Series Parallel Circuit, Branch Current Analysis

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SERIES-PARALLEL CIRCUIT

A series-parallel configuration is one that is formed by a combination of series and parallel elements

A complex configuration is one in which none of the elements are in series or parallel.

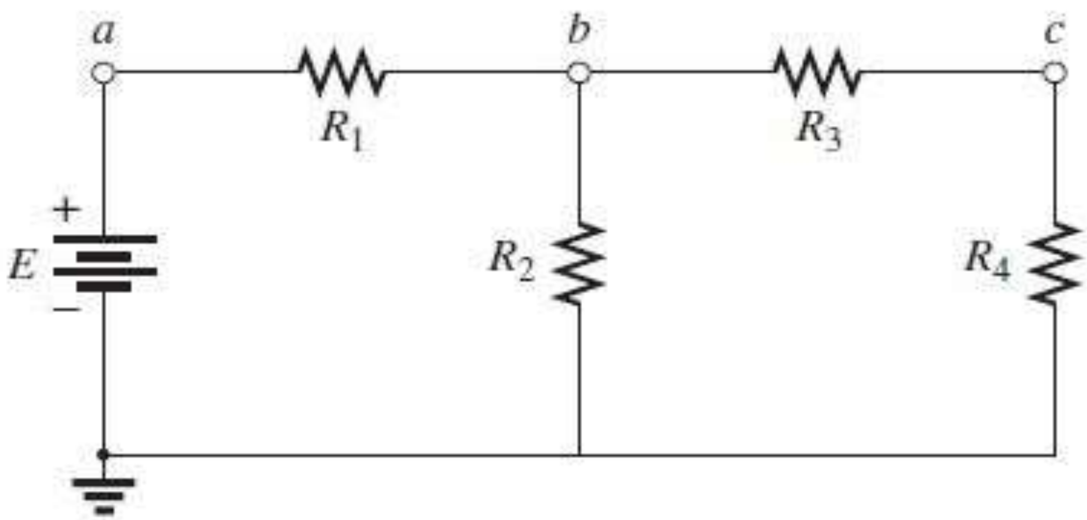
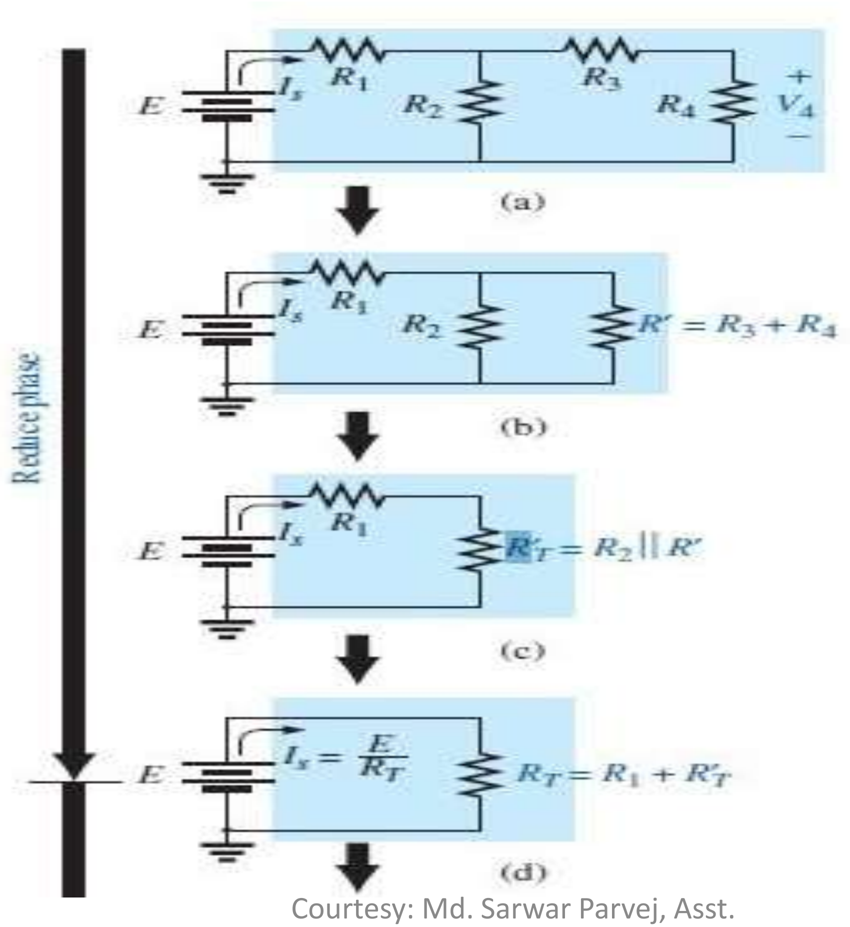


FIG. 7.1

Series-parallel dc network.

SERIES-PARALLEL CIRCUIT

REDUCE AND RETURN APPROACH :



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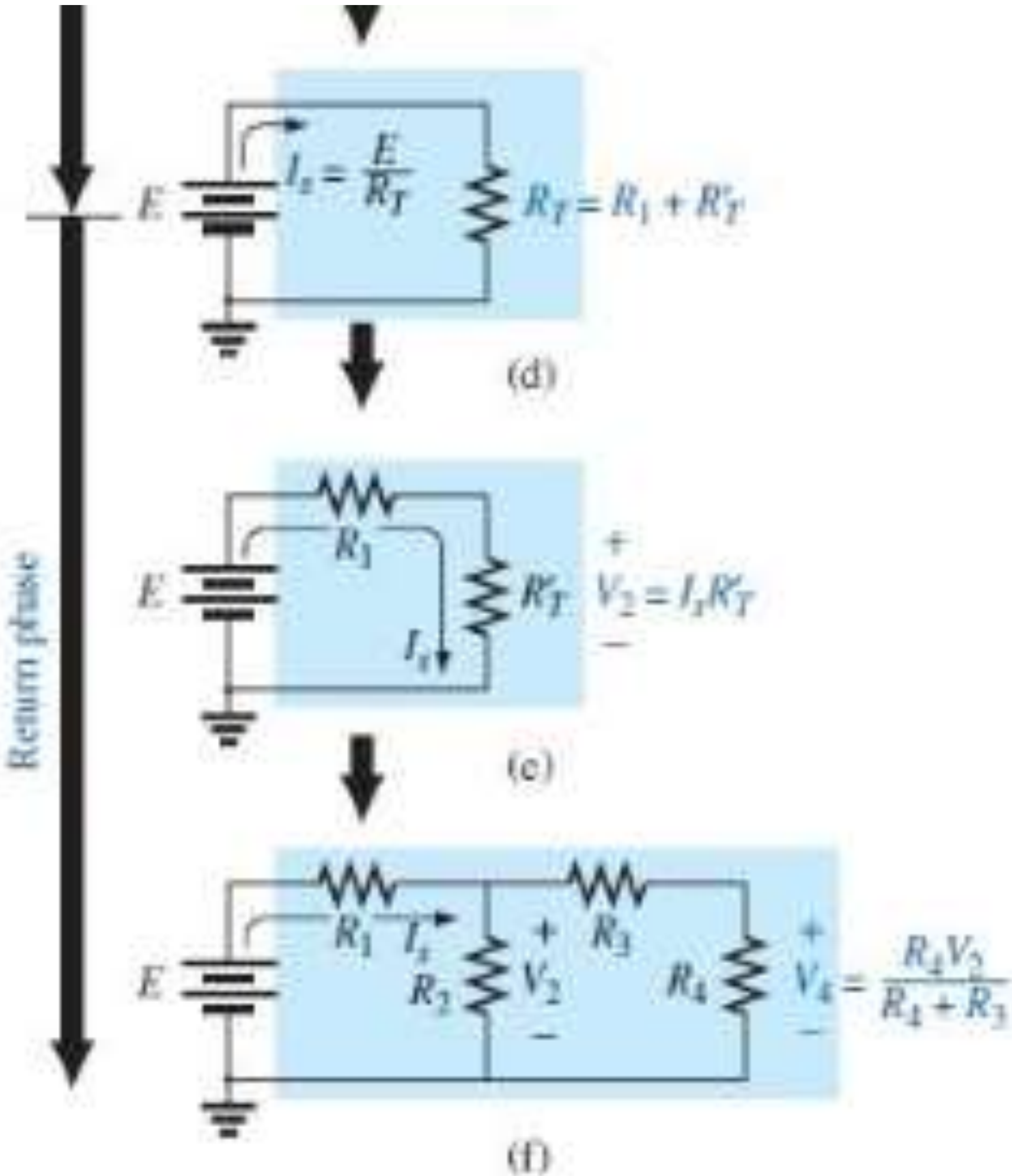


$I_s = \frac{E}{R_T}$
$R_T = R_1 + R'_T$
E
(d)
R_1
R'_T
$V_2 = I_s R'_T$
I_s
(e)
R_1
I_s
R_2
V_2
R_3
R_4
$V_4 = \frac{R_4 V_2}{R_4 + R_3}$
(f)
Return phase

SERIES-PARALLEL CIRCUIT

EXAMPLE 7.1 Find current I_3 for the series-parallel network in Fig. 7.3.

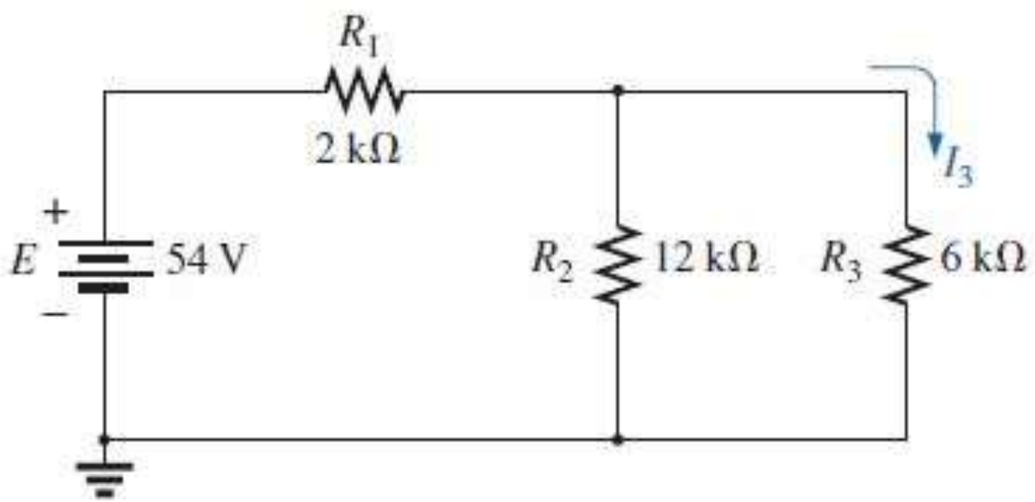


FIG. 7.3
Series-parallel network for Example 7.1.

SERIES-PARALLEL CIRCUIT

Solution: Checking for series and parallel elements, we find that resistors R_2 and R_3 are in parallel. Their total resistance is

$$R' = R_2 \parallel R_3 = \frac{R_2R_3}{R_2 + R_3} = \frac{(12\ \text{k}\Omega)(6\ \text{k}\Omega)}{12\ \text{k}\Omega + 6\ \text{k}\Omega} = 4\ \text{k}\Omega$$

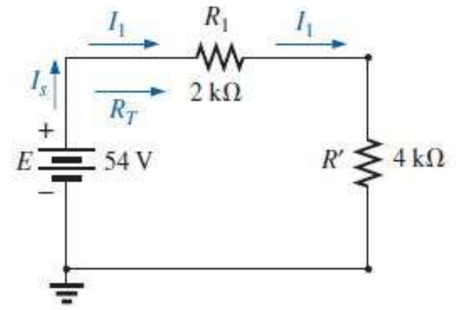


FIG. 7.4
Substituting the parallel equivalent resistance for resistors R_2 and R_3 in Fig. 7.3.

Replacing the parallel combination with a single equivalent resistance results in the configuration in Fig. 7.4. Resistors R_1 and $R_2$are then in series, resulting in a total resistance of

$$R_T = R_1 + R' = 2\ \text{k}\Omega + 4\ \text{k}\Omega = 6\ \text{k}\Omega$$

SERIES-PARALLEL CIRCUIT

Solution:

The source current is then determined using Ohm's law:

$$I_s = \frac{E}{R_T} = \frac{54\text{ V}}{6\text{ k}\Omega} = 9\text{ mA}$$

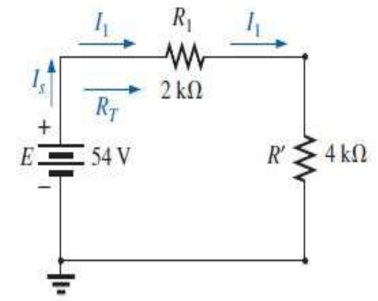


FIG. 7.4
Substituting the parallel equivalent resistance for resistors R_2 and R_3 in Fig. 7.3.

In Fig. 7.4, since *R*1 and *R*2 are in series, they have the same current *Is*.The result is

$$I_1 = I_s = 9\text{ mA}$$

Returning to Fig. 7.3, we find that *I*1 is the total current entering the parallel combination of *R*2 and *R*3. Applying the current divider rule results in the desired current:

$$I_3 = \left(\frac{R_2}{R_2 + R_3}\right)I_1 = \left(\frac{12\text{ k}\Omega}{12\text{ k}\Omega + 6\text{ k}\Omega}\right)9\text{ mA} = 6\text{ mA}$$

SERIES-PARALLEL CIRCUIT

EXAMPLE 7.2 For the network in Fig. 7.5:Determine currents I_4 and I_s and voltage V_2.

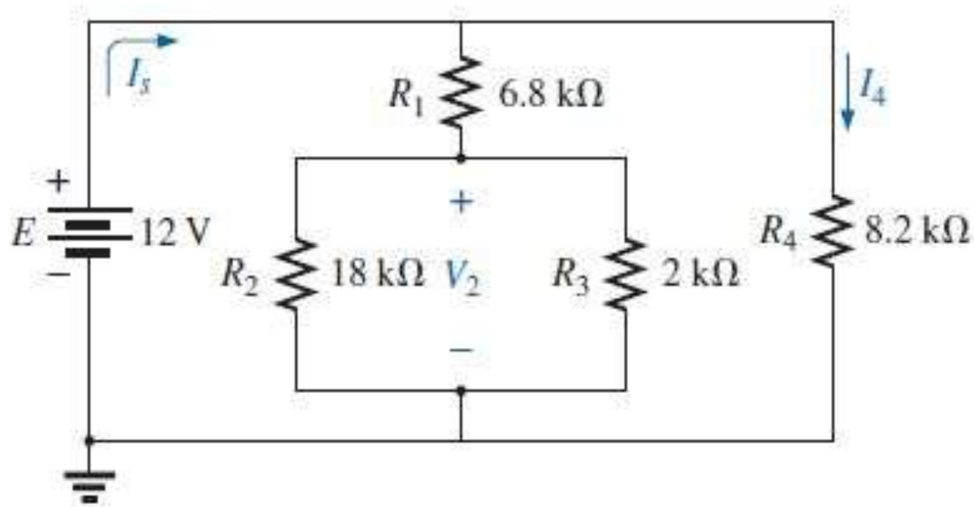


FIG. 7.5
Series-parallel network for Example 7.2.

SERIES-PARALLEL CIRCUIT

Solutions: Checking out the network, we find that there are no two resistors in series and the only parallel combination is resistors *R*2 and *R*3. Combining the two parallel resistors results in a total resistance of

$$R' = R_2 \parallel R_3 = \frac{R_2 R_3}{R_2 + R_3} = \frac{(18\ \text{k}\Omega)(2\ \text{k}\Omega)}{18\ \text{k}\Omega + 2\ \text{k}\Omega} = 1.8\ \text{k}\Omega$$

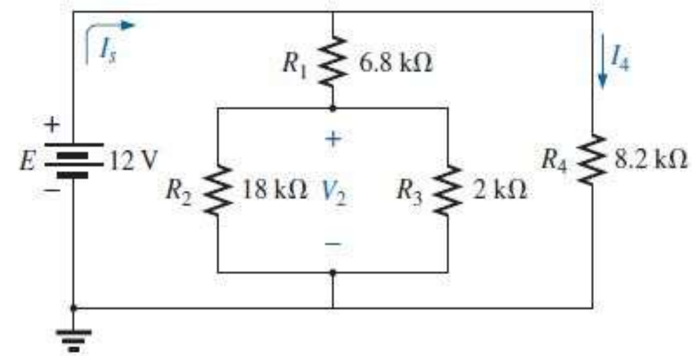


FIG. 7.5
Series-parallel network for Example 7.2.

Redrawing the network with resistance *R*’ inserted results in the configuration in Fig. 7.6.

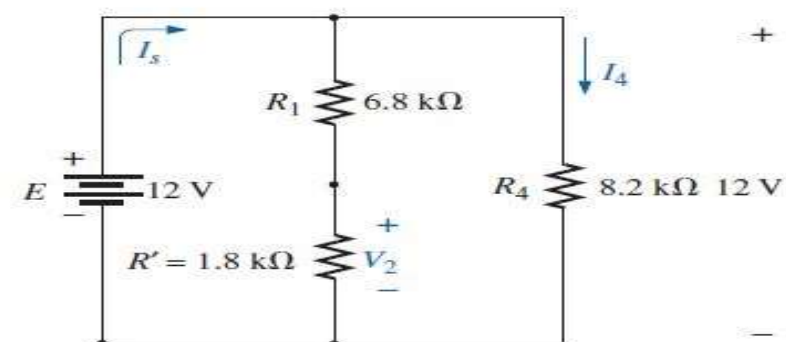


FIG. 7.6

SERIES-PARALLEL CIRCUIT

Solutions: the
voltage is the same across each branch. That is, the voltage across the series combination of *R*1 and *R'* is 12 V and that across resistor *R*4 is 12 V. The result is that *I*4 can be determined directly using Ohm's law as follows:

$$I_4 = \frac{V_4}{R_4} = \frac{E}{R_4} = \frac{12\text{ V}}{8.2\text{ k}\Omega} = \mathbf{1.46\text{ mA}}$$

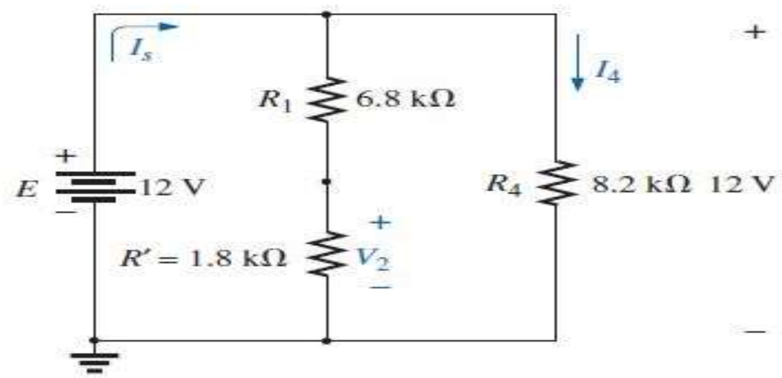


FIG. 7.6

the total voltage across the series combinatic
Of *R*1 and R'_T is 12 V, the voltage divider rule
be applied to determine voltage *V*2 as follows:

$$V_2 = \left(\frac{R'}{R' + R_1}\right)E = \left(\frac{1.8\text{ k}\Omega}{1.8\text{ k}\Omega + 6.8\text{ k}\Omega}\right)12\text{ V} = \mathbf{2.51\text{ V}}$$

SERIES-PARALLEL CIRCUIT

Solutions: The current *Is* can be found one of two ways. Find the total resistance and use Ohm's law or find the current through the other parallel branch and apply Kirchh off's current law. Since we already have the current *I*4, the latter approach will be applied:

$$I_1 = \frac{E}{R_1 + R'} = \frac{12\text{ V}}{6.8\text{ k}\Omega + 1.8\text{ k}\Omega} = 1.40\text{ mA}$$

and $$I_s = I_1 + I_4 = 1.40\text{ mA} + 1.46\text{ mA} = 2.86\text{ mA}$$

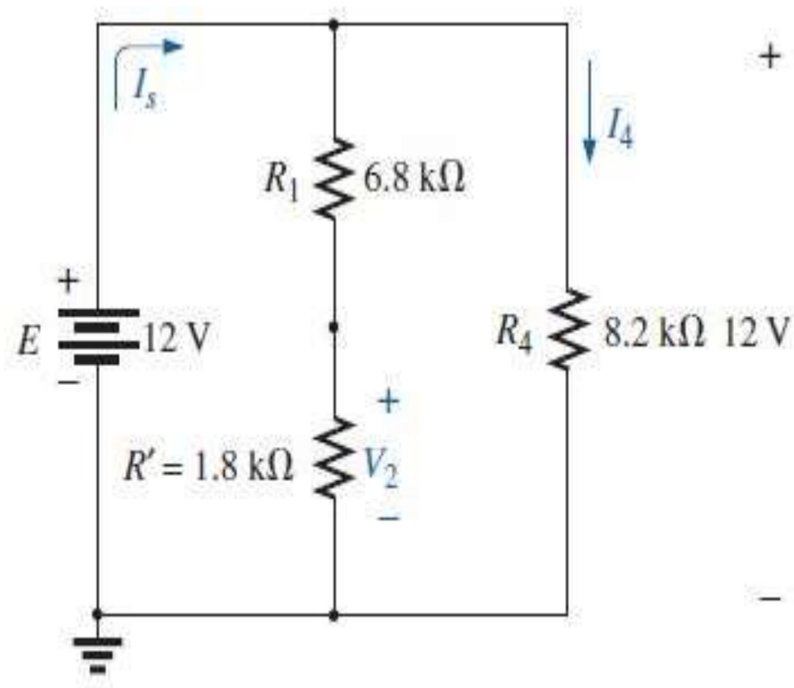


FIG. 7.6

SERIES-PARALLEL CIRCUIT

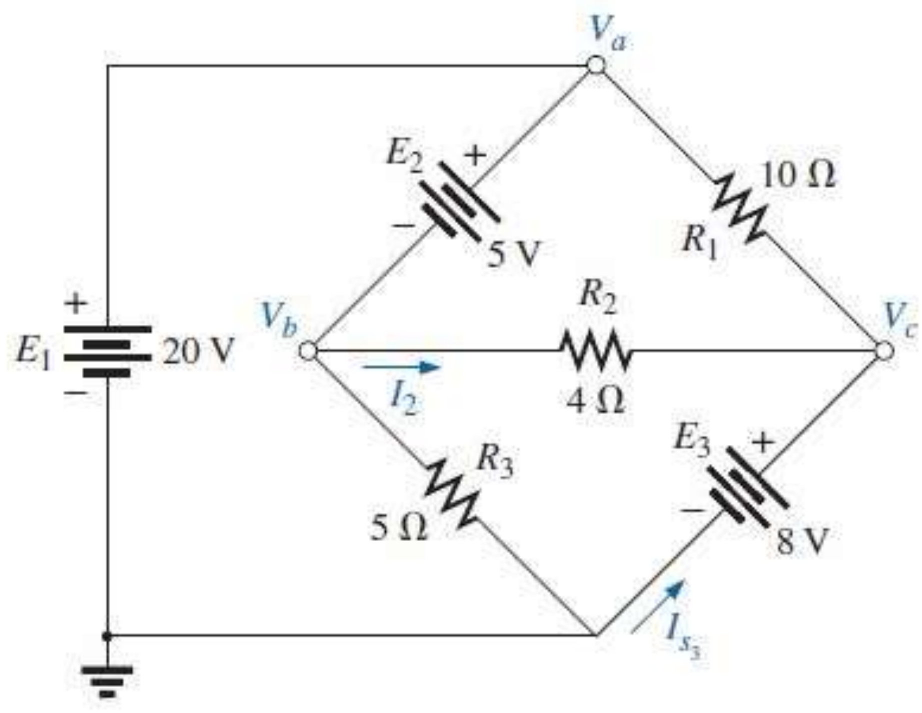
PRACTICE PROBLE : For the network in FOLLOWING FIGURE:

a. Determine voltages V_a, V_b, and V_c.

b. Find voltages V_{ac} and V_{bc}.

c. Find current I_2.

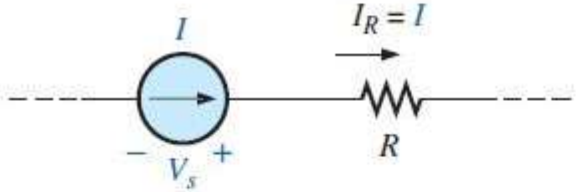
D. Find the source current I_{s3}



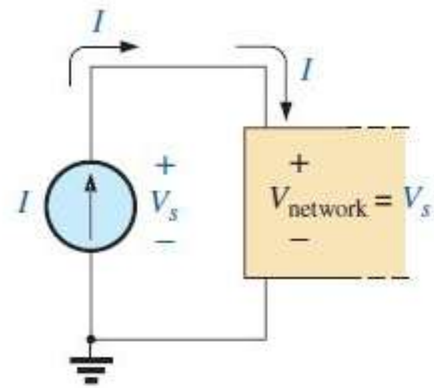
CURRENT SOURCES

The current source is often described as the *dual* of the voltage source .Just as a battery provides a fixed voltage to a network, a current source establishes a fixed current in the branch where it is located

The symbol for a current source appears in Fig. 8.1(a). The arrow indicates the direction in which it is supplying current to the branch where it is located. In Fig. 8.1(b),



(a)



(b)

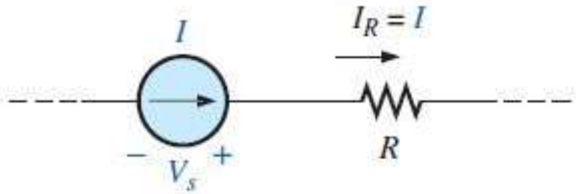
CURRENT SOURCES

In general, therefore,

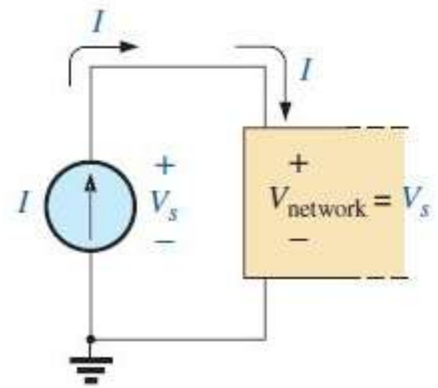
a current source determines the direction and magnitude of the current in the branch where it is located.

Furthermore,

the magnitude and the polarity of the voltage across a current source are each a function of the network to which the voltage is applied.



(a)



(b)

CURRENT SOURCES

EXAMPLE 8.1 Find the source voltage, the voltage V_1, and current I_1 for the circuit in Fig. 8.2.

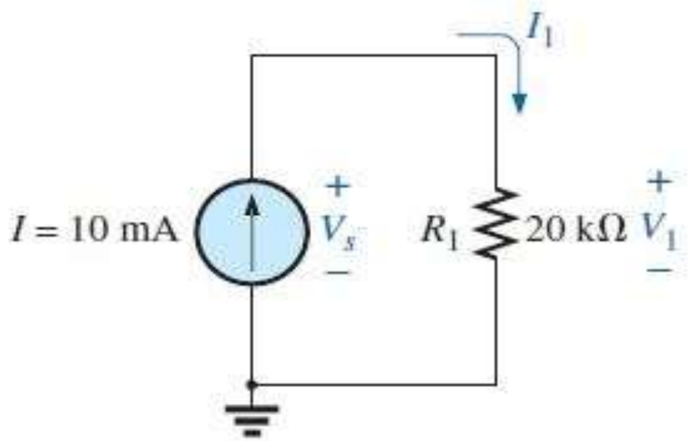


FIG. 8.2
Circuit for Example 8.1.

CURRENT SOURCES

EXAMPLE 8.2 Find the voltage *Vs* and currents *I*1 and *I*2 for the network in Fig. 8.3.

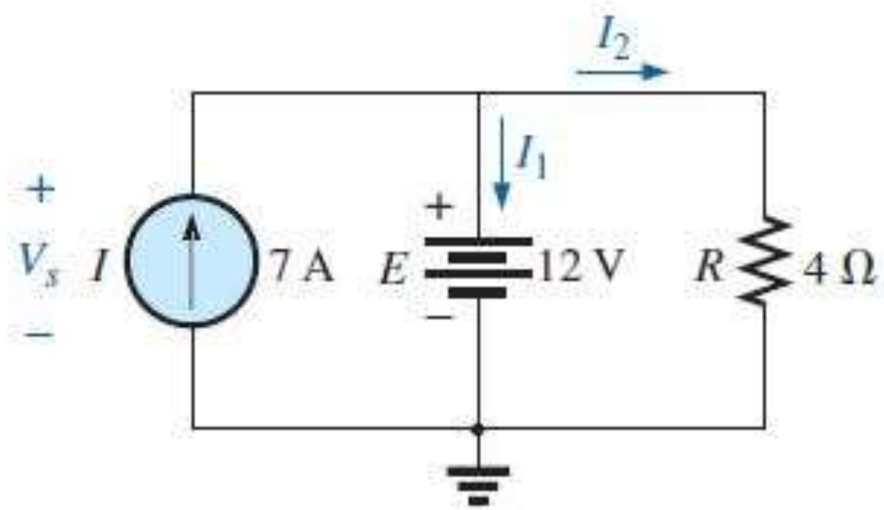


FIG. 8.3
Network for Example 8.2.

CURRENT SOURCES

SOLUTION :

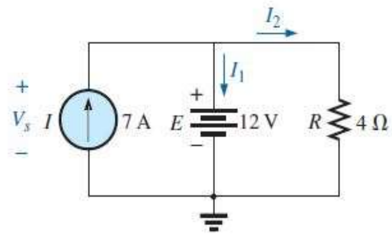


FIG. 8.3
Network for Example 8.2.

Since the current source and voltage source are in parallel,

$$V_s = E = \mathbf{12\ V}$$

Further, since the voltage source and resistor R are in parallel,

$$V_R = E = 12\text{ V}$$

and
$$I_2 = \frac{V_R}{R} = \frac{12\text{ V}}{4\ \Omega} = \mathbf{3\ A}$$

The current I_1 of the voltage source can then be determined by applying Kirchhoff's current law at the top of the network as follows:

$$\Sigma I_i = \Sigma I_o$$
$$I = I_1 + I_2$$

and
$$I_1 = I - I_2 = 7\text{ A} - 3\text{ A} = \mathbf{4\ A}$$

CURRENT SOURCES

EXAMPLE 8.3 Determine the current I_1 and the voltage V_s for the network in Fig. 8.4.

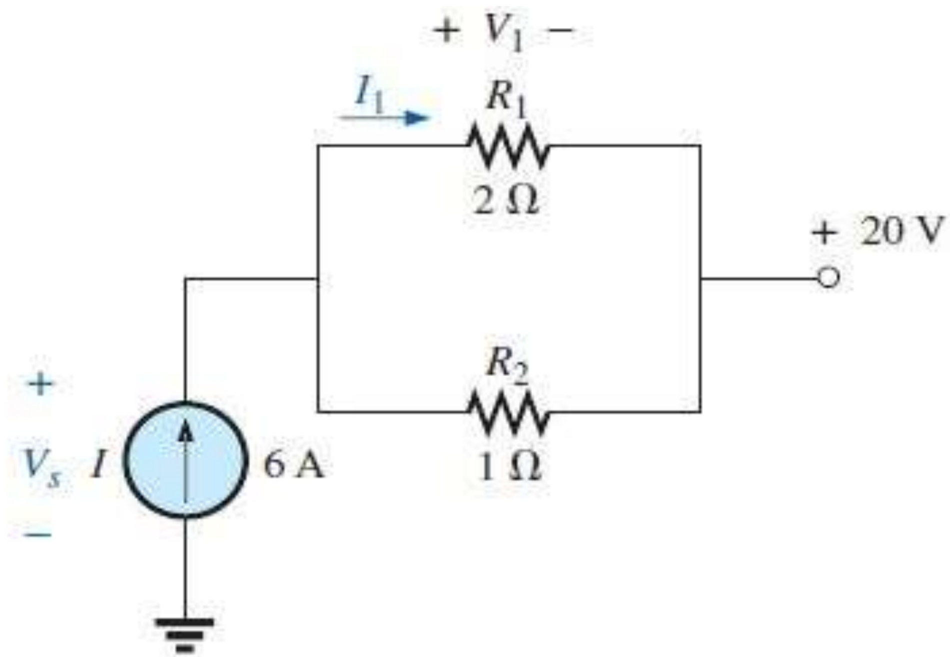


FIG. 8.4
Example 8.3.

CURRENT SOURCES

SOLUTION:

Using the current divider rule:

$$I_1 = \frac{R_2 I}{R_2 + R_1} = \frac{(1\,\Omega)(6\,\text{A})}{1\,\Omega + 2\,\Omega} = \frac{1}{3}(6\,\text{A}) = \mathbf{2\,A}$$

The voltage V_1:

$$V_1 = I_1 R_1 = (2\,\text{A})(2\,\Omega) = 4\,\text{V}$$

Applying Kirchhoff's voltage rule to determine V_s:

$$+V_s - V_1 - 20\,\text{V} = 0$$

and

$$V_s = V_1 + 20\,\text{V} = 4\,\text{V} + 20\,\text{V} = \mathbf{24\,V}$$

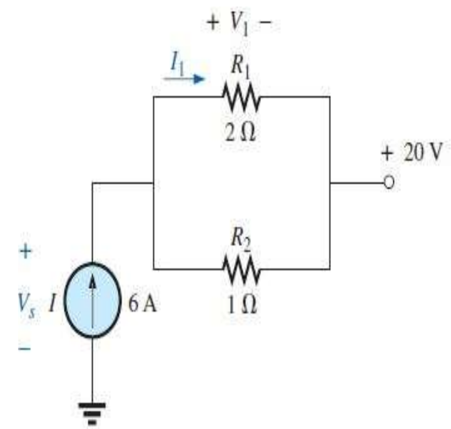


FIG. 8.4
Example 8.3.