Department of Electronics & Electrical Engineering

Lecture 2

Basic Nodal and Mesh Analysis

By

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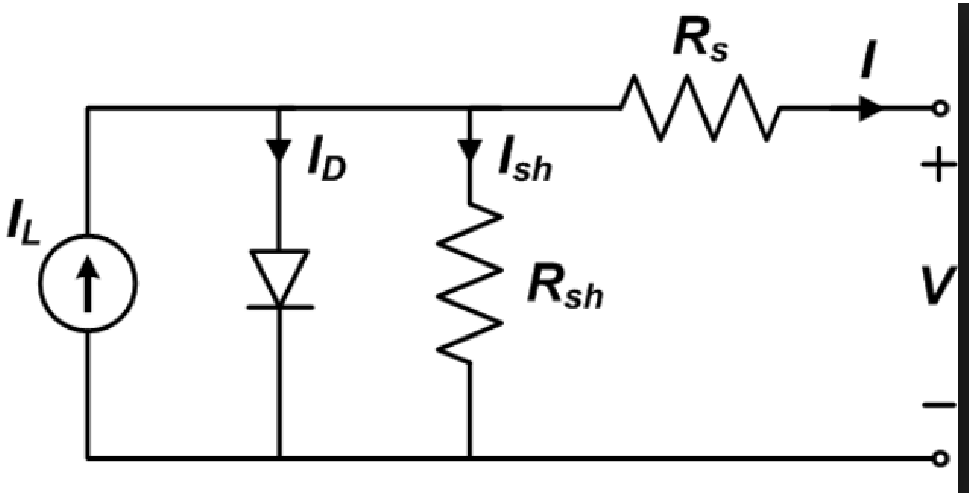
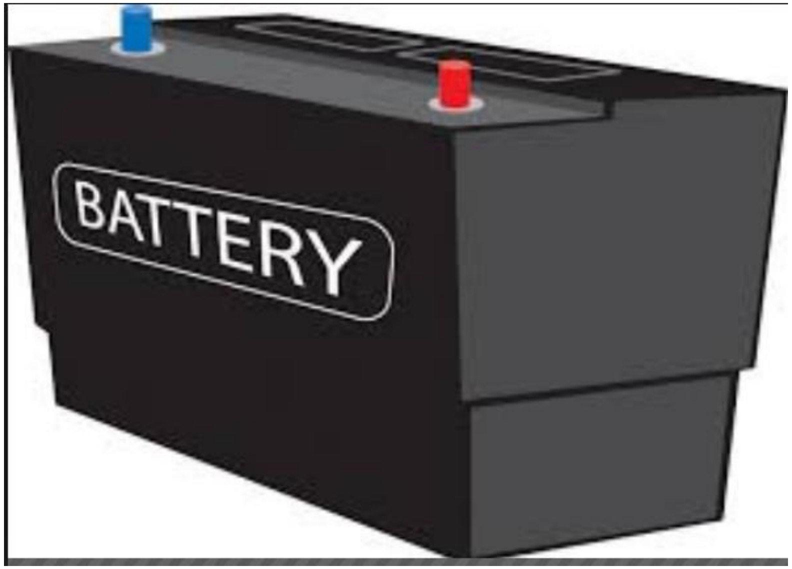
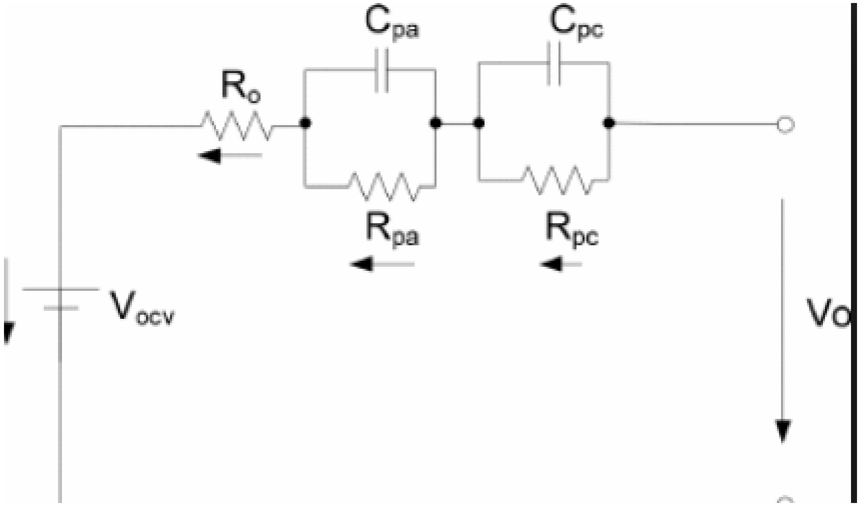
Why Electrical Circuits

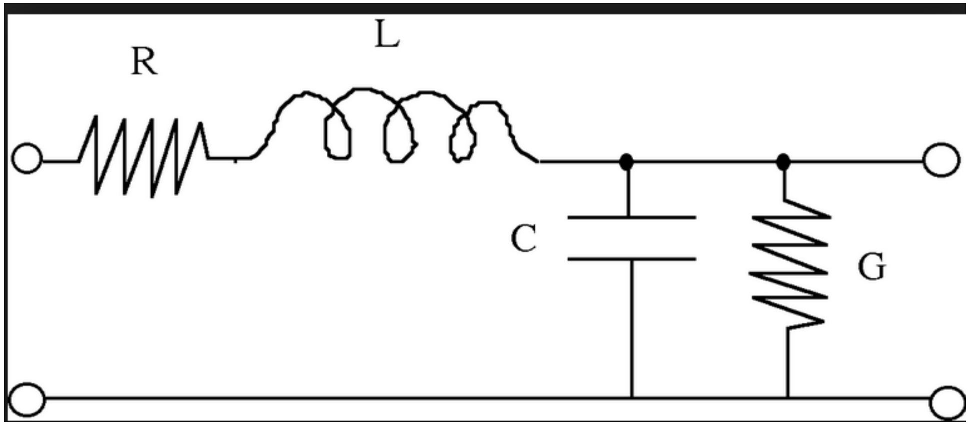


Why Electrical Circuits





Why Electrical Circuits



Nodal Analysis

- To illustrate the basic mechanics of the technique, consider the three node circuit shown in Fig.1. In this network there are three nodes.

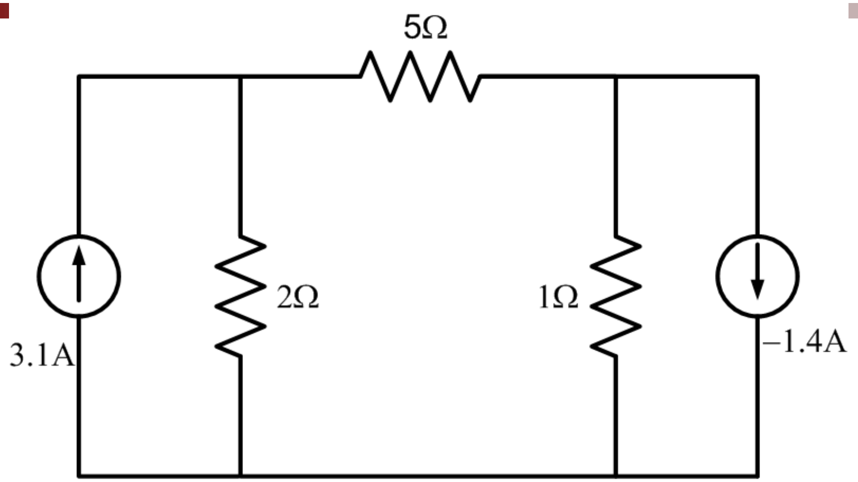
- A three node circuit should have two unknown voltages and two equations; a 10-node circuit will have nine unknown voltages and nine equations; an N-node circuit will need (N-1) voltages and (N-1) equations.

- In the Fig.1b, it is shown that the network has three unique nodes. One node is designated as a ***reference node*** (Fig.1c) and it is the negative terminal of the nodal voltages.

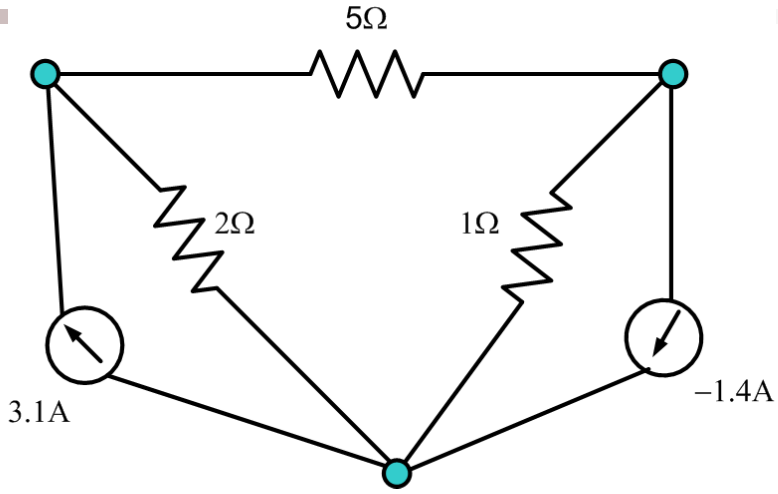
- As a general rule, a node having maximum number of branches is chosen as the reference node. By doing so the number of equations defining the network reduce.

- In Fig.1c, the voltage of node 1 relative to the reference node is defined as V_1 and V_2 is defined as the voltage of node 2 with respect to the reference node. The voltage between any other pair of nodes may be found in terms of V_1 and V_2.

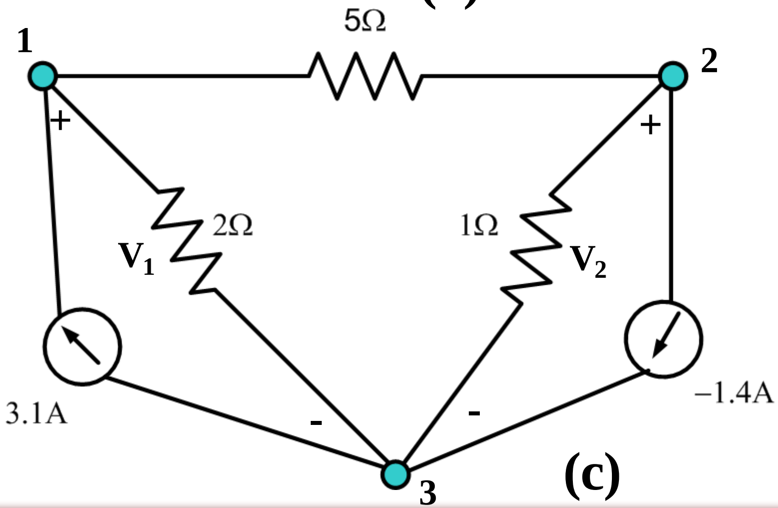
Nodal Analysis



(a)



(b)



(c)

Nodal Analysis Steps

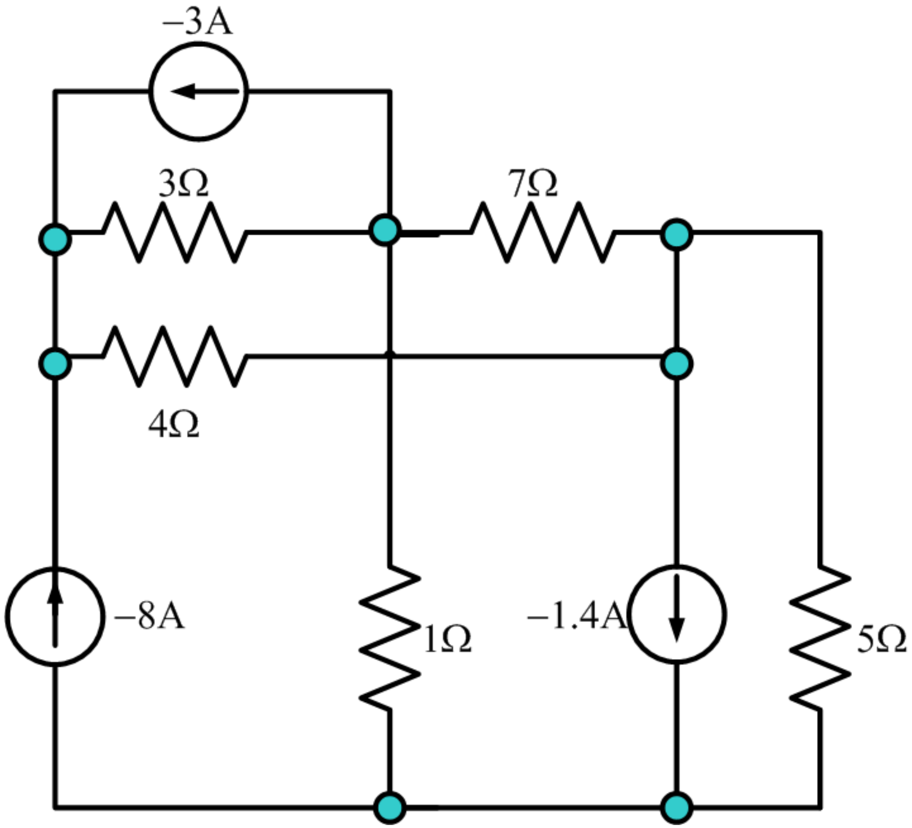


Fig.2a: A 4 node network

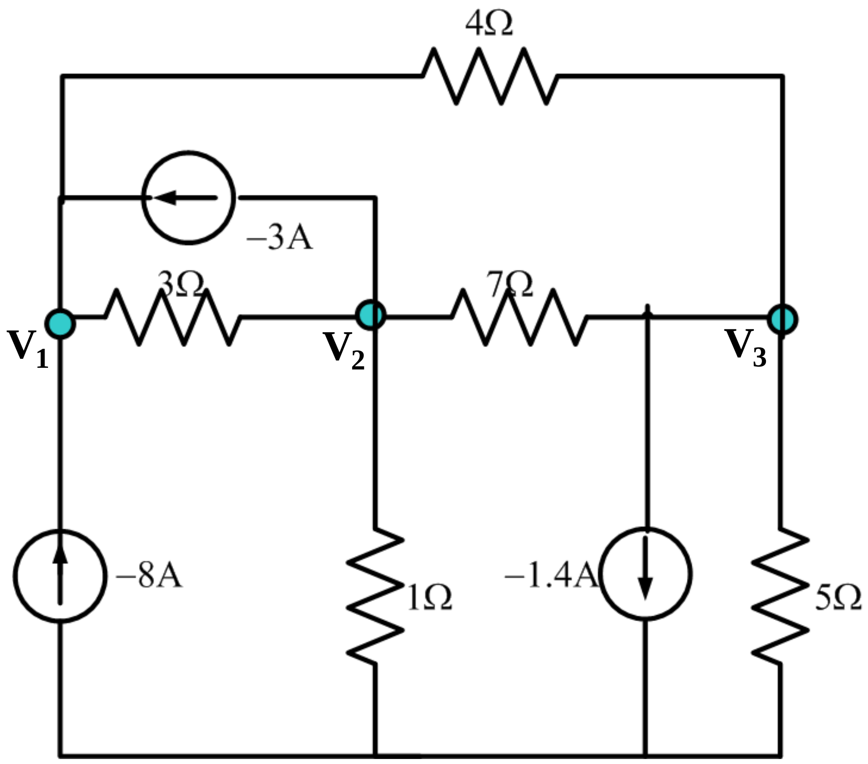


Fig.2b: Redrawn network

Nodal Analysis Steps

- ***Identify the goal of the problem***: *There are four nodes in this network. The bottom most node is selected as the reference node and all the other three nodes are labeled as shown in Fig.2b.*

- ***Collect the information***: *There are three unknown voltages V1, V2 and V3. All current sources and resistors have designated values which are marked on the schematic.*

- ***Devise a plan***: *This problem is well suited for nodal analysis and three independent KCL equations may be written.*

- ***Construct an appropriate set of equations***:

$$\begin{aligned}
&\frac{V_1-V_2}{3}+\frac{V_1-V_3}{4}=-8-3 \text{ at node 1}\\
&\frac{V_2-V_1}{3}+V_2+\frac{V_2-V_3}{7}=3 \text{ at node 2}\\
&\frac{V_3}{5}+\frac{V_3-V_2}{7}+\frac{V_3-V_1}{4}=1.4 \text{ at node 3}
\end{aligned} \qquad (1)$$

The Supernode

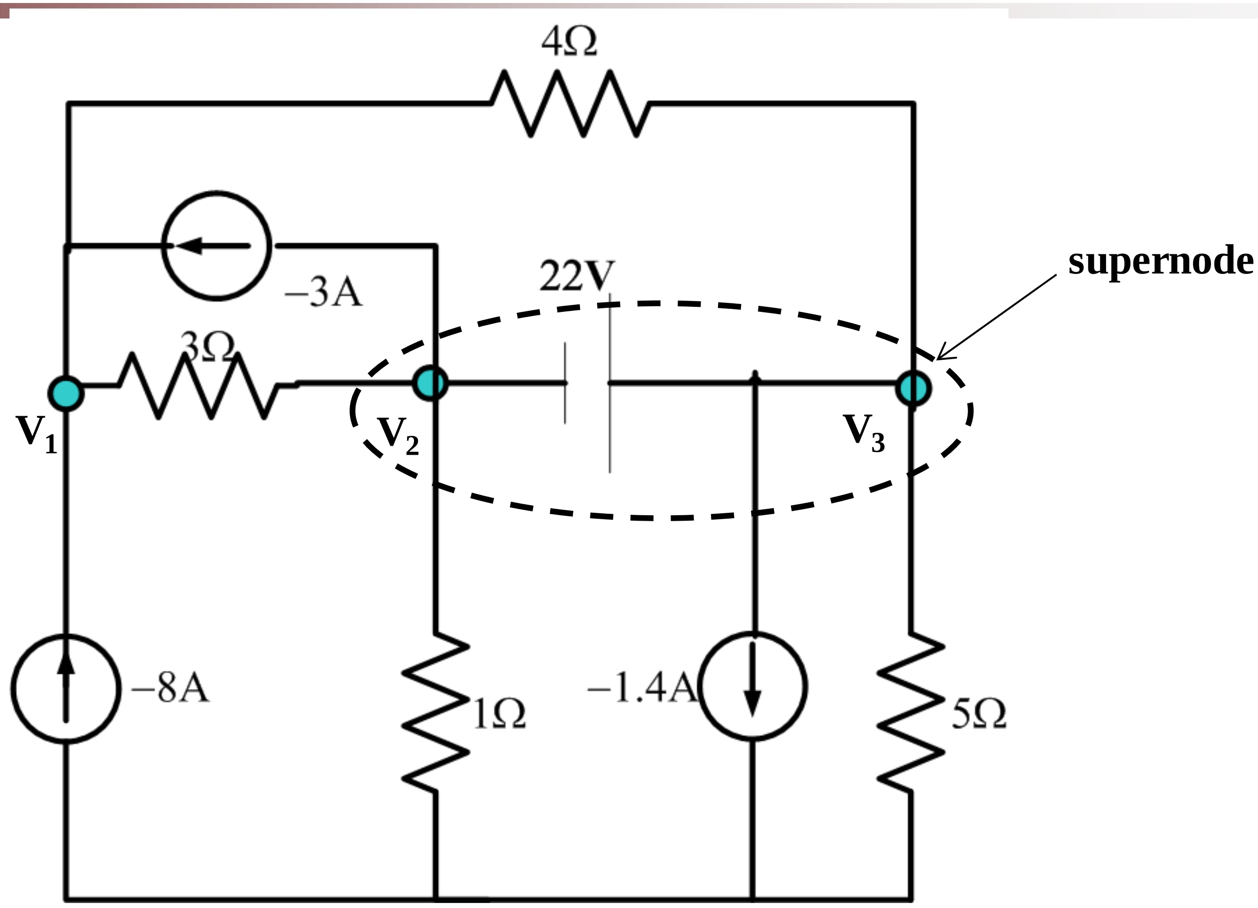


Fig.3: A network with a supernode

The Supernode

- Consider the network shown in Fig.3. If KCL is applied as in the previous example then we will run into difficulty at nodes 2 and 3 because the current in that branch is unknown.

- To overcome the dilemma the node 2, node 3 and the voltage source together are considered as a ***supernode*** and then KCL is applied. The super node is shown as a region enclosed by the broken lines.

- The system of equations are:

$$\frac{V_1 - V_2}{3} + \frac{V_1 - V_3}{4} = -8 - 3 \text{ at node 1}$$

$$\frac{V_2 - V_1}{3} + \frac{V_3 - V_1}{4} + \frac{V_3}{5} + V_2 = 3 + 1.4 \text{ at supernode} \qquad (2)$$

The third equation is

$$V_2 - V_3 = -22$$

Mesh Analysis

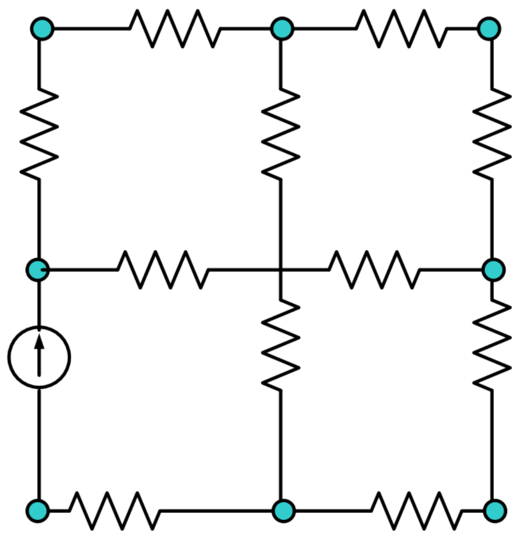
- The node analysis is a general method and can always be applied to any electrical network.

- An alternative technique to analyse thew networks is ***mesh analysis***. ***This technique is not general and can be applied to only planar networks***.

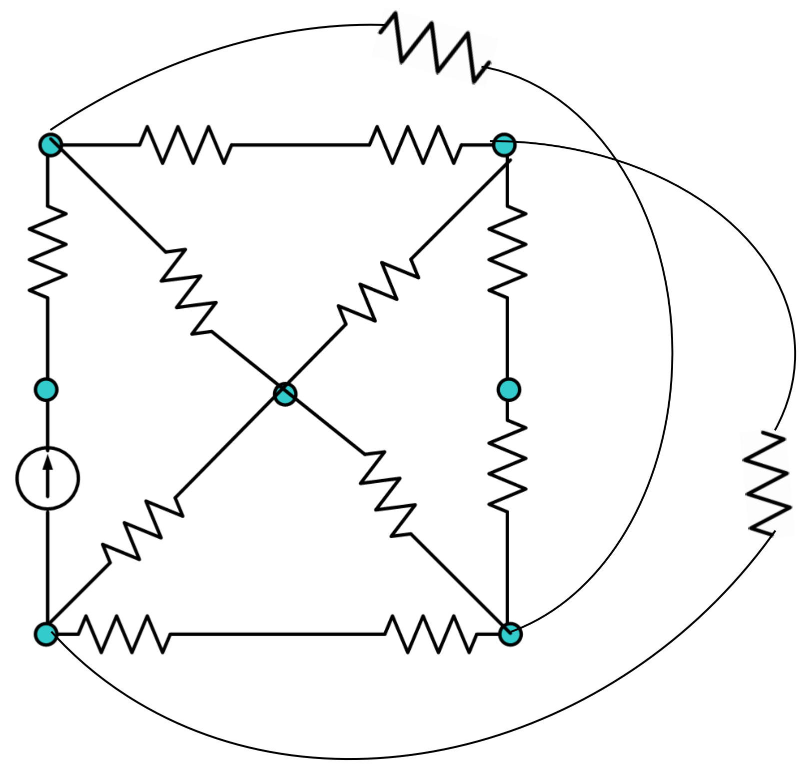
- If it is possible to draw the diagram of the network on a plane surface in such a way that no branch passes over or under any other branch, then the network is said to be a ***planar network*** (Fig.4).

- If a network is planar, mesh analysis can be used to accomplish the analysis. This concept involves the concept of a ***mesh current***.

Planar and Non Planar Networks



a. Planar network



b. Non-planar network

Fig.4: Planar and non planar networks

Mesh Analysis

- A two mesh circuit is shown in Fig.5. We define a ***mesh current*** as a current that flows only around the perimeter of a mesh.

- The left hand mesh has a current $\mathbf{i_1}$ flowing in a clockwise direction and a mesh current of $\mathbf{i_2}$ is established in the remaining mesh.

- The system of equations for the network is as follows:

$$\begin{aligned} &6i_1 + 3(i_1 - i_2) = 42 \quad \text{for mesh 1} \\ &3(i_2 - i_1) + 4i_2 = 10 \quad \text{for mesh 2} \end{aligned} \tag{3}$$

- Solving the above two equations, the mesh currents $\mathbf{i_1}$ and $\mathbf{i_2}$ are obtained as

$$i_1 = 6A$$
$$i_2 = 4A$$

Mesh Analysis

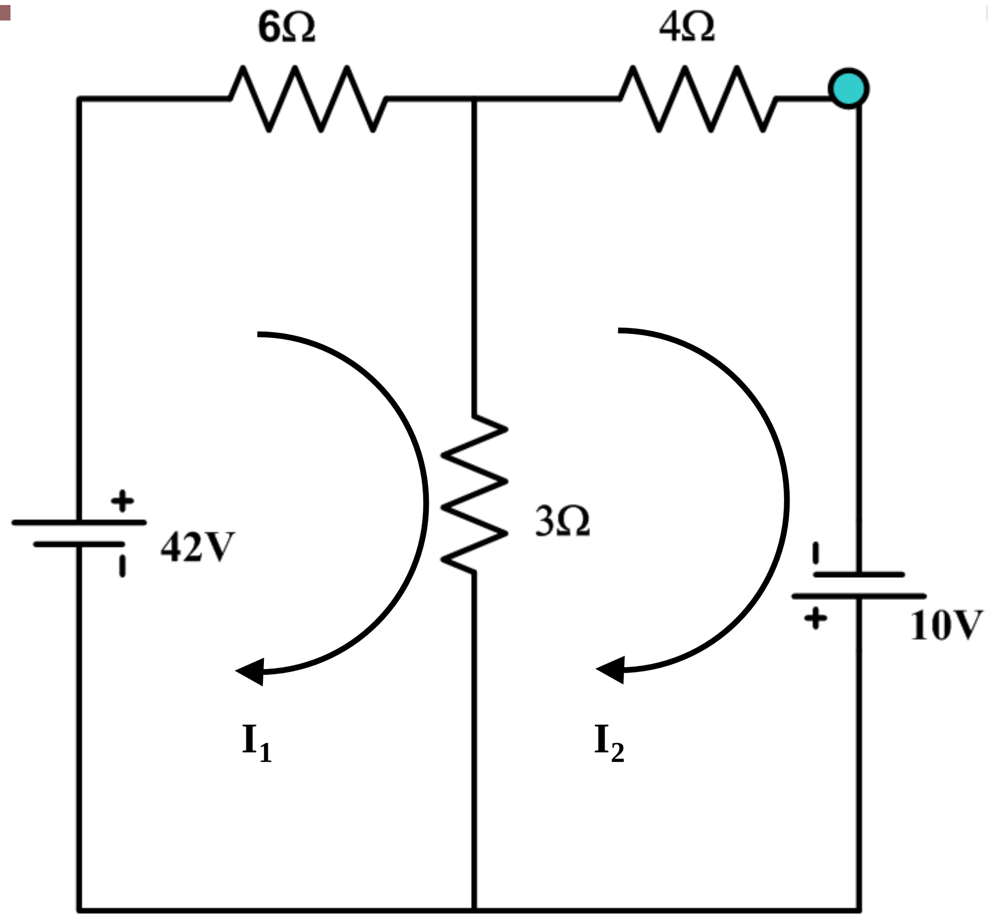


Fig.5: Mesh Analysis

Ideal Independent Current Source

- The ideal independent current source is a two terminal element which supplies its specified current to the circuit in which it is placed independent of the value and direction of the voltage appearing across its terminals.

- In Fig.6, the voltage vs. current characteristics of the ideal current source are shown.

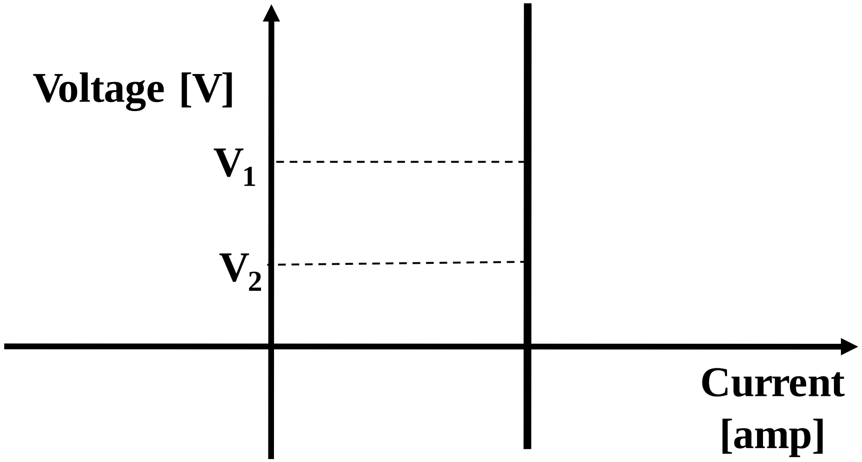


Fig.6: Characteristics of ideal current source

Ideal Dependent Sources

- In case of ideal ***dependent*** or ***controlled*** source, the source quantity is determined by a voltage or current existing at some other location in the system being analyzed.
- The ***dependent*** sources appear in the equivalent electrical models for many electronic devices such as transistors, operational amplifiers and integrated circuits.
- The dependent sources are represented as diamonds to distinguish them from independent sources (Fig.7).

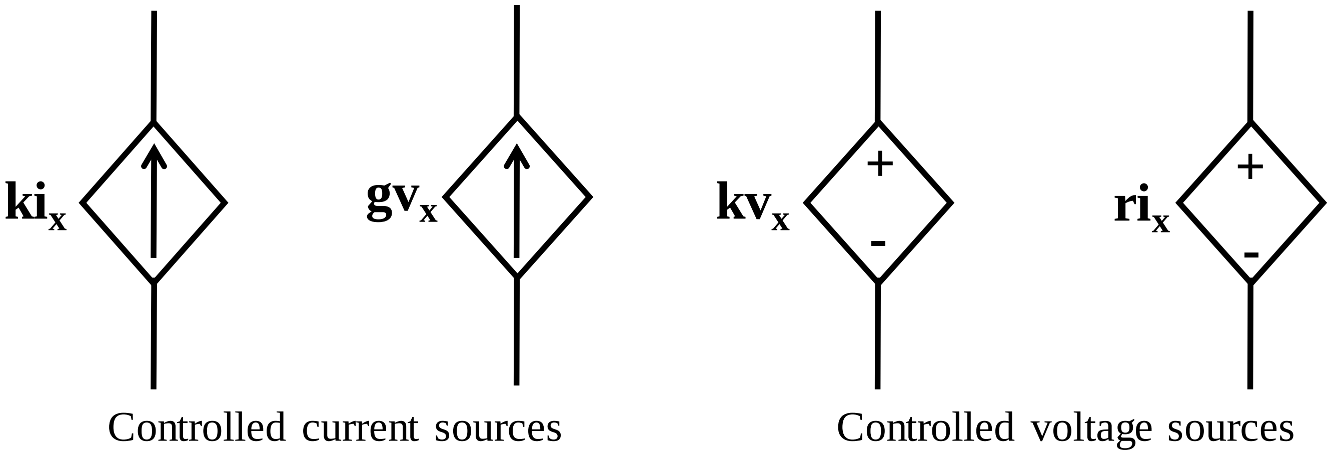


Fig.7: Controlled or dependent sources

Example 1

- Determine $\mathbf{v_x}$ in the circuit shown in Fig.8

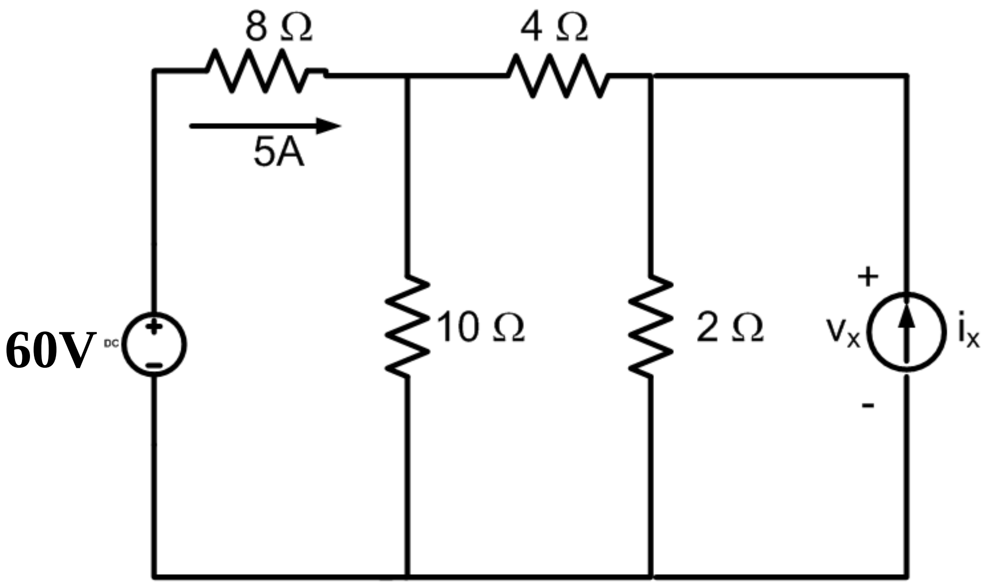


Fig.8: Circuit for the example 1

Solution

- First the given network is properly labeled (Fig.9)
- Using KVL

$$-60 + v_8 + v_{10} = 0$$

$$-v_{10} + v_4 + v_x = 0$$

- The value of v_8 and v_{10} are

$$v_8 = 5 \times 8 = 40V$$

$$\therefore V_{10} = 20V$$

- To determine v_x, v_4 has to be determined
- To determine v4, i4 has to be determine

and using KCL

$$i_4 = 5 - i_{10} = 5 - \frac{v_{10}}{10} = 3$$

$$\Rightarrow v_4 = 4 \times 3 = 12$$

$$\therefore v_x = 20 - 12 = 8$$

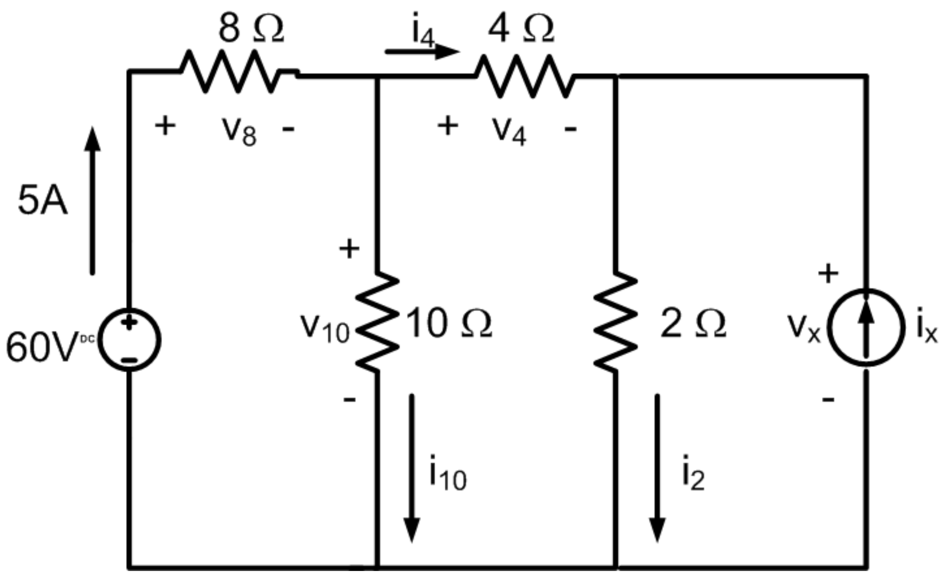


Fig.9: Labeled circuit