

MODULE - I

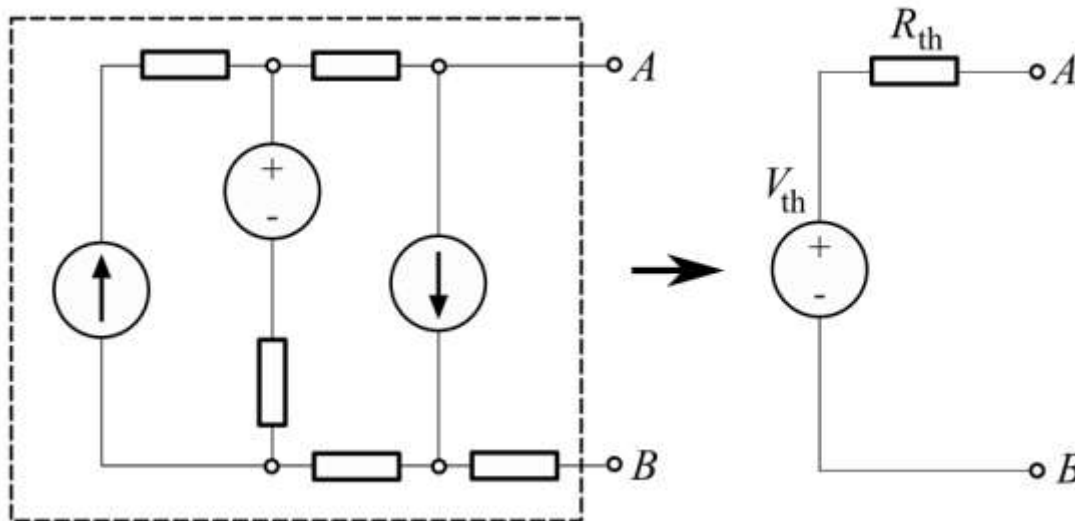
DC CIRCUITS

Contents

- Basic circuit elements and sources
- Ohms law
- Kirchhoff's laws
- Series & Parallel connection of circuit elements
- Mesh current analysis
- Node voltage analysis
- Thevenin's Theorem
- Maximum power transfer theorem.

Thevenin's Theorem

- Statement:
- Thevenin's Theorem states that it is possible to simplify any linear circuit, no matter how complex, to an equivalent circuit with just a single voltage source V_{th} and series resistance R_{th} connected to a load 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.



- The equivalent voltage V_{th} is the voltage obtained at terminals A-B of the network with terminals A-B open circuited.
- The equivalent resistance R_{th} is the resistance that the circuit between terminals A and B would have if all ideal voltage sources in the circuit were replaced by a short circuit and all ideal current sources were replaced by an open circuit.
- If terminals A and B are connected to one another, the current flowing from A to B will be V_{th}/R_{th} . This means that R_{th} could alternatively be calculated as V_{th} divided by the short-circuit current between A and B when they are connected together

- The qualification of “linear” is identical to that found in the Superposition Theorem, where all the underlying equations must be linear (no exponents or roots).
- In general, a circuit is linear if it is both additive and homogeneous. A linear circuit consists of only linear elements, linear dependent sources, and independent sources.
- The additivity property requires that the response to a sum of inputs is the sum of the responses to each input applied separately.
- The homogeneity property requires that if the input (also called the *excitation*) is multiplied by a constant, then the output (also called the *response*) is multiplied by the same constant.

Why?

- It often occurs in practice that a particular element in a circuit is variable (usually called the *load*) while other elements are fixed. As a typical example, a household outlet terminal may be connected to different appliances constituting a variable load. Each time the variable element is changed, the entire circuit has to be analyzed all over again. To avoid this problem, Thevenin's theorem provides a technique by which the fixed part of the circuit is replaced by an equivalent circuit.

Consider the following:

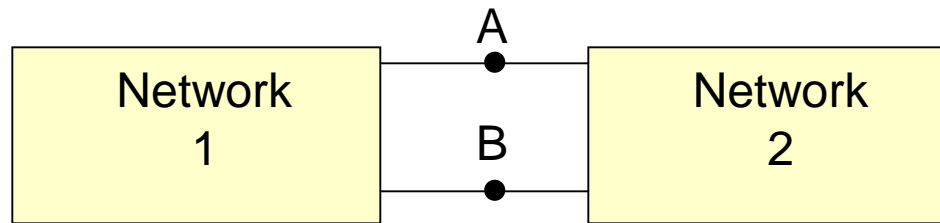


Figure : Coupled networks.

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

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

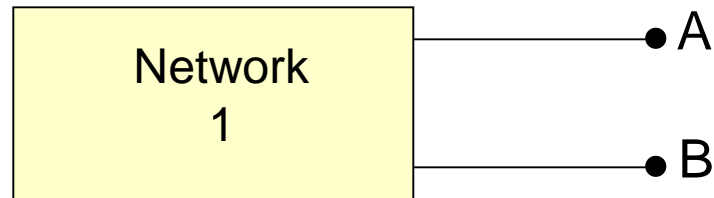
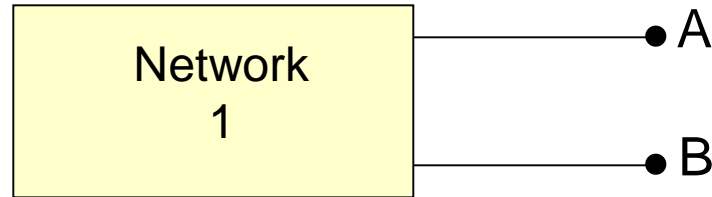


Figure : Network 1, open-circuited.

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

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'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.

Now place an ohmmeter across A – B and read the resistance, that is the Thevenin's resistance R_{TH}

Therefore, the important results are that we can replace Network 1 with the following network.

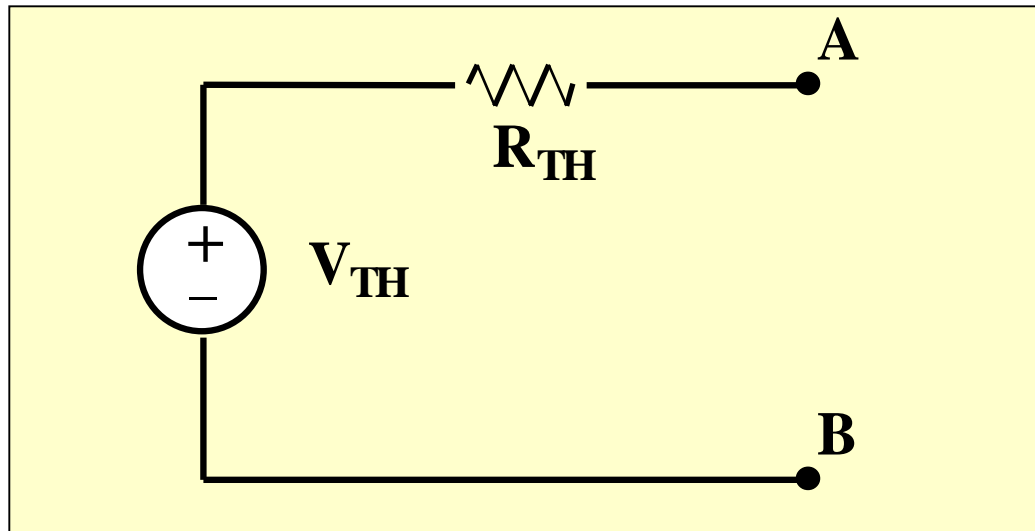


Figure : The Thevenin equivalent structure.

We can now tie (reconnect) Network 2 back to terminals A-B.

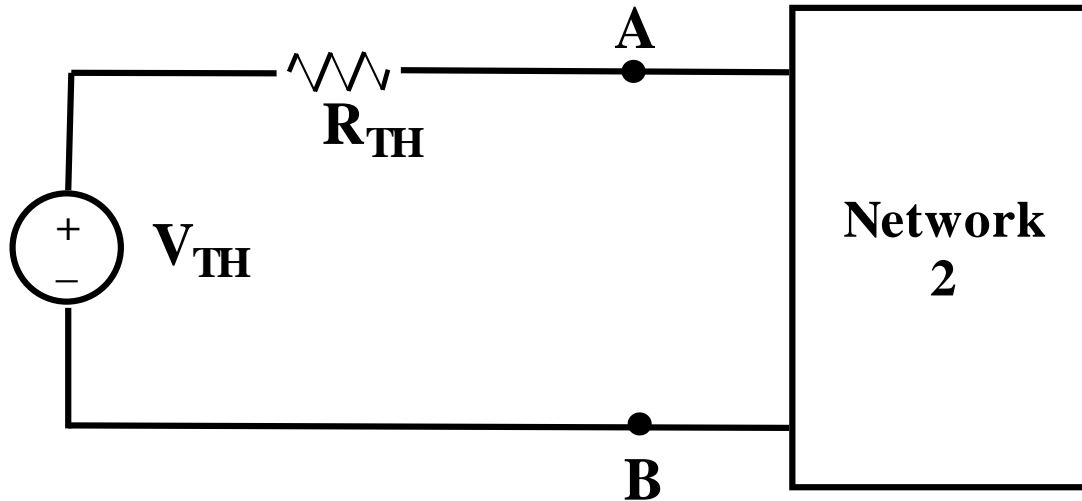


Figure : System of Figure 1 with Network 1 replaced by the Thevenin equivalent circuit.

We can now make any calculations we desire within Network 2 and they will give the same results as if we still had Network 1 connected.

It follows that we could also replace Network 2 with a Thevenin voltage and Thevenin resistance. The results would be as shown in Figure

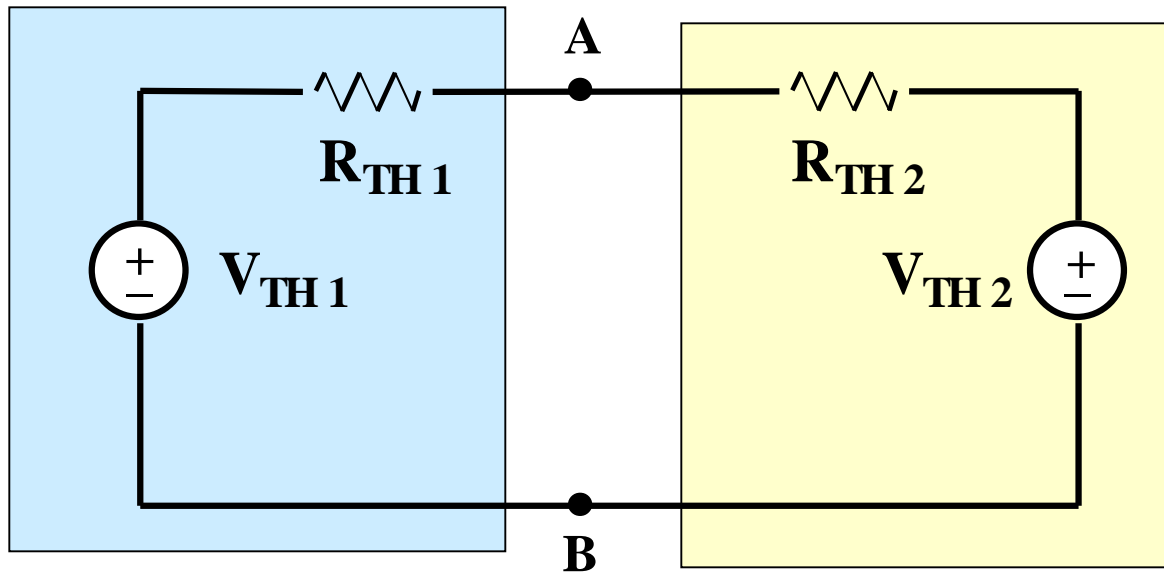
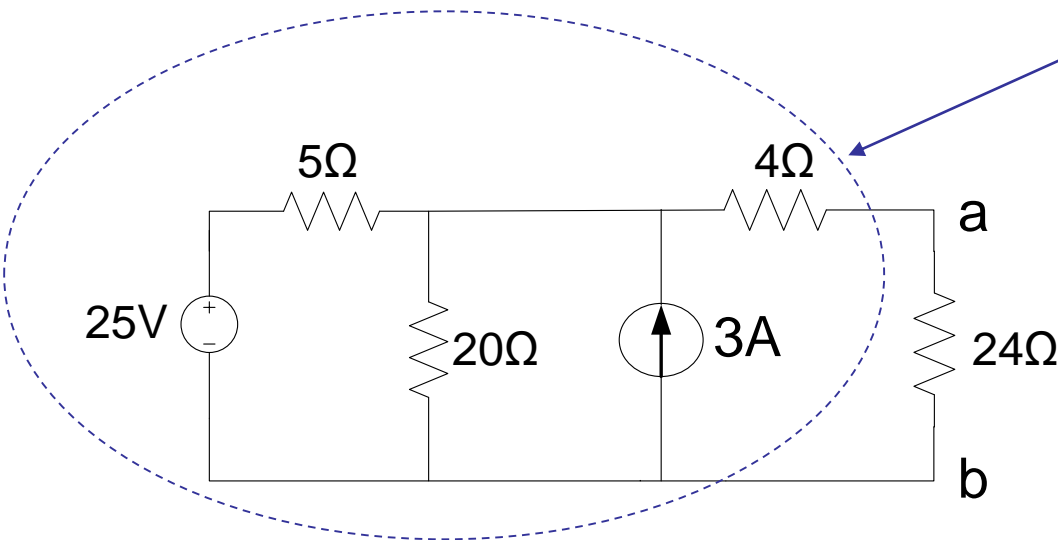
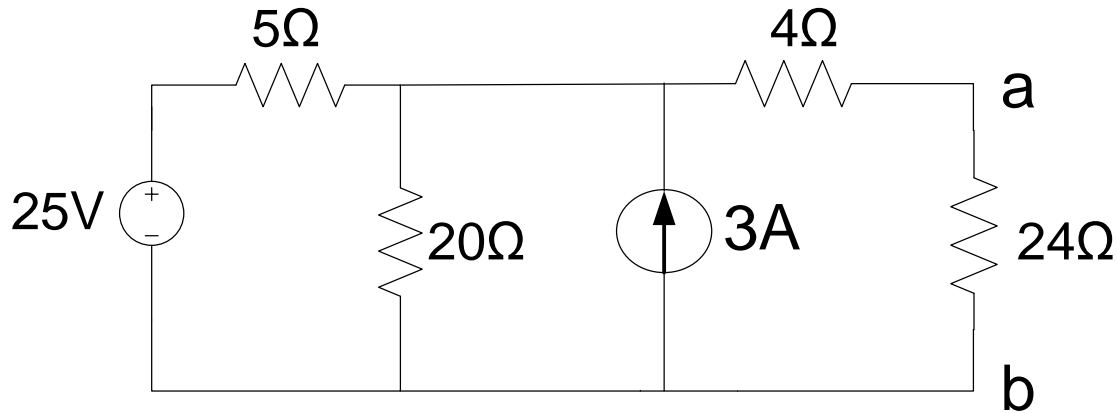


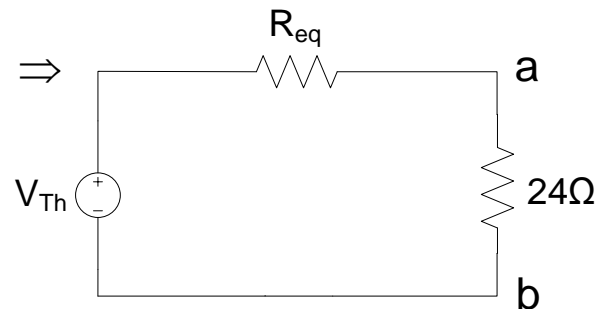
Figure : The network system of Figure 1 replaced by Thevenin voltages and resistances.

Problems

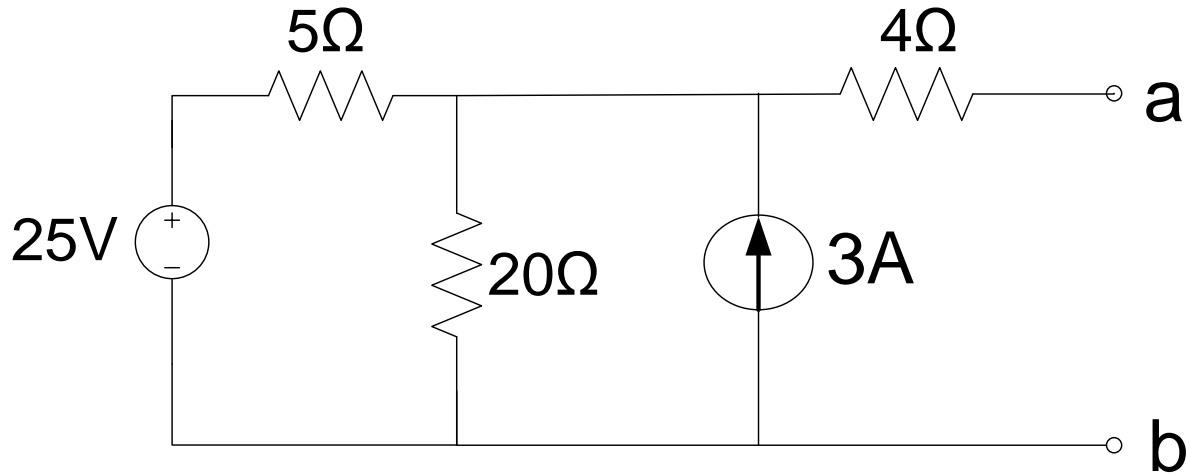
Find voltage V_{ab} across terminal ab



Replace by
Thevenin's Equivalent Circuit

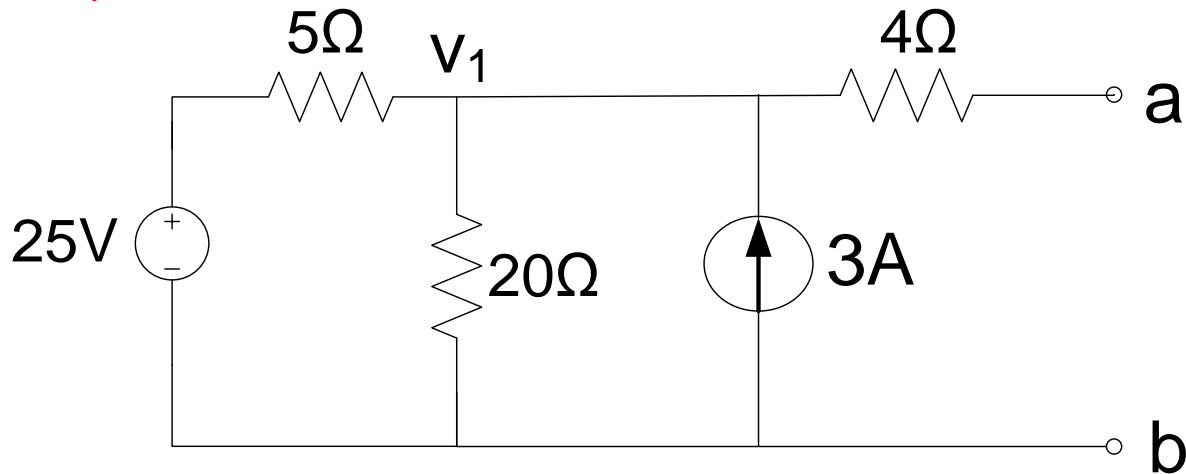


1. Open Circuit ab



$$V_{Th}$$

$$V_{Th} = V_1$$



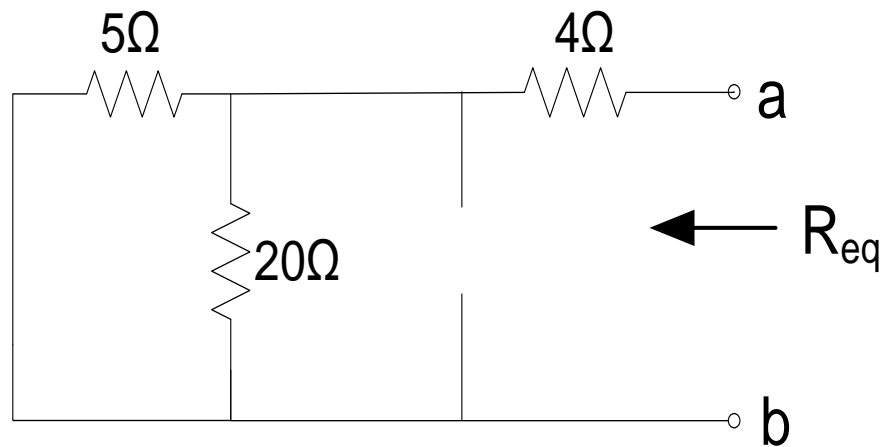
Applying nodal analysis,

$$\frac{v_1 - 25}{5} + \frac{v_1}{20} = 3$$

$$v_1 = 32\text{V} \quad v_{\text{Th}} = 32\text{V}$$

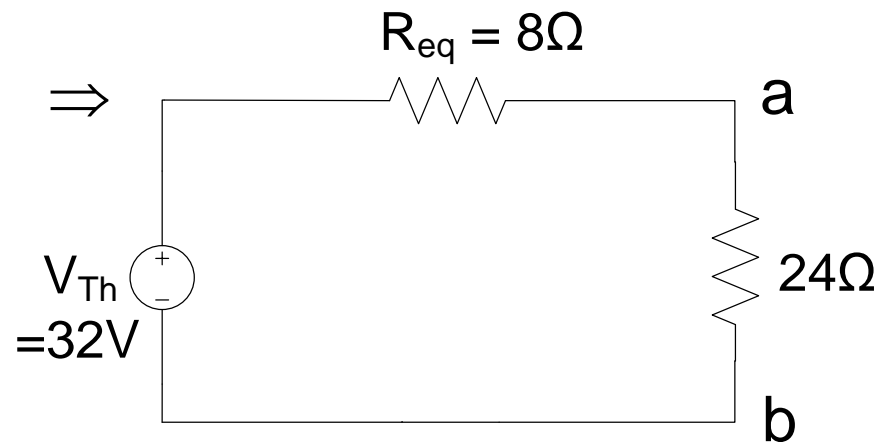
R_{eq}

- Deactivate all independent sources
- ✓ Voltage sources – short circuit
- ✓ Current sources – Open circuit



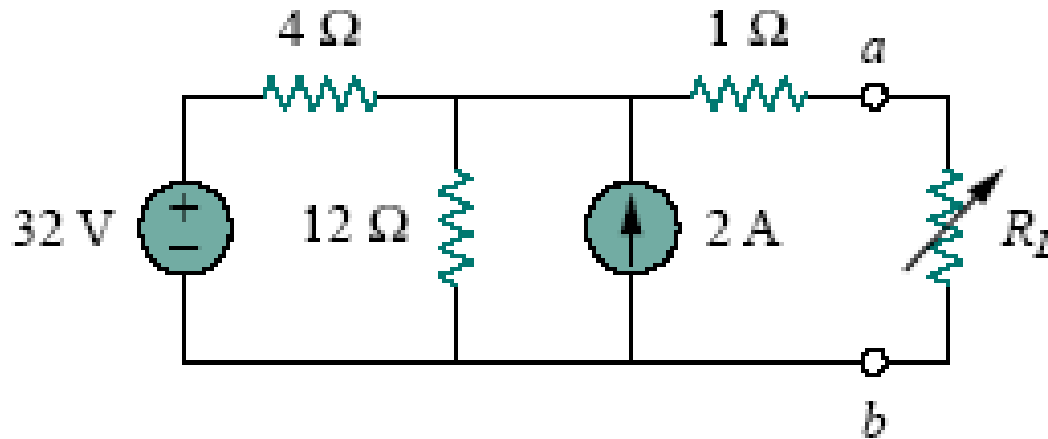
$$R_{eq} = 4 + (20 \parallel 5) = 4 + 4 = 8\Omega$$

Thevenin's Equivalent Circuit



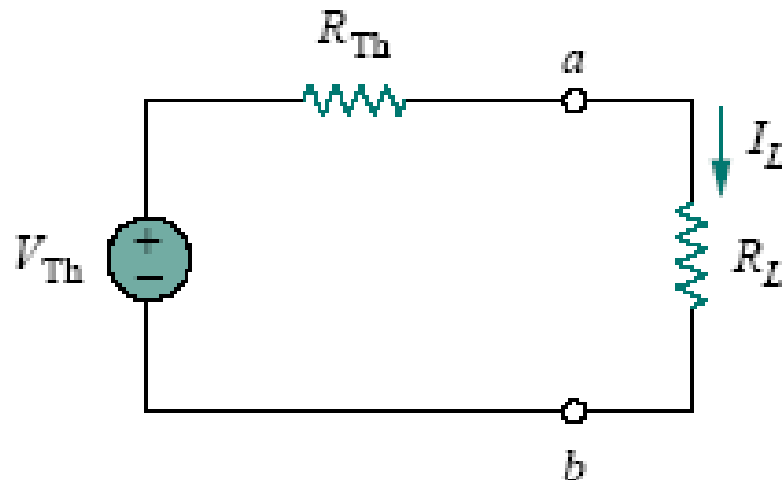
$$V_{ab} = 32 \times \frac{24}{24 + 8} = 24V$$

Find the Thevenin equivalent circuit of the circuit shown in Fig., to the left of the terminals $a-b$. Then find the current through $R_L = 6, 16,$ and 36 .



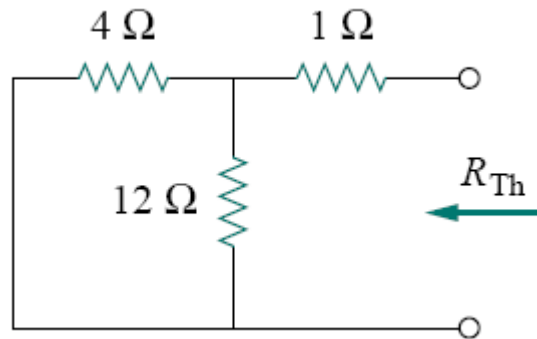
Solution:

Thevenin equivalent circuit



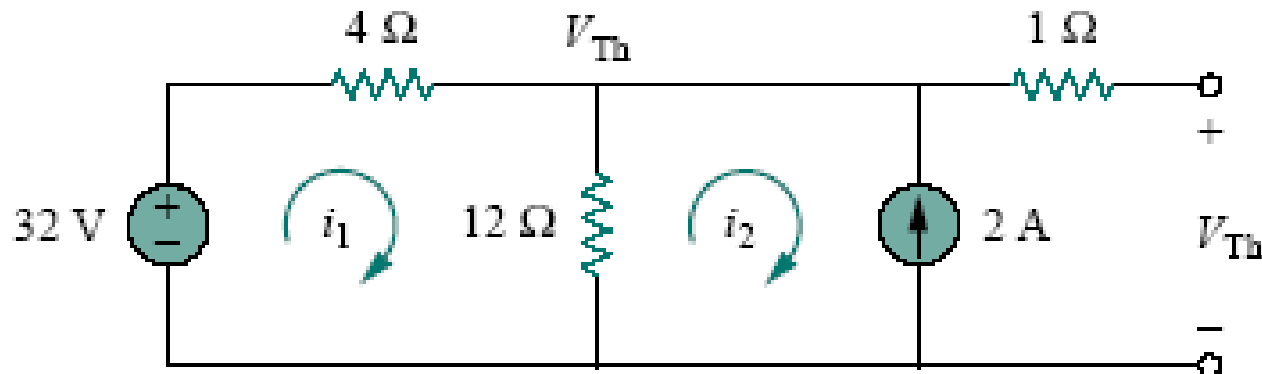
To find R_{Th}

We find R_{Th} by turning off the voltage source (replacing it with a short circuit) and the current source (replacing it with an open circuit). The circuit becomes what is shown in Fig.



$$R_{Th} = 4 \parallel 12 + 1 = \frac{4 \times 12}{16} + 1 = 4\ \Omega$$

To find V_{Th} ,



Applying mesh analysis to the two loops, we obtain

$$-32 + 4i_1 + 12(i_1 - i_2) = 0, \quad i_2 = -2 \text{ A}$$

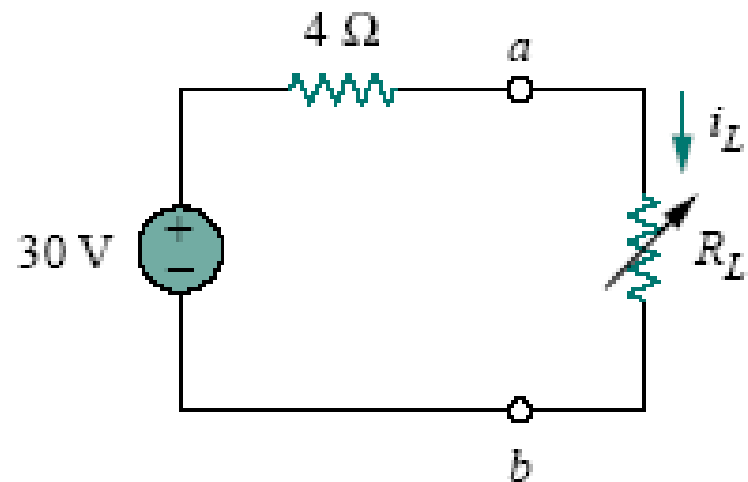
Solving for i_1 , we get $i_1 = 0.5 \text{ A}$. Thus,

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

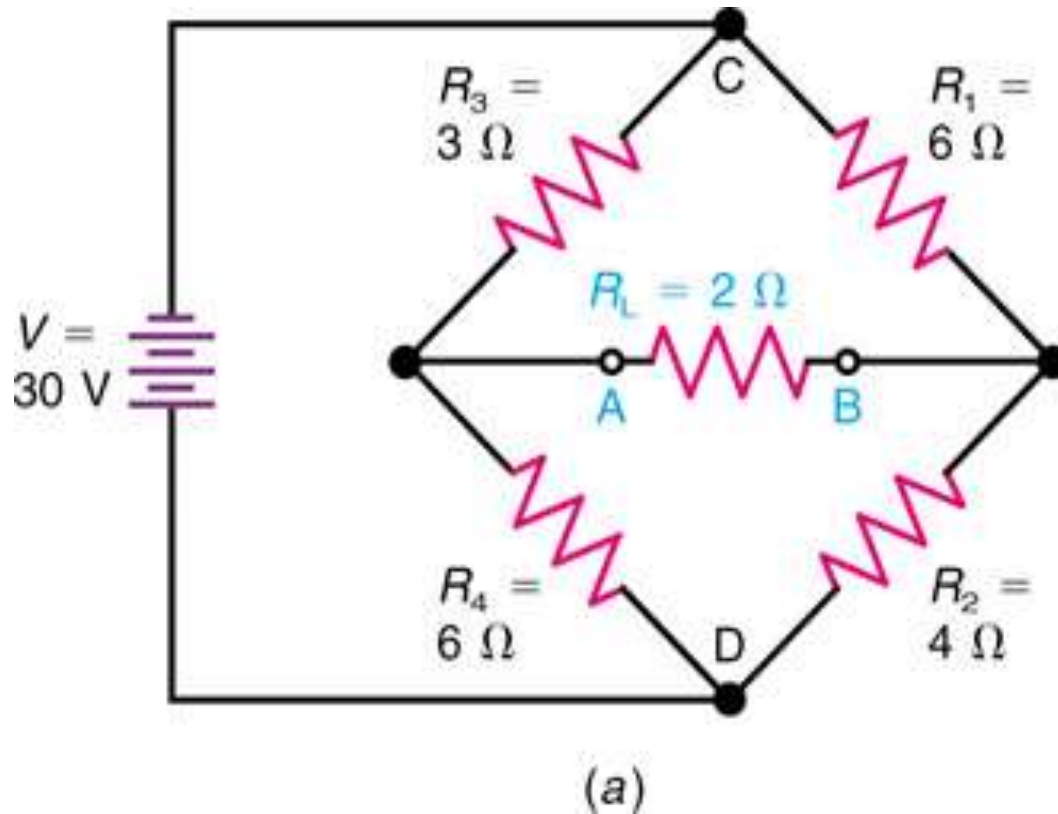
Thevenin equivalent circuit

The current through R_L is

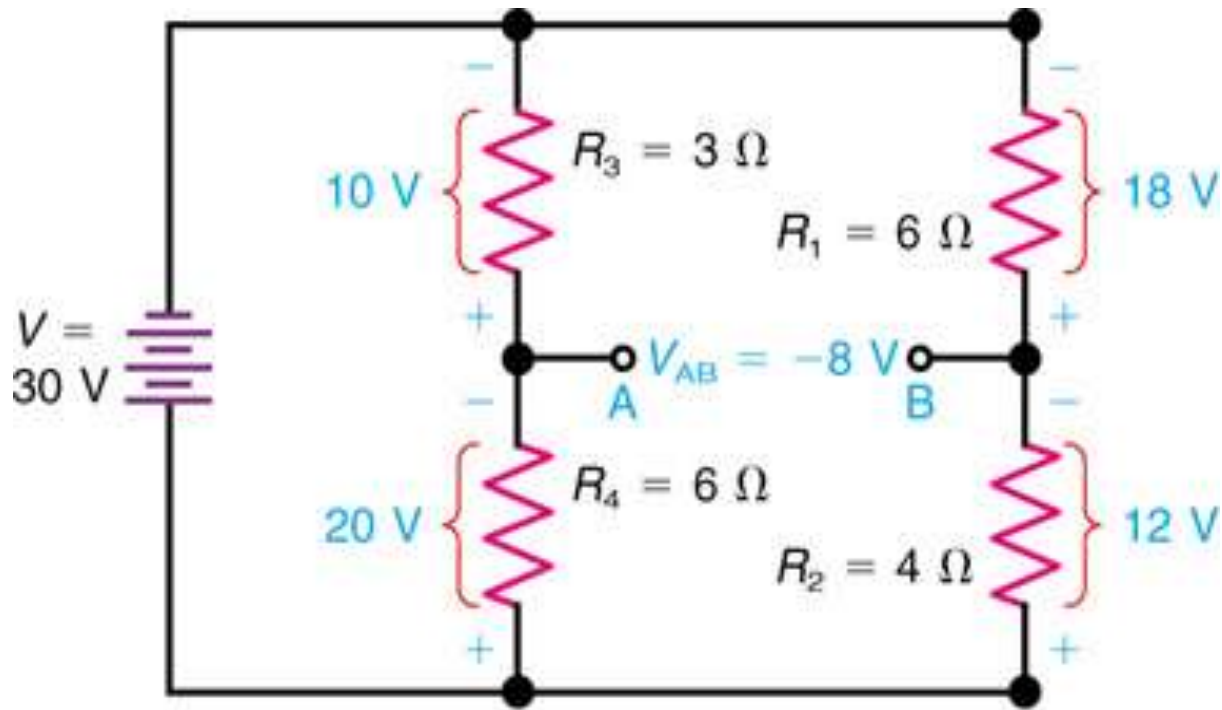
$$I_L = \frac{V_{\text{Th}}}{R_{\text{Th}} + R_L} = \frac{30}{4 + R_L}$$



Find the voltage drop across R_L .



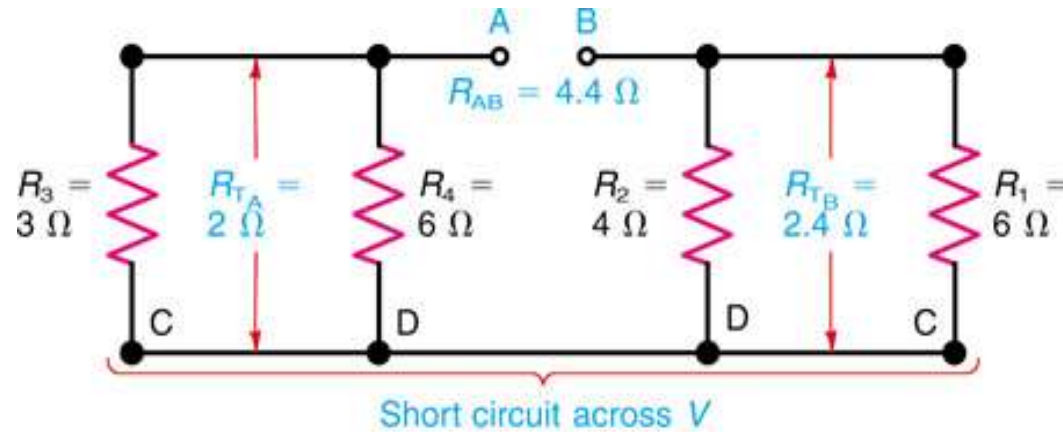
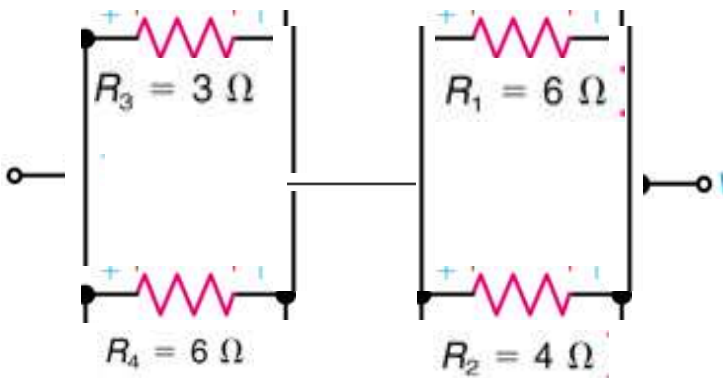
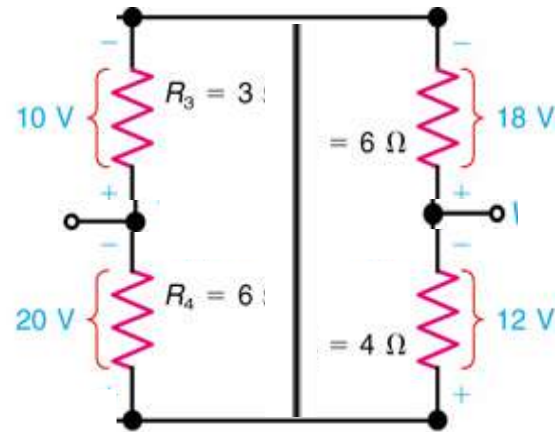
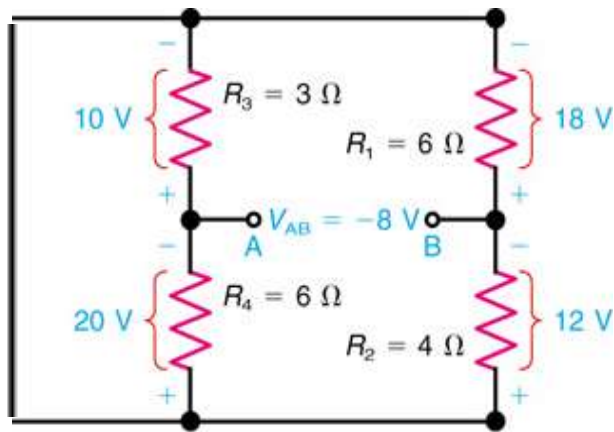
R_L will be removed in this procedure making A and B the Thevenin terminals



(b)

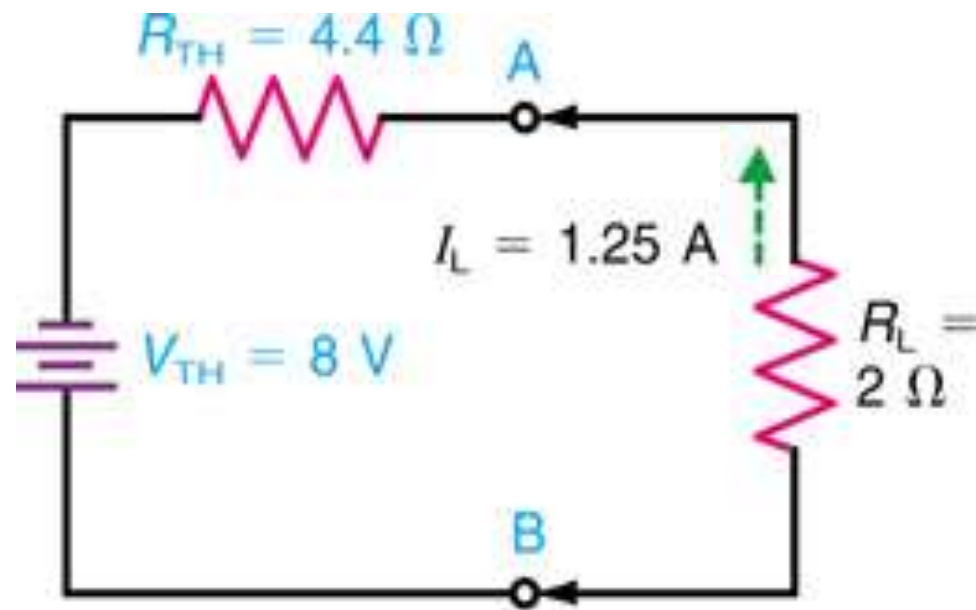
$$V_{AB} = -20 - (-12) = -8V$$

R_{TH}



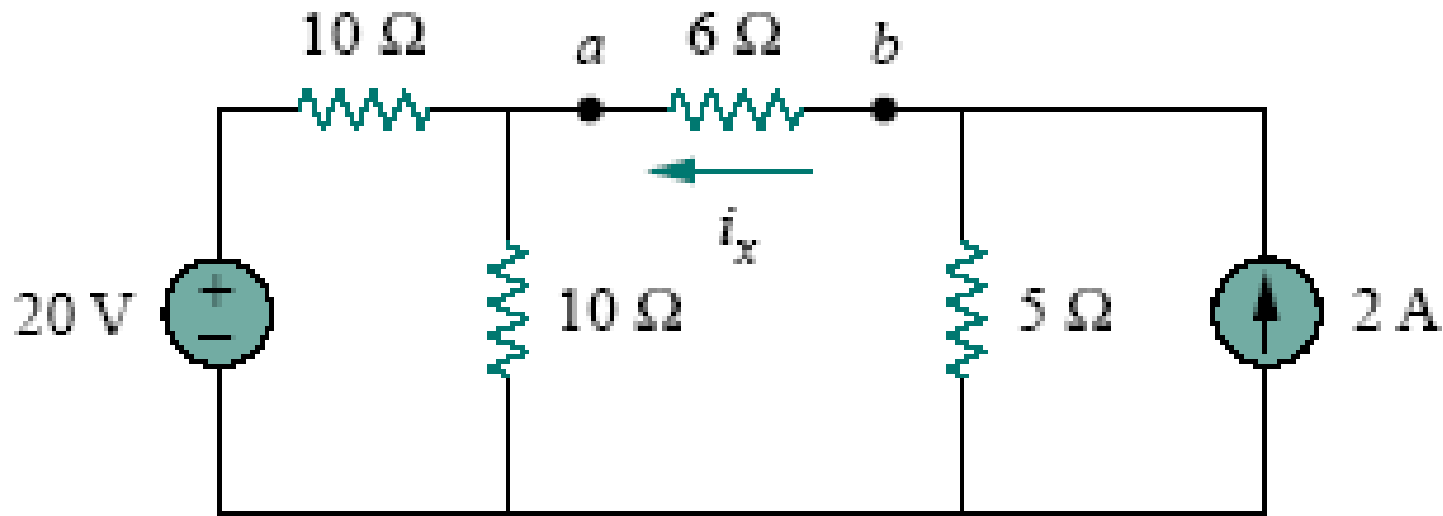
(c)

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

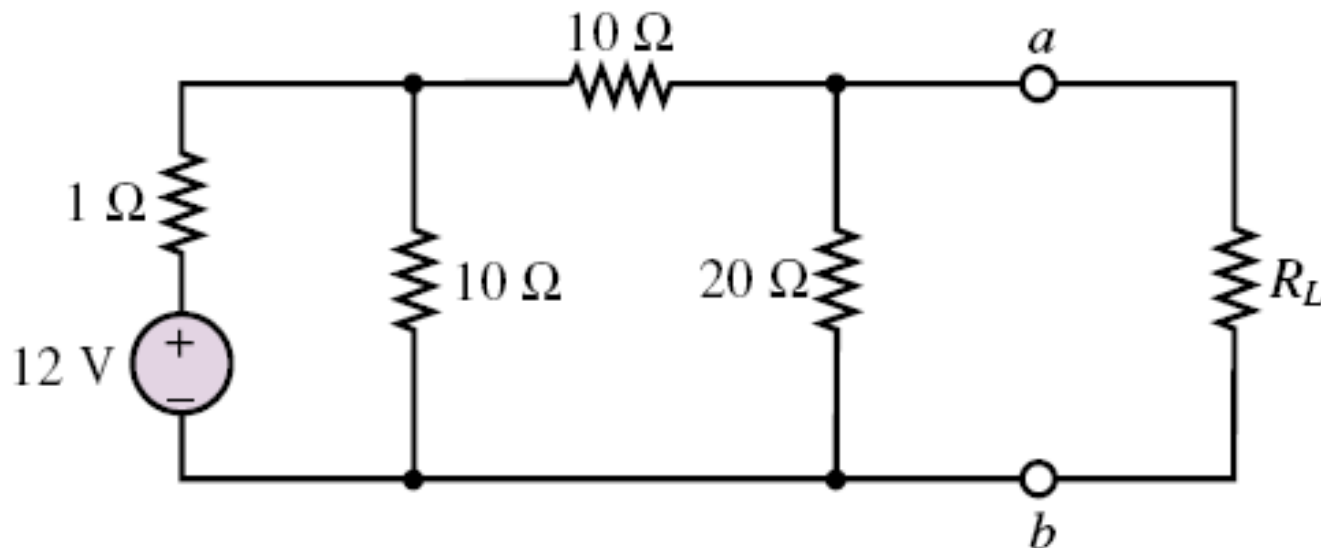


(d)

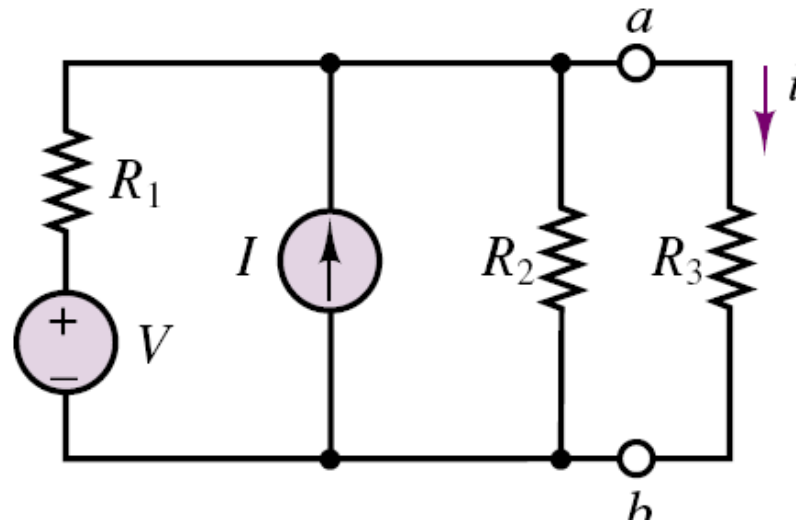
P1.20. Find the Thevenin equivalent looking into terminals a - b of the circuit in Fig. and solve for i_x .



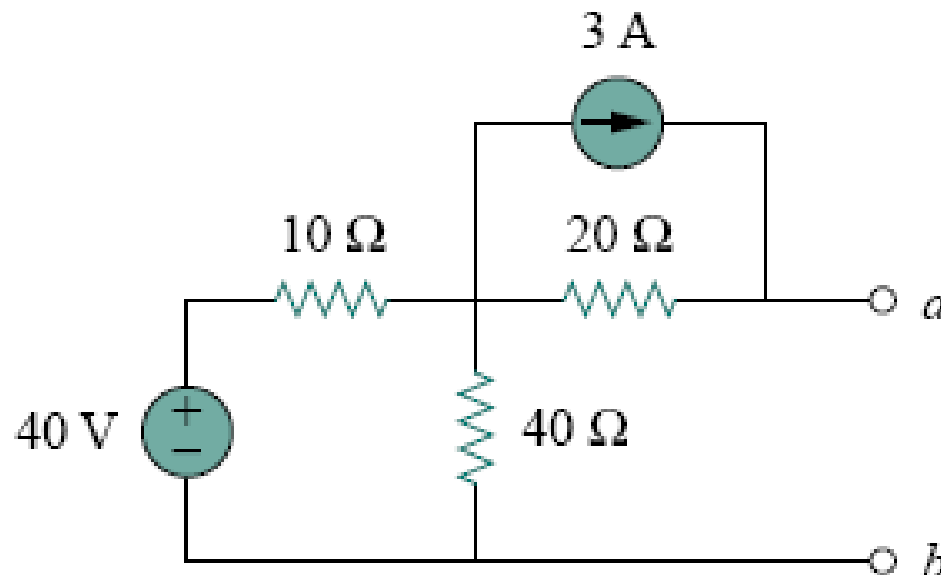
P1.21. For the circuit of Figure, find the Thevenin equivalent circuit seen by the load resistor, R_L .



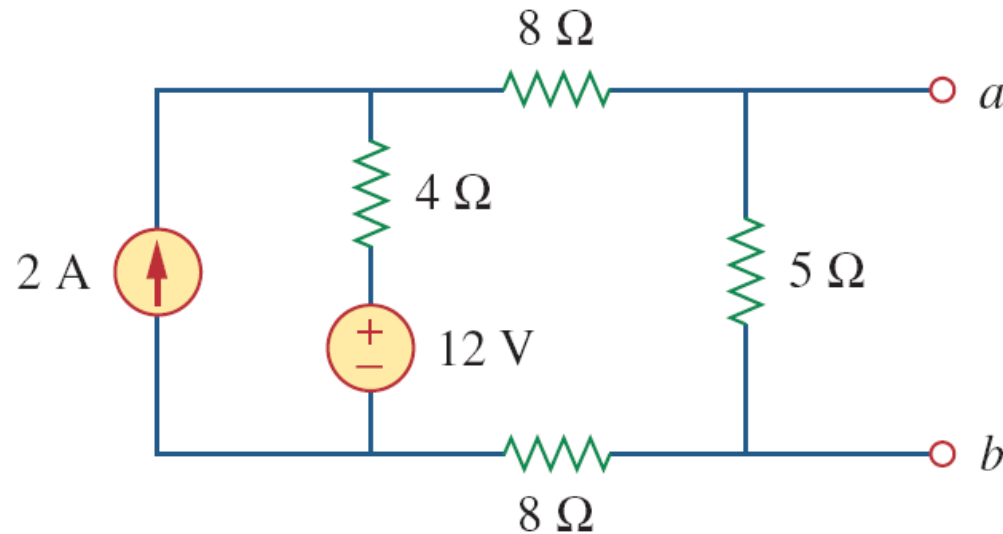
P1.22. Compute the load current, i , by the Thevenin equivalent method in the circuit of Figure.



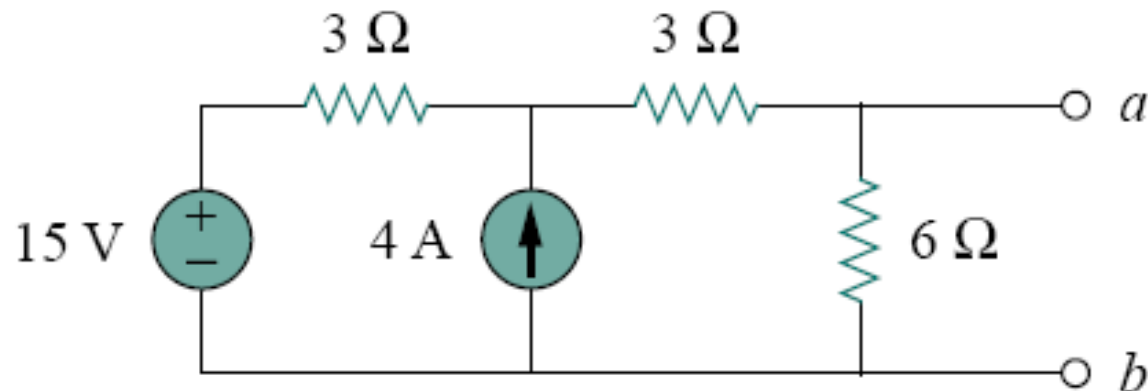
P1.23. Find the Thevenin equivalent at terminals $a-b$ of the circuit in Fig.



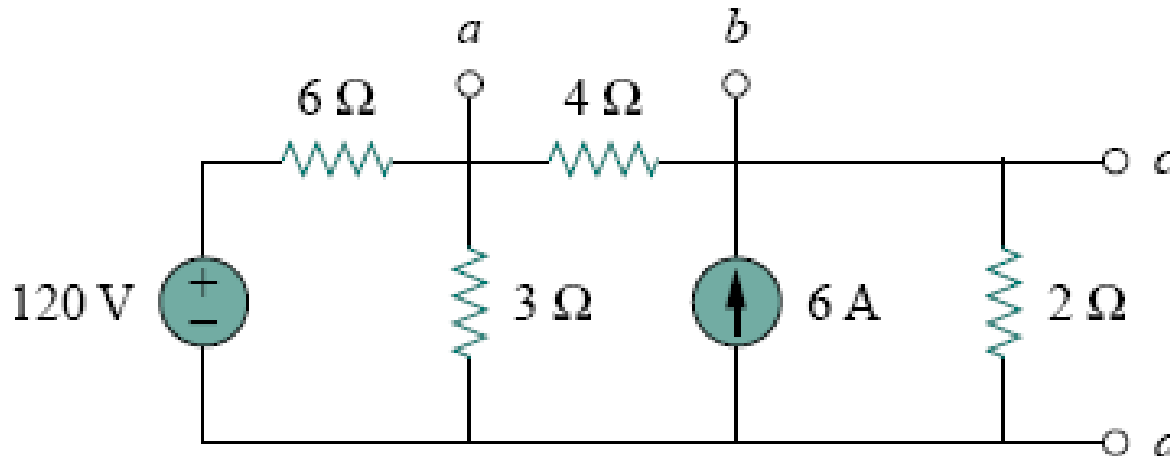
P1.24. Find Thevenin's equivalent circuit of the circuit in Fig.



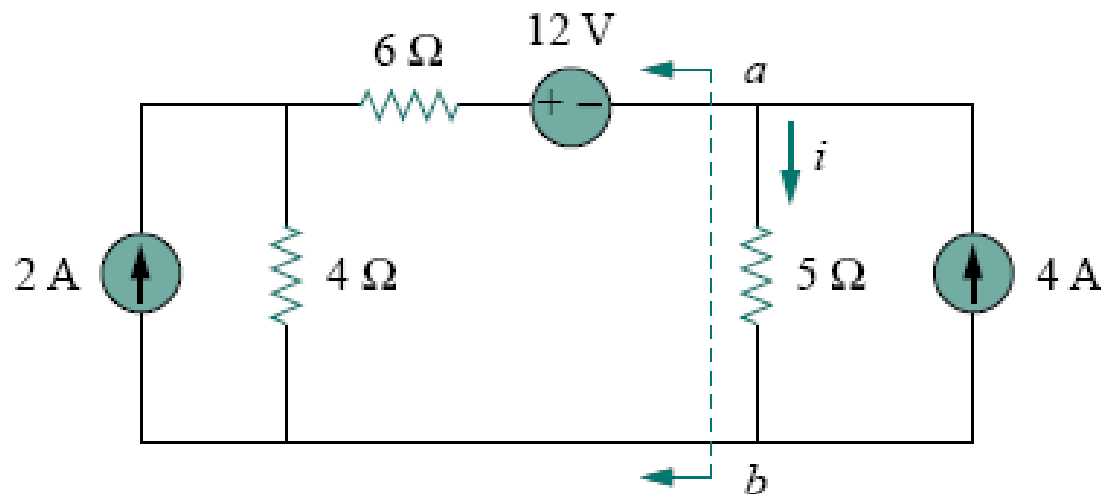
P1.25. Find Thevenin's equivalent circuit for the circuit in Fig.



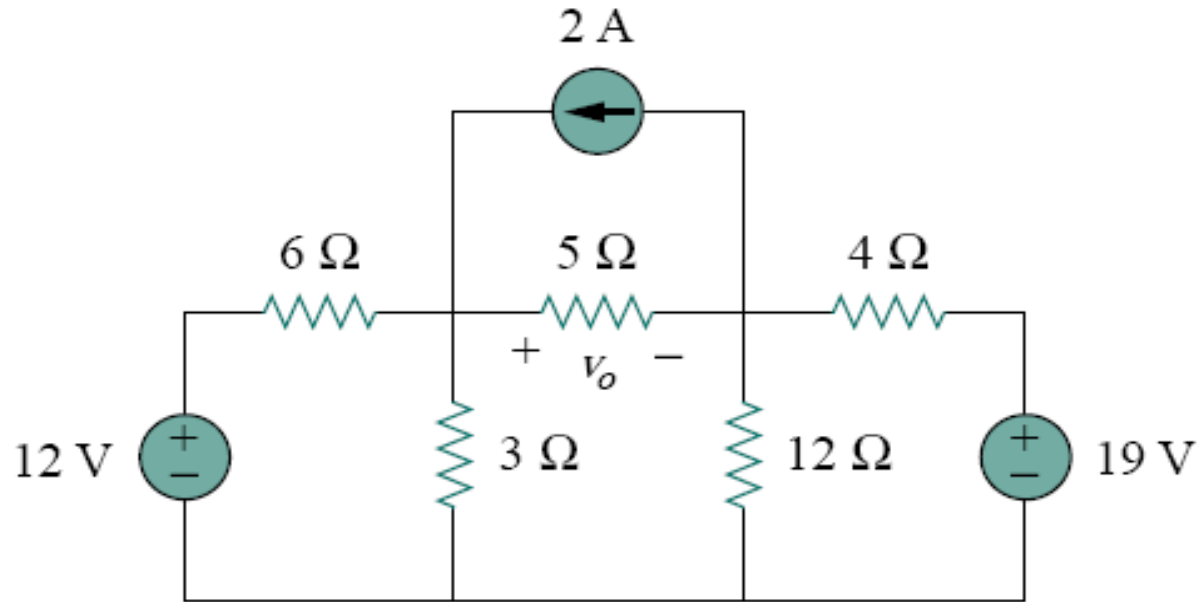
- P1.26.** Obtain Thevenin's equivalent as viewed from terminals:
 (a) $a-b$ (b) $c-d$



- P1.27.** Obtain Thevenin's equivalent of the circuit in Fig. Find current i .



P1.28. Determine v_o in the circuit of Fig.



P1.29. Find current i_x .

