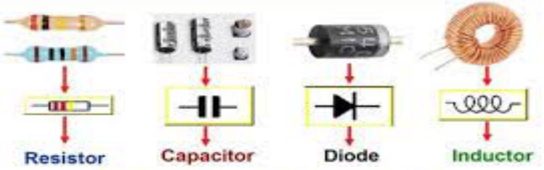
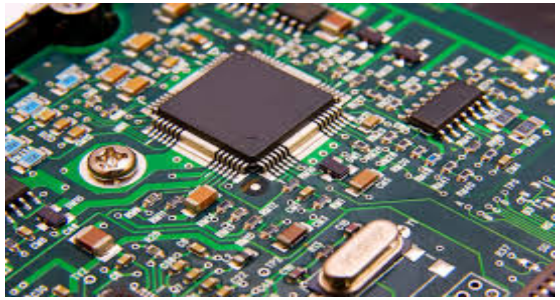


Electronics 1

BSC 113

Fall 2022-2023

Lecture 6



Thevenin's & Norton theorems & Maximum Power Transfer and Source Transformation

INSTRUCTOR

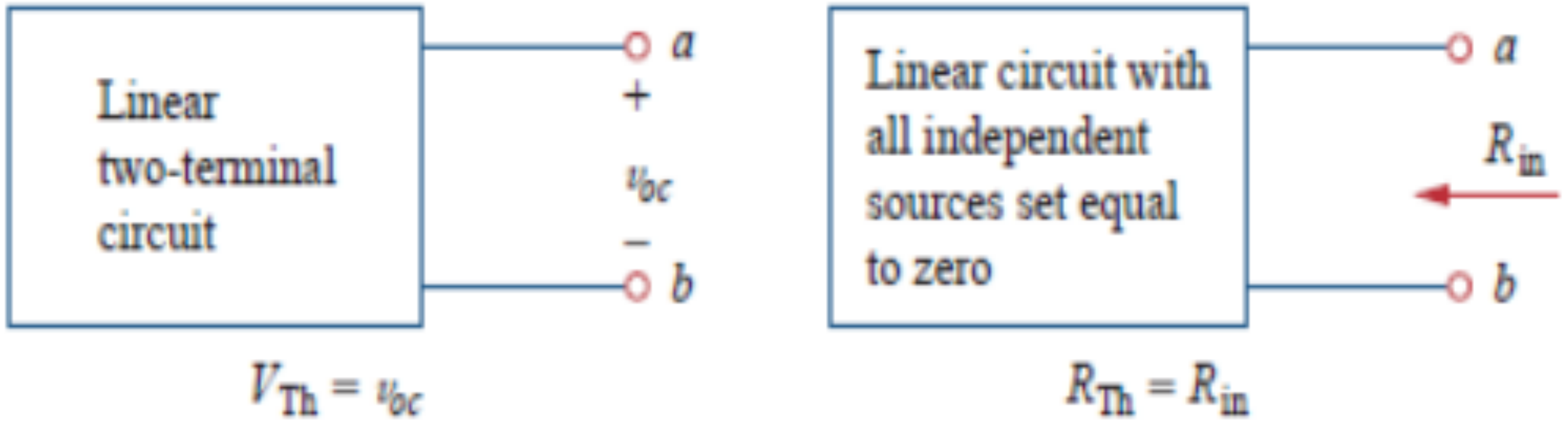
DR / AYMAN SOLIMAN

Contents

1) Thevenin's theorem
2) Norton theorem
3) Maximum Power Transfer
4) Source Transformation

❑ Thevenin's theorem

- Thevenin's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}, where V_{Th} is the open-circuit voltage at the terminals and R_{Th} is the input or equivalent resistance at the terminals when the independent sources are turned off as shown in figure



THEVENIN

THEVENIN'S THEOREM:

Consider the following:

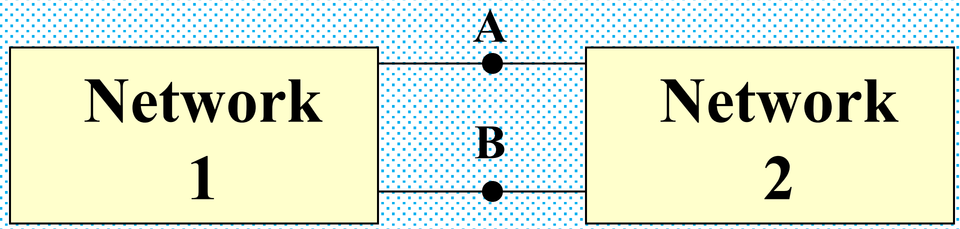


Figure: Coupled networks.

For purposes of discussion, at this point, we consider that both networks are composed of resistors and independent voltage and current sources

THEVENIN

THEVENIN'S THEOREM:

Suppose Network 2 is detached from Network 1 and we focus temporarily only on Network 1.

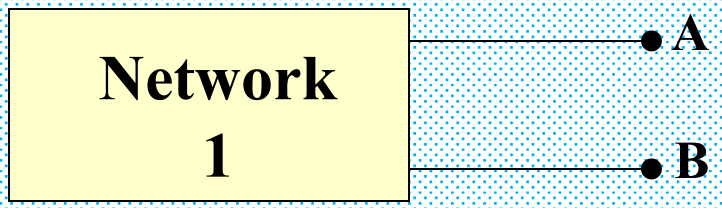
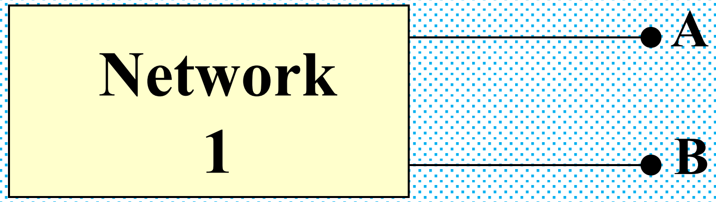


Figure: Network 1, open-circuited.

- **Network 1 can be as complicated in structure as one can imagine.**
  - ✓ **Maybe 45 meshes**
  - ✓ **387 resistors**
  - ✓ **91 voltage sources**
  - ✓ **39 current sources.**

THEVENIN

THEVENIN'S THEOREM:



Now place a voltmeter across terminals A-B and read the voltage. We call this the open-circuit voltage.

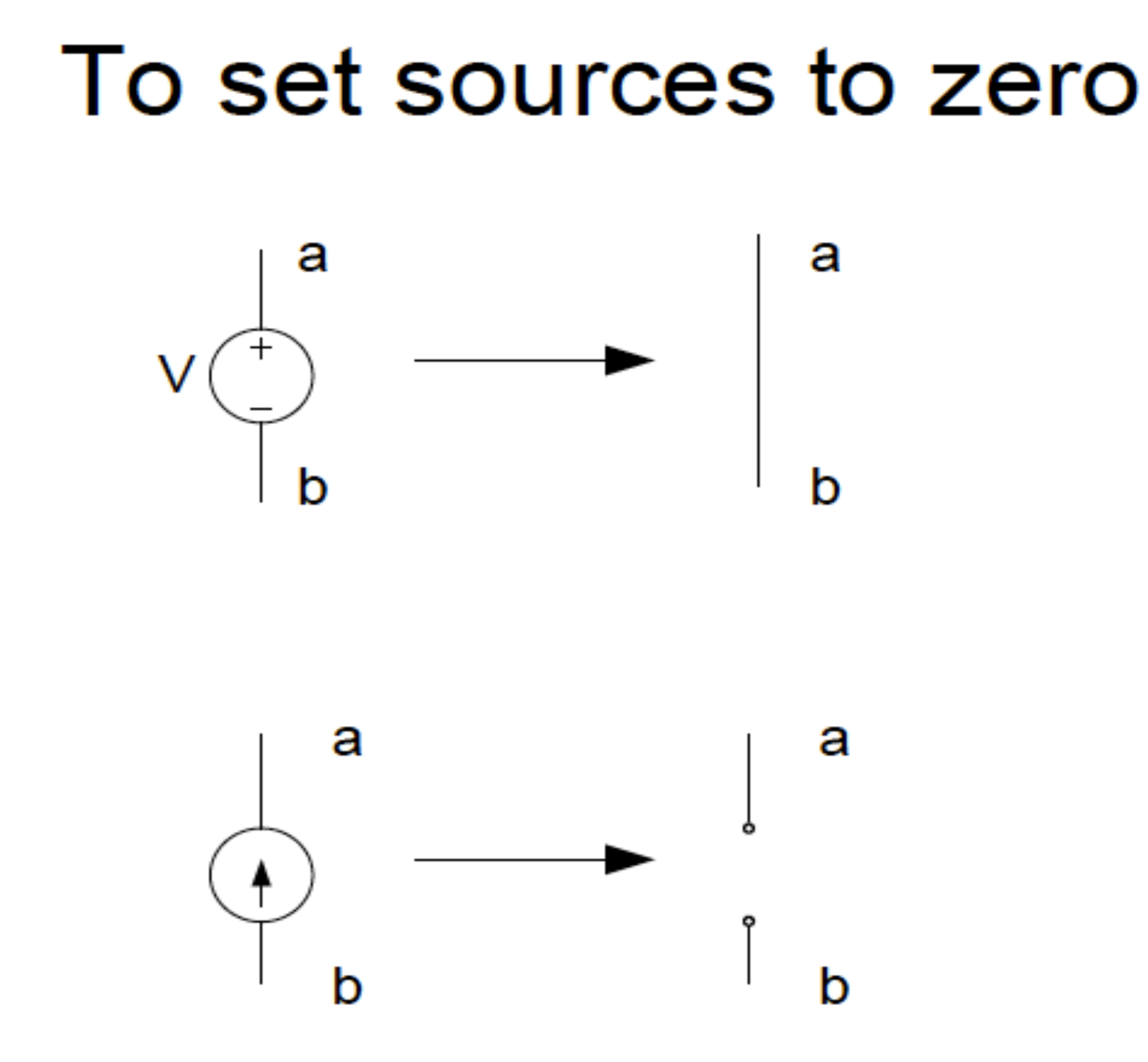
No matter how complicated Network 1 is, we read one voltage. It is either positive at A, (with respect to B) or negative at A.

We call this voltage V_{os} and we also call it $V_{THEVENIN} = V_{TH}$

THEVENIN

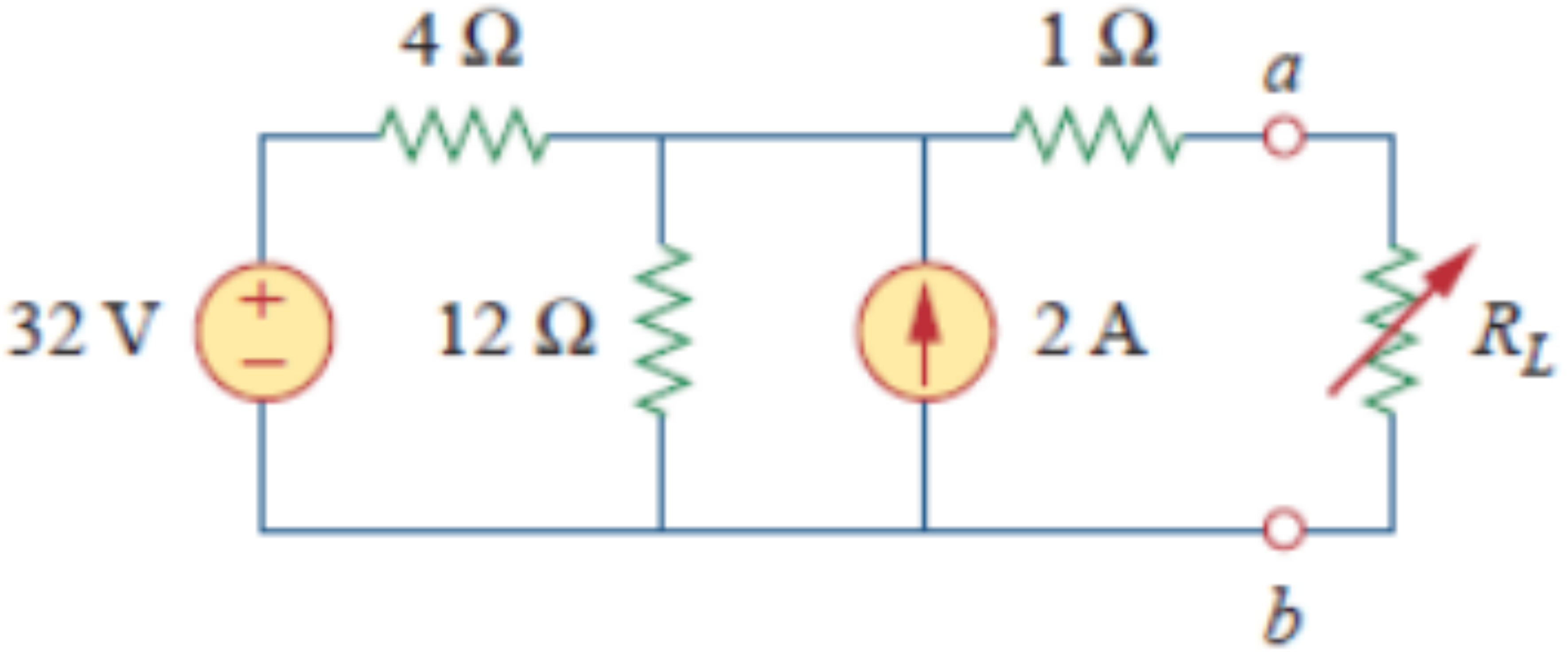
THEVENIN'S THEOREM:

- We now deactivate all sources of Network 1.
- To deactivate a voltage source, we remove the source and replace it with a short circuit.
- To deactivate a current source, we remove the source.



❑ Example1

- Find the Thevenin equivalent circuit of the circuit shown, to the left of the terminals a - b.

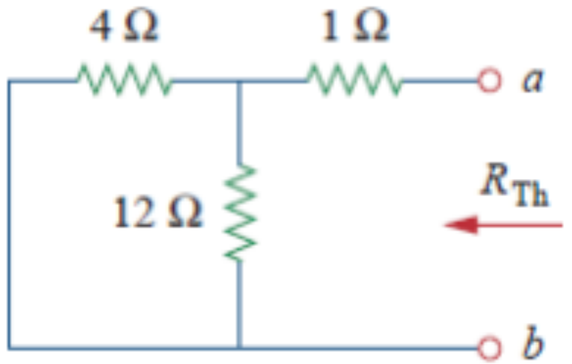


❑ Example1

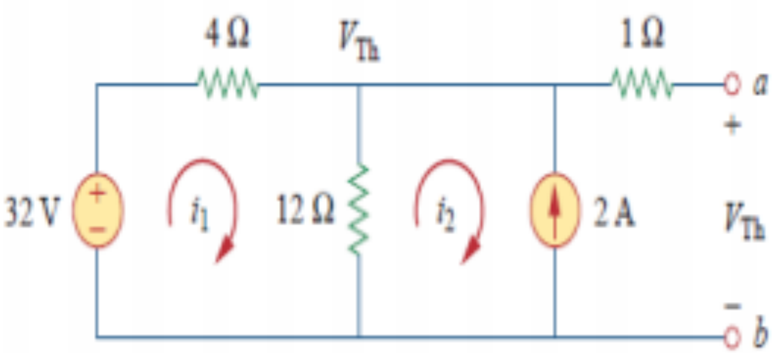
➢ Find the Thevenin equivalent circuit of the circuit shown, to the left of the terminals a - b.

Answer:

R_{th}= (4//12) +1= 4Ω



$$i_2 = -2A$$
$$-32 + 16i_1 - 12i_2 = 0$$
$$i_1 = 0.5A$$
$$V_{Th} = 12(i_1 - i_2) = 30V$$



THEVENIN

THEVENIN'S THEOREM: Example 2.

Find V_X by first finding V_{TH} and R_{TH} to the left of A-B.

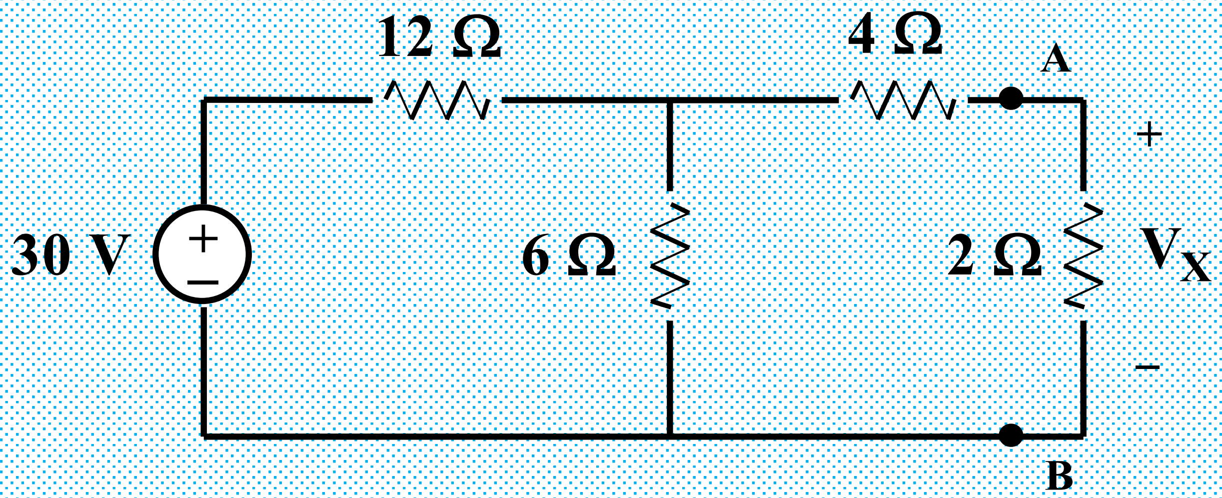


Figure: Circuit for Example 2.

First remove everything to the right of A-B.

THEVENIN & NORTON

THEVENIN'S THEOREM: Example 2. continued

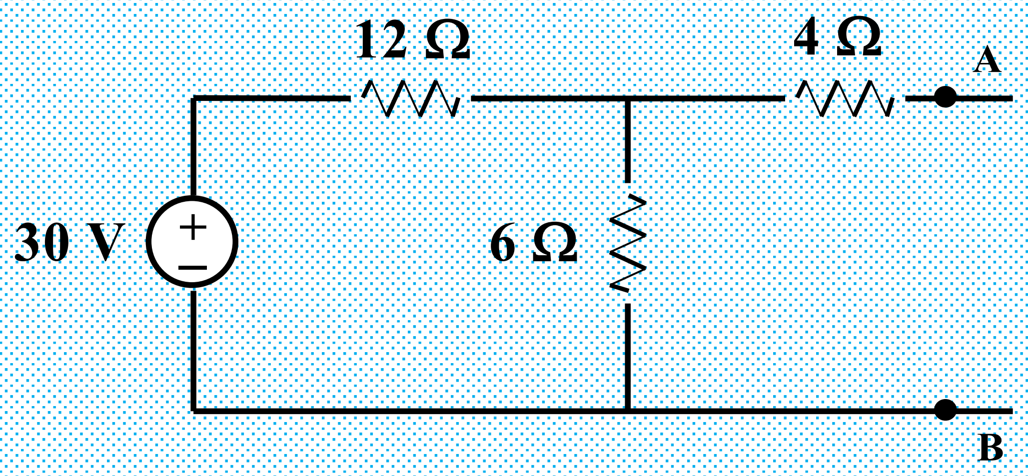


Figure: Circuit for finding V_{TH} for Example 2.

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

Notice that there is no current flowing in the 4 Ω resistor (A-B) is open. Thus, there can be no voltage across the resistor.

THEVENIN & NORTON

THEVENIN'S THEOREM: Example 2. continued

We now deactivate the sources to the left of A-B and find the resistance seen looking in these terminals.

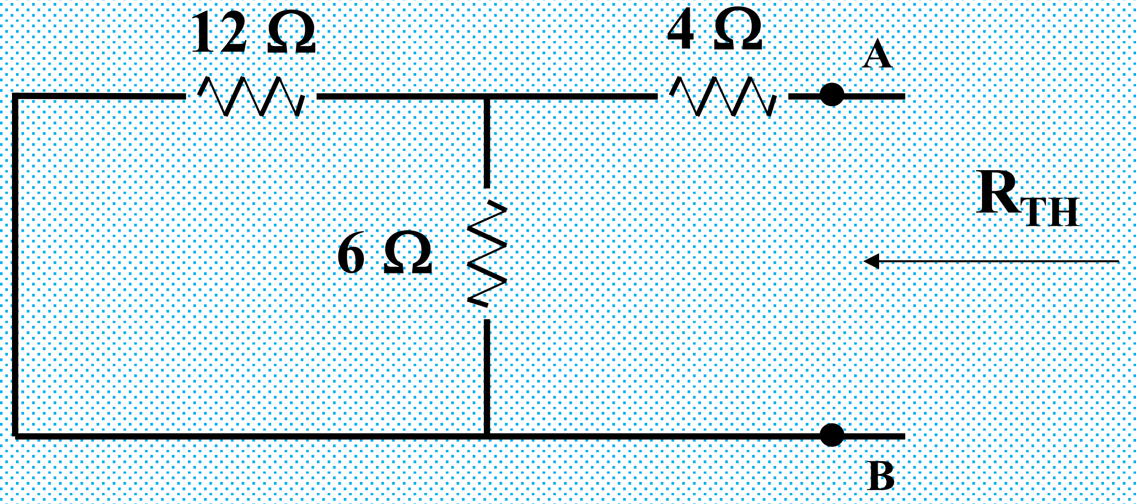


Figure: Circuit for find R_{TH} for Example 2.

We see,

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

THEVENIN & NORTON

THEVENIN'S THEOREM: Example 2. continued

After having found the Thevenin circuit, we connect this to the load in order to find V_X.

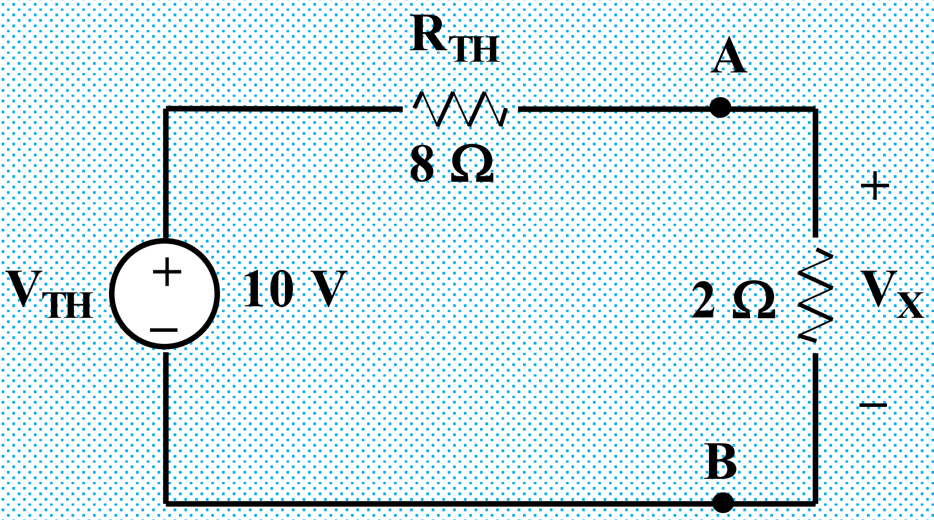


Figure: Circuit of Ex 2 after connecting Thevenin circuit.

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

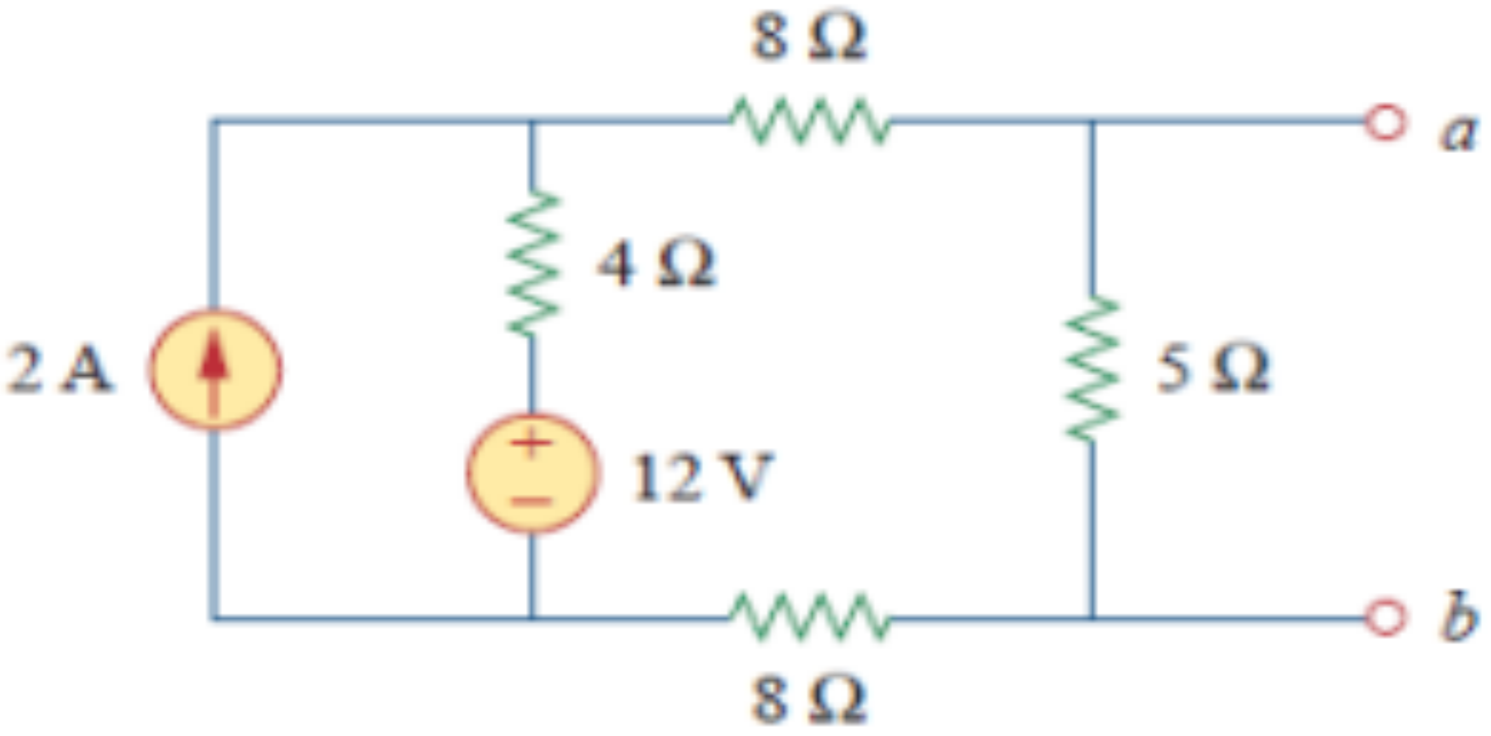
Norton theorem

❑ Norton theorem

- Norton's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source $I_N = V_{Th}/R_{Th}$ in parallel with a resistor $R_N = R_{Th}$, where I_N is the short-circuit current through the terminals and R_N is the input or equivalent resistance at the terminals when the independent sources are turned off.

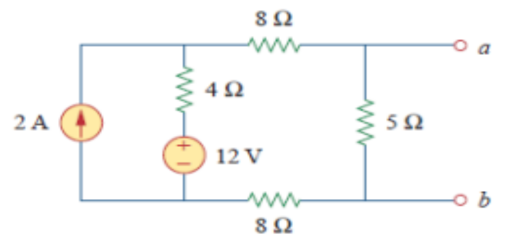
❑ Example

➢ Find the Norton equivalent circuit of the circuit shown, to the left of the terminals a - b.



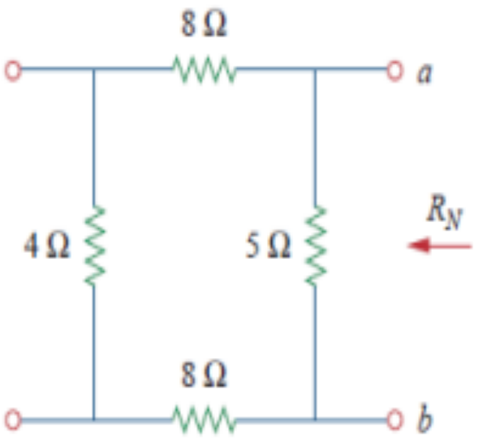
❑ Example

➢ Find the Norton equivalent circuit of the circuit shown, to the left of the terminals a - b.



Answer:

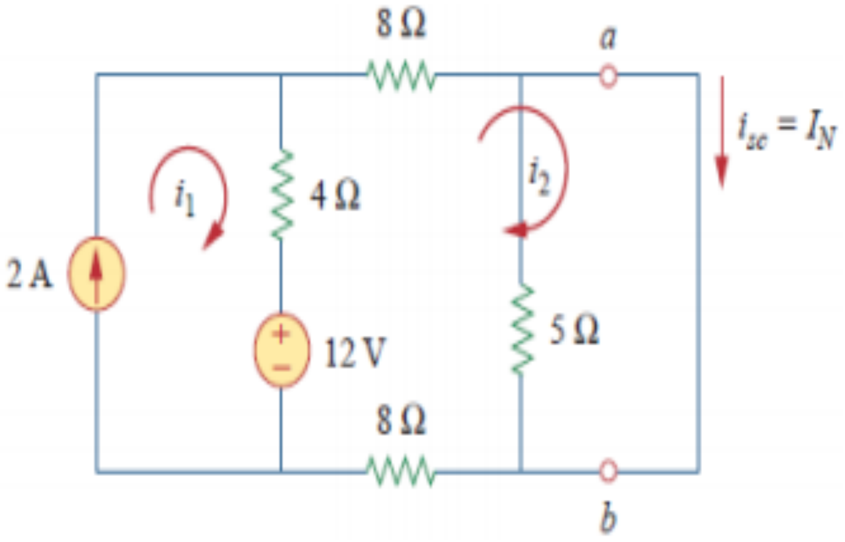
R_N =5//(8+4+8)= 4Ω



$i_1 = 2A$

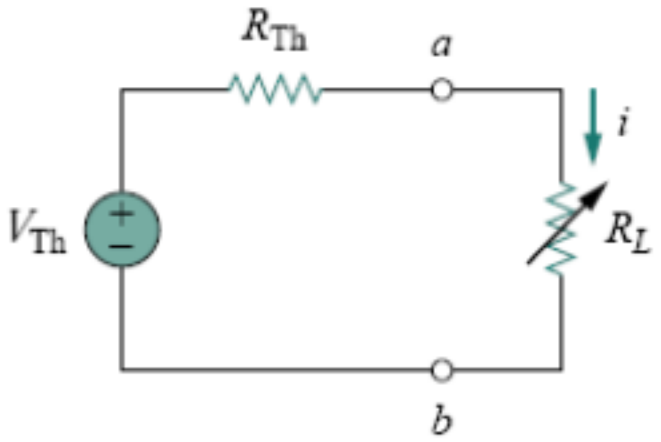
$20i_2 - 4i_1 - 12 = 0$

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

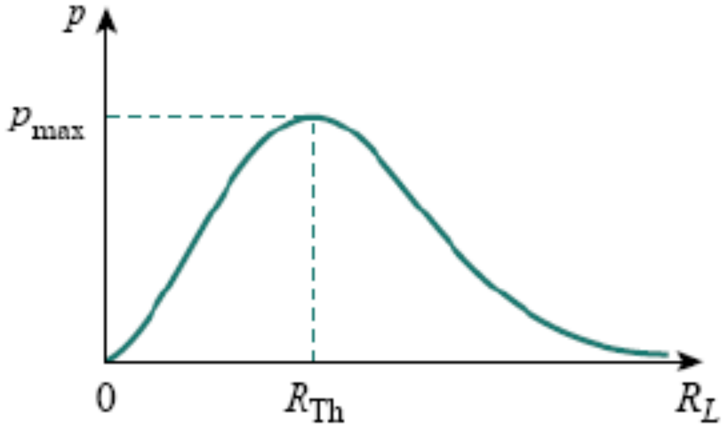


Maximum Power Transfer

❑ Maximum Power Transfer



$$p = i^2 R_L = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L$$



❑ Maximum Power Transfer

$$\frac{dp}{dR_L} = V_{\text{Th}}^2 \left[\frac{(R_{\text{Th}} + R_L)^2 - 2R_L(R_{\text{Th}} + R_L)}{(R_{\text{Th}} + R_L)^4} \right]$$

$$= V_{\text{Th}}^2 \left[\frac{(R_{\text{Th}} + R_L - 2R_L)}{(R_{\text{Th}} + R_L)^3} \right] = 0$$

$$0 = (R_{\text{Th}} + R_L - 2R_L) = (R_{\text{Th}} - R_L)$$

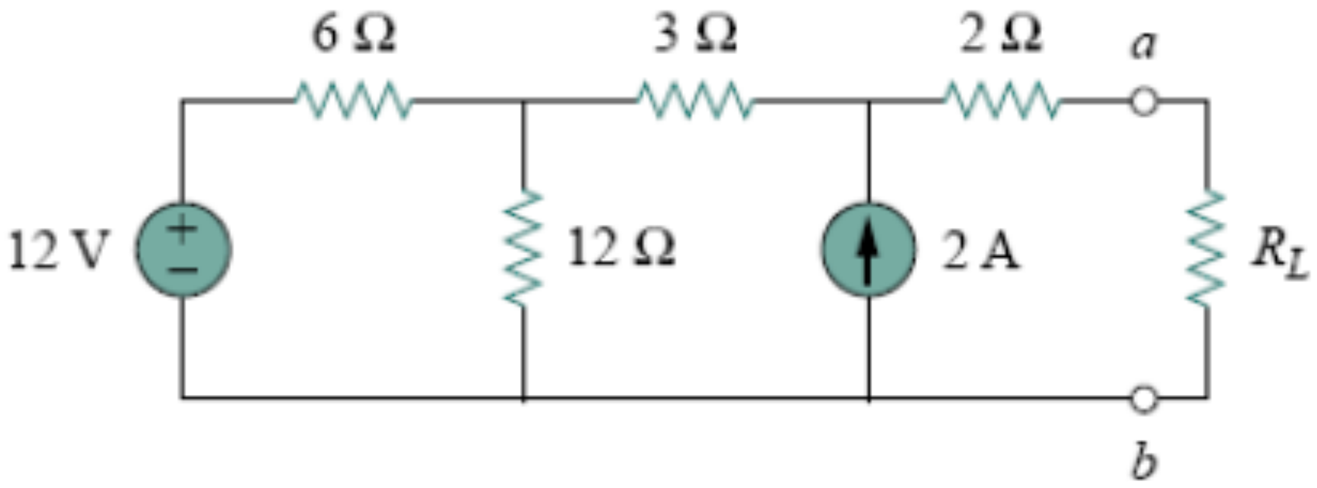
$$\boxed{R_L = R_{\text{Th}}}$$

$$\boxed{p_{\max} = \frac{V_{\text{Th}}^2}{4R_{\text{Th}}}}$$

Maximum power is transferred to the load when the load resistance equals the Thevenin resistance as seen from the load ($R_L = R_{\text{Th}}$).

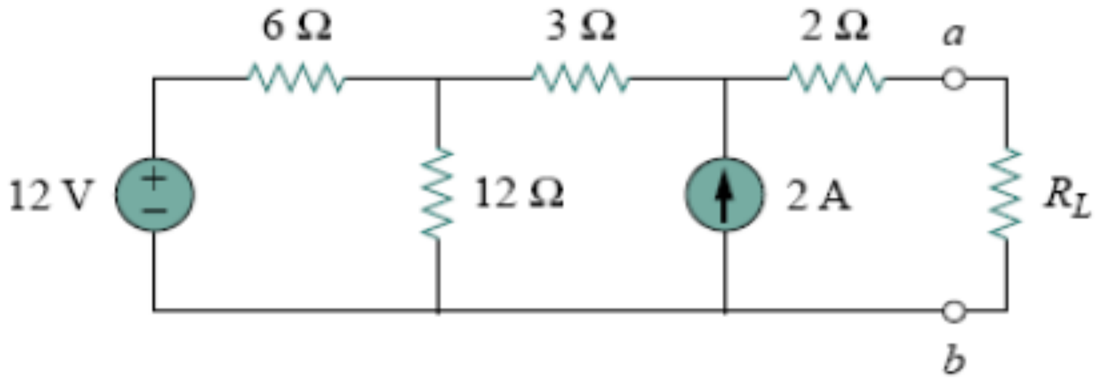
applies only when $R_L = R_{\text{Th}}$.

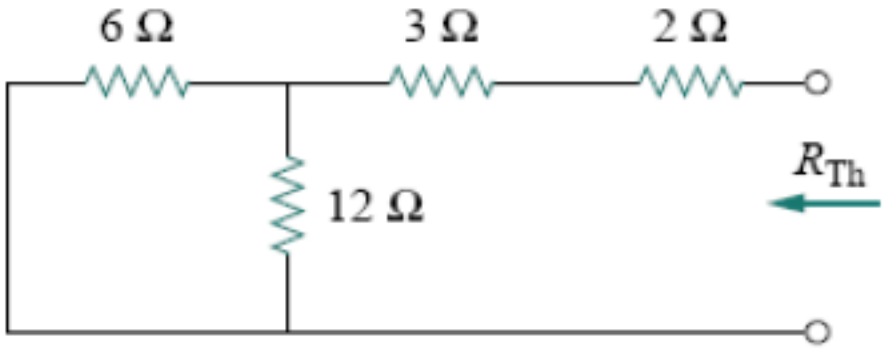
❑ Example



Find the value of R_L for maximum power transfer in the circuit of Fig. Find the maximum power.

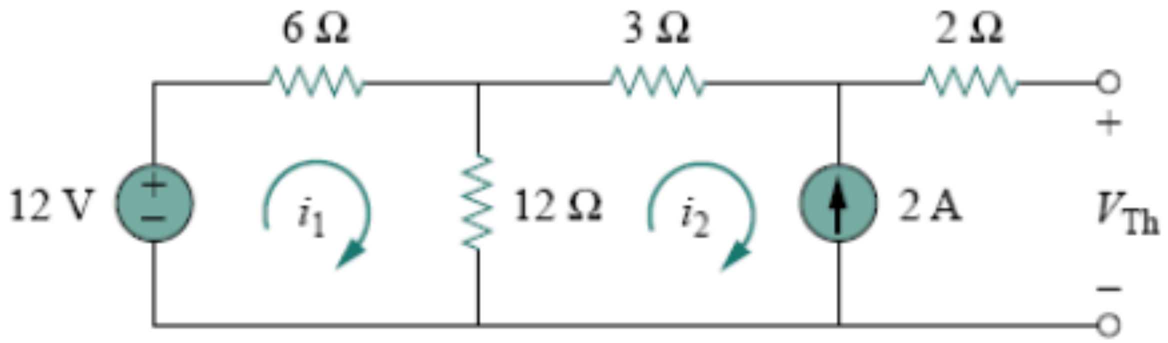
❑ Example





$$R_{Th} = 2 + 3 + 6 \parallel 12 = 5 + \frac{6 \times 12}{18} = 9\ \Omega$$

❑ Example



$$-12 + 18i_1 - 12i_2 = 0, \qquad i_2 = -2\text{ A}$$

$$i_1 = -2/3$$

$$-12 + 6i_1 + 3i_2 + 2(0) + V_{Th} = 0$$

$$V_{Th} = 22\text{ V}$$

❑ Example

For maximum power transfer,

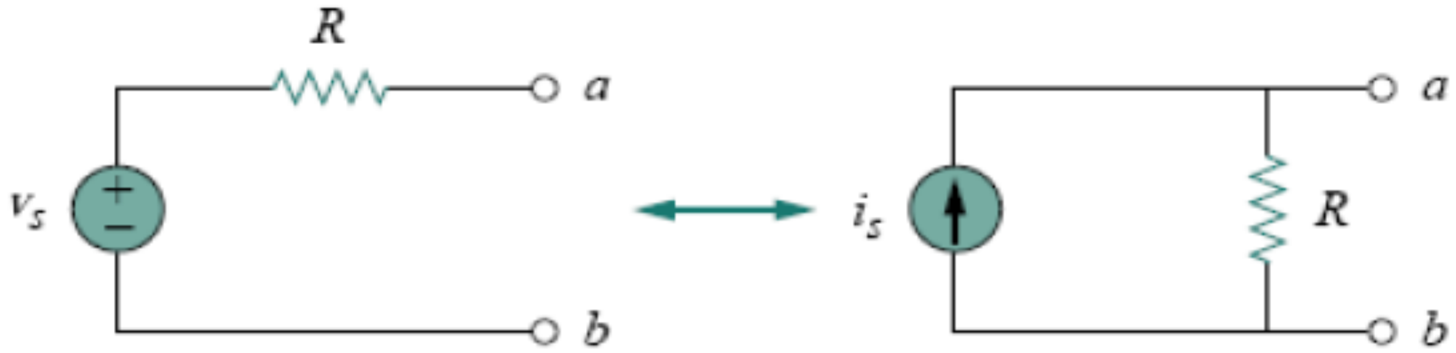
$$R_L = R_{\text{Th}} = 9\ \Omega$$

and the maximum power is

$$p_{\max} = \frac{V_{\text{Th}}^2}{4R_L} = \frac{22^2}{4 \times 9} = 13.44\ \text{W}$$

Source Transformation

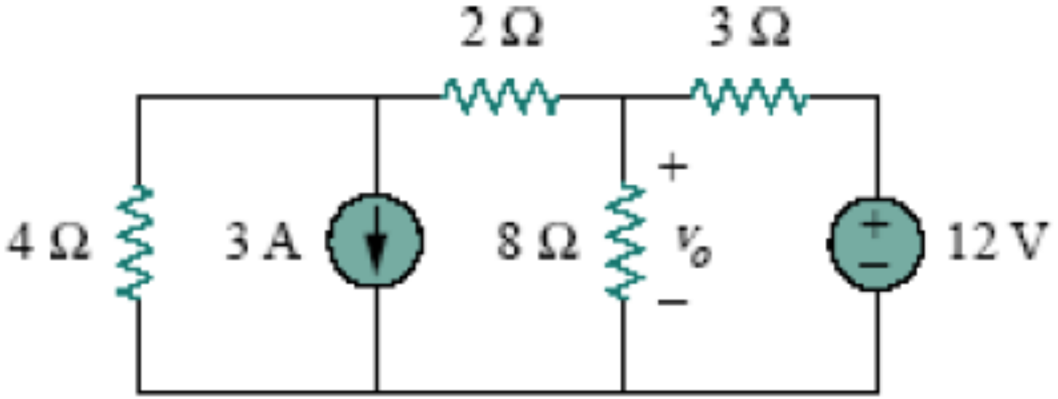
❑ Source Transformation



$$v_s = i_s R \qquad \text{or} \qquad i_s = \frac{v_s}{R}$$

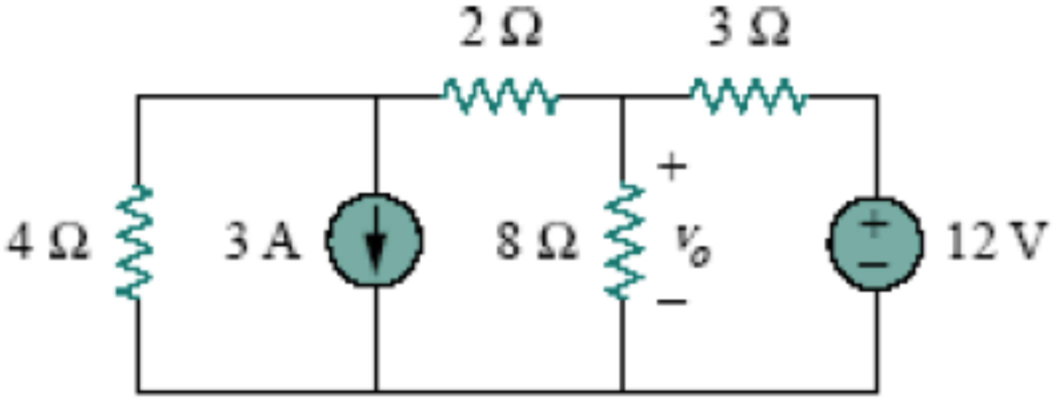
A source transformation is the process of replacing a voltage source v_s in series with a resistor R by a current source i_s in parallel with a resistor R, or vice versa.

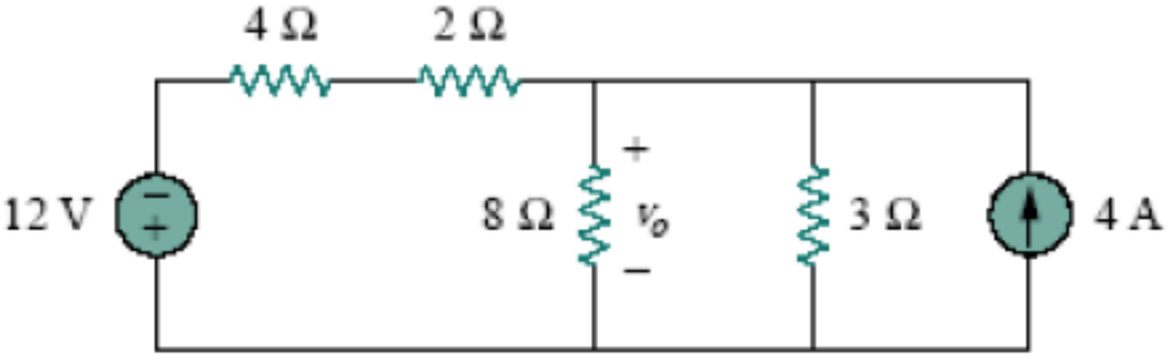
❑ Example



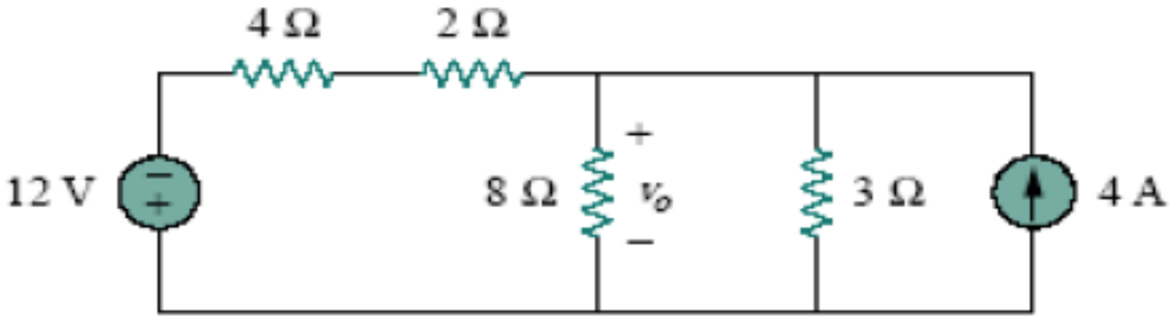
Use source transformation to find v_o in the circuit in Fig.

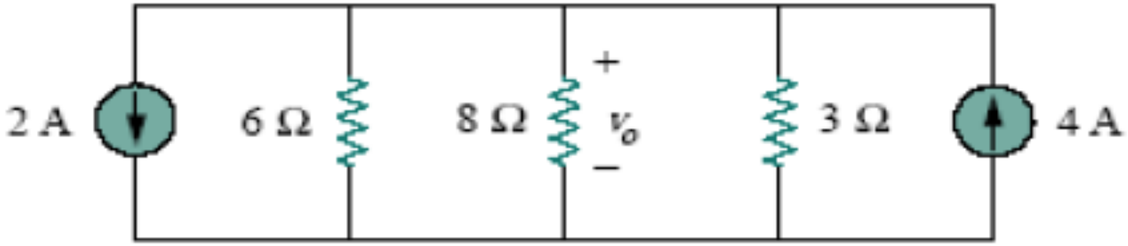
❑ Example

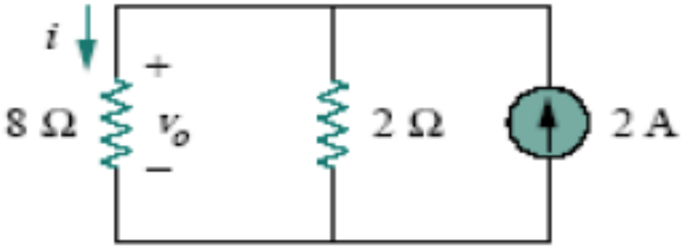




❑ Example







$$i = \frac{2}{2+8}(2) = 0.4$$

$$v_o = 8i = 8(0.4) = 3.2 \text{ V}$$


Thank
you