EEE 141
ELECTRICAL CIRCUITS

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METHODS OF ANALYSIS

Mesh Analysis.

Nodal Analysis.

EXAMPLE

EXAMPLE 8.16 Write the mesh equations for the network of Fig. 8.36, and find the current through the 7-Ω resistor.

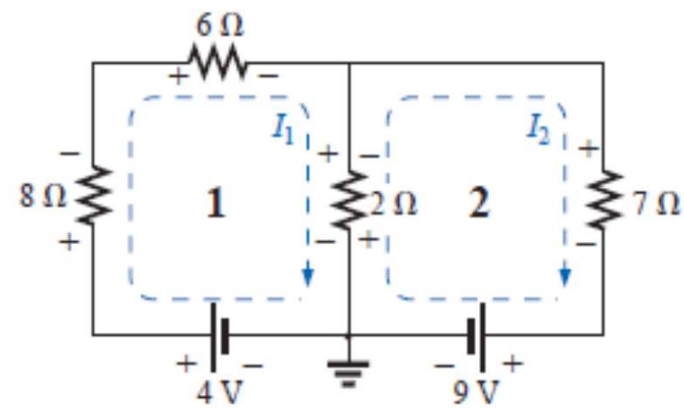


FIG. 8.36
Example 8.16.

Solution:

Step 1: As indicated in Fig. 8.36, each assigned loop current has a clockwise direction.

Steps 2 to 4:

$$I_1: \quad (8\ \Omega + 6\ \Omega + 2\ \Omega)I_1 - (2\ \Omega)I_2 = 4\ \text{V}$$
$$I_2: \quad (7\ \Omega + 2\ \Omega)I_2 - (2\ \Omega)I_1 = -9\ \text{V}$$

and

$$16I_1 - 2I_2 = 4$$
$$9I_2 - 2I_1 = -9$$

which, for determinants, are

$$16I_1 - 2I_2 = 4$$
$$-2I_1 + 9I_2 = -9$$

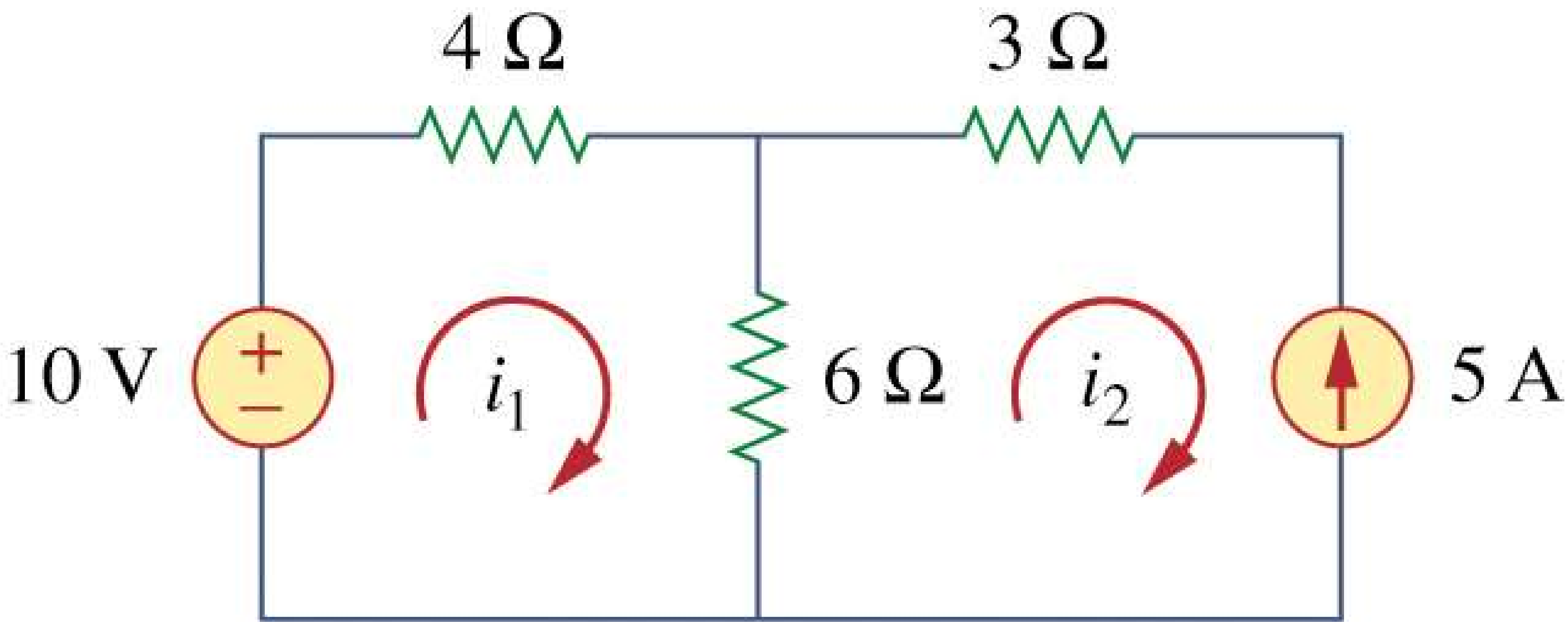
and

$$I_2 = I_{7\Omega} = \frac{\begin{vmatrix} 16 & 4 \\ -2 & -9 \end{vmatrix}}{\begin{vmatrix} 16 & -2 \\ -2 & 9 \end{vmatrix}} = \frac{-144 + 8}{144 - 4} = \frac{-136}{140}$$

$$= \mathbf{-0.971\ A}$$

MESH ANALYSIS WITH CURRENT SOURCES

A circuit with a current source.



MESH ANALYSIS WITH CURRENT SOURCES

Case 1

- Current source exist only in one mesh

$$i_1 = -2\,\mathrm{A}$$

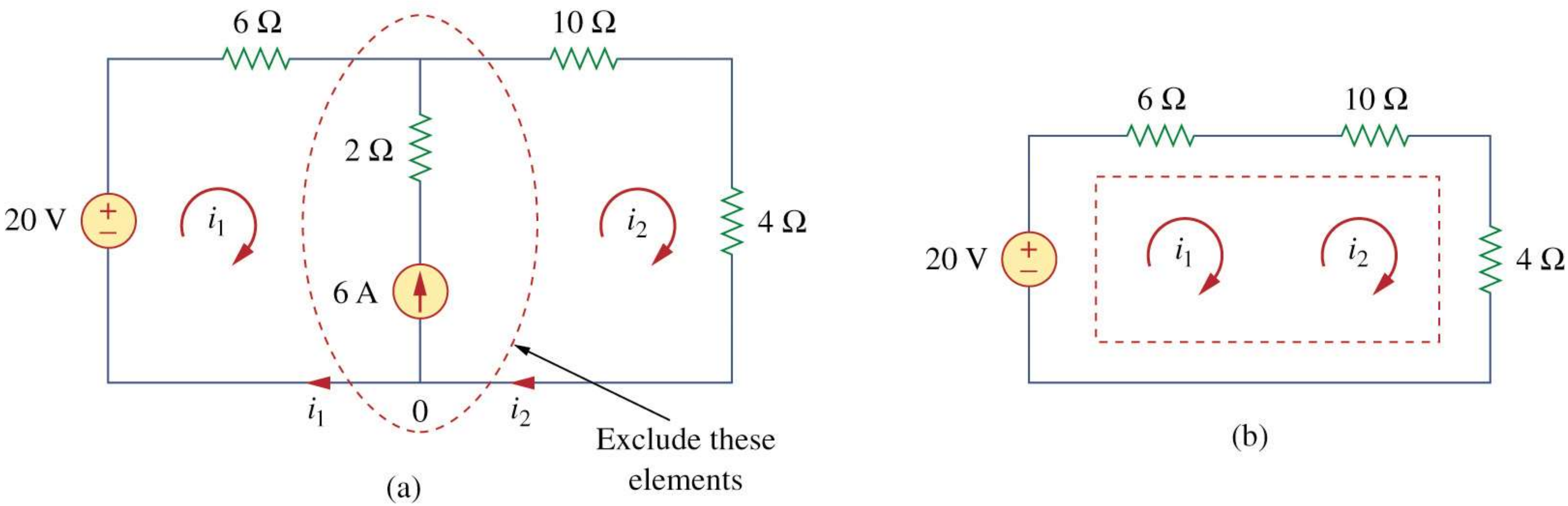
- One mesh variable is reduced

Case 2

- Current source exists between two meshes, a super-mesh is obtained.

SUPERMESH

a supermesh results when two meshes have a (dependent , independent) current source in common.



PROPERTIES OF A SUPERMESH

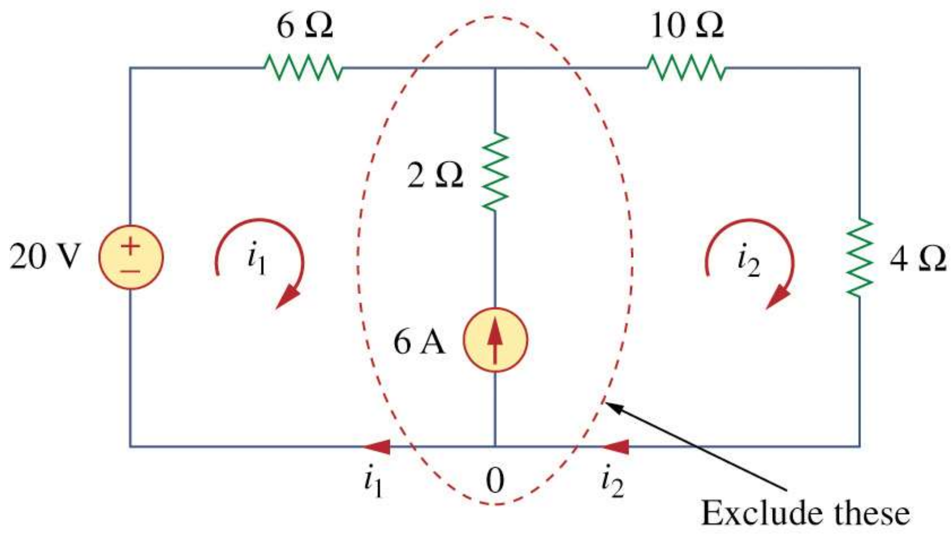
1. The current is not completely ignored
   - provides the constraint equation necessary to solve for the mesh current.
2. A supermesh has no current of its own.
3. Several current sources in adjacency form a bigger supermesh.

EXAMPLE

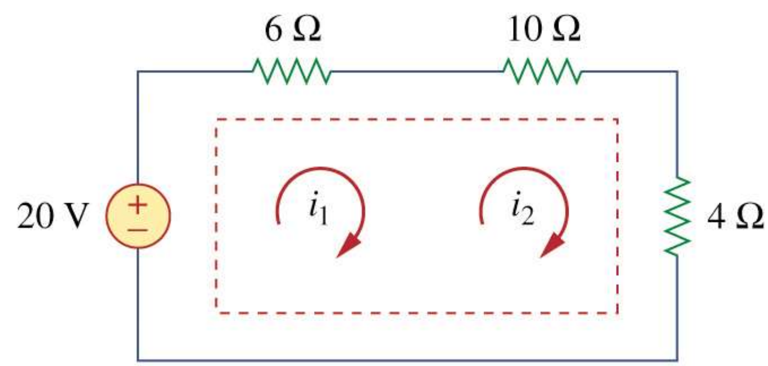
If a supermesh consists of two meshes, two equations are needed; one is obtained using KVL and Ohm's law to the supermesh and the other is obtained by relation regulated due to the current source.

$$6i_1 + 14i_2 = 20$$

$$i_1 - i_2 = -6$$



(a)



(b)

SUPERMESH CURRENTS

When there is a current source in the network:

- Start as before step 1 and 2, (current source is treated as resistor)
- Mentally remove the current source (open circuit) and apply KVL to the remaining loops
- Any resulting open window, including two or more mesh current current is said **supermesh.**
- Relate the currents to the independent current sources, and solve.

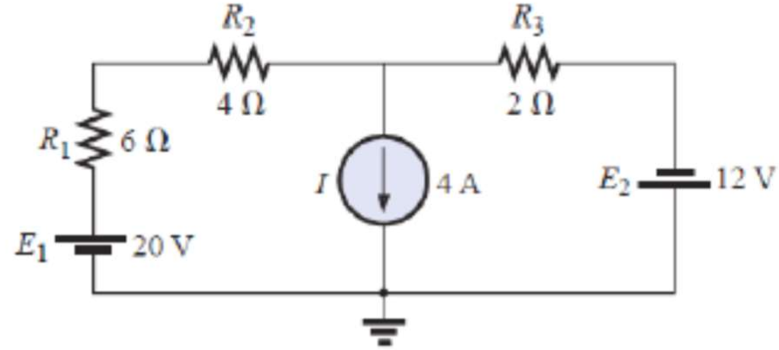


FIG. 8.29
Example 8.14.

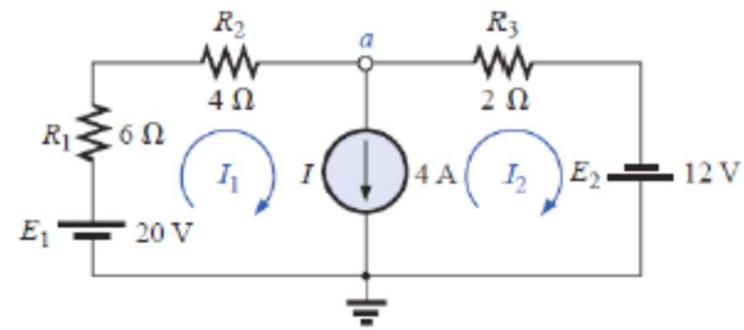


FIG. 8.30
Defining the mesh currents for the network of Fig. 8.29.

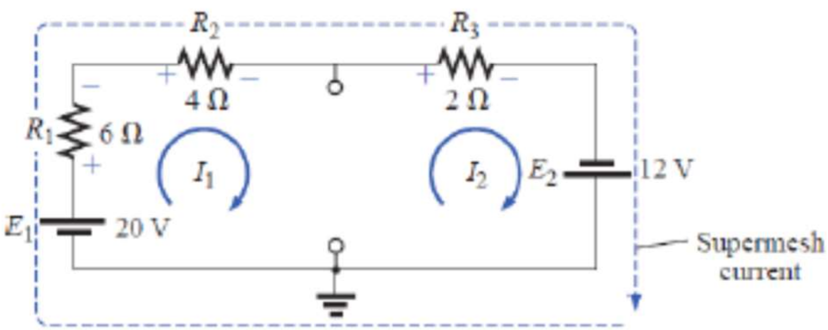


FIG. 8.31
Defining the supermesh current.

EXAMPLE

Node a is then used to relate the mesh currents and the current source using Kirchhoff's current law:

$$I_1 = I + I_2$$

The result is two equations and two unknowns:

$$\begin{aligned} 10I_1 + 2I_2 &= 32 \\ I_1 - I_2 &= 4 \end{aligned}$$

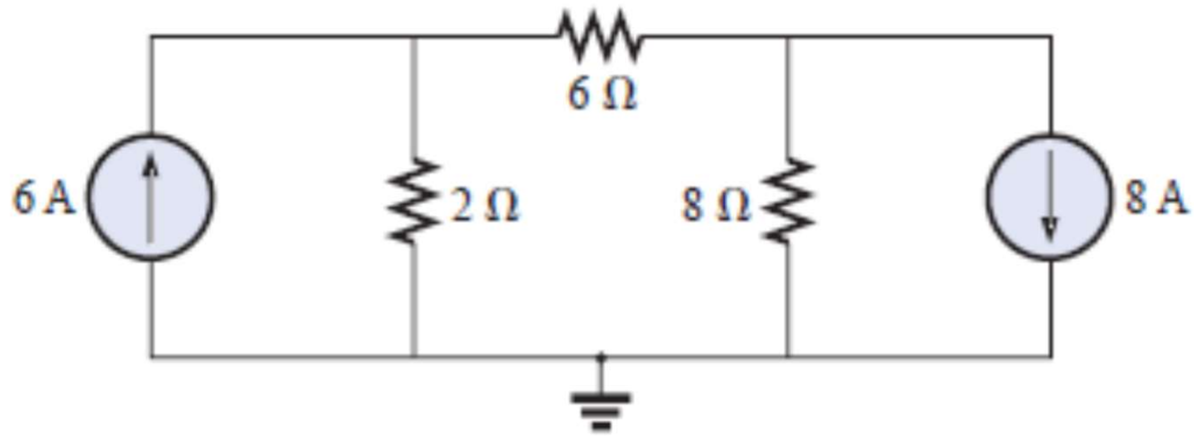
Applying determinants:

$$I_1 = \frac{\begin{vmatrix} 32 & 2 \\ 4 & -1 \end{vmatrix}}{\begin{vmatrix} 10 & 2 \\ 1 & -1 \end{vmatrix}} = \frac{(32)(-1) - (2)(4)}{(10)(-1) - (2)(1)} = \frac{40}{12} = 3.33\ \text{A}$$

and $$I_2 = I_1 - I = 3.33\ \text{A} - 4\ \text{A} = -0.67\ \text{A}$$

In the above analysis, it might appear that when the current source was removed, $I_1 = I_2$. However, the supermesh approach requires that we stick with the original definition of each mesh current and not alter those definitions when current sources are removed.

SUPERMESH (EXAMPLE)



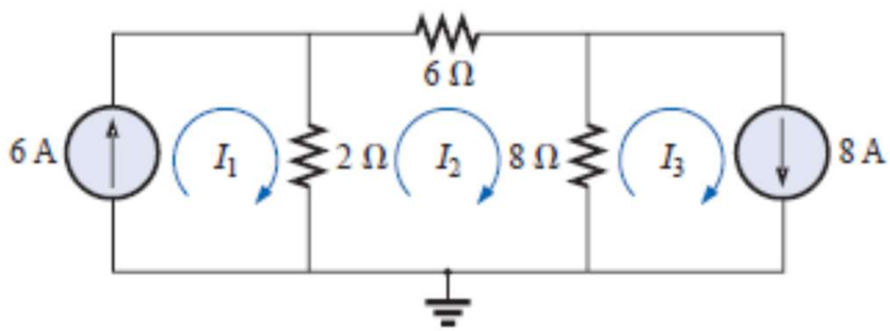


FIG. 8.33
Defining the mesh currents for the network of Fig. 8.32.

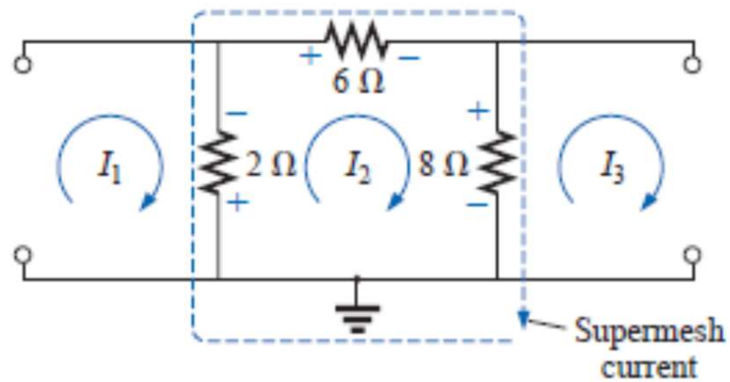


FIG. 8.34
Defining the supermesh current for the network of Fig. 8.32.

SOLUTION

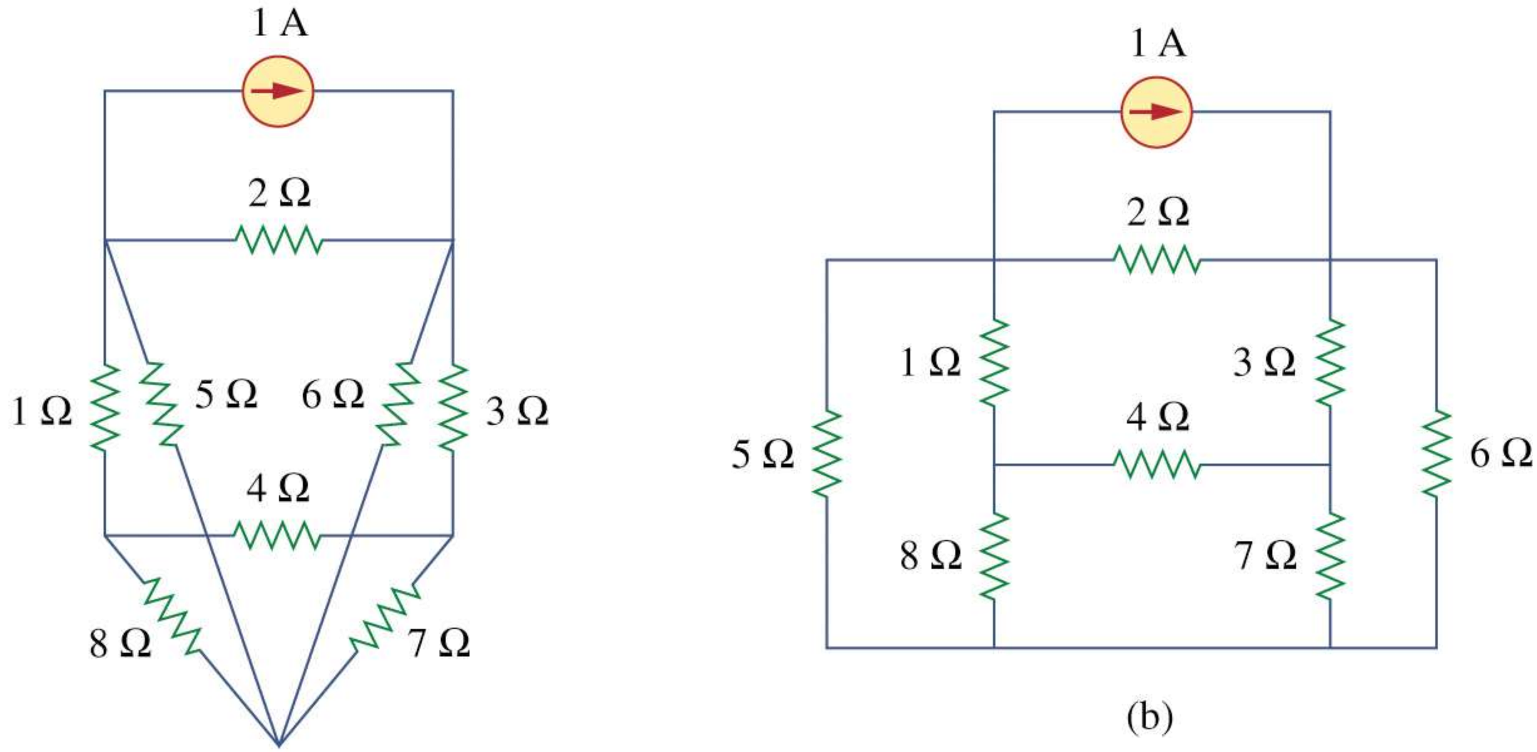
$$-V_{2\Omega} - V_{6\Omega} - V_{8\Omega} = 0$$
$$-(I_2 - I_1)2\ \Omega - I_2(6\ \Omega) - (I_2 - I_3)8\ \Omega = 0$$
$$-2I_2 + 2I_1 - 6I_2 - 8I_2 + 8I_3 = 0$$
$$2I_1 - 16I_2 + 8I_3 = 0$$

$$2I_1 - 16I_2 + 8I_3 = 0$$
$$2(6\ \text{A}) - 16I_2 + 8(8\ \text{A}) = 0$$
$$I_2 = \frac{76\ \text{A}}{16} = \mathbf{4.75\ A}$$

PLANAR CIRCUIT

(a) A Planar circuit with crossing branches,

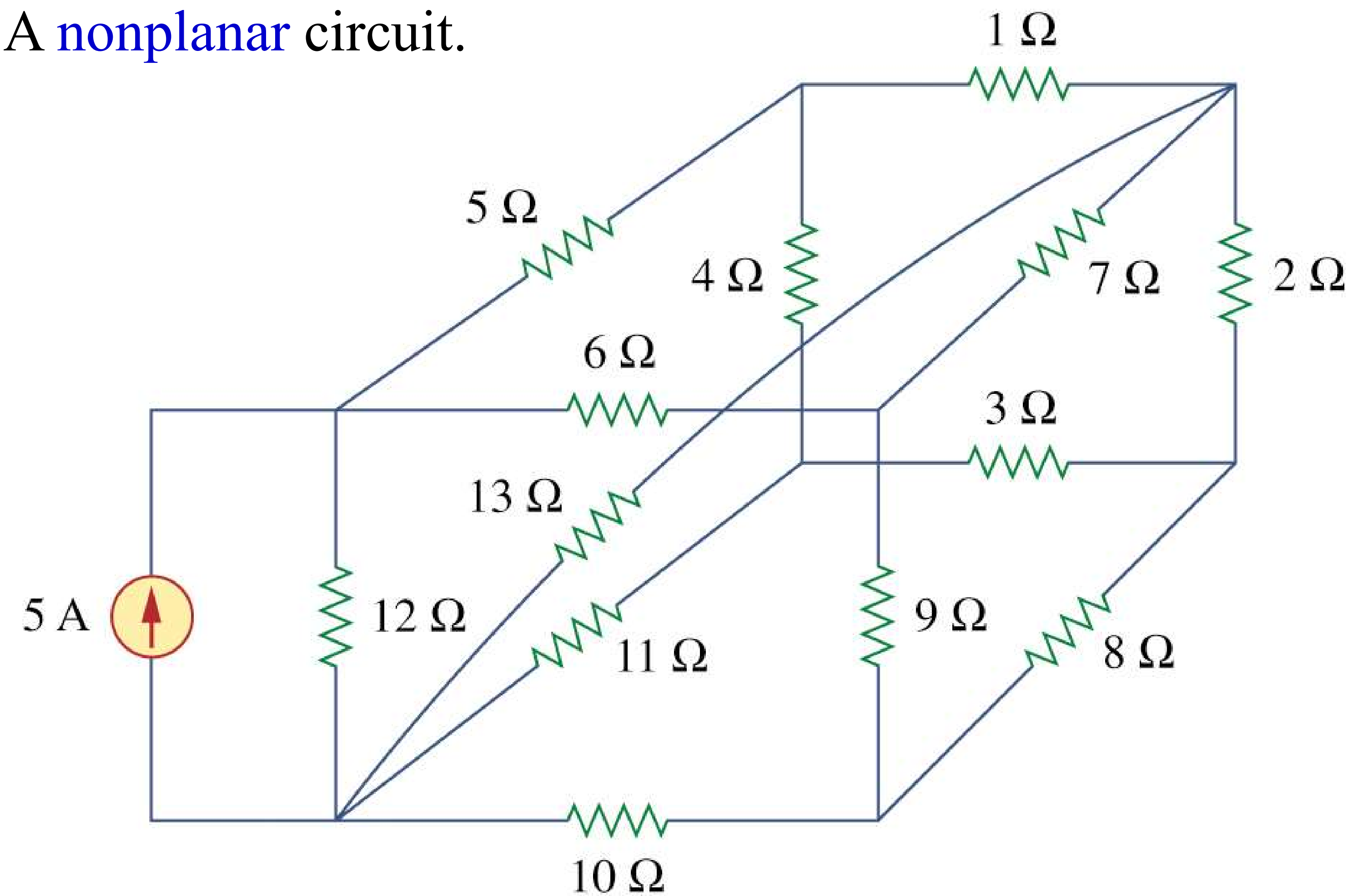
(b) The same circuit redrawn with no crossing branches.



(a) (b)

NONPLANAR CIRCUIT

A nonplanar circuit.



NODAL ANALYSIS

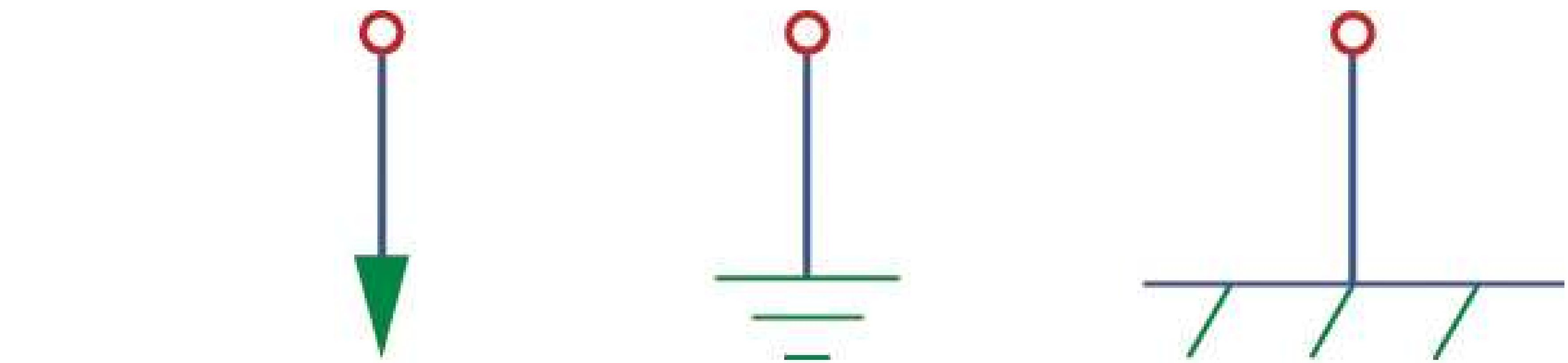
A general procedure for analyzing circuits using node voltages.

Steps to Determine Node Voltages:

1. Select a node as the reference node. Assign voltage v_1, v_2, ...v_{n-1} to the remaining n-1 nodes. The voltages are referenced with respect to the reference node.
2. Apply KCL to each of the n-1 nonreference nodes. Use Ohm's law to express the branch currents in terms of node voltages.
3. Solve the resulting simultaneous equations to obtain the unknown node voltages.

REFERENCE NODE

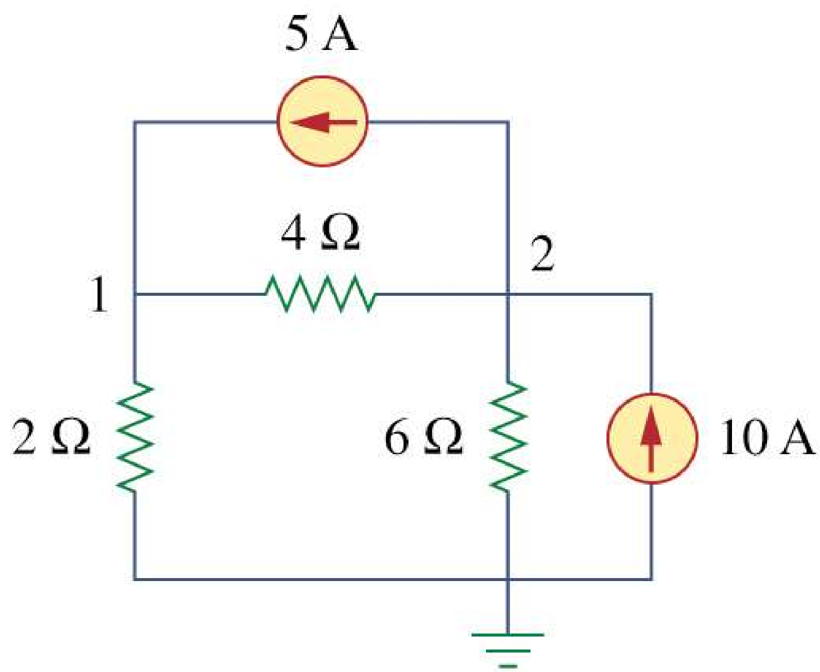
Common symbols for indicating a reference node,
(a) common ground, (b) ground, (c) chassis.



(a) (b) (c)

EXAMPLE

Calculate the node voltage in the circuit shown in Fig(a)



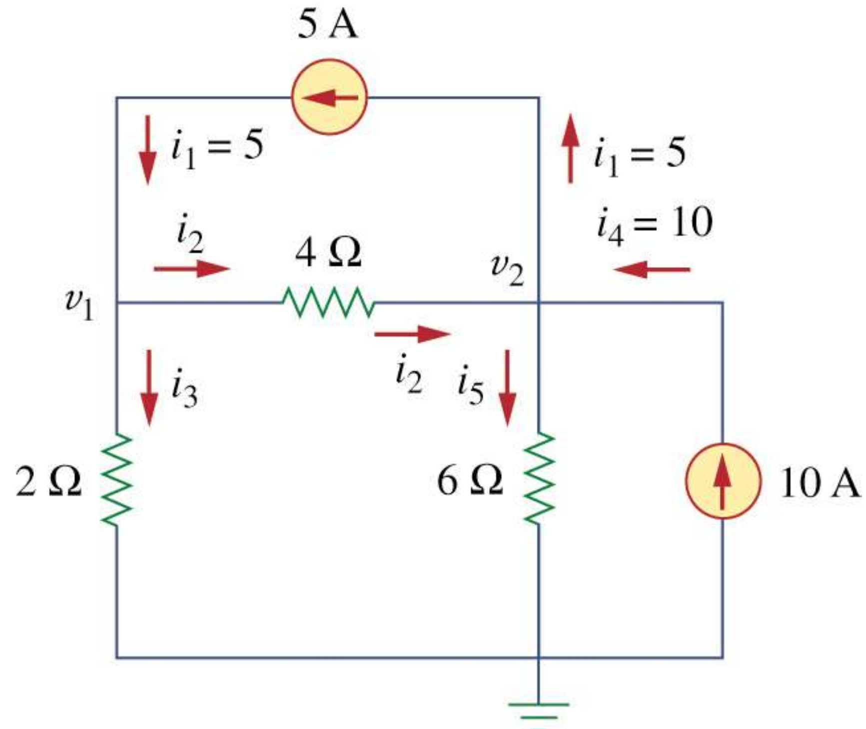
(a)

EXAMPLE

At node 1

$$i_1 = i_2 + i_3$$

$$\Rightarrow 5 = \frac{v_1 - v_2}{4} + \frac{v_1 - 0}{2}$$



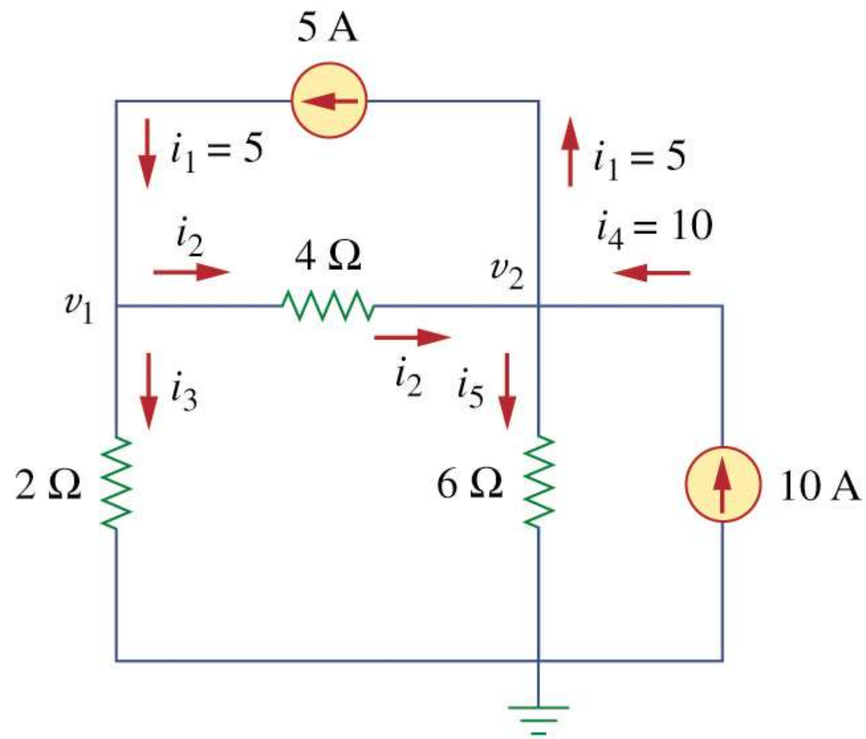
(b)

EXAMPLE

At node 2

$$i_2 + i_4 = i_1 + i_5$$

$$\Rightarrow 5 = \frac{v_2 - v_1}{4} + \frac{v_2 - 0}{6}$$



(b)

EXAMPLE

In matrix form:

$$\begin{bmatrix} \frac{1}{2}+\frac{1}{4} & -\frac{1}{4} \\ -\frac{1}{4} & \frac{1}{6}+\frac{1}{4} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 5 \end{bmatrix}$$