EEE 141
ELECTRICAL CIRCUITS

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BASIC LAWS

Nodes, Branches, and Loops.

Kirchhoff's Laws.

Series Resistors and Voltage Division.

Parallel Resistors and Current Division.

NODES, BRANCHES AND LOOPS

A branch represents a single element such as a voltage source or a resistor.

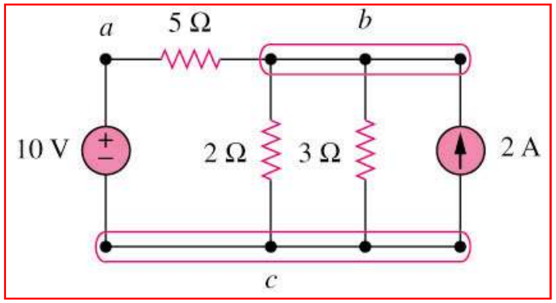
A node is the point of connection between two   or more branches.

A loop is any closed path in a circuit.

A network with b branches, n nodes, and l independent loops will satisfy the fundamental theorem of network topology:

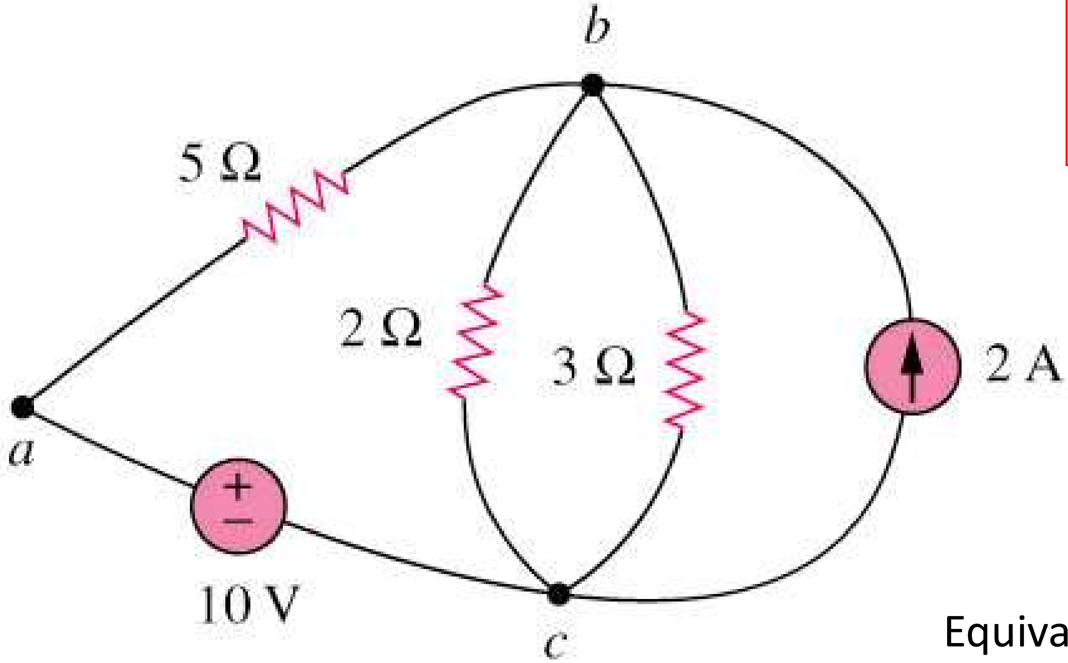
$$b = l + n - 1$$

NODES, BRANCHES AND LOOPS



Original circuit

Exa

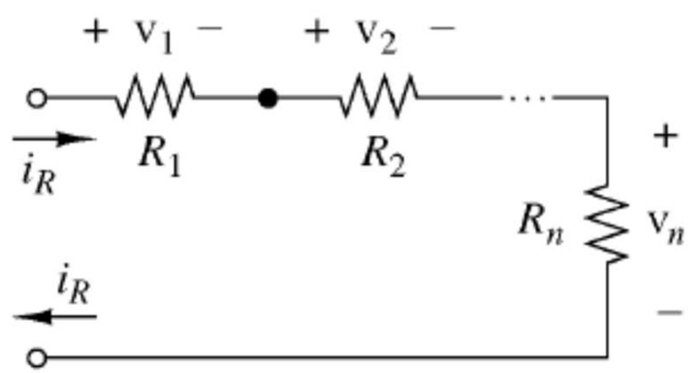


Equivalent circuit

How many branches, nodes and loops are there?

Series and Parallel Connections

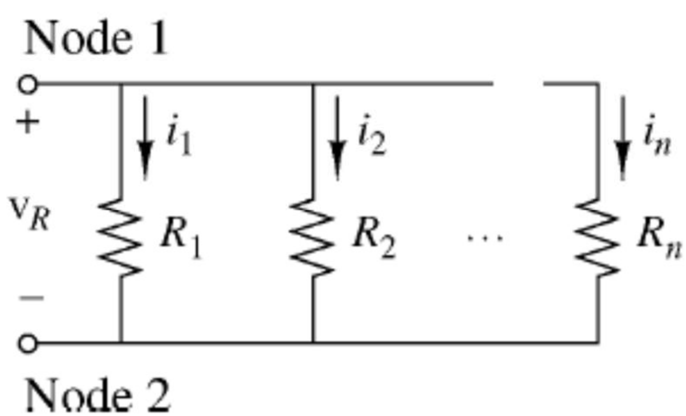
- Two or more elements are connected "**in series**" when they belong to the same branch.(even if they are separated by other elements).
- In general, circuit elements are in series when they are sequentially connected end-to-end and only share binary nodes among them.
- Elements that are in series carry the same current.



Series and Parallel Circuits

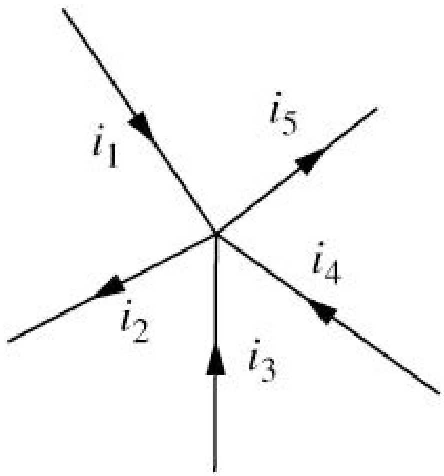
- Two or more circuit elements are "**in parallel**" if they are connected between the same two "true nodes".

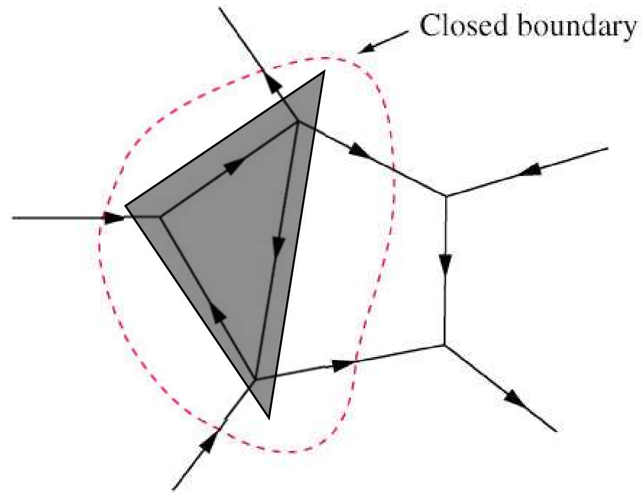
- Consequently, parallel elements have the same voltage



KIRCHHOFF'S LAWS

Kirchhoff's current law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero.

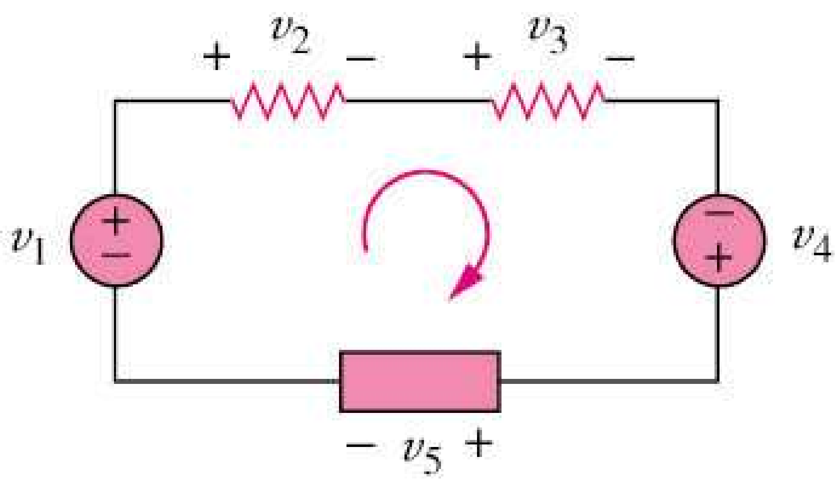




Mathematically, $$\sum_{n=1}^{N} i_n = 0$$

KIRCHHOFF'S LAWS

Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.



Mathematically, $$\sum_{m=1}^{M} v_n = 0$$

EXAMPLE

For the circuit in Fig. 2.21(a), find voltages v_1 and v_2.

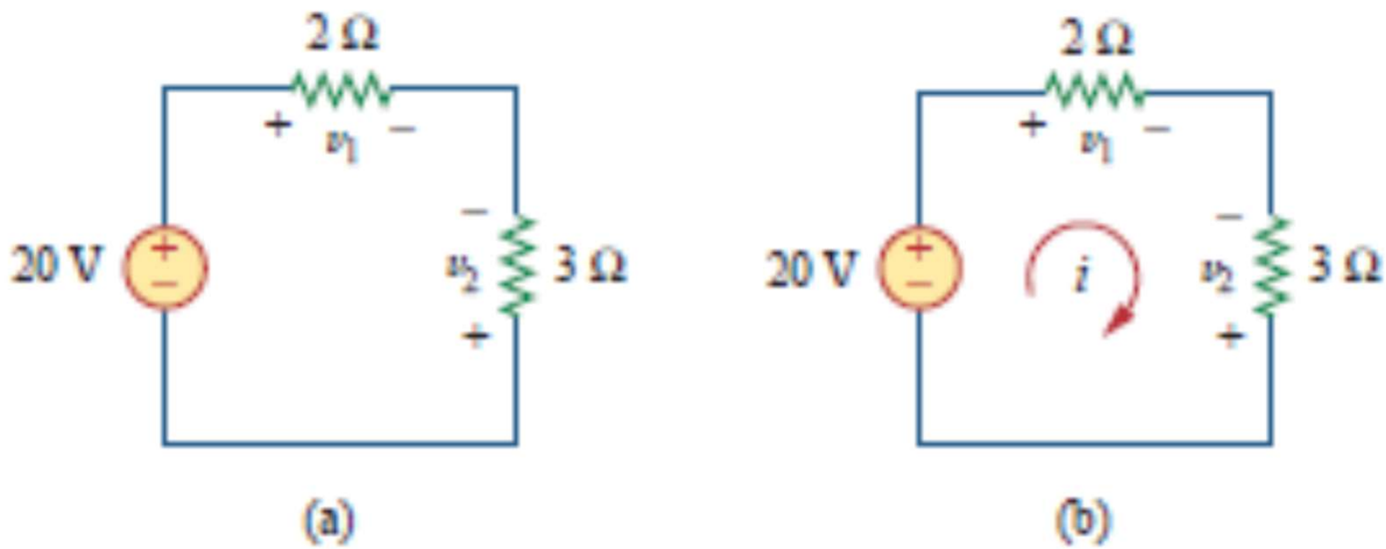


Figure 2.21
For Example 2.5.

EXAMPLE

Determine v_o and i in the circuit shown in Fig. 2.23(a).

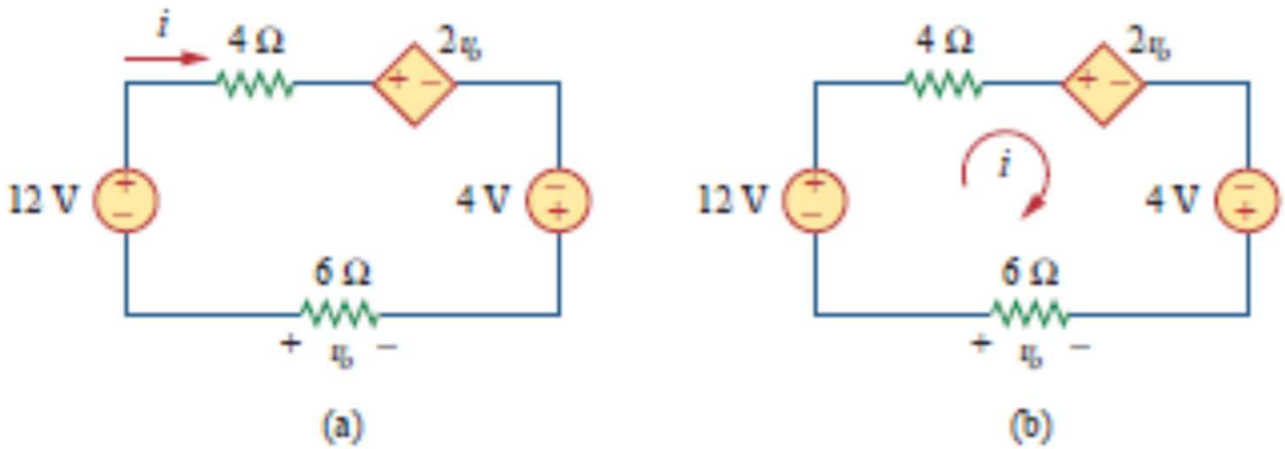


Figure 2.23
For Example 2.6.

Solution:
We apply KVL around the loop as shown in Fig. 2.23(b). The result is

$$-12 + 4i + 2v_o - 4 + 6i = 0 \qquad (2.6.1)$$

Applying Ohm's law to the 6-Ω resistor gives

$$v_o = -6i \qquad (2.6.2)$$

EXAMPLE

Example 2.7 Find current i_o and voltage v_o in the circuit shown in Fig. 2.25.

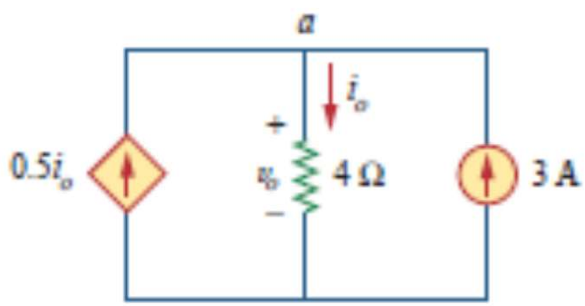


Figure 2.25
For Example 2.7.

Solution:
Applying KCL to node a, we obtain

$$3 + 0.5i_o = i_o \quad \Rightarrow \quad i_o = 6 \text{ A}$$

For the 4-Ω resistor, Ohm's law gives

$$v_o = 4i_o = 24 \text{ V}$$

EXAMPLE

Example 2.8 Find currents and voltages in the circuit shown in Fig. 2.27(a).

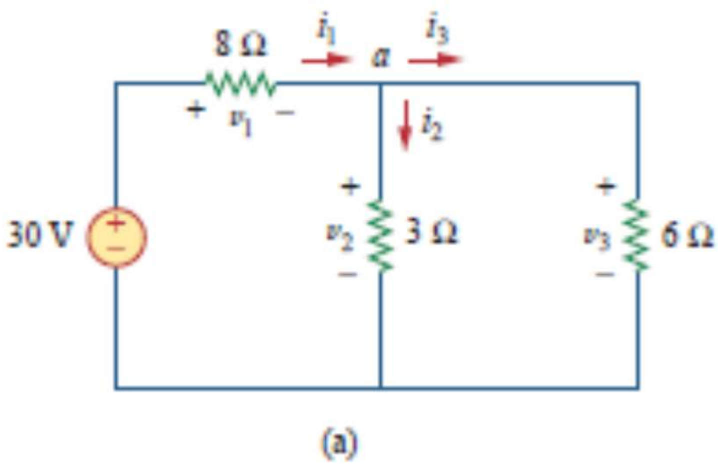


Figure 2.27
For Example 2.8.

Solution:
We apply Ohm's law and Kirchhoff's laws. By Ohm's law,

$$v_1 = 8i_1, \qquad v_2 = 3i_2, \qquad v_3 = 6i_3 \tag{2.8.1}$$

SERIES RESISTORS AND VOLTAGE DIVISION (1)

Series: Two or more elements are in series if they are cascaded or connected sequentially and consequently carry the same current.

The equivalent resistance of any number of resistors connected in a series is the sum of the individual resistances.

$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

The voltage divider can be expressed as

$$v_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} v$$

EXAMPLE

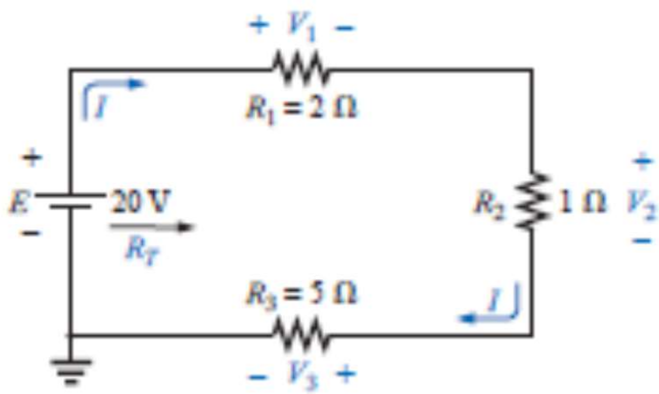


FIG. 5.7
Example 5.1.

EXAMPLE 5.1

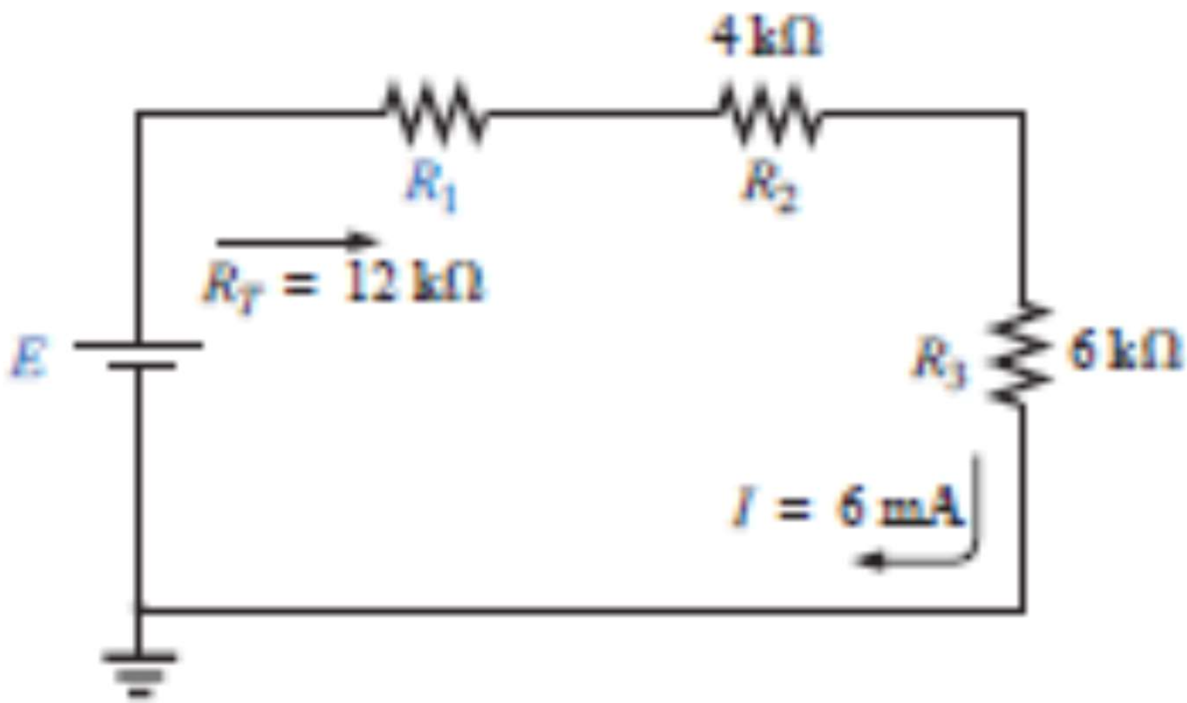
a. Find the total resistance for the series circuit of Fig. 5.7.
b. Calculate the source current I_s.
c. Determine the voltages V_1, V_2, and V_3.
d. Calculate the power dissipated by R_1, R_2, and R_3.
e. Determine the power delivered by the source, and compare it to the sum of the power levels of part (d).

Solutions:

a. $R_T = R_1 + R_2 + R_3 = 2\ \Omega + 1\ \Omega + 5\ \Omega = \mathbf{8\ \Omega}$

b. $I_s = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{8\ \Omega} = \mathbf{2.5\ A}$

EXAMPLE



EXAMPLE

EXAMPLE 5.11 Using the voltage divider rule, determine the voltages V_1 and V_3 for the series circuit of Fig. 5.28.

Solution:

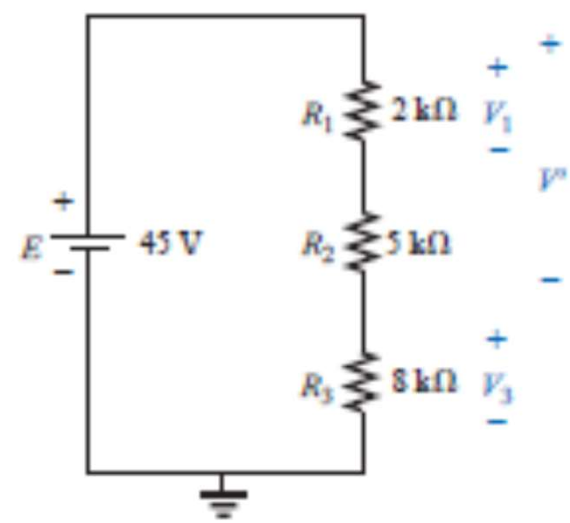
$$V_1 = \frac{R_1E}{R_T} = \frac{(2\text{ k}\Omega)(45\text{ V})}{2\text{ k}\Omega + 5\text{ k}\Omega + 8\text{ k}\Omega} = \frac{(2\text{ k}\Omega)(45\text{ V})}{15\text{ k}\Omega}$$

$$= \frac{(2\times 10^3\ \Omega)(45\text{ V})}{15\times 10^3\ \Omega} = \frac{90\text{ V}}{15} = \mathbf{6\ V}$$

$$V_3 = \frac{R_3E}{R_T} = \frac{(8\text{ k}\Omega)(45\text{ V})}{15\text{ k}\Omega} = \frac{(8\times 10^3\ \Omega)(45\text{ V})}{15\times 10^3\ \Omega}$$

$$= \frac{360\text{ V}}{15} = \mathbf{24\ V}$$

FIG. 5.27
Example 5.10.



EXAMPLE

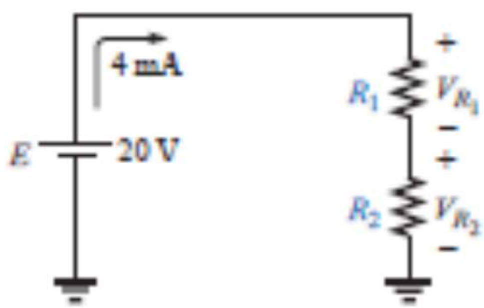


FIG. 5.30
Example 5.13.

EXAMPLE 5.13 Design the voltage divider of Fig. 5.30 such that $V_{R_1} = 4V_{R_2}$.

Solution: The total resistance is defined by

$$R_T = \frac{E}{I} = \frac{20\text{ V}}{4\text{ mA}} = 5\text{ k}\Omega$$

Since $V_{R_1} = 4V_{R_2}$,

$$R_1 = 4R_2$$

Thus $$R_T = R_1 + R_2 = 4R_2 + R_2 = 5R_2$$

and $$5R_2 = 5\text{ k}\Omega$$
$$R_2 = \mathbf{1\text{ k}\Omega}$$

and $$R_1 = 4R_2 = \mathbf{4\text{ k}\Omega}$$

INTERCHANGING SERIES ELEMENTS

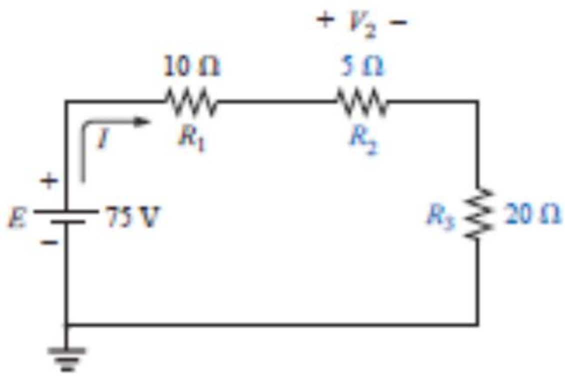


FIG. 5.19
Series dc circuit with elements to be interchanged.

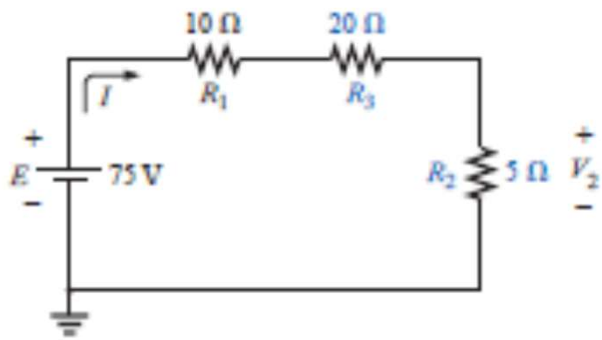
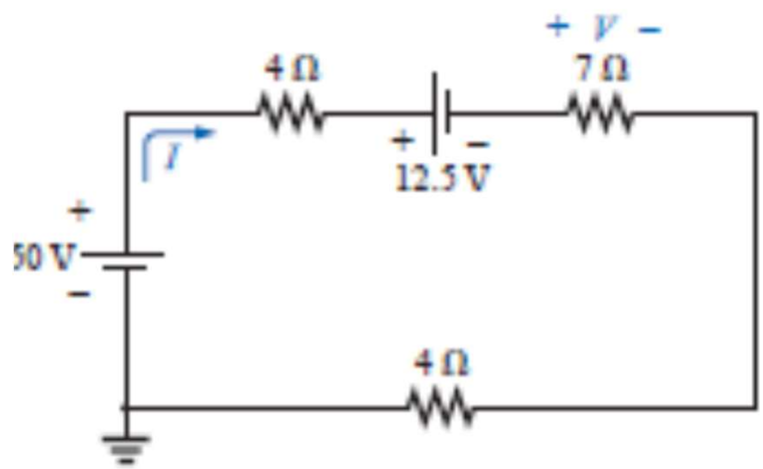


FIG. 5.20
Circuit of Fig. 5.19 with R_2 and R_3 interchanged.



EXAMPLE

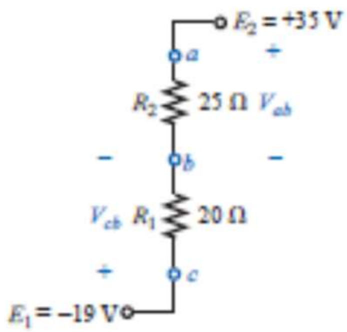


FIG. 5.45
Example 5.18.

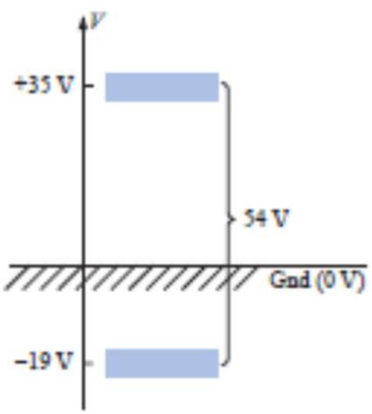


FIG. 5.46

EXAMPLE 5.18 Determine V_{ab}, V_{cb}, and V_c for the network of Fig. 5.45.

Solution: There are two ways to approach this problem. The first is to sketch the diagram of Fig. 5.46 and note that there is a 54-V drop across the series resistors R_1 and R_2. The current can then be determined using Ohm's law and the voltage levels as follows:

$$I = \frac{54\text{ V}}{45\ \Omega} = 1.2\text{ A}$$

$$V_{ab} = IR_2 = (1.2\text{ A})(25\ \Omega) = \mathbf{30\ V}$$

$$V_{cb} = -IR_1 = -(1.2\text{ A})(20\ \Omega) = \mathbf{-24\ V}$$

$$V_c = E_1 = \mathbf{-19\ V}$$

EXAMPLE

EXAMPLE 5.20 For the network of Fig. 5.50:

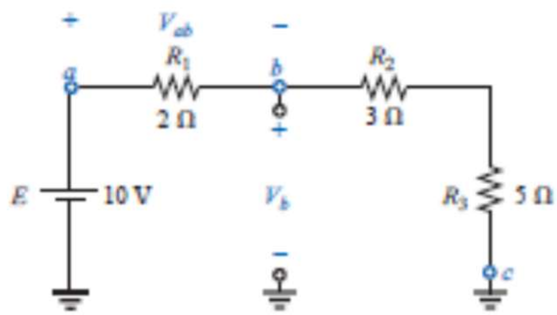


FIG. 5.50
Example 5.20.

a. Calculate V_{ab}.
b. Determine V_b.
c. Calculate V_c.

Solutions:

a. Voltage divider rule:

$$V_{ab} = \frac{R_1 E}{R_T} = \frac{(2\ \Omega)(10\ \text{V})}{2\ \Omega + 3\ \Omega + 5\ \Omega} = \mathbf{+2\ V}$$

b. Voltage divider rule:

$$V_b = V_{R_2} + V_{R_3} = \frac{(R_2 + R_3)E}{R_T} = \frac{(3\ \Omega + 5\ \Omega)(10\ \text{V})}{10\ \Omega} = \mathbf{8\ V}$$

or $\quad V_b = V_a - V_{ab} = E - V_{ab} = 10\ \text{V} - 2\ \text{V} = \mathbf{8\ V}$

c. V_c = ground potential = **0 V**