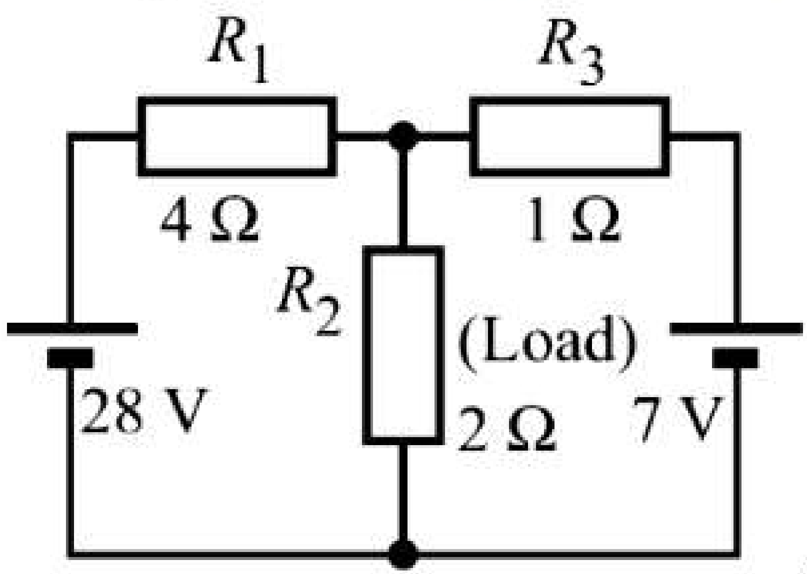
$$I_L = \frac{30}{40} = 0.75 \text{ A}$$

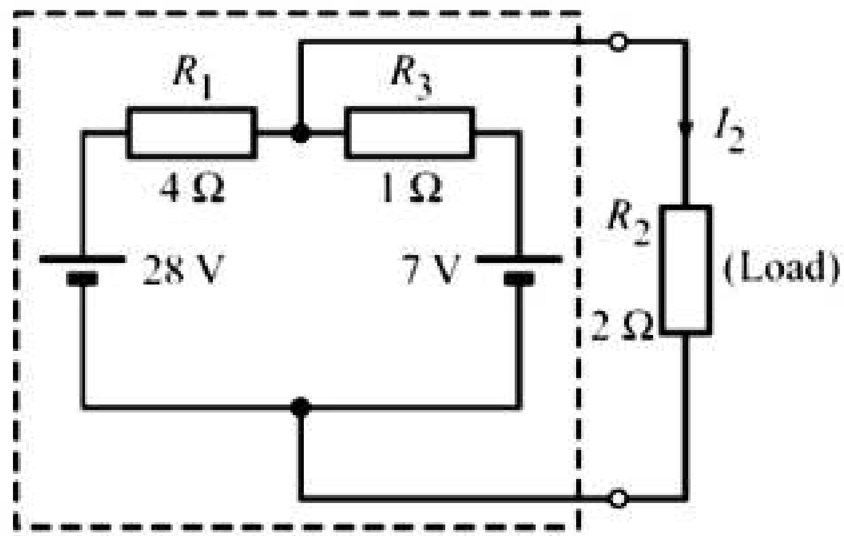
# Ex: 11 Using Thevenin's theorem, find the current in resistor $R_2$ of 2 Ω.




## Solution :

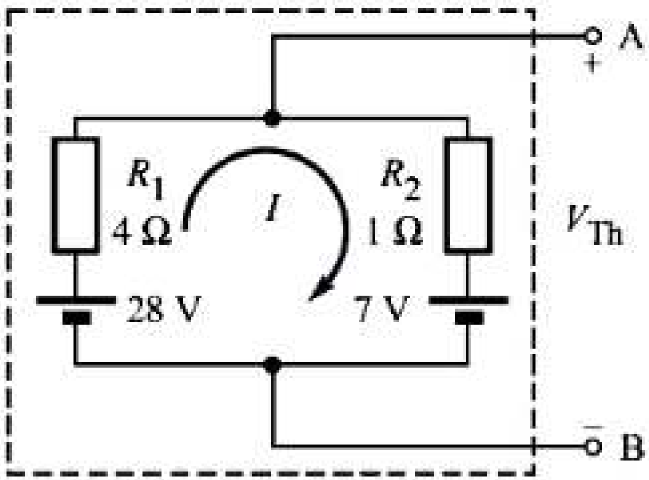
1. Designate the resistor $R_2$ as "load".



# Ex: 11 Using Thevenin's theorem, find the current in resistor $R_2$ of 2 Ω.

## Calculation of $V_{Th}$



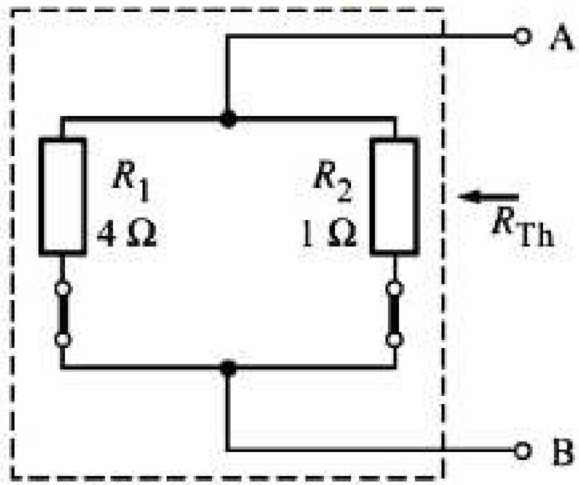

**Find the *open-circuit voltage* across the terminals A-B,**

$$I = \frac{28-7}{4+1} = \frac{21}{5} = 4.2\,\mathrm{A};$$

$$V_{AB} = 7 + 4.2 \times 1 = \mathbf{11.2\ V}$$

***Thevenin's voltage*, $V_{Th} = V_{AB} = 11.2$ V**

## Calculation of $R_{Th}$

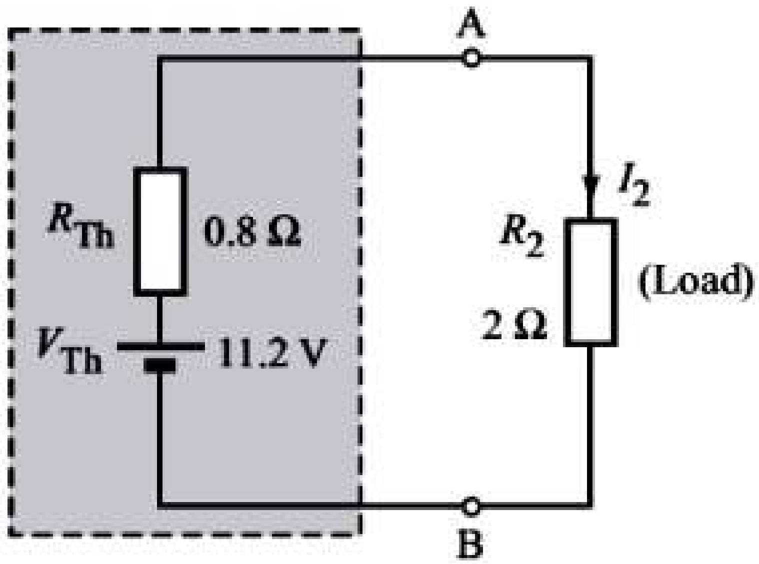



Find the resistance between terminals $A$ and B. This is the ***Thevenin's resistance***, $R_{Th}$. Thus,

$$R_{Th} = 1\ \Omega \,||\, 4\ \Omega = \frac{1 \times 4}{1+4} = \mathbf{0.8\ \Omega}$$

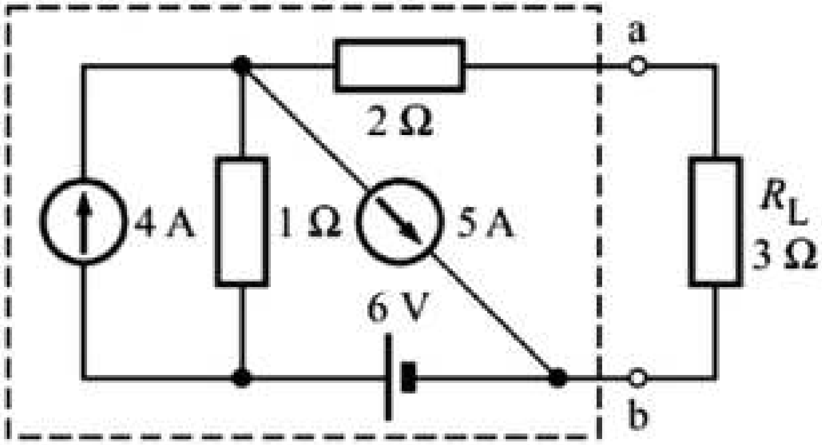
# Ex:11 Using Thevenin's theorem, find the current in resistor $R_2$ of 2 Ω.

*Thevenin's equivalent*



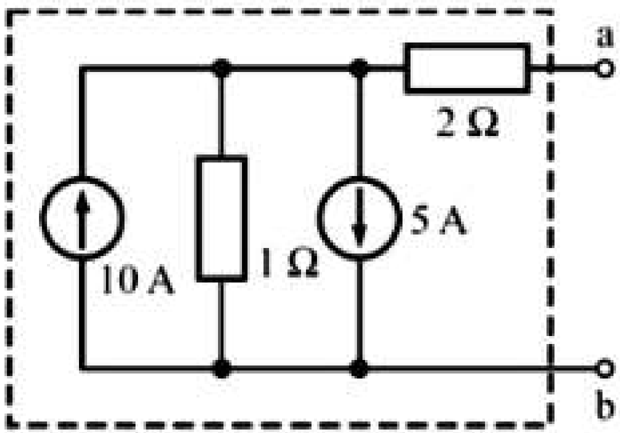

$$I_2 = \frac{V_{Th}}{R_{Th} + R_2} = \frac{11.2}{0.8 + 2} = \mathbf{4\ A}$$

# Ex:12 Determine voltage across 3-Ω by applying Thevenin's theorem.

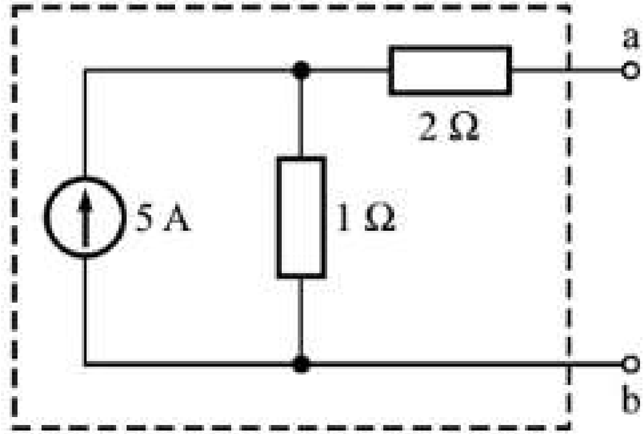



**Solution : Calculation of $V_{Th}$**

- We treat the 3-Ω resistor as load.
- $V_{Th}$ = open-circuit voltage(with $R_L$ removed).

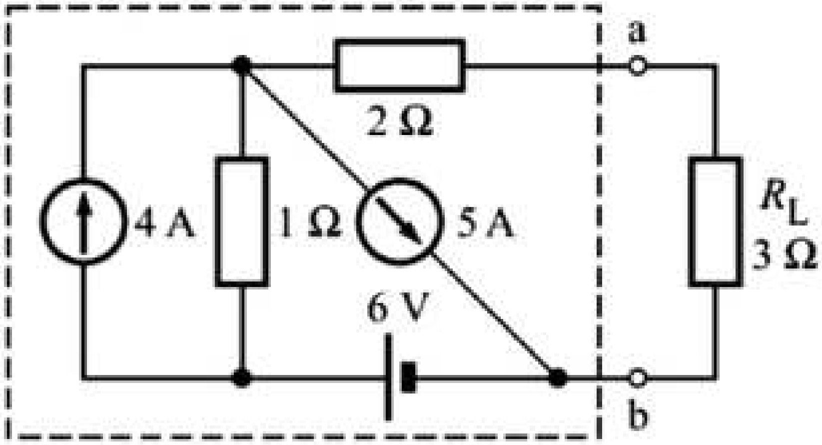



Use Source transformation Technique



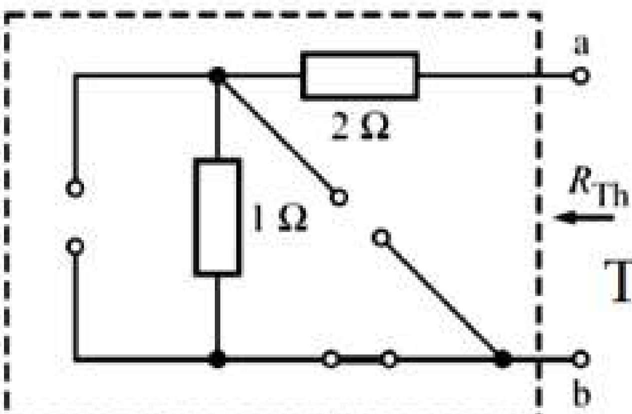

$$V_{Th} = 5 \times 1 = \mathbf{5\ V}$$

# Ex:12 Determine voltage across 3-Ω by applying Thevenin’s theorem.



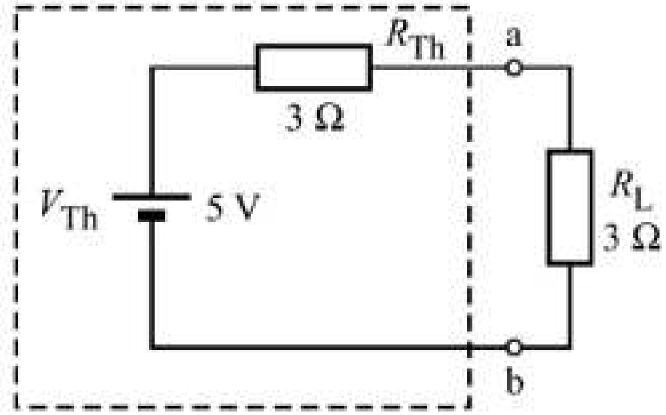

## Calculation of $R_{Th}$

turn off all the sources in the circuit within box and get the circuit




Thus, $R_{Th} = 3$

## *Thevenin’s equivalent*

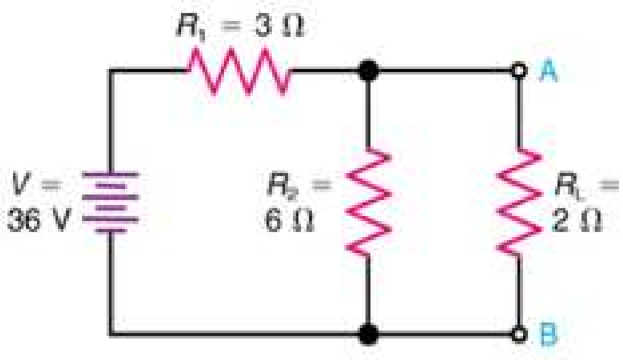



Now, apply VDR, we get

$$V_L = 5 \times \frac{3}{3+3} = \mathbf{2.5\ V}$$

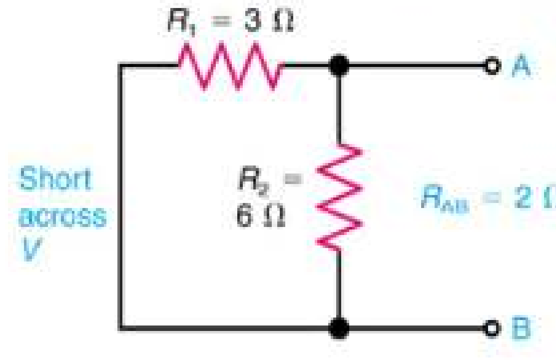
# Ex:13 Determine voltage across 2-Ω by applying Thevenin's theorem.

(a) Given circuit



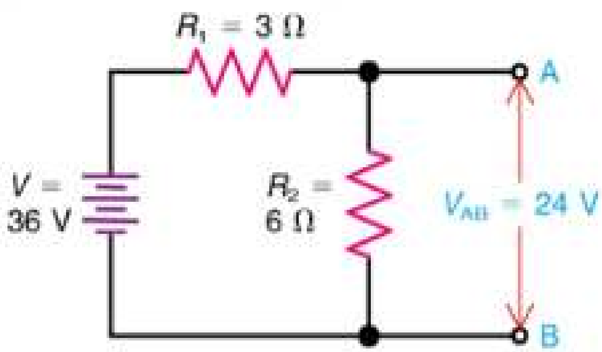

(a)

(c) Short-circuit $V$ to find that $R_{AB}$ is 2Ω.



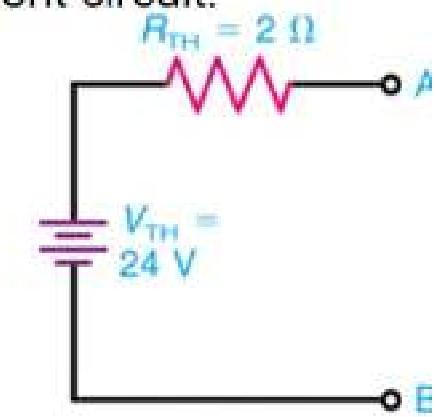

(c)

(b) Disconnect $R_L$ to find that $V_{AB}$ is 24V.



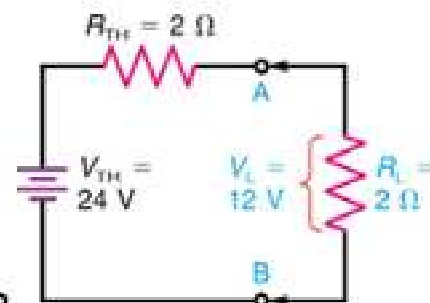

(b)

(d) Thevenin equivalent circuit.




(d)

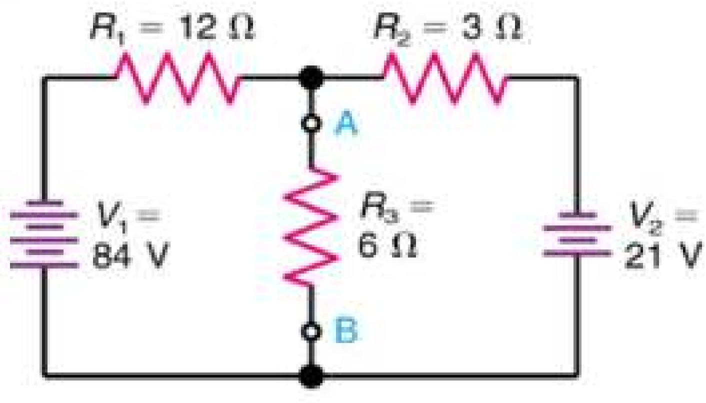
(e) Reconnect $R_L$ at terminals A and B to find that $V_L$ is 12V.




(e)

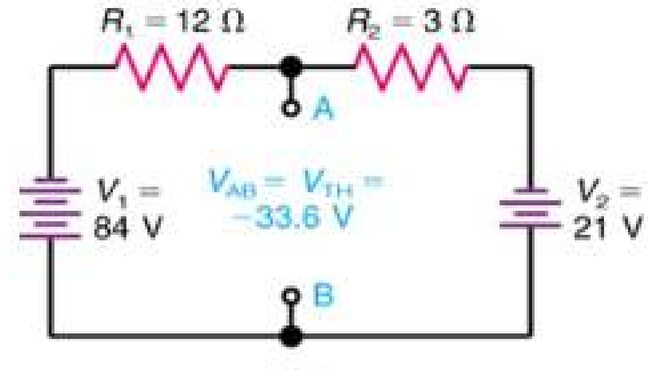
# Ex:14 Determine voltage across 6-Ω by applying Thevenin's theorem.

(a) Given circuit




(a)

b) Disconnect $R_3$ to find that $V_{AB}$

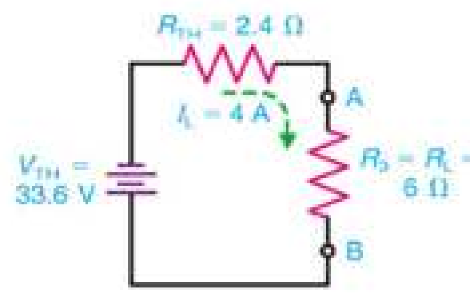



(b)

(c) Short-circuit $V_1$ and $V_2$ to find that $R_{AB}$


(c)

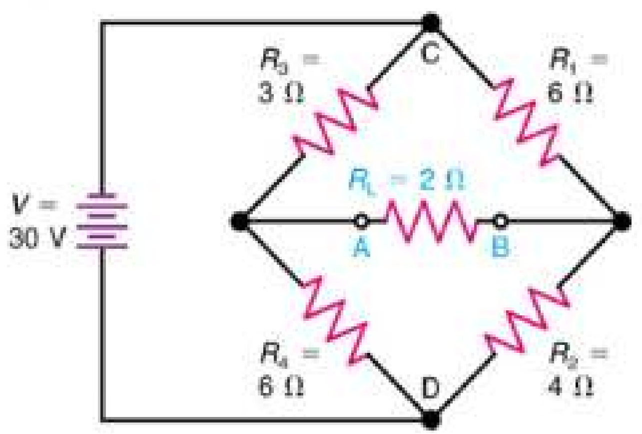
(d) Thevenin equivalent




(d)

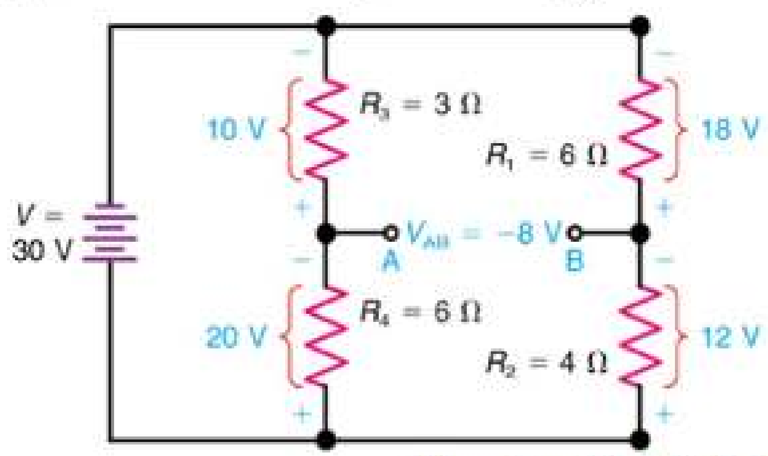
# Ex:15 Find the voltage drop across $R_L$

(a) Given circuit



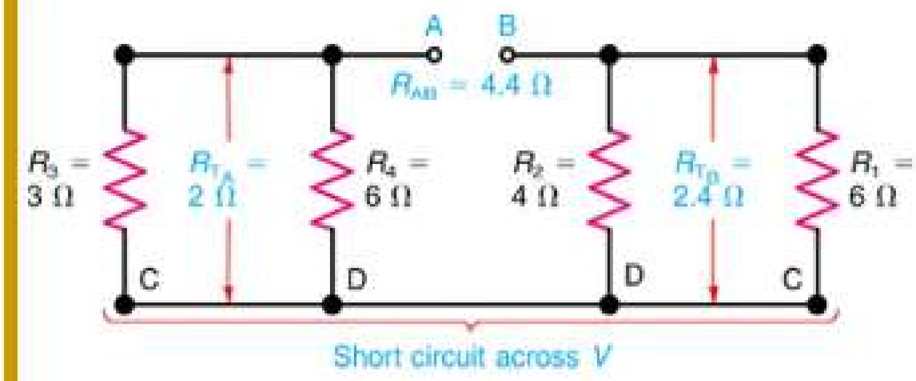

(a)

(b) Disconnect $R_L$ to find $V_{AB}$




(b) $V_{AB} = -20 - (-12) = -8V$

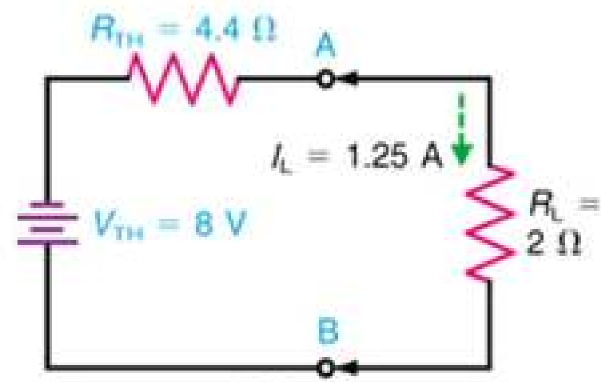
(c) With source V short-circuited




(c)

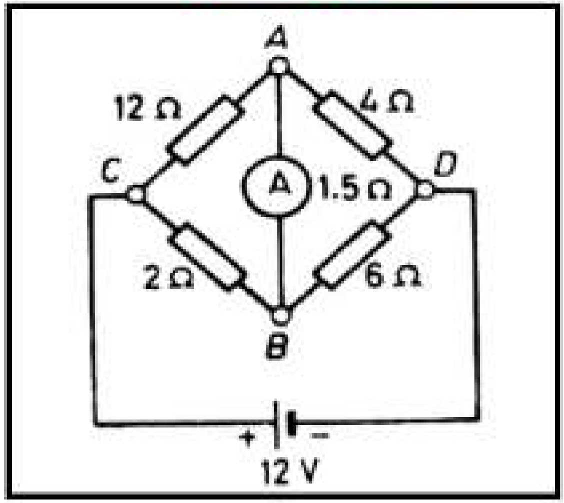
$R_{AB} = R_{TA} + R_{TB} = 2 + 2.4 = 4.4\ \Omega$

(d) Thevenin equivalent

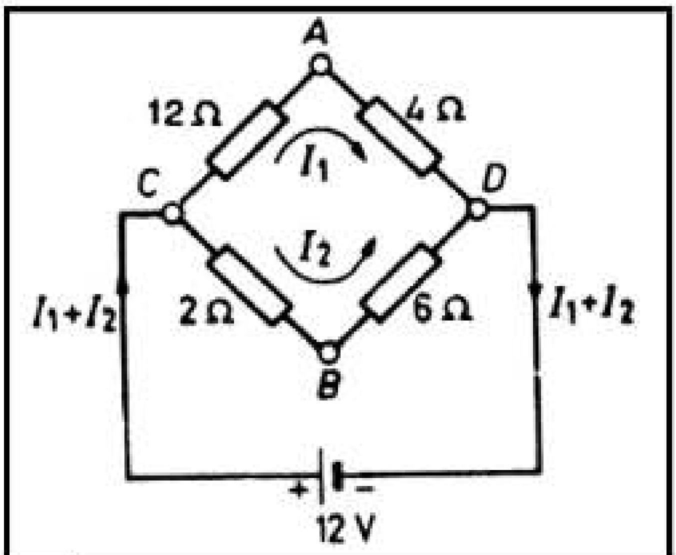



(d)

Ex:16 Using Thevenin's Theorem, find current in ammeter $A$ of resistance 1.5 Ω for the given circuit




**Solution :** **Calculation of $V_{Th}$**




$$I_1 = \frac{12}{12+4} = 0.75 \text{ A} \qquad \text{and}$$

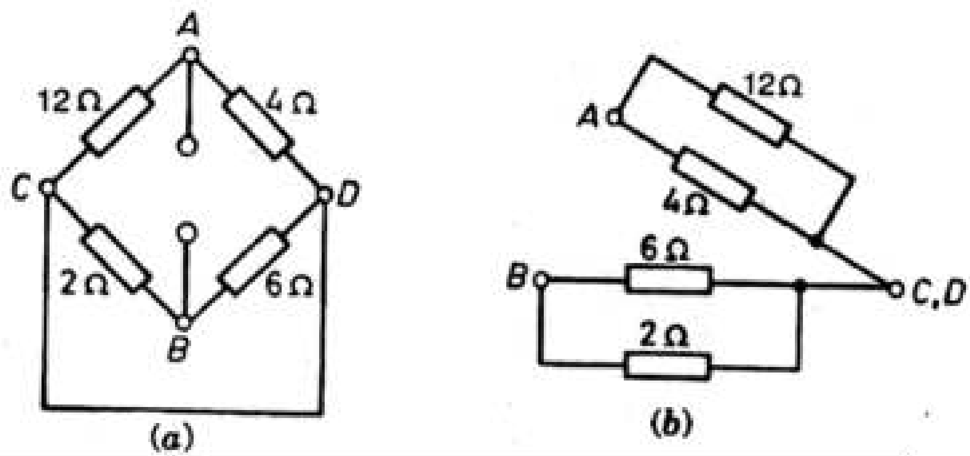
$$I_2 = \frac{12}{2+6} = 1.5 \text{ A}$$

$$\therefore \quad V_{Th} = V_{oc} = V_{AB} = V_{AD} - V_{BD}$$

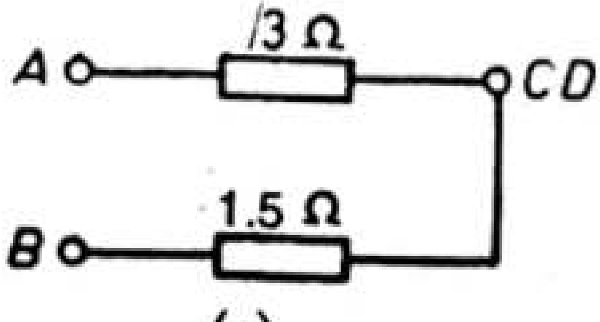
$$= 0.75 \times 4 - 1.5 \times 6 = \mathbf{-6\ V}$$

**Calculation of $R_{Th}$**

Replace the voltage sources by a short-circuit, and find resistance between $A$ and $B$.

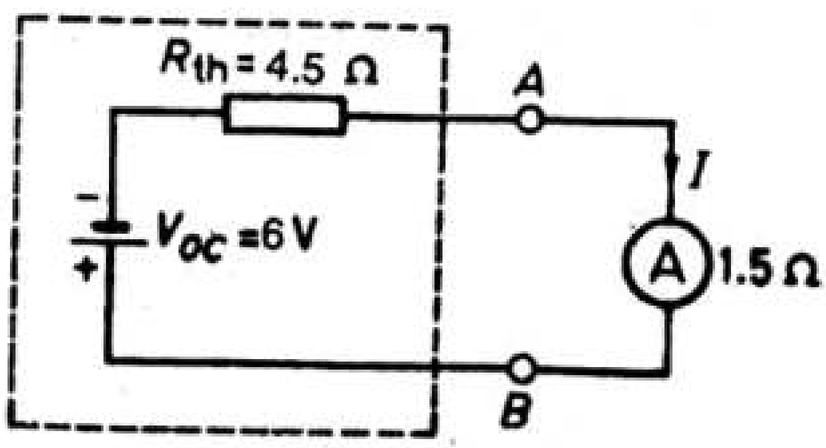


Ex:16 Using Thevenin's Theorem, find current in ammeter *A* of resistance 1.5 Ω for the given circuit



(c)

*Thevenin's equivalent*



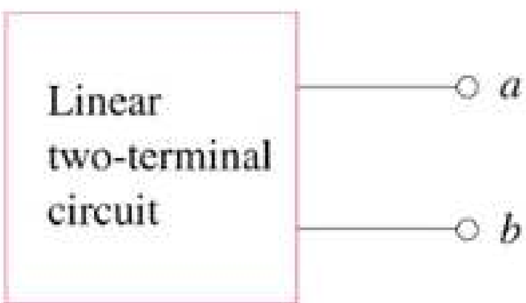
(d)

$$\therefore \quad I = \frac{V_{\text{Th}}}{R_{\text{Th}} + R_{\text{L}}} = \frac{-6}{4.5+1.5} = \mathbf{-1\,A}$$

# Norton's Theorem

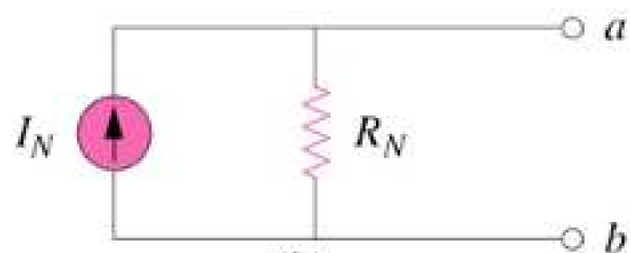
- It is dual of Thevenin's Theorem.
- **Statement:** It states that a linear two-terminal circuit (Fig. a) composed of passive and active elements can be replaced by an equivalent circuit (Fig. b) consisting of a current source $I_N$ in parallel with a resistor $R_N$,
- Where, $I_N$ is the short circuit current through the terminals.

  $R_N$ is the input or equivalent resistance at the terminals when the independent sources are turned off.




(a)

**Original circuit**



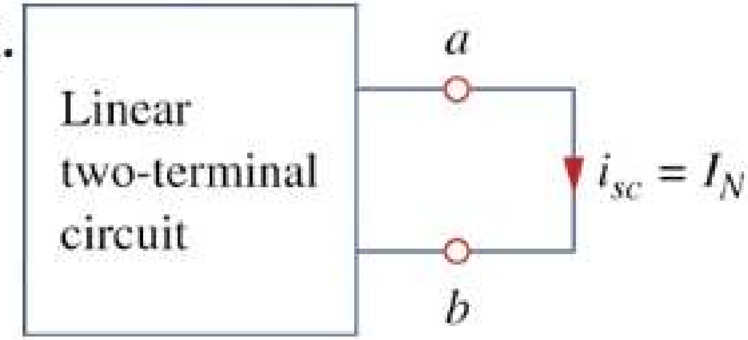

(b)

**Norton's equivalent Circuit**

# Norton's Theorem

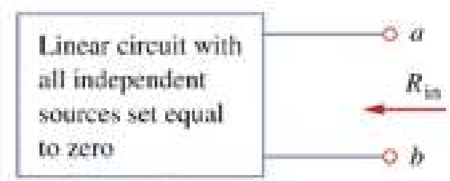
- Calculation of $I_N$

  The current $I_N$ is the short-circuit current developed through 'ab' terminals when the load is replaced with short circuit in original network.




- Calculation of $R_N$

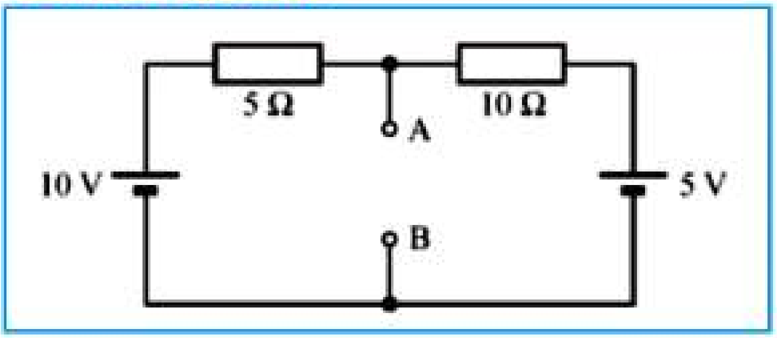
  The parallel resistance $R_N$ is the equivalent resistance looking back into the network at the terminals 'ab' with all the sources within the network made inactive, or dead (as in Thevenin's Theorem).



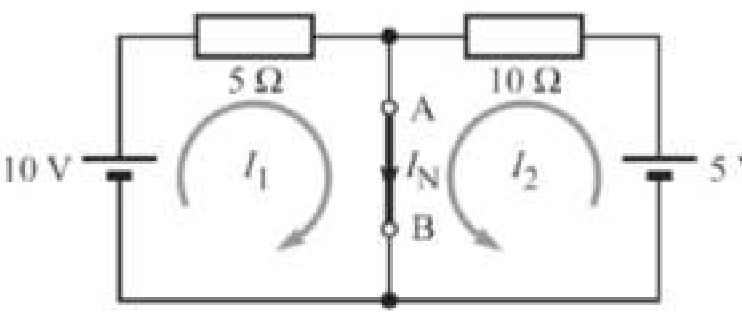

$R_N = R_{in}$

# Norton's Theorem

**Ex:1** Obtain the Norton's equivalent circuit with respect to the terminals AB for the network shown and also find current in 5Ω if connected between AB.

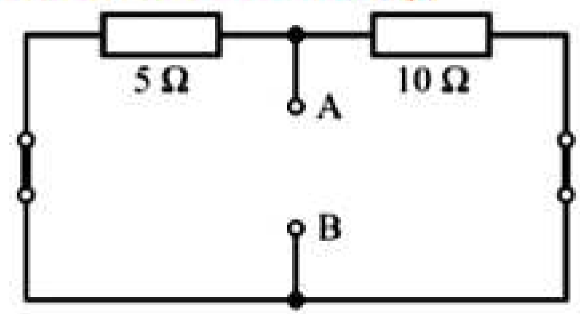



**Solution : ( i) Calculation of $I_N$**



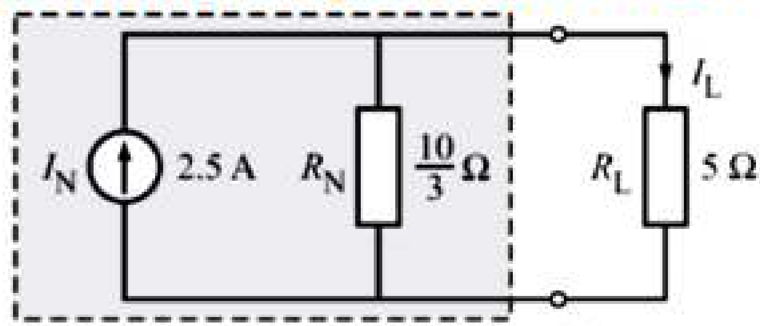

$$\therefore \quad I_N = I_1 + I_2 = \frac{10}{5} + \frac{5}{10} = \mathbf{2.5\ A}$$

**( ii) Calculation of $R_N$**




$$\therefore \quad R_N = \frac{5\times 10}{5+10} = \frac{\mathbf{10}}{\mathbf{3}}\ \mathbf{\Omega}$$

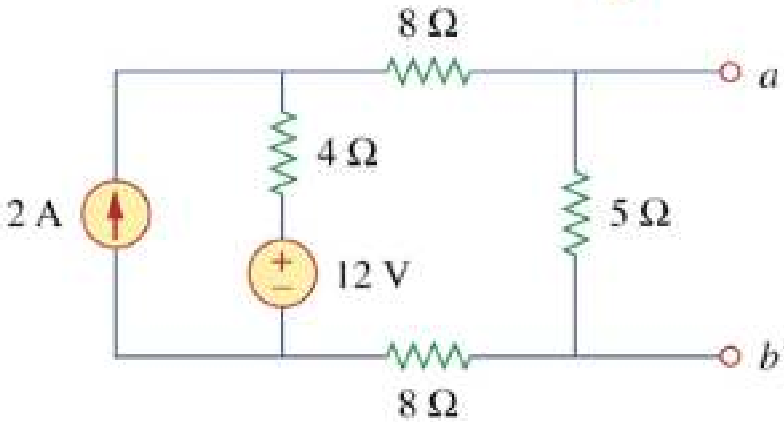
**(iii) Norton's equivalent circuit**



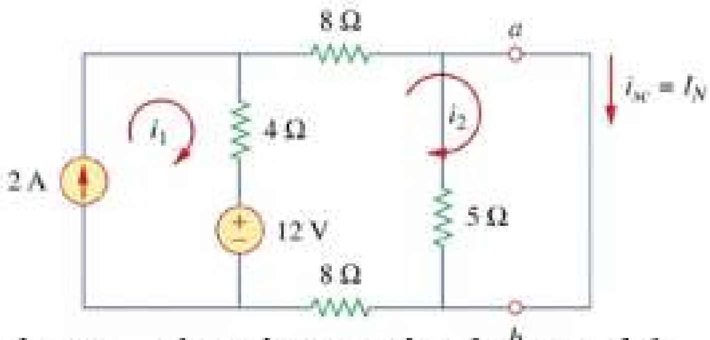

$$I_L = I_N \frac{R_N}{R_N + R_L} = 2.5\times\frac{(10/3)}{(10/3)+5} = 1\,\mathrm{A}$$

# Norton's Theorem

**Ex:2** Find the Norton equivalent circuit of the circuit in Fig




## Solution : ( i) Calculation of $I_N$

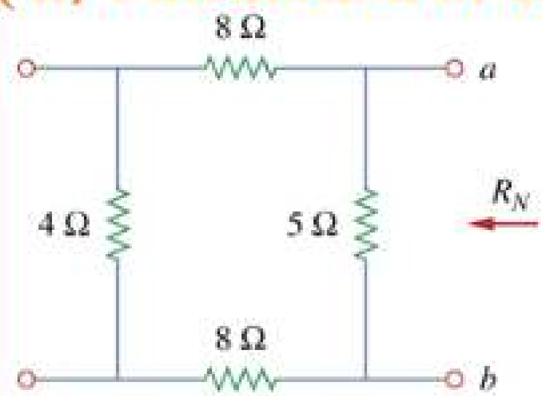



short – circuit terminals $a$ and $b$.

$$\text{Mesh}: \; i_1 = 2\text{A}, \; 20i_2 - 4i_1 - i_2 = 0$$

$$i_2 = 1\text{A} = i_{sc} = I_N$$

## ( ii) Calculation of $R_N$



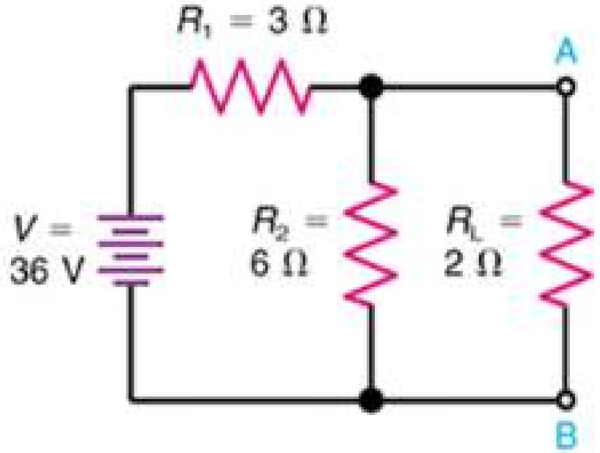

$$R_N = 5 \,||\, (8 + 4 + 8)$$

$$= 5 \,||\, 20 = \frac{20 \times 5}{25} = 4\Omega$$

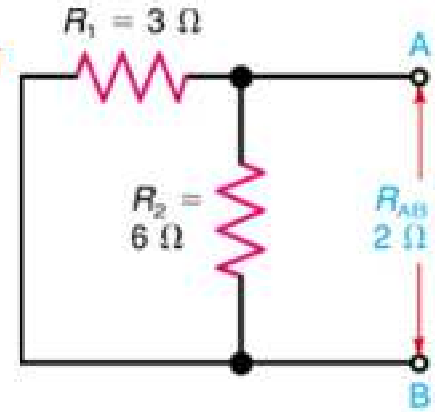
## (iii) Norton's equivalent circuit

# Norton's Theorem

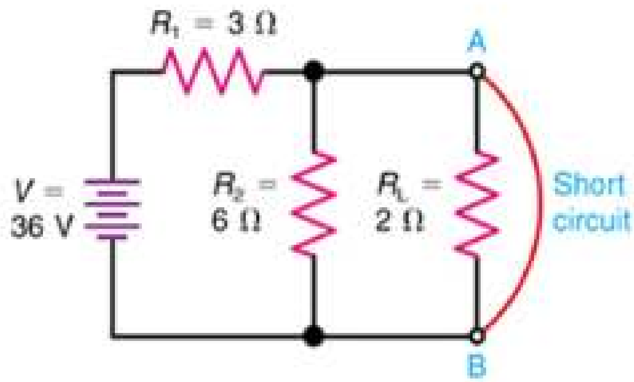
**Ex:3** Find current in 2 Ω using Norton theorem



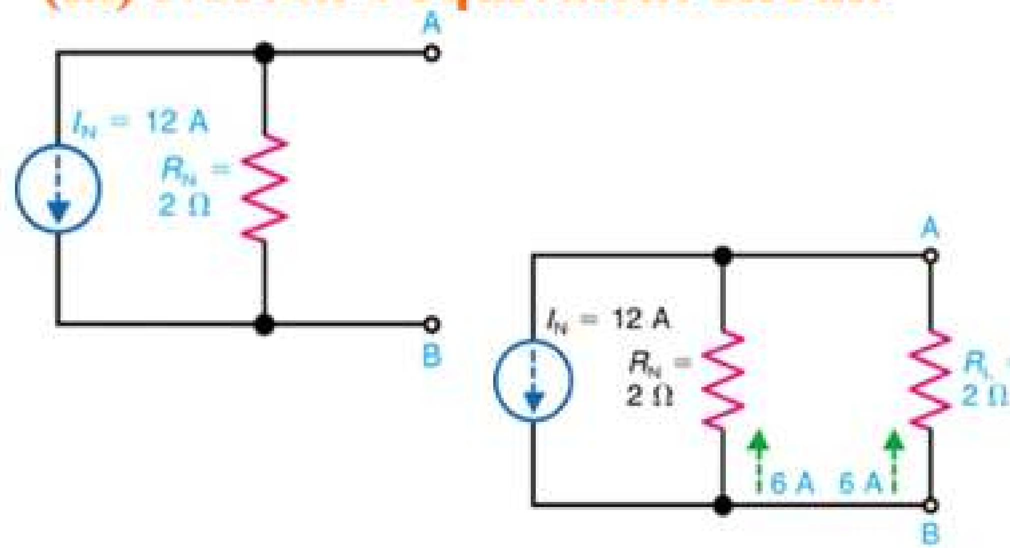

**( ii) Calculation of $R_N$**




**Solution : ( i) Calculation of $I_N$**



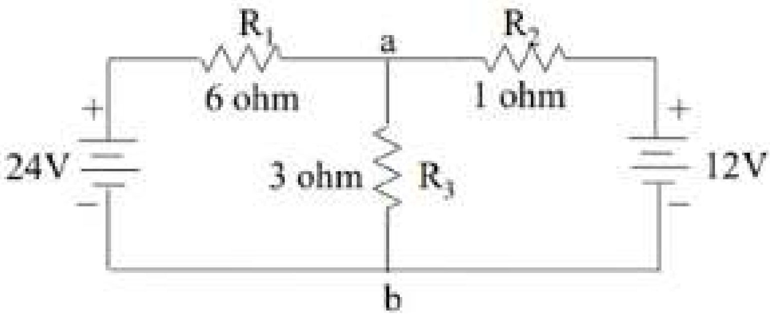

**(iii) Norton's equivalent circuit**



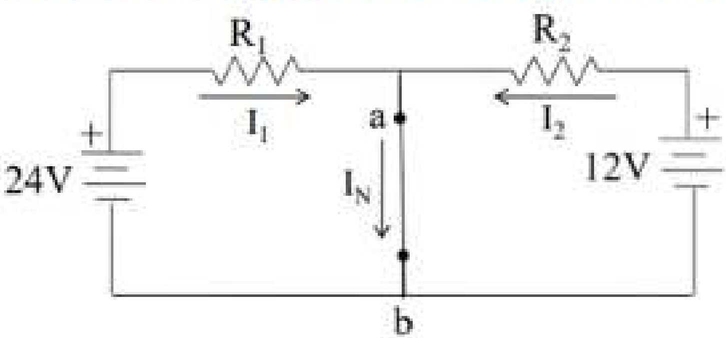

$$I_L = I_N \times R_N/R_N + R_L = 12 \times 2/4 = 6\ A$$

# Norton's Theorem

**Ex:4** Find the current through 3 Ω by Norton's Theorem

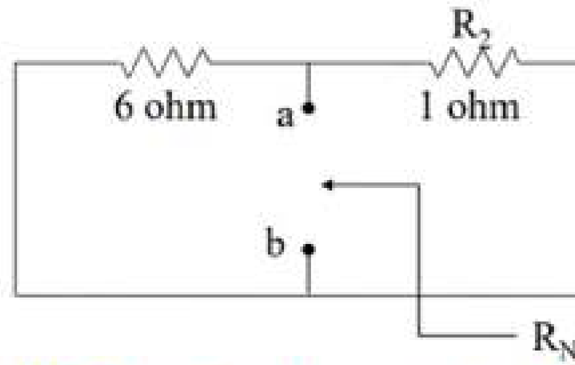



**Solution :** **( i) Calculation of $I_N$**




$$I_N = I_1 + I_2 = \frac{24}{6} + \frac{12}{1} = 16\text{A}$$

**( ii) Calculation of $R_N$**

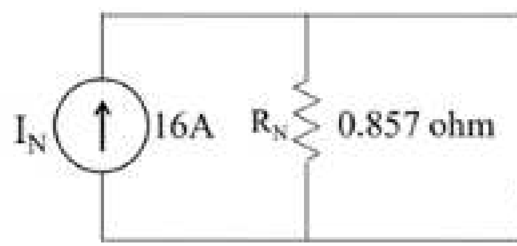



$$R_N = \frac{R_1 R_2}{R_1 + R_2}$$

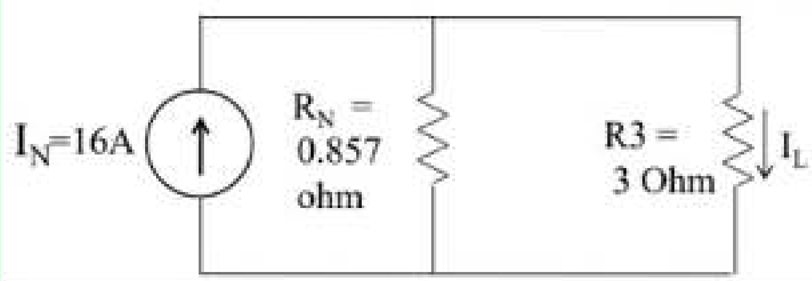
$$= \frac{6 \times 1}{6+1}$$

$$= 0.857\Omega$$

**(iii) Norton's equivalent circuit**

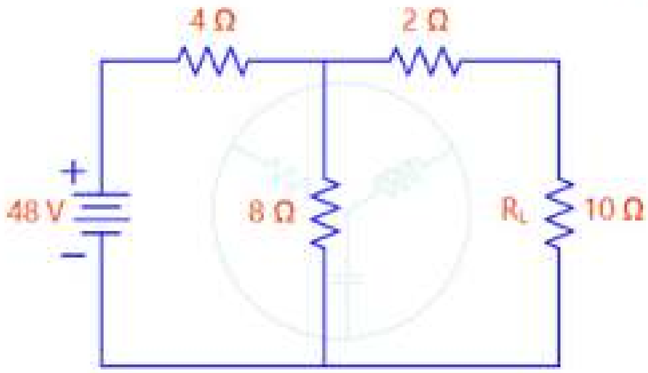



$$I_L = 16 \frac{0.857}{0.857+3} = 3.55\text{A}$$

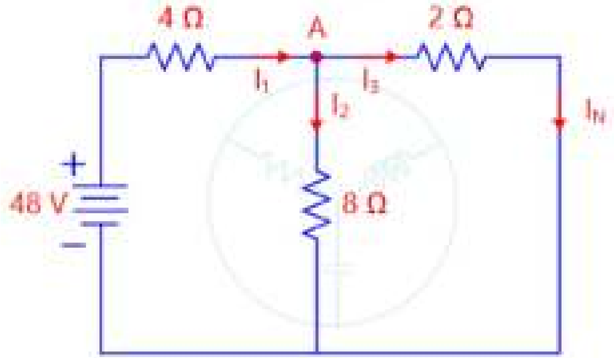


# Norton's Theorem

## Ex:5 Find the current through 10 Ω by Norton's Theorem




## Solution : ( i) Calculation of $I_N$

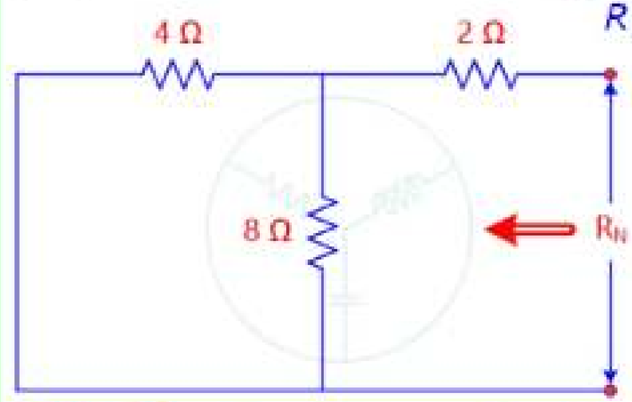



$$R_{eq} = 4 + \frac{82}{8+2} = 5.6\ \Omega$$

$$I_1 = \frac{V}{Req} = \frac{48}{5.6} = 8.57\ A$$

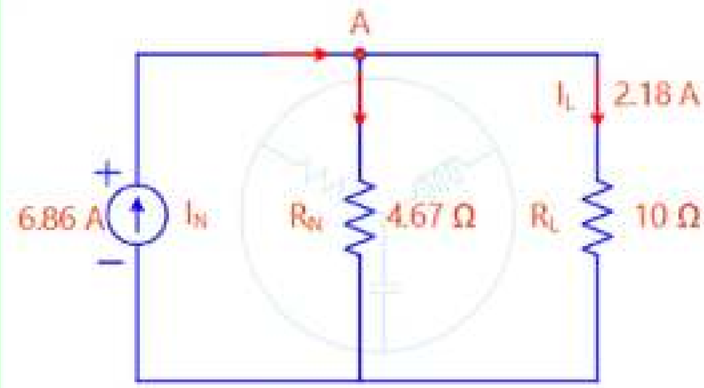
$$I_N = I_3 = 8.57 \times \frac{8}{8+2} = 6.86\ A$$

## ( ii) Calculation of $R_N$




$$R_N = \frac{4 \times 8}{4+8} + 2 = 4.67\ \Omega$$

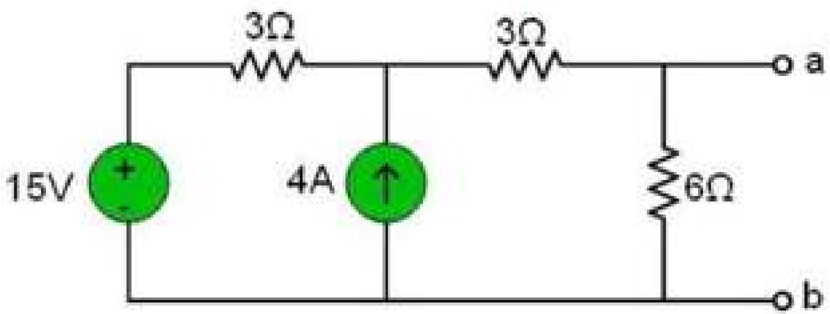
## (iii) Norton's equivalent circuit



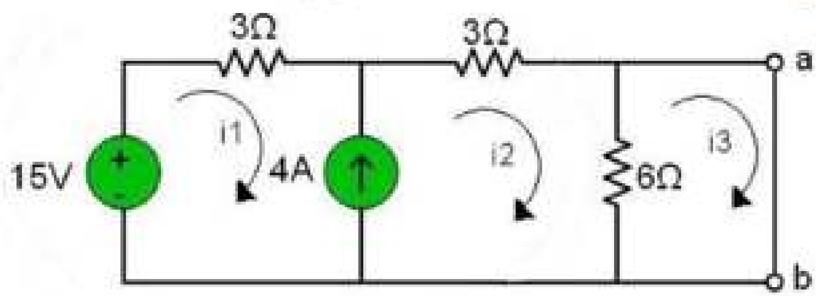

$$I_L = I_N \times \frac{R_N}{R_N + R_L} = 6.86 \times \frac{4.67}{4.67 + 10} = 2.18\ A$$

# Norton's Theorem

**Ex:6** Find Norton equivalent circuit across 'ab'

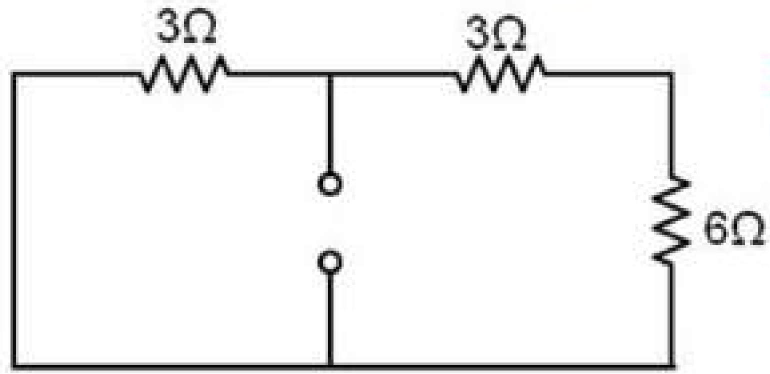



**Solution :** **( i) Calculation of $I_N$**



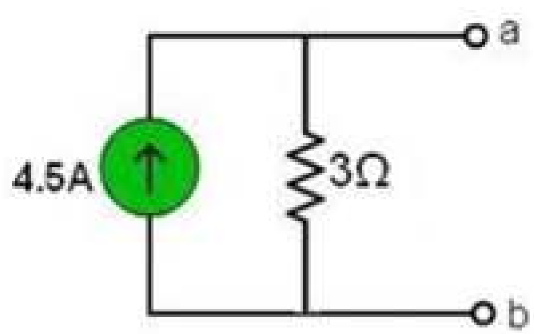

$I_N = 4.5A$

**( ii) Calculation of $R_N$**



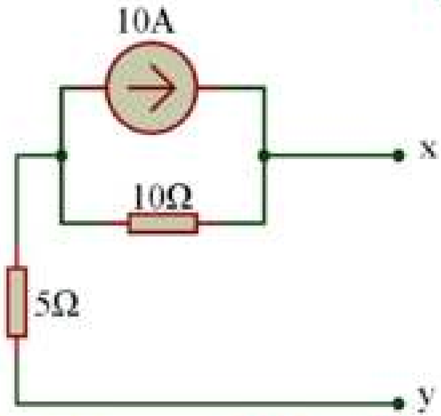

Rn = 3Ω.

**(iii) Norton's equivalent circuit**

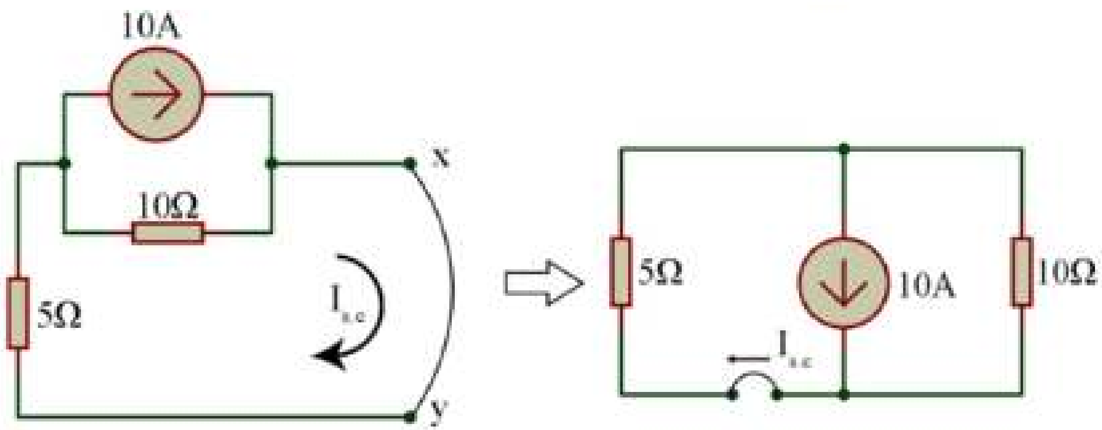


# Norton's Theorem

**Ex:7** Find Norton equivalent circuit across 'XY'



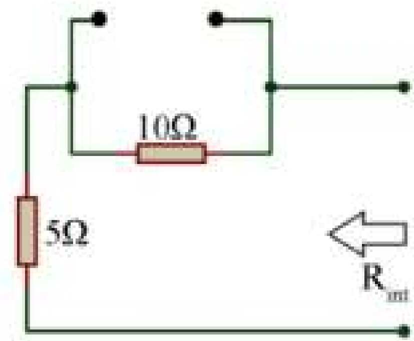

**Solution :** **( i) Calculation of $I_N$**




Here, $I_{s.c}$ is the current through 5Ω resistor.

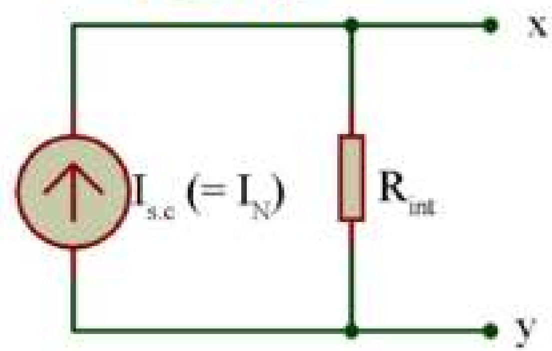
$$\therefore I_{s.c} = 10 \times \frac{10}{10+5} = 6.67A$$

## ( ii) Calculation of $R_N$




$= 10 + 5 = 15\Omega$

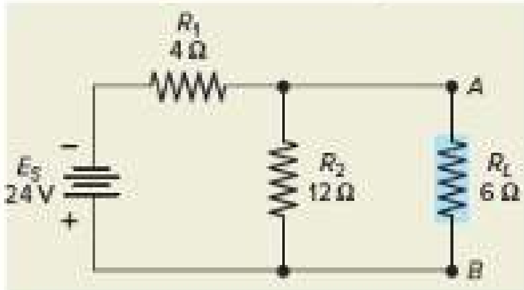
## (iii) Norton's equivalent circuit



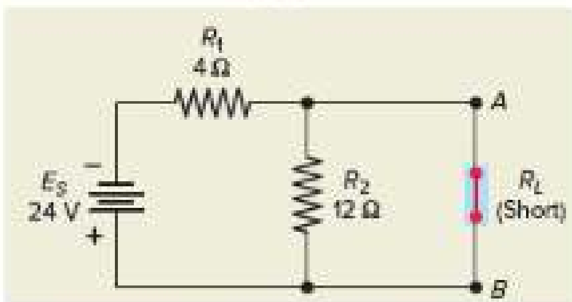

$I_N = 6.67A;\ R_{int} = 15\Omega.$

# Norton's Theorem

**Ex:8** Find current flowing in the 6Ω and also find current through 3Ω if 6Ω is replaced by 3Ω Norton theorem

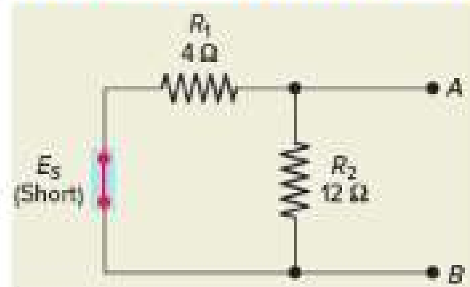



**Solution : ( i) Calculation of $I_N$**



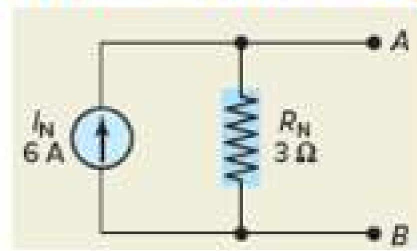

$$I_N = \frac{E_S}{R_1} = \frac{24\ \text{V}}{4\ \Omega} = 6\ \text{A}$$

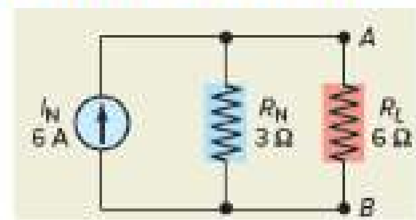
**( ii) Calculation of $R_N$**




$$R_N = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{4\ \Omega \times 12\ \Omega}{4\ \Omega + 12\ \Omega} = 3\ \Omega$$

**(iii) Norton's equivalent circuit**




$$I_{R_L} = \frac{R_N}{R_N + R_L} \times I_N = \frac{3\ \Omega}{3\ \Omega + 6\ \Omega} \times 6\ \text{A} = 2\ \text{A}$$

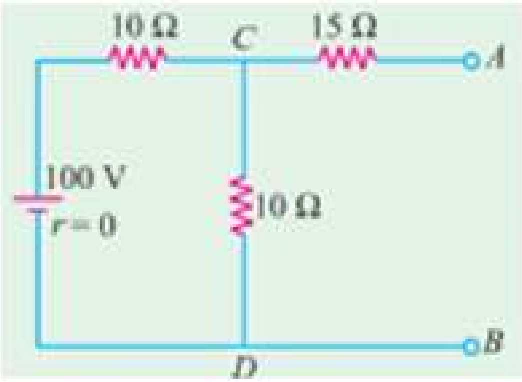
$$E_{R_L} = I_{R_L} \times R_L = 2\ \text{A} \times 6\ \Omega = 12\ \text{V}$$

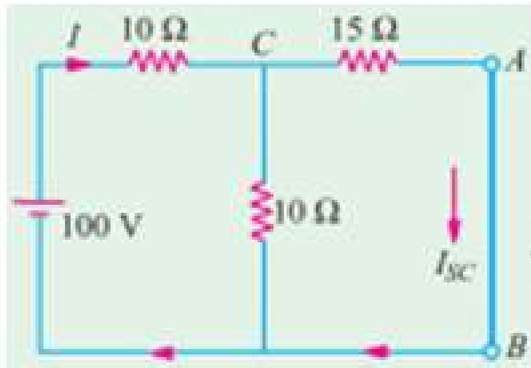
$$I_{R_L} = \frac{R_N}{R_N + R_L} \times I_N = \frac{3\ \Omega}{3\ \Omega + 3\ \Omega} \times 6\ \text{A} = 3\ \text{A}$$

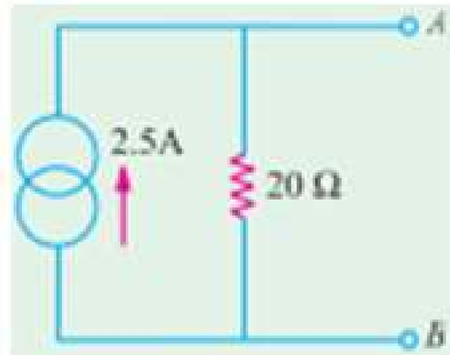
$$E_{R_L} = I_{R_L} \times R_L = 3\ \text{A} \times 3\ \Omega = 9\ \text{V}$$

# Norton's Theorem

**Ex:9** Find Norton equivalent circuit across 'ab'




**Ex:10** Find Current through 5 Ω Norton theorem