REVIEW ON THE LAST CLASS

Series Circuit: Calculation of Current, Voltage drop, Power supply and consumption; Voltage Divider Rule (VDR); KIRCHHOFF'S VOLTAGE LAW (KVL)

Parallel Circuit: Calculation of Total Resistance, Current, Voltage drop, Power supply and consumption; Current Divider Rule (CDR)

6.5 KIRCHHOFF'S CURRENT LAW (KCL)

Statement:

(**1**) The algebraic sum of the currents entering and leaving a junction (or region) of a network is zero.

$$\sum I_{entering} - \sum I_{leaving} = 0 \qquad \textbf{(6.13.1)}$$

(**2**) The sum of the currents entering a junction (or region) of a network must equal the sum of the currents leaving the same junction (or region).

$$\sum I_{entering} = \sum I_{leaving} \qquad \textbf{(6.13)}$$

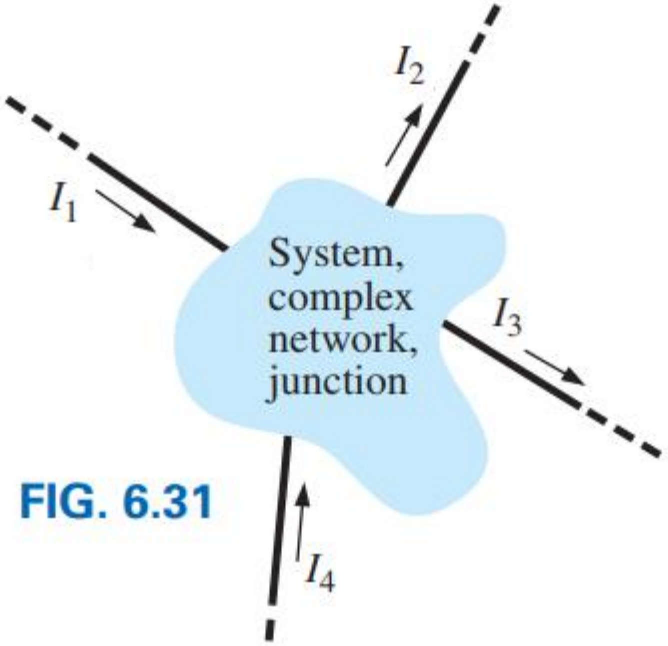


FIG. 6.31

$$I_1 + I_4 - I_2 - I_3 = 0$$

$$I_1 + I_4 = I_2 + I_3$$

EXAMPLE 6.17 Determine currents I_1, I_3, I_4, and I_5 for the network in Fig. 6.34.

Solution: At node *a:*

$$\Sigma I_i = \Sigma I_o$$
$$I = I_1 + I_2$$
$$5\text{ A} = I_1 + 4\text{ A}$$

and $$I_1 = 5\text{ A} - 4\text{ A} = \mathbf{1\ A}$$

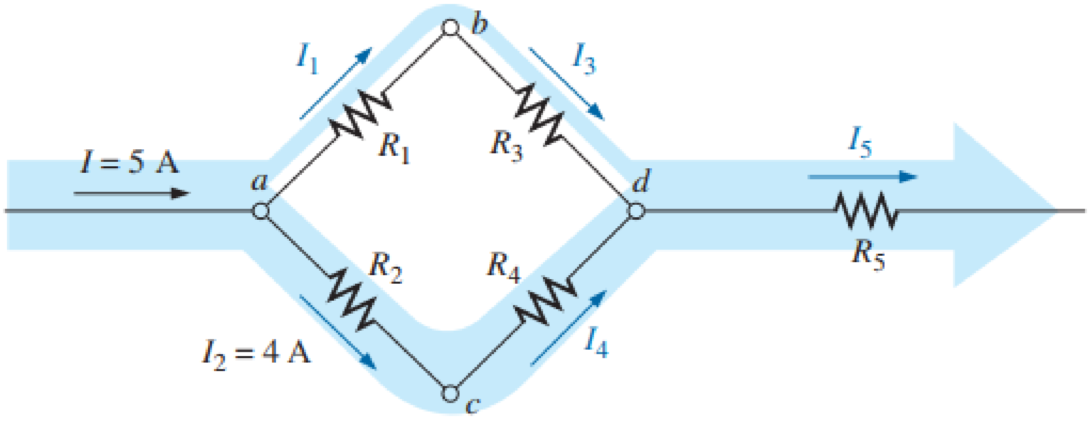


FIG. 6.34
Four-node configuration for Example 6.17.

At node *b:*

$$\Sigma I_i = \Sigma I_o$$
$$I_1 = I_3$$

and $$I_3 = I_1 = \mathbf{1\ A}$$

At node *c:*

$$\Sigma I_i = \Sigma I_o$$
$$I_2 = I_4$$

and $$I_4 = I_2 = \mathbf{4\ A}$$

At node *d:*

$$\Sigma I_i = \Sigma I_o$$
$$I_3 + I_4 = I_5$$
$$1\text{ A} + 4\text{ A} = I_5 = \mathbf{5\ A}$$

EXAMPLE 6.21

a. Determine currents I_1 and I_3 for the network in Fig. 6.40.
b. Find the source current I_s.

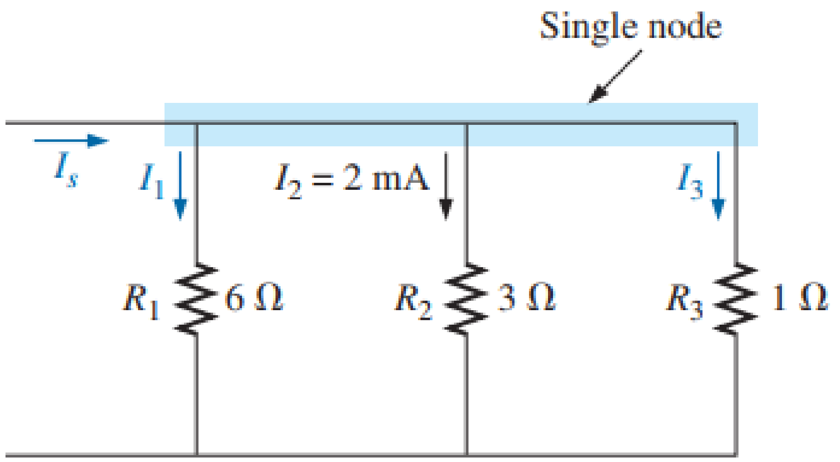


FIG. 6.40
Parallel network for Example 6.21.

Solutions:

a. Since R_1 is twice R_2, the current I_1 must be one-half I_2, and

$$I_1 = \frac{I_2}{2} = \frac{2\text{ mA}}{2} = \mathbf{1\ mA}$$

Since R_2 is three times R_3, the current I_3 must be three times I_2, and

$$I_3 = 3I_2 = 3(2\text{ mA}) = \mathbf{6\ mA}$$

b. Applying Kirchhoff's current law:

$$\Sigma I_i = \Sigma I_o$$
$$I_s = I_1 + I_2 + I_3$$
$$I_s = 1\text{ mA} + 2\text{ mA} + 6\text{ mA} = \mathbf{9\ mA}$$

Problem 25 [P. 238] Using Kirchoff's current law, find the unknown currents for the complex configurations in Fig. 6.95(b).

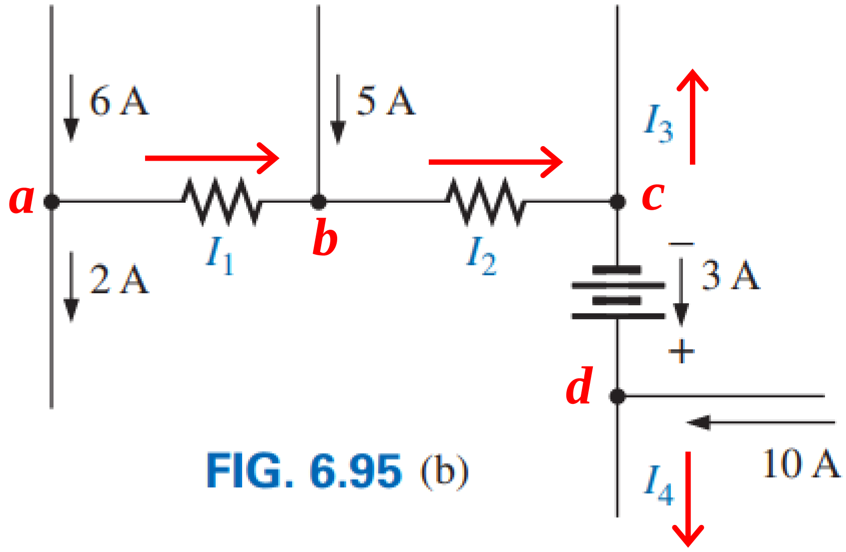


FIG. 6.95 (b)

Solution: Consider four (a, b, c, and d) nodes are here.

At node *a*: 6 A is entering and 2 A is leaving so consider I_1 is leaving.

According to KCL at node a, we have: $6\text{ A} = I_1 + 2\text{ A} = 9\text{ A}$

$\therefore I_1 = 6\text{ A} - 2\text{ A} = 4\text{ A}$

At node *b*: $I_1 = 4$ A and 5 A are entering so consider I_2 is leaving.

According to KCL at node b, we have: $I_2 = 4\text{ A} + 5\text{ A} = 9\text{ A}$

At node *c*: $I_2 = 9$ A current is entering and 3 A is leaving so consider I_3 is leaving.

According to KCL at node c, we have: $9\text{ A} = I_3 + 3\text{ A}$ $\therefore I_3 = 9\text{ A} - 3\text{ A} = 6\text{ A}$

At node *d*: 3 A and 10 A are entering so consider I_4 is leaving.

According to KCL at node d, we have: $I_4 = 3\text{ A} + 10\text{ A} = 13\text{ A}$

Practice Book Problem [SECTION 6.5 KCL] Problems: 24 to 28

6.4 Power Distribution in a Parallel Circuit

In any electrical system, the power supplied or applied or delivered will equal the power dissipated or absorbed or consumed.

$$P_E = P_{R1} + P_{R2} + P_{R3} \qquad \textbf{(6.10)}$$

$$P_E = EI_s \ \text{(watt, W)} \qquad \textbf{(6.11)}$$

$$P_{R1} = V_1 I_1 = I_1^2 R_1 = \frac{V_1^2}{R_1}$$

$$P_{R2} = V_2 I_2 = I_2^2 R_2 = \frac{V_2^2}{R_2} \qquad \text{(watt, W)} \qquad \textbf{(6.12)}$$

$$P_{R3} = V_3 I_3 = I_3^2 R_3 = \frac{V_3^2}{R_3}$$

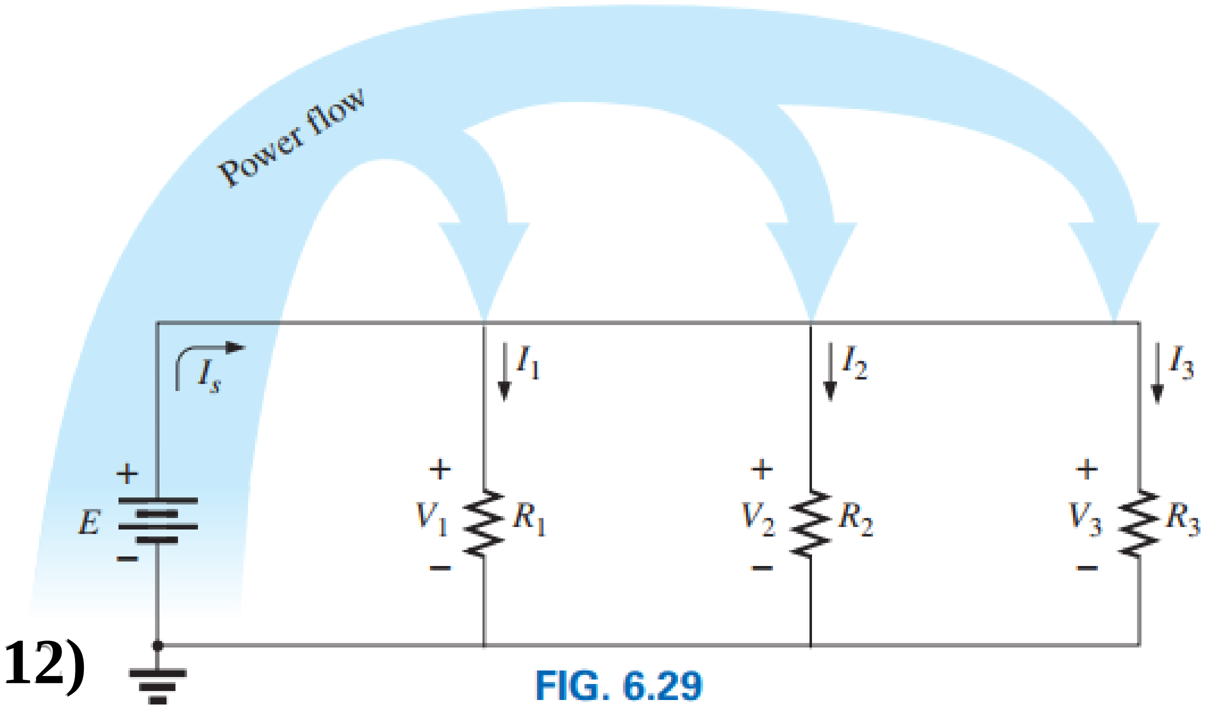


FIG. 6.29

Power flow in a dc parallel network.

EXAMPLE 6.15 For the parallel network in Fig. 6.30:

a. Determine the total resistance R_T.

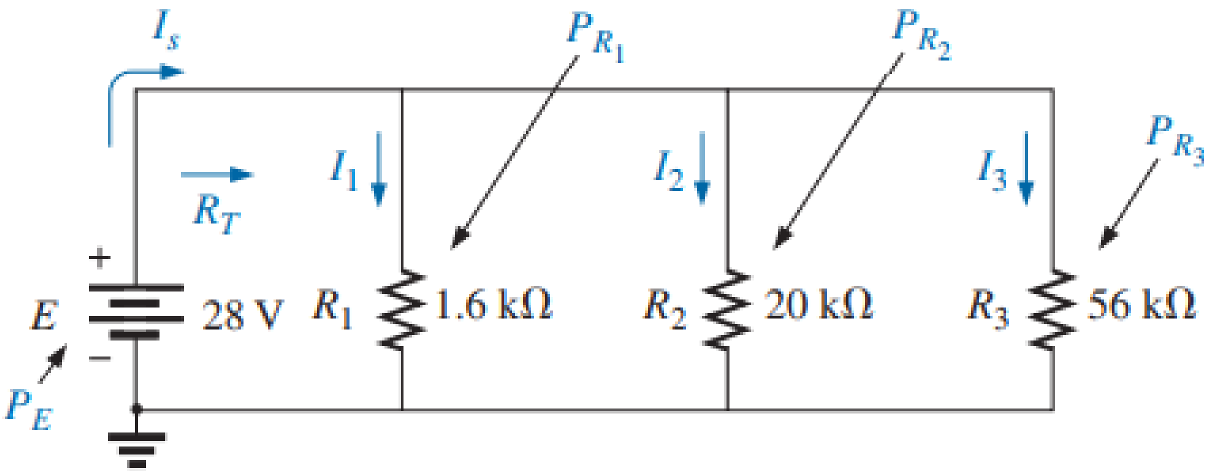
b. Find the source current (I_s) and the current (I_1, I_2, and I_3) through each resistor.

c. Verify KCL.

d. Calculate the power delivered by the source.

e. Determine the power absorbed by each parallel resistor.

f. Verify Eq. (6.10)



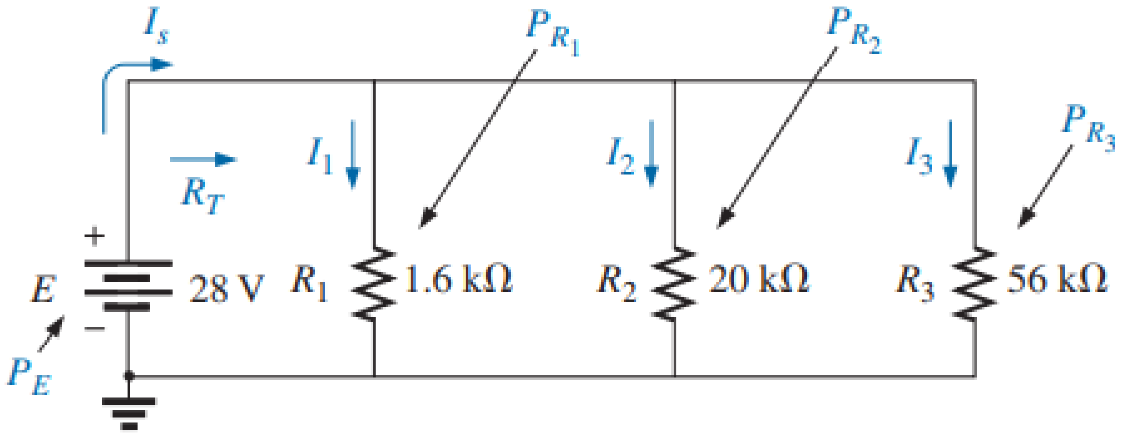
Solution: (***a***)

$$R_T = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}} = \frac{1}{\frac{1}{1.6\times10^3\,\Omega}+\frac{1}{20\times10^3\,\Omega}+\frac{1}{56\times10^3\,\Omega}}$$

$$= \frac{1}{625\times10^{-6}\,\text{S}+50\times10^{-6}\,\text{S}+17.867\times10^{-6}\,\text{S}} = \frac{1}{692.867\times10^{-6}\,\text{S}} = \mathbf{1.44\ k\Omega}$$

b. Find the source current (I_s) and the current (I_1, I_2, and I_3) through each resistor.

$R_T = \mathbf{1.44\ k\Omega}$



(*b*) Applying Ohm's Law:

$$I_s = \frac{E}{R_T} = \frac{28\ \text{V}}{1.44\times10^3\ \Omega} = \mathbf{19.4\ mA}$$

$$I_1 = \frac{R_T}{R_1} I_s = \frac{E}{R_1} = \frac{26\ \text{V}}{1.6\times10^3\ \Omega} = \mathbf{17.5\ A}$$

$$I_2 = \frac{R_T}{R_2} I_s = \frac{E}{R_2} = \frac{26\ \text{V}}{20\times10^3\ \Omega} = \mathbf{1.4\ A}$$

$$I_3 = \frac{R_T}{R_3} I_s = \frac{E}{R_3} = \frac{26\ \text{V}}{56\times10^3\ \Omega} = \mathbf{0.5\ A}$$

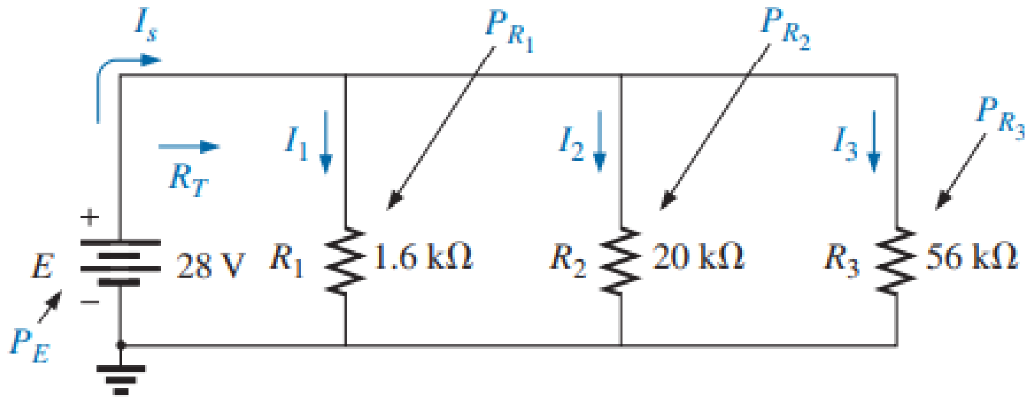
(*c*) According to KCL: $I_s = I_1 + I_2 + I_3$

$$\mathbf{19.4\ mA} = 17.5\,\text{mA} + 1.4\,\text{mA} + 0.5\,\text{mA} = \mathbf{19.4\ mA}$$

d. Calculate the power delivered by the source.

e. Determine the power absorbed by each parallel resistor.

f. Verify Eq. (6.10)



Solution: $R_T = \mathbf{1.44\ k\Omega}$ $\quad I_S = \mathbf{19.44\ mA}$

$I_1 = \mathbf{17.5\ A};\ I_2 = \mathbf{1.4\ A};\ I_3 = \mathbf{0.5\ A}$

d. Applying Eq. (6.11): $P_E = EI_s = (28\text{ V})\,(19.4\text{ mA}) = \mathbf{543.2\ mW}$

e. Applying each form of the power equation:

$$P_1 = V_1 I_1 = EI_1 = (28\text{ V})(17.5\text{ mA}) = \mathbf{490\ mW}$$

$$P_2 = I_2^2 R_2 = (1.4\text{ mA})^2(20\text{ k}\Omega) = \mathbf{39.2\ mW}$$

$$P_3 = \frac{V_3^2}{R_3} = \frac{E^2}{R_3} = \frac{(28\text{ V})^2}{56\text{ k}\Omega} = \mathbf{14\ mW}$$

f. $P_E = P_{R_1} + P_{R_2} + P_{R_3}$

$\mathbf{543.2\ mW} = 490\text{ mW} + 39.2\text{ mW} + 14\text{ mW} = \mathbf{543.2\ mW}$ (checks)

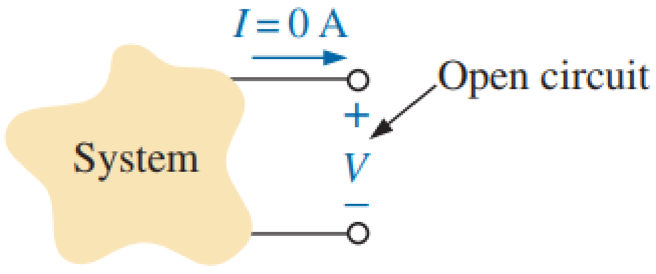
Practice Book Problem
[SECTION 6.4 Power Distribution]

Problems: 19 to 23

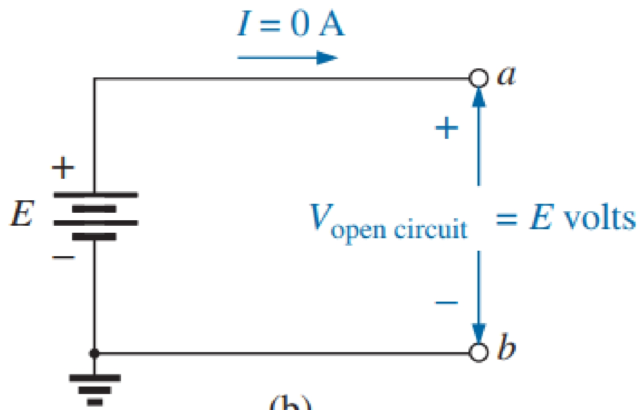
6.8 OPEN AND SHORT CIRCUITS

OPEN CIRCUITS

An **open circuit** is two isolated terminals not connected by any kind of element.



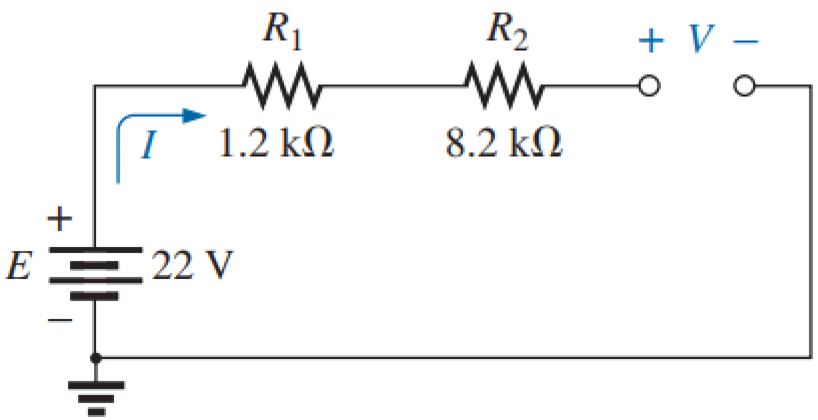
(a)

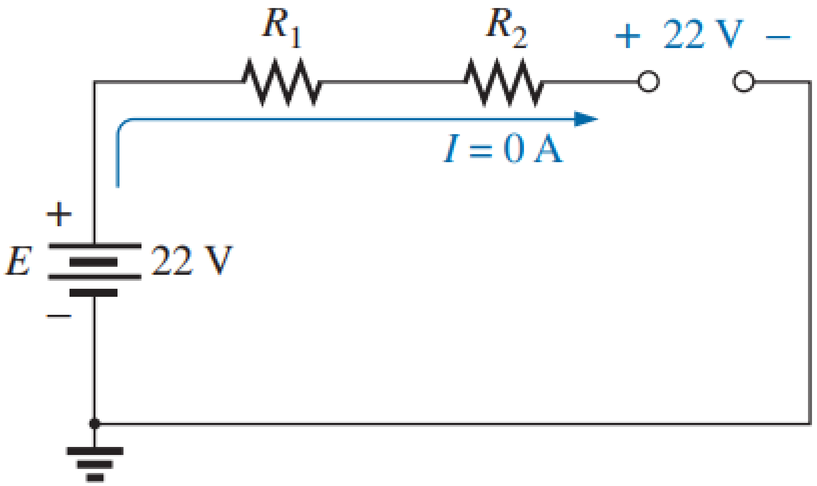


(b)

An open circuit can have a potential difference (voltage) across its terminals, but the current is always zero (0) amperes.

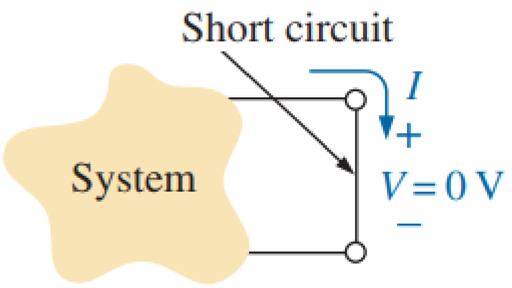
EXAMPLE 6.27.1 Determine the unknown voltage (V) and current (I) for the following network.

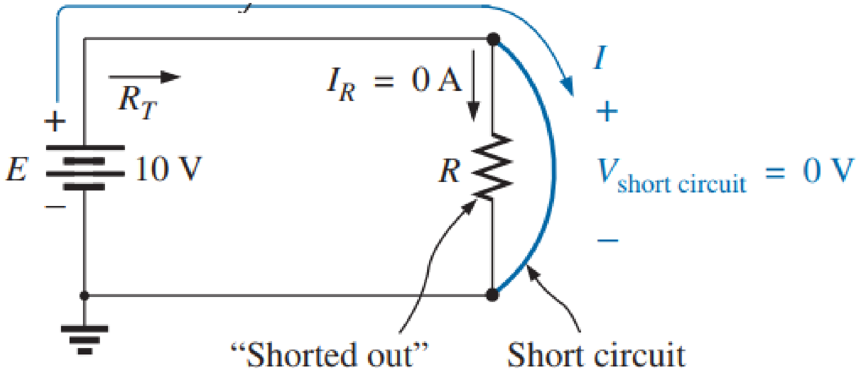




Short CIRCUITS

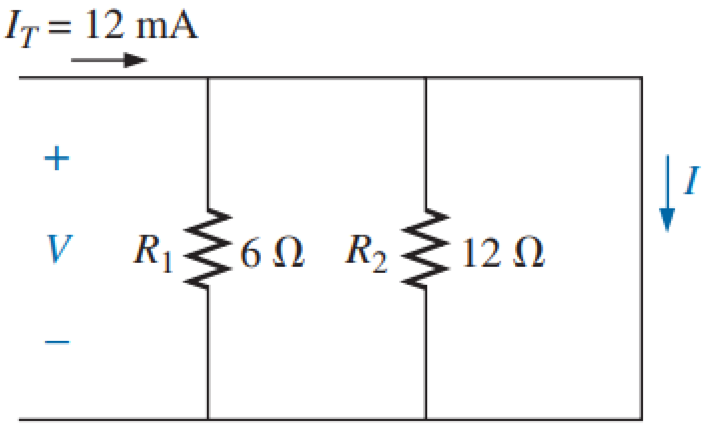
A **short circuit** is a very low resistance, direct connection between two terminals of a network.

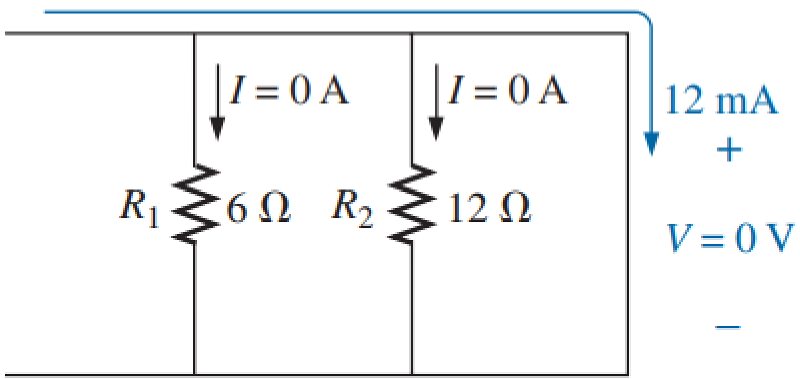




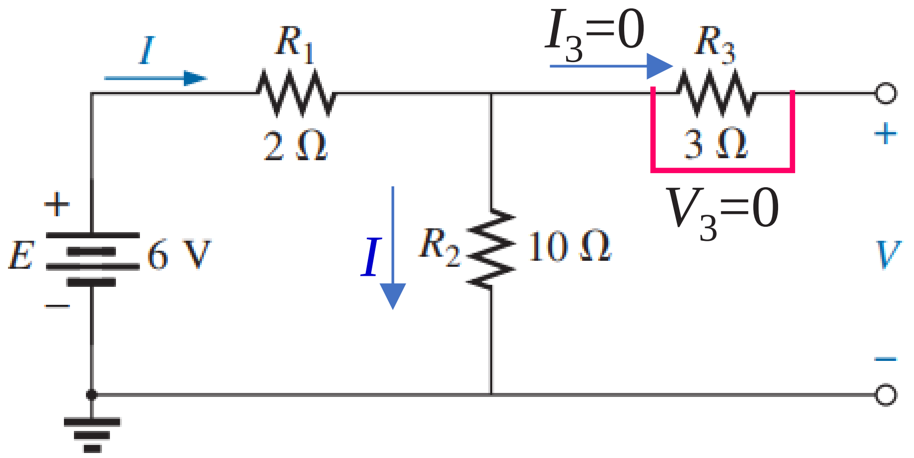
Aa short circuit can carry a current of a level determined by the external circuit, but the potential difference (voltage) across its terminals is always zero (0) volts.

EXAMPLE 6.27.2 Determine the unknown voltage (V) and current (I) for the following network.





EXAMPLE 6.28.1 Determine the unknown voltage (V) and current (I) for the following network.

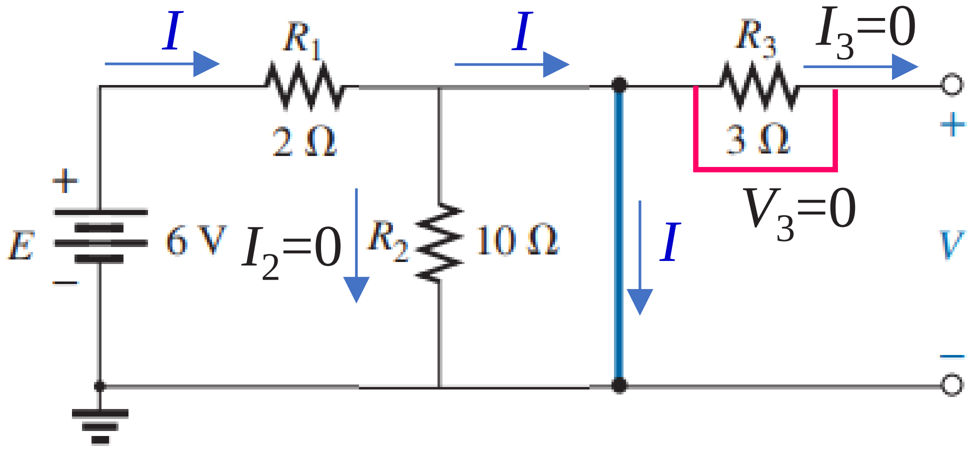


Due to the open circuit, the current flow (I_3) through the R_3 is zero. Thus, the current I flows through R_1 and R_2 and V is equal to the voltage drop across the resistance R_2.

$$V = \frac{R_2}{R_1 + R_2} E = \frac{10\ \Omega}{2\ \Omega + 10\ \Omega} \times 6\ \text{V} = \mathbf{5\ V}$$

$$I = \frac{E}{R_1 + R_2} = \frac{6\ \text{V}}{2\ \Omega + 10\ \Omega} = \mathbf{0.5\ A}$$

EXAMPLE 6.28.2 Determine the unknown voltage (V) and current (I) for the following network.



Due to the open circuit, the current flow (I_3) through the R_3 is zero and since R_2 is shorted the current flow (I_2) through the R_2 is zero. Thus, the current I flows through R_1 and short circuit and $V = \mathbf{0\ V}$.

$$I = \frac{E}{R_1} = \frac{6\ \text{V}}{2\ \Omega} = \mathbf{3\ A}$$

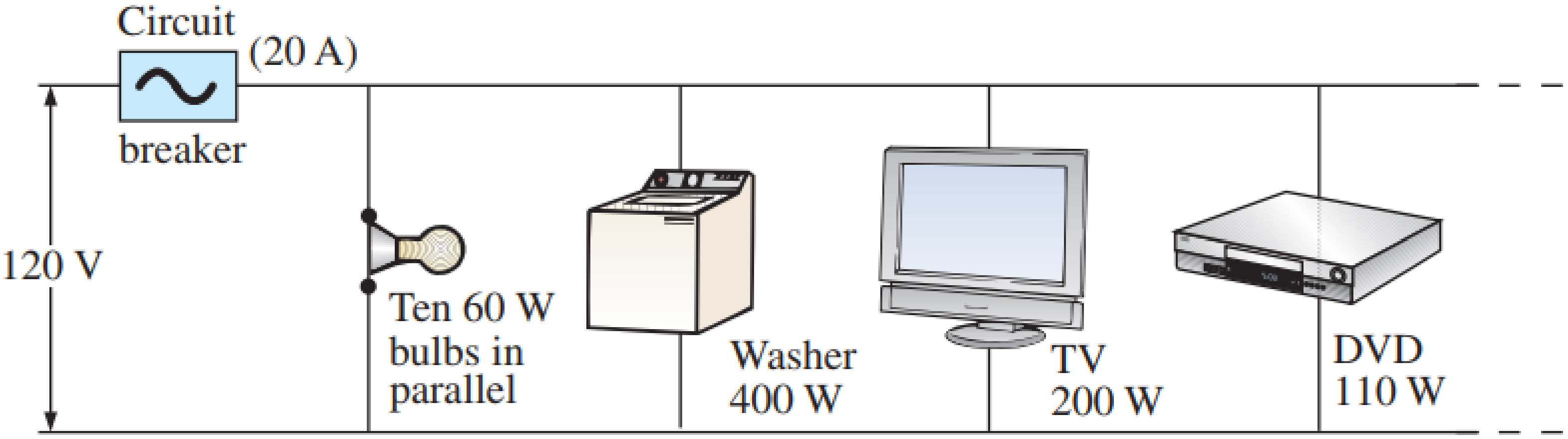
Problem 22 [P. 238] A portion of a residential service to a home is depicted in Fig. 6.92.

a. Determine the current through each parallel branch of the system.

b. Calculate the current drawn from the 120 V source. Will the 20 A breaker trip?

c. What is the total resistance of the network?

d. Determine the power delivered by the source. How does it compare to the sum of the wattage ratings appearing in Fig. 6.92?



Solution: **a**. We know that: $P = VI \quad \therefore\ I = \dfrac{P}{V}$

$$\text{For bulbs:}\quad I_b = \frac{10 \times 60\ \text{W}}{120\ \text{V}} = 5\ \text{A}$$

$$\text{For washer:}\quad I_w = \frac{400\ \text{W}}{120\ \text{V}} = 3.33\ \text{A}$$

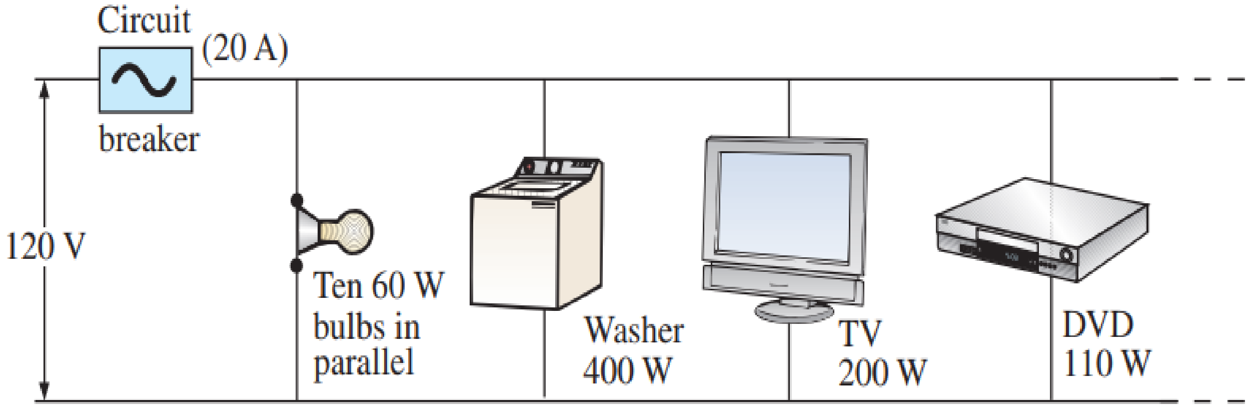
$$\text{For TV:}\quad I_{tv} = \frac{200\ \text{W}}{120\ \text{V}} = 1.667\ \text{A}$$

$$\text{For DVD:}\quad I_{dvd} = \frac{110\ \text{W}}{120\ \text{V}} = 0.917\ \text{A}$$

b. Calculate the current drawn from the 120 V source. Will the 20 A breaker trip?

c. What is the total resistance of the network?

d. Determine the power delivered by the source. How does it compare to the sum of the wattage ratings appearing in Fig. 6.92?



b. Applying KCL we have:

$$I_s = I_b + I_w + I_{tv} + I_{dvd}$$
$$= 5\text{ A} + 3.333\text{ A} + 1.667\text{ A} + 0.917\text{ A}$$
$$= 10.917\text{ A}$$

Since source current less than 20 circuit breaker will not trip.

c. $$R_T = \frac{E}{I_s} = \frac{120\text{ V}}{10.917\text{ A}} = 10.99\ \Omega$$

d. $$P_E = EI_s = (120\text{ V})(10.917\text{ A}) = 1310\text{ W}$$

$$P_w = (10 \times 60)\text{W} + 400\text{W} + 200\text{W} + 110\text{W} = 1310\text{ W}$$

Power delivered by the source (P_E) is **equal** to the sum of the wattage ratings (P_w).

Problem 38 [Ch 6] A For the network in Fig. 6.108:

(**a**) Determine I_s and V_L.

(**b**) Determine I_s if R_L is shorted out.

(**c**) Determine V_L if R_L is replaced by an open circuit.

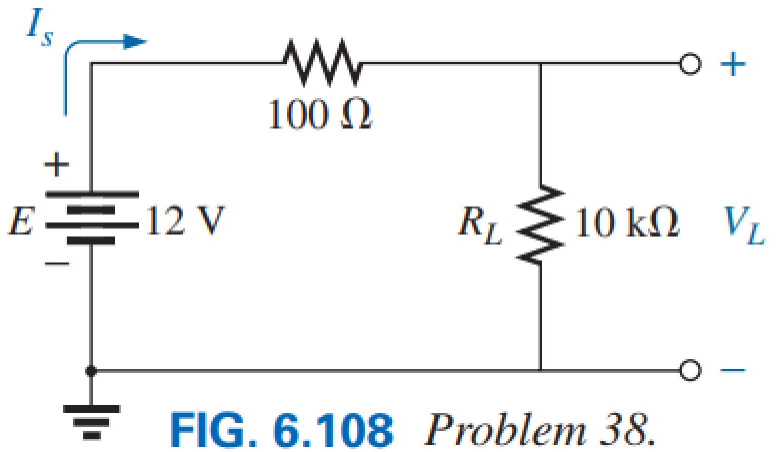
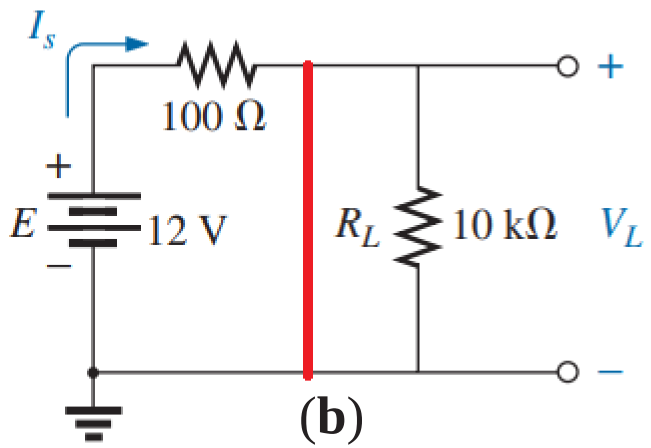


FIG. 6.108 *Problem 38.*

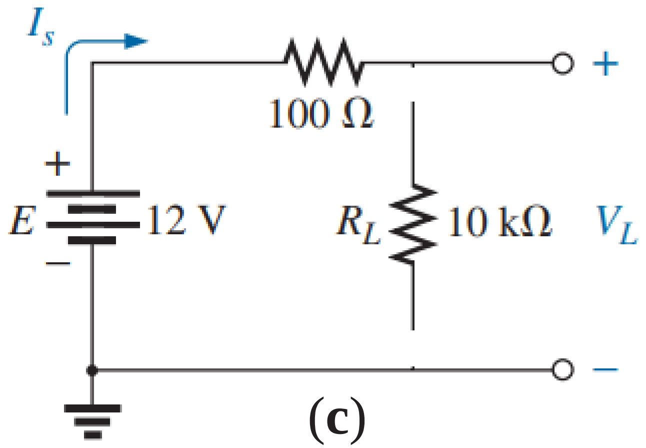
$$\textbf{(a)}\quad I_S = \frac{12\text{ V}}{100\ \Omega + 1\text{ k}\Omega} = \mathbf{10.91\ mA}$$

$$V_L = I_S R_L = (10.91\times10^{-3})\times(1\times10^{3}) = \mathbf{10.91\ V}$$



(**b**)

$$\textbf{(b)}\quad I_S = \frac{12\text{ V}}{100\ \Omega} = \mathbf{120\ mA}$$



(**c**)

$$\textbf{(c)}\quad V_L = E = \mathbf{12\ V}$$

Problem 39 [Ch 6] For the network in Fig. 6.109:

a. Determine the open-circuit voltage V_L.

b. If the 2.2 kΩ resistor is short circuited, what is the new value of V_L?

c. Determine V_L if the 4.7 k Ω resistor is replaced by an open circuit.

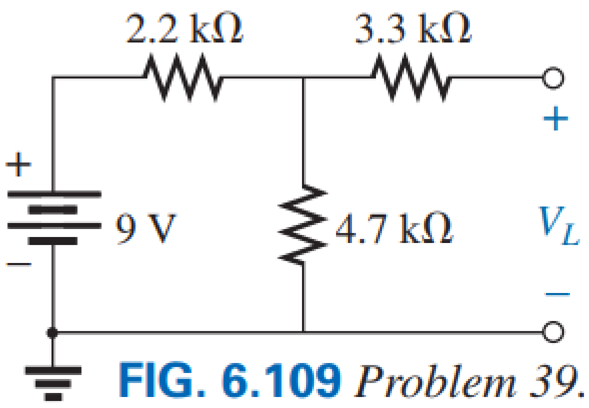
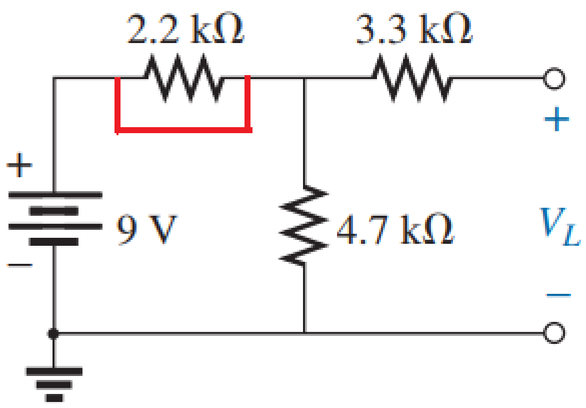
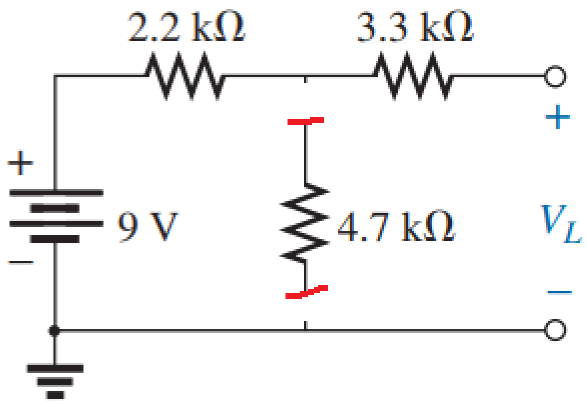


FIG. 6.109 *Problem 39.*

$$\text{(a)} \quad V_L = \frac{(4.7\,\text{k}\Omega)\times(9\ \text{V})}{2.2\,\text{k}\Omega + 4.7\,\text{k}\Omega} = \mathbf{6.13\ V}$$



$$\text{(b)} \quad V_L = E = \mathbf{9\ V}$$



$$\text{(c)} \quad V_L = E = \mathbf{9\ V}$$

Chapter 7

Series Parallel DC Circuit

SERIES/PARALLEL CONNECTION OF VOLTAGE/CURRENT SOURCES

VOLTAGE SOURCES IN SERIES

Voltage sources can be connected in series.

The voltage sources to be connected in series must have same current ratings through their voltage rating may be same or different.

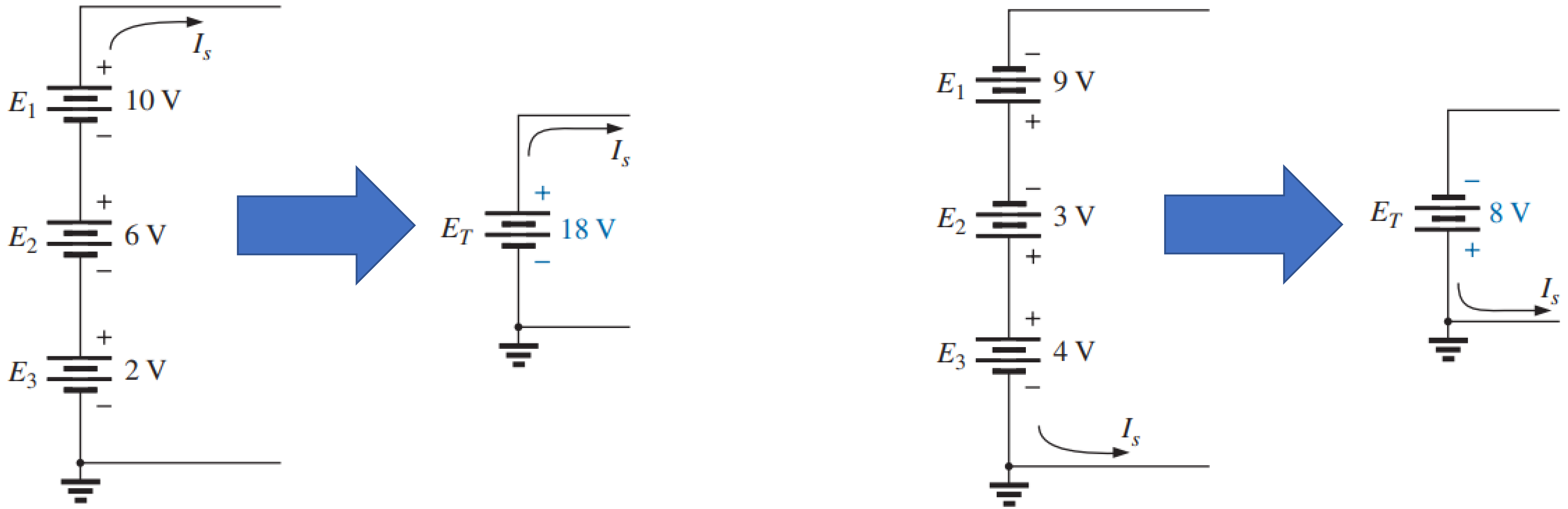
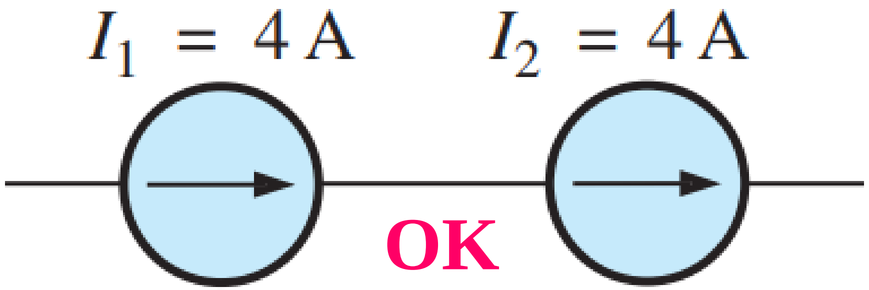


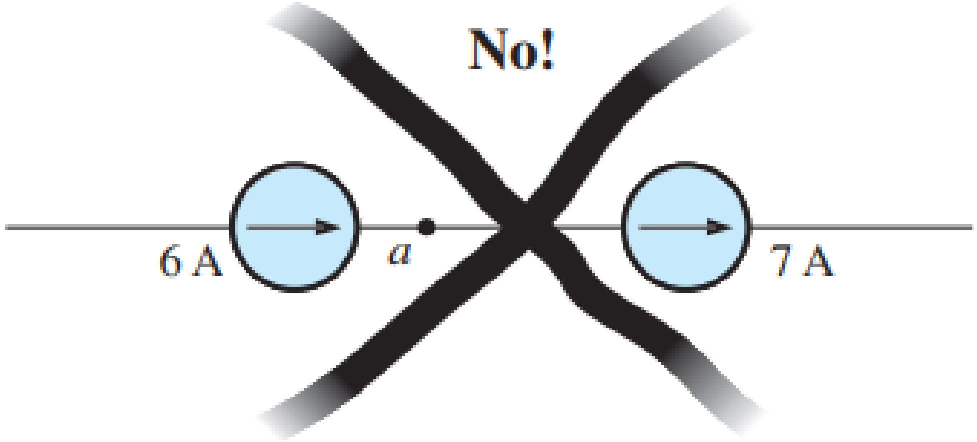
Fig. 5.3 Reducing Series Voltage Sources to a Single Source

CURRENT SOURCES IN SERIES

Current sources to be connected in series must have same current ratings through their voltage ratings may be same or different.



Current sources of different current ratings should not be connected in series.



6.7 VOLTAGE SOURCES IN PARALLEL

Voltage sources can be placed in parallel only if:

(***i***) They have the same voltage rating.

(***ii***) Positive terminal should be connected with positive terminal and Negative terminal should be connected with negative terminal

Voltage sources to be connected in parallel must have same voltage rating through their current rating may be same or different.

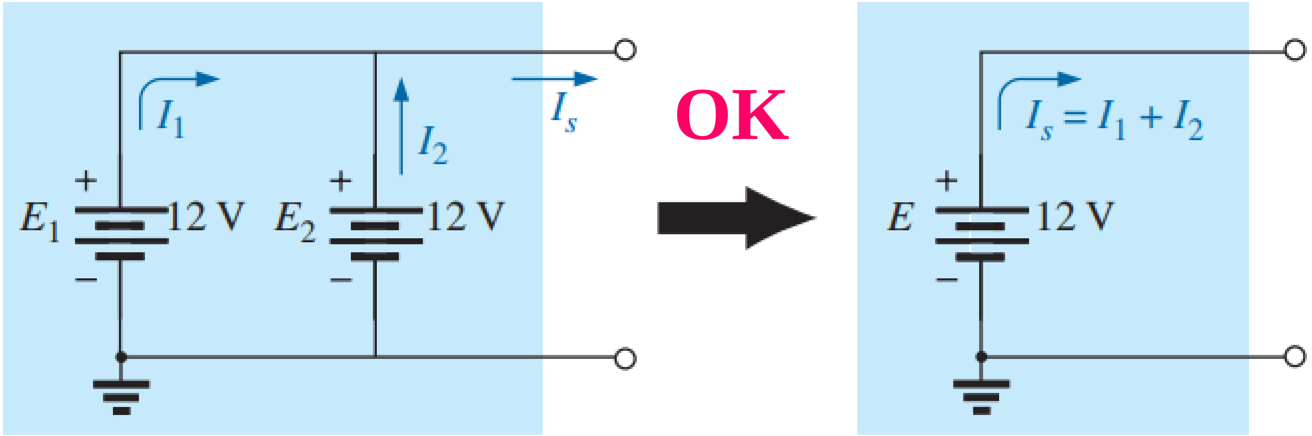


FIG. 6.47

Demonstrating the effect of placing two ideal supplies of the same voltage in parallel.

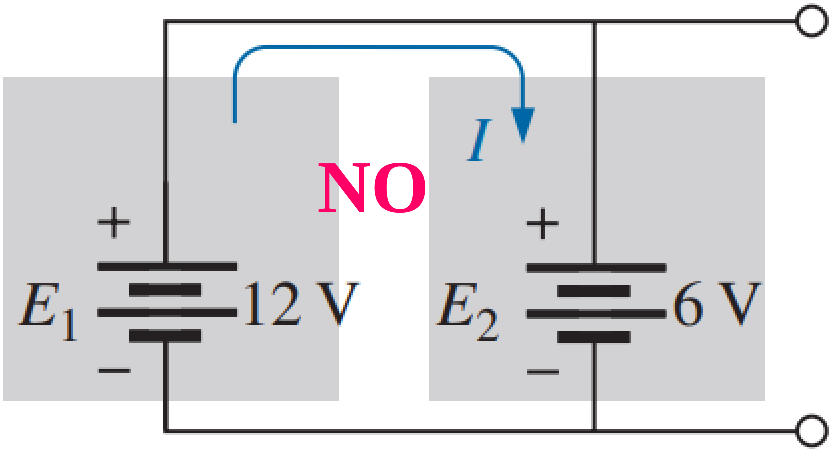


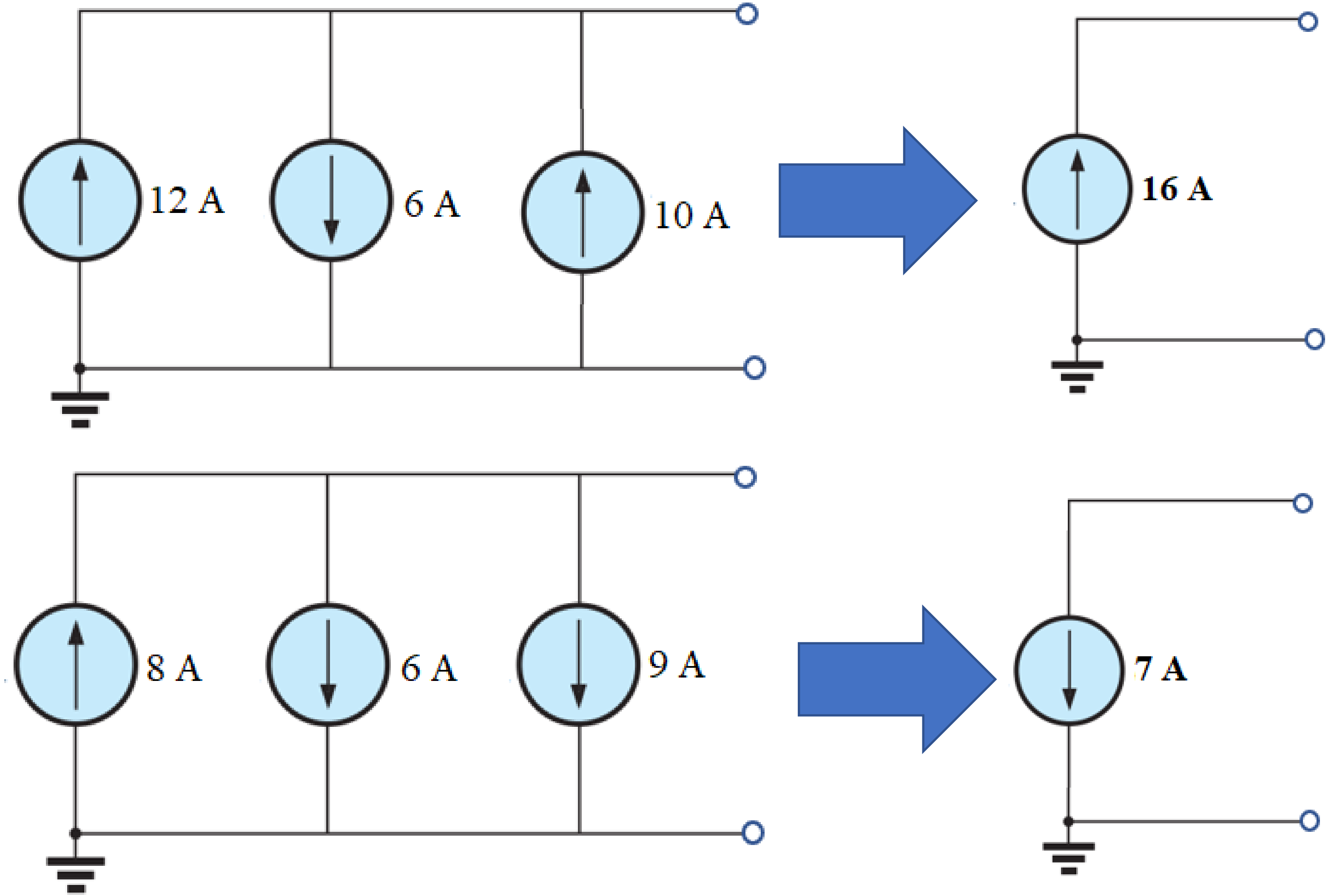
FIG. 6.48

Should not be connected

CURRENT SOURCES IN PARALLEL

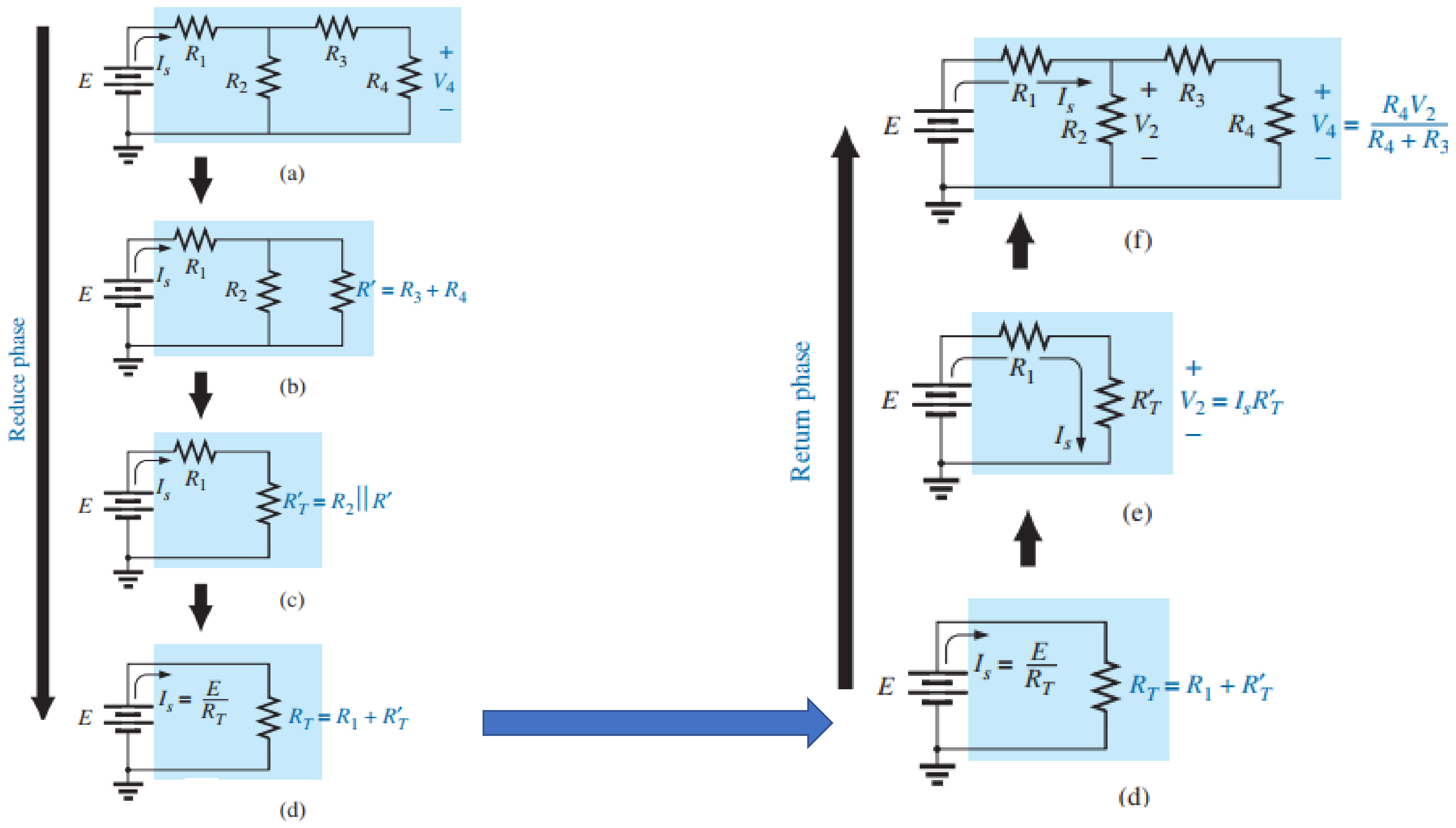
Current sources of different current ratings are not connected in series.

The current sources to be connected in parallel must have same voltage rating through their current ratings may be same or different.



Reducing Parallel Current Sources to a Single Source

7.3 REDUCE AND RETURN APPROACH



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

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

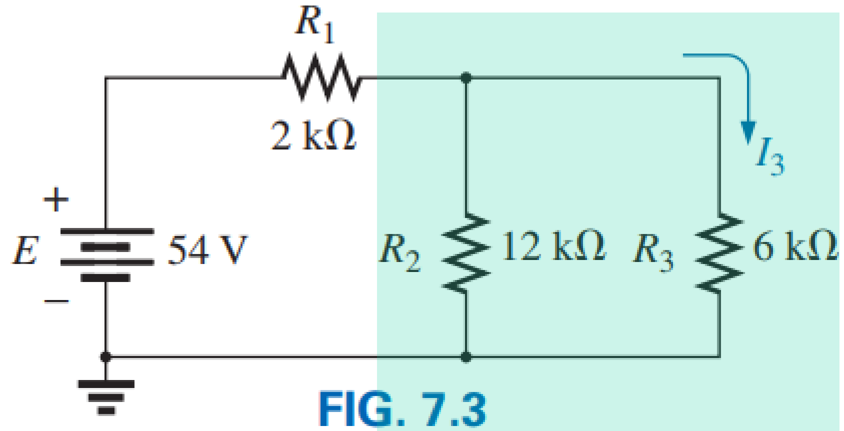


FIG. 7.3

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

$$R_4 = R_2 \parallel R_3 = \frac{R_2R_3}{R_2 + R_3} = \frac{(12\text{ k}\Omega)(6\text{ k}\Omega)}{12\text{ k}\Omega + 6\text{ k}\Omega} = 4\text{ k}\Omega$$

Redraw the circuit showing the calculated resistance R_4.

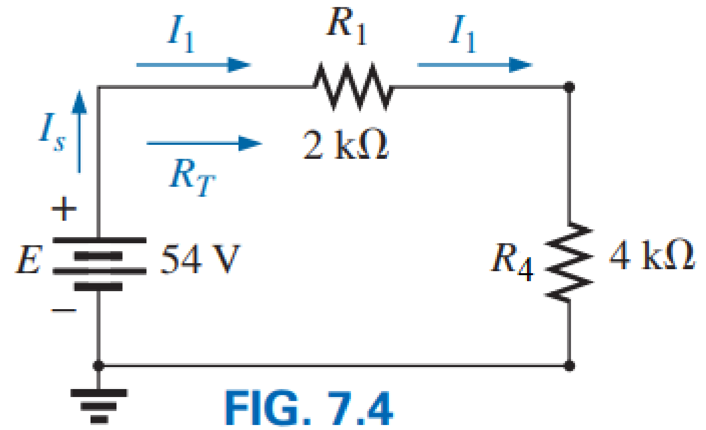


FIG. 7.4

Now, resistors R_1 and R_4 are in series, resulting in a total resistance of

$$R_T = R_1 + R_4 = 2\text{ k}\Omega + 4\text{ k}\Omega = 6\text{ k}\Omega$$

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

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

Returning to Fig. 7.3, we find the current I_3 as follows:

$$I_3 = \frac{R_4}{R_3} I_1 = \left(\frac{R_2}{R_2 + R_3}\right) I_1 = \left(\frac{12\text{ k}\Omega}{12\text{ k}\Omega + 6\text{ k}\Omega}\right) 9\text{ mA} = \mathbf{6\text{ mA}}$$

EXAMPLE 7.2 For the network in Fig. 7.5:

a. Determine currents I_4 and I_s and voltage V_2.
b. Insert the meters to measure current I_4 and voltage V_2.

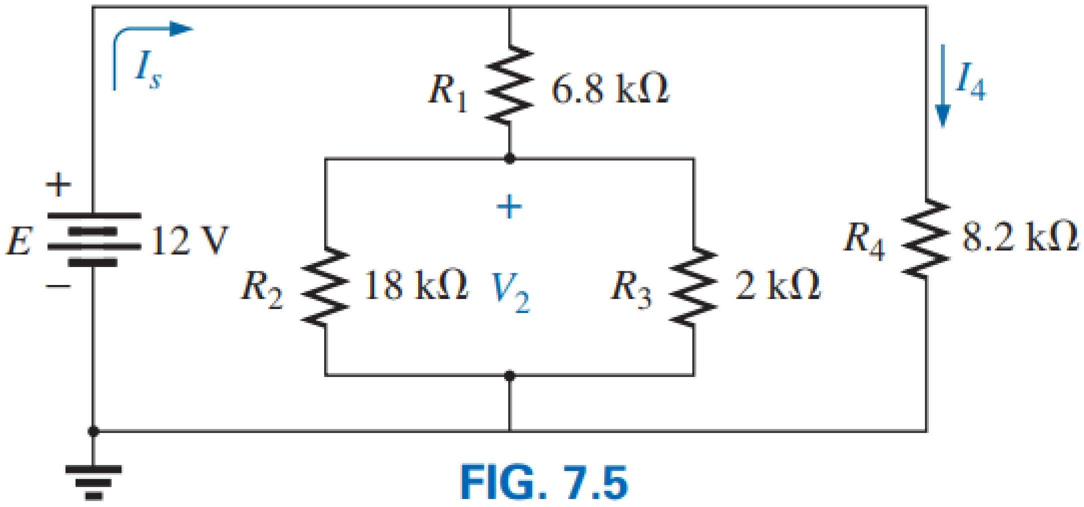


FIG. 7.5

Solution:

$$R_5 = R_2 \parallel R_3 = \frac{R_2R_3}{R_2 + R_3} = \frac{(18\text{ k}\Omega)(2\text{ k}\Omega)}{18\text{ k}\Omega + 2\text{ k}\Omega} = 1.8\text{ k}\Omega$$

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

$$V_2 = \left(\frac{R_5}{R' + R_1}\right)E = \left(\frac{1.8\text{ k}\Omega}{1.8\text{ k}\Omega + 6.8\text{ k}\Omega}\right)12\text{ V} = \mathbf{2.51\text{ V}}$$

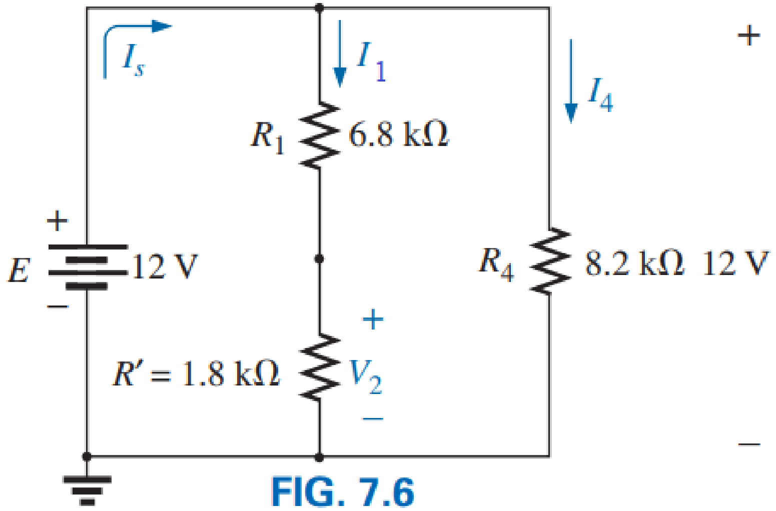


FIG. 7.6

$$I_1 = \frac{E}{R_1 + R_5} = \frac{12\text{ V}}{6.8\text{ k}\Omega + 1.8\text{ k}\Omega} = 1.40\text{ mA}$$

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

Practice Book Problem [SECTIONS 7.2–7.5 Series Parallel Networks] Problems: 1 ~ 24

7.4 BLOCK DIAGRAM APPROACH

EXAMPLE 7.4 Determine all the currents and voltages for the series-parallel network in Fig. 7.12.

Solution:

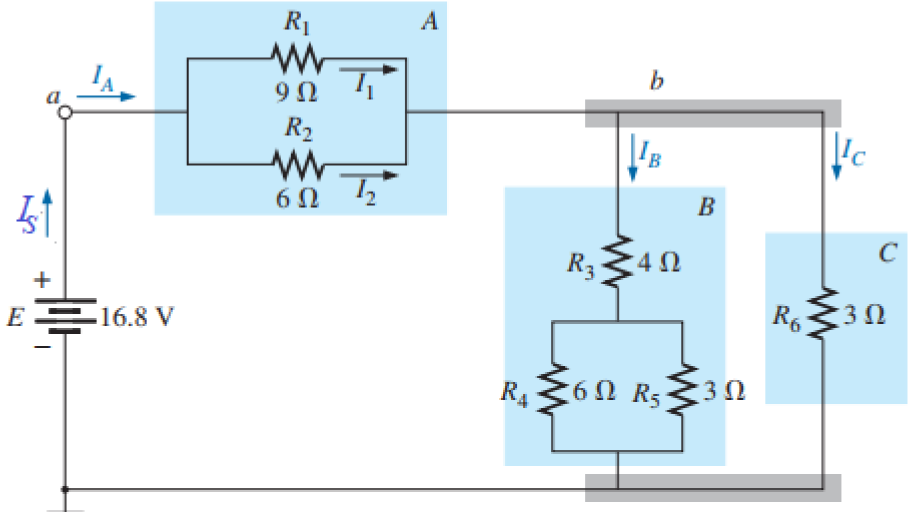


FIG. 7.12

$$R_A=\frac{R_1R_2}{R_1+R_2}=\frac{(9\ \Omega)\times(6\ \Omega)}{9\ \Omega+6\ \Omega}=3.6\ \Omega$$

$$R_B=R_3+\frac{R_4R_5}{R_4+R_5}=4\ \Omega+\frac{(3\ \Omega)\times(3\ \Omega)}{6\ \Omega+3\ \Omega}=4\ \Omega+2\ \Omega=6\ \Omega$$

$$R_C=R_6=3\ \Omega$$

$$R_{B//C}=\frac{R_BR_C}{R_B+R_C}=\frac{(6\ \Omega)\times(3\ \Omega)}{6\ \Omega+3\ \Omega}=2\ \Omega$$

$$R_T=R_A+R_{B//C}=36\ \Omega+2\ \Omega=5.6\ \Omega$$

$$I_s=I_A=\frac{E}{R_T}=\frac{16.8\ \text{V}}{5.6\ \Omega}=\mathbf{3\ A}$$

$$I_1=\frac{R_A}{R_1}I_s=\frac{R_2}{R_1+R_2}I_s=\frac{6\ \Omega}{9\ \Omega+6\ \Omega}\times 3\ \text{A}=\mathbf{1.2\ A}$$

$$I_2=\frac{R_A}{R_2}I_s=\frac{R_1}{R_1+R_2}I_s=I_s-I_1=3\ \text{A}-1.2\ \text{A}=\mathbf{1.8\ A}$$

$$I_B=\frac{R_{B//C}}{R_B}I_s=\frac{R_C}{R_B+R_C}I_s=\frac{3\ \Omega}{6\ \Omega+3\ \Omega}\times 3\ \text{A}=\mathbf{1\ A}$$

$$I_C=\frac{R_{B//C}}{R_C}I_s=\frac{R_B}{R_B+R_C}I_s=I_s-I_B=3\ \text{A}-1\ \text{A}=\mathbf{2\ A}$$

EXAMPLE 7.7

a. Find the voltages V_1, V_3, and V_{ab} for the network in Fig. 7.20.
b. Calculate the source current I_s.

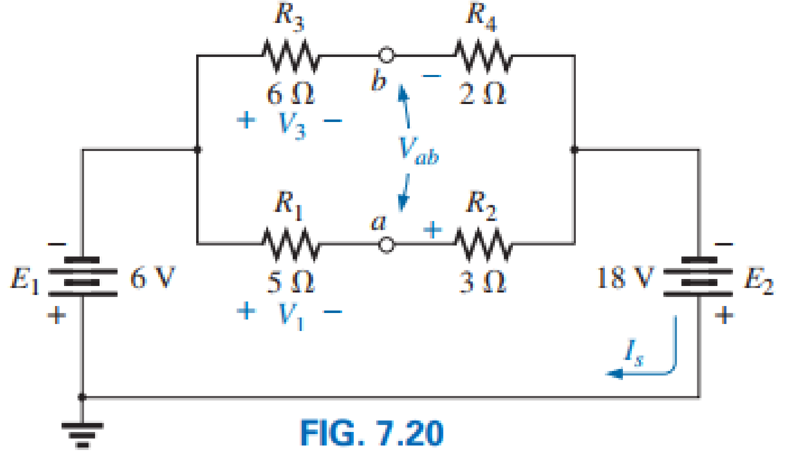


FIG. 7.20

Solution:

$$V_1 = \frac{R_1E}{R_1 + R_2} = \frac{(5\ \Omega)(12\ \text{V})}{5\ \Omega + 3\ \Omega} = \frac{60\ \text{V}}{8} = \mathbf{7.5\ V}$$

$$V_3 = \frac{R_3E}{R_3 + R_4} = \frac{(6\ \Omega)(12\ \text{V})}{6\ \Omega + 2\ \Omega} = \frac{72\ \text{V}}{8} = \mathbf{9\ V}$$

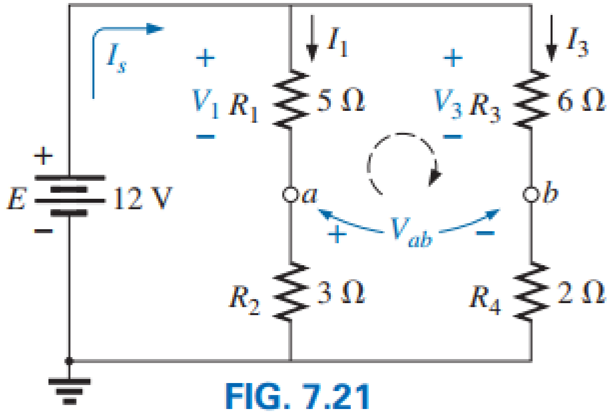


FIG. 7.21

$$+V_1 - V_3 + V_{ab} = 0$$

and $V_{ab} = V_3 - V_1 = 9\ \text{V} - 7.5\ \text{V} = \mathbf{1.5\ V}$

b. By Ohm's law, $I_1 = \frac{V_1}{R_1} = \frac{7.5\ \text{V}}{5\ \Omega} = 1.5\ \text{A}$

$$I_3 = \frac{V_3}{R_3} = \frac{9\ \text{V}}{6\ \Omega} = 1.5\ \text{A}$$

Applying Kirchhoff's current law,

$$I_s = I_1 + I_3 = 1.5\ \text{A} + 1.5\ \text{A} = \mathbf{3\ A}$$

EXAMPLE 7.8 For the network in Fig. 7.22, determine the voltages V_1 and V_2 and the current I.

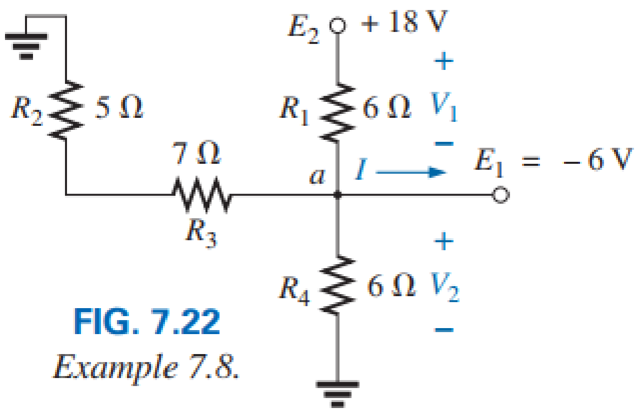


FIG. 7.22
Example 7.8.

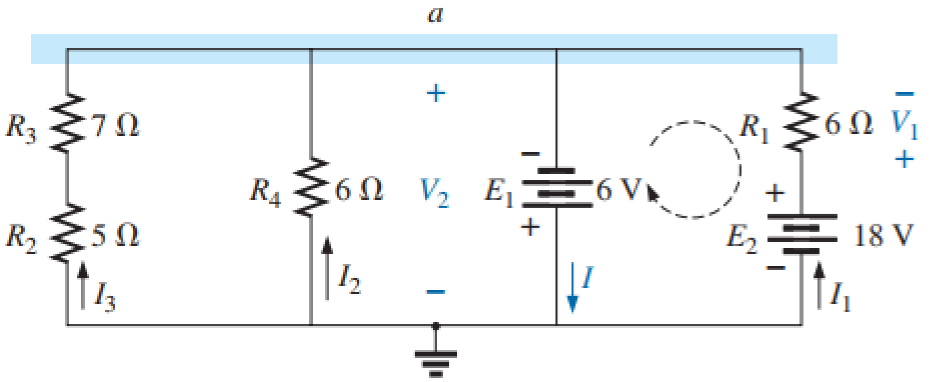


FIG. 7.23
Network in Fig. 7.22 redrawn.

Solution:

Applying Kirchhoff's voltage law:

$$V_2 = -E_1 = \mathbf{-6\ V}$$

Applying Kirchhoff's voltage law:

$$-E_1 + V_1 - E_2 = 0$$

and $\quad V_1 = E_2 + E_1 = 18\text{ V} + 6\text{ V} = \mathbf{24\ V}$

Applying Kirchhoff's current law to note a yields

$$I = I_1 + I_2 + I_3$$
$$= \frac{V_1}{R_1} + \frac{E_1}{R_4} + \frac{E_1}{R_2 + R_3}$$
$$= \frac{24\text{ V}}{6\ \Omega} + \frac{6\text{ V}}{6\ \Omega} + \frac{6\text{ V}}{12\ \Omega}$$
$$= 4\text{ A} + 1\text{ A} + 0.5\text{ A}$$
$$I = \mathbf{5.5\ A}$$

Problem 10:

a. Find the magnitude and direction for current I, I_1, I_2, and I_3, for the network in Fig. 7.70.

b. Indicate their direction on Fig. 7.70.

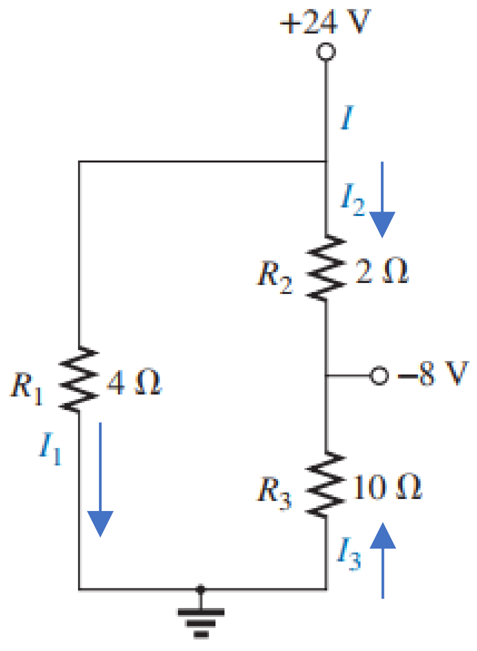


FIG. 7.70 Problem 10.

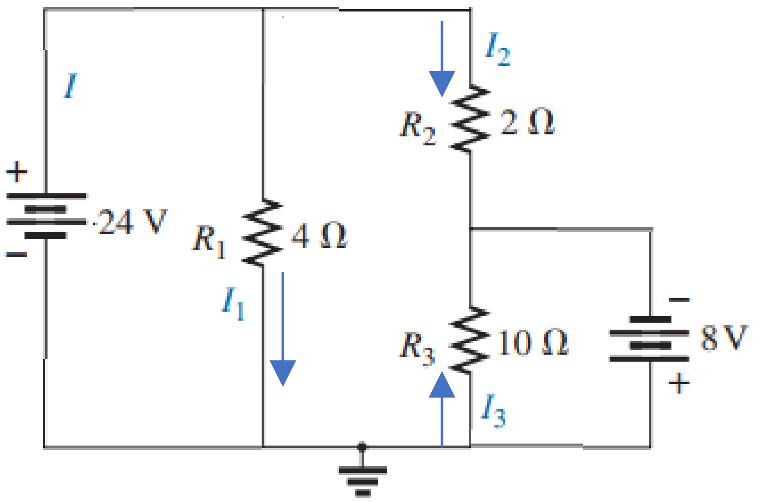
Solution: Voltage drop across the resistance R_1 equal to 24 V. So:

$$I_1 = \frac{24\text{ V}}{4\ \Omega} = \mathbf{6\ A}$$

Voltage drop across the resistance R_3 equal to 8 V. So: $I_3 = \dfrac{8\text{ V}}{10\ \Omega} = \mathbf{0.8\ A}$

Voltage drop across the resistance R_2 equal to the difference of 24 V and –8 V. So:

$$I_2 = \frac{24\text{ V} - (-8\text{ V})}{2\ \Omega} = \frac{32\text{ V}}{2\ \Omega} = \mathbf{16\ A}$$



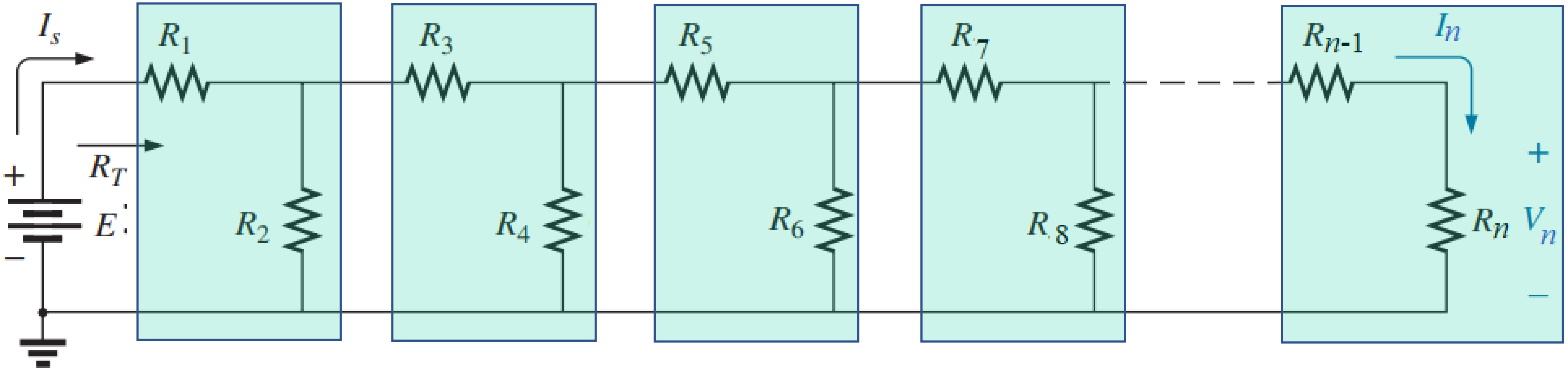
According to KCL: $I = I_1 + I_2 = 6\text{ A} + 16\text{ A} = 22\text{ A}$

Practice Book Problem [SECTIONS 7.2–7.5 Series Parallel Networks] Problems: 1 ~ 24

7.6 LADDER NETWORKS

A ***n*-section ladder network** appears in the following Figure.

The reason for the terminology is quite obvious for the repetitive structure.

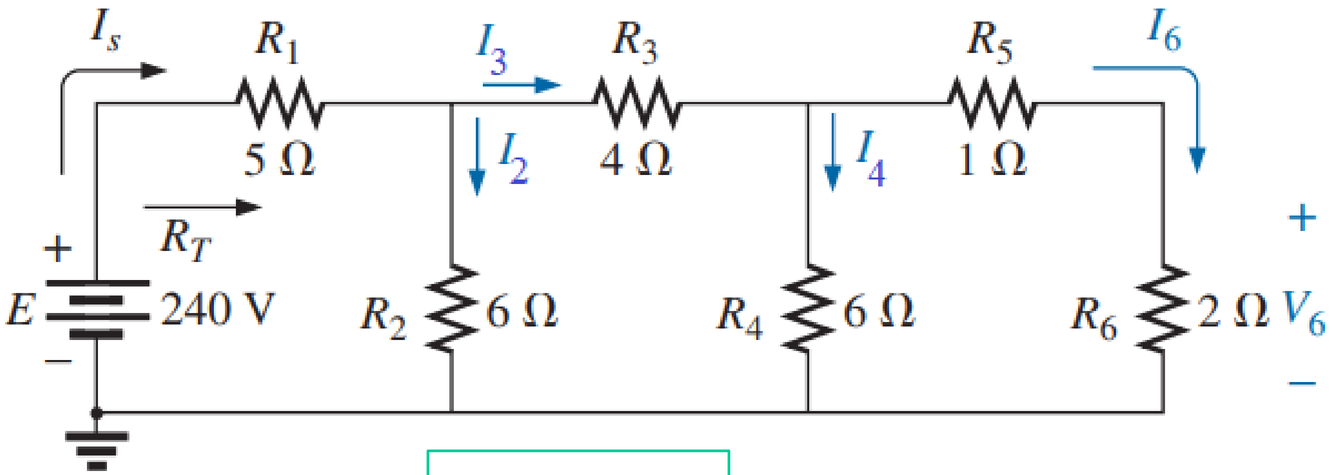


Basically, **two approaches** are used to solve networks of this type.

(**1**) Calculate the total resistance and resulting source current, and then work back through the ladder until the desired current or voltage is obtained [**Reduce and Return Approach**].

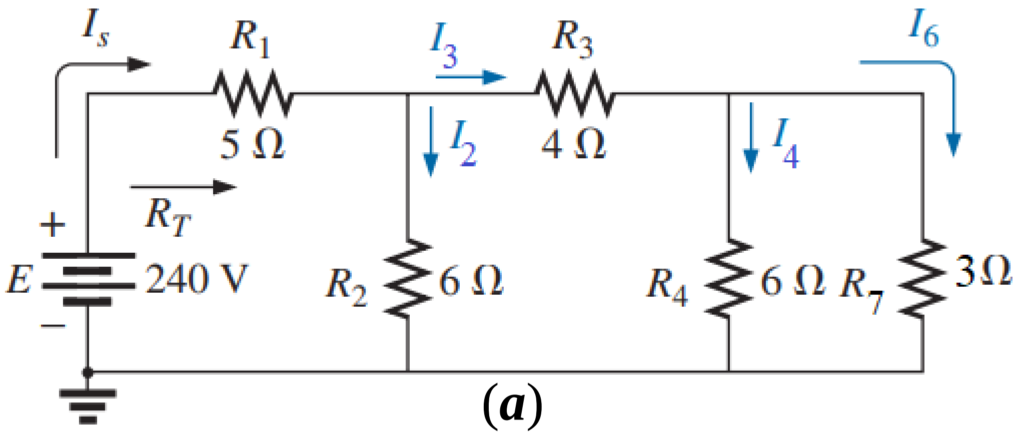
(**2**) Assign a letter symbol to the last branch current (I_n) and voltage (V_n) and work back through the network to the source, maintaining this assigned current or other current of interest. The desired current can then be found directly.

EXAMPLE FIG. 7.3 Determine the unknown currents I_s, I_2, I_3, I_4, and I_6 and voltage (V_6) for the following network.



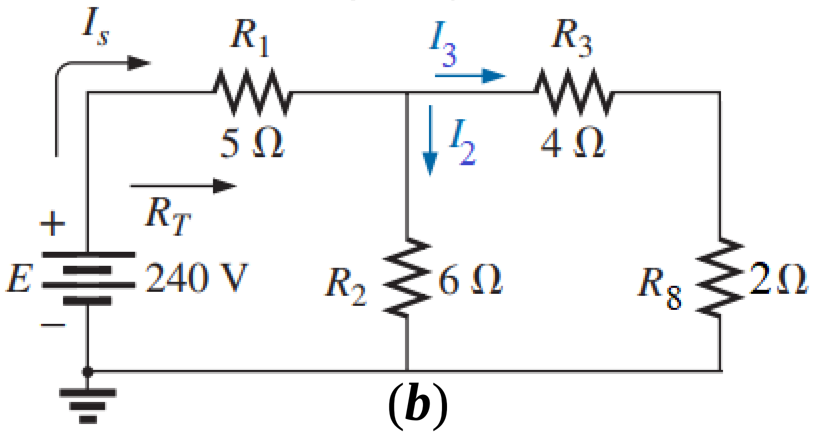
Method 1

$$R_7 = R_5 + R_6 = 3\ \Omega$$



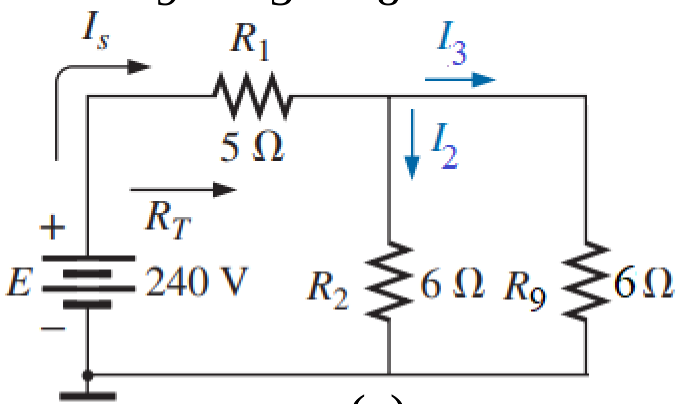
(*a*)

$$R_8 = \frac{R_4 R_7}{R_4 + R_7} = 2\ \Omega$$



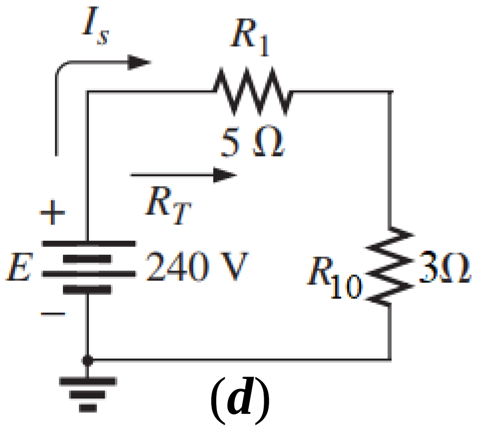
(*b*)

$$R_9 = R_3 + R_8 = 6\ \Omega$$



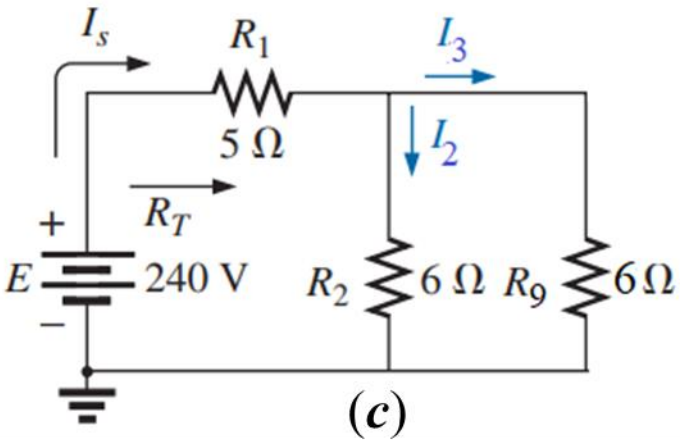
(*c*)

$$R_{10} = \frac{R_2 R_9}{R_2 + R_9} = 3\ \Omega$$



(*d*)

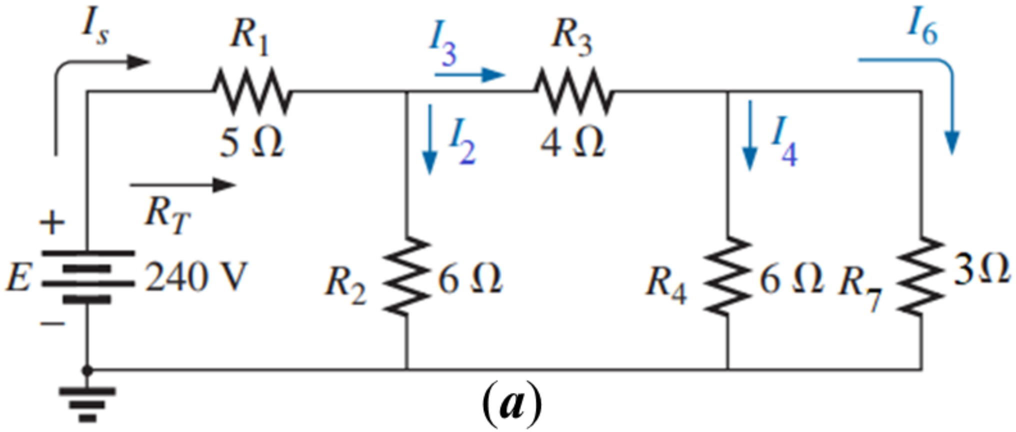
$$I_s = \frac{E}{R_1 + R_{10}} = \frac{240\,\text{V}}{5\ \Omega + 3\ \Omega} = 30\,\text{A}$$



(*c*)

From Fig. (c), we have:

$$I_2 = I_3 = \frac{I_s}{2} = 15\,\text{A}$$



(*a*)

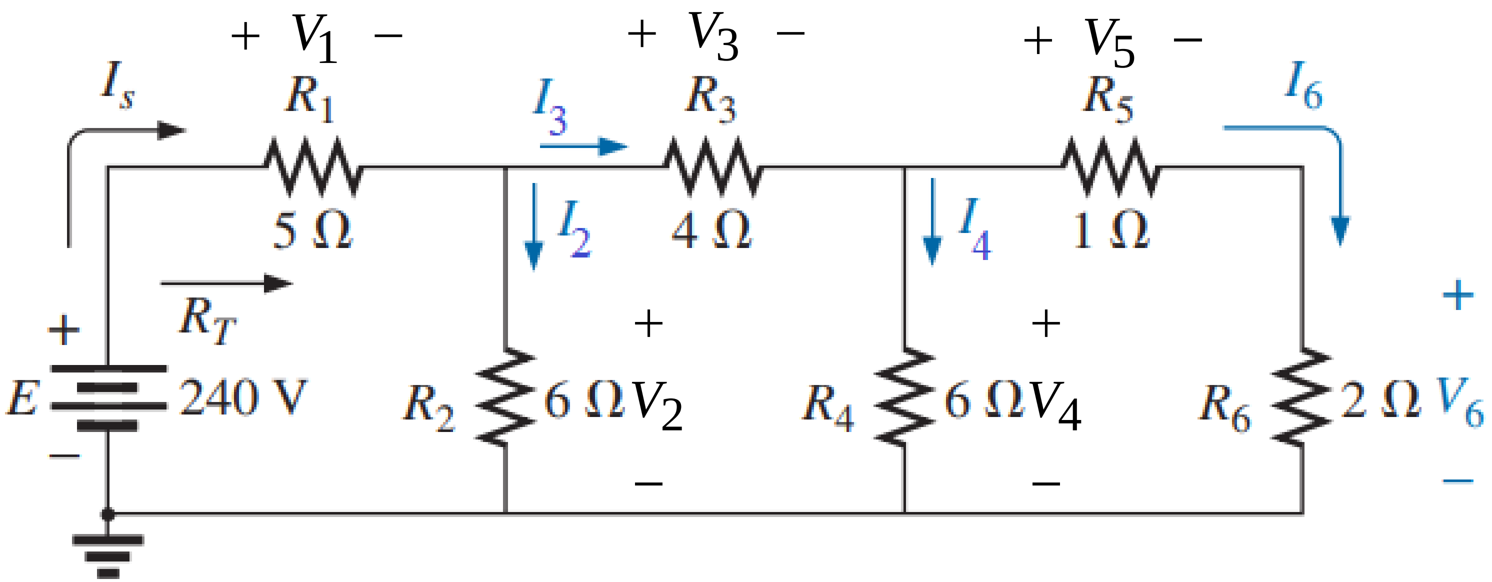
From Fig. (a), we have:

$$I_4 = \frac{R_7}{R_4 + R_7} I_3 = 5\,\text{A}$$

$$I_6 = \frac{R_4}{R_4 + R_7} I_3 = 10\,\text{A}$$

$$V_6 = I_6 R_6 = 10\,\text{A} \times 2\,\Omega = \mathbf{20\,V}$$

Method 2



The assigned notation for the current through the final branch is I_6:

$$I_6 = \frac{V_5 + V_6}{R_5 + R_6} = \frac{V_4}{R_5 + R_6} = \frac{V_4}{3\,\Omega} \qquad \therefore V_4 = (3\,\Omega)I_6$$

$$I_4 = \frac{V_4}{R_4} = \frac{V_4}{6\,\Omega} = \frac{(3\Omega)I_6}{6\,\Omega} = 0.5I_6$$

$$I_3 = I_4 + I_6 = 0.5I_6 + I_6 = 1.5I_6$$

$$V_3 = I_3R_3 = (1.5I_6)(4\Omega) = (6\Omega)I_6$$

Practice Problem
[SECTIONS 7.6]
Problems: 25 ~ 28

$$V_2 = V_3 + V_4 = (6\Omega)I_6 + (3\Omega)I_6 = (9\Omega)I_6$$

$$I_2 = \frac{V_2}{R_2} = \frac{(9\Omega)I_6}{6\,\Omega} = 1.5I_6$$

$$I_s = I_2 + I_3 = 1.5I_6 + 1.5I_6 = 3I_6$$

$$V_1 = I_sR_1 = 3I_6(5\Omega) = (15\Omega)I_6$$

$$E = V_1 + V_2 = (15\Omega)I_6 + (9\Omega)I_6 = (24\Omega)I_6$$

$$I_6 = \frac{E}{24\Omega} = \frac{240\,\text{V}}{24\Omega} = \mathbf{10\ A}$$

$$V_6 = I_6R_6 = 10\,\text{A} \times 2\Omega = \mathbf{20\,V}$$

$$I_4 = 0.5I_6 = 0.5 \times 10\ \text{A} = \mathbf{5\ A}$$

$$I_3 = 1.5I_6 = 1.5 \times 10\ \text{A} = \mathbf{15\ A}$$

$$I_2 = 1.5I_6 = 1.5 \times 10\ \text{A} = \mathbf{15\ A}$$

$$I_s = 3I_6 = 3 \times 10\ \text{A} = \mathbf{30\ A}$$

Some More Examples and Solution of Problems

Problem 12 [Ch 7]: For the network in Fig. 7.72:

a. Determine the current I_1.

b. Calculate the currents I_2 and I_3.

c. Determine the voltage levels V_a and V_b.

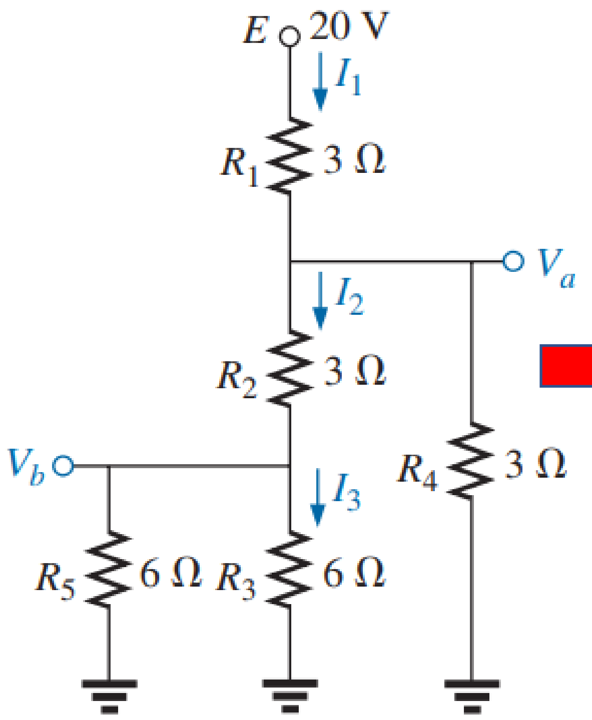
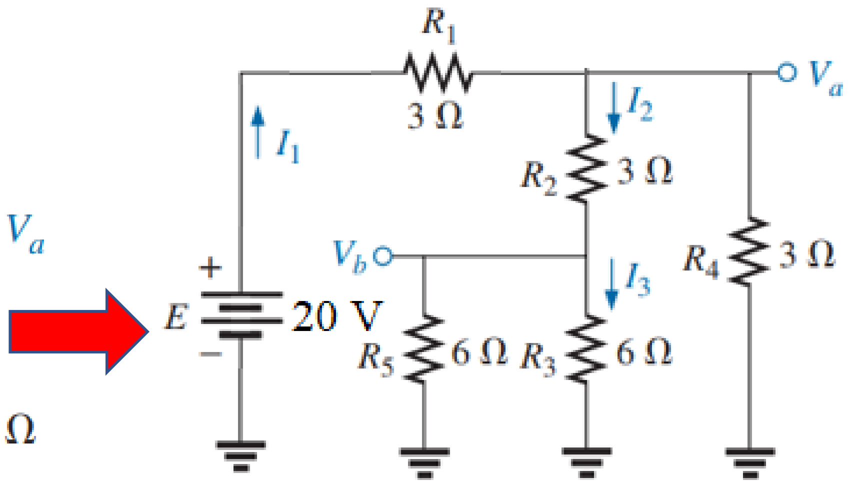


FIG. 7.72
Problem 12.



$$R_b = R_5 \,//\, R_6 = \frac{6\ \Omega}{2} = 3\ \Omega$$

$$R_{b2} = R_b + R_2 = 3\ \Omega + 3\ \Omega = 6\ \Omega$$

$$R_a = \frac{R_{b2}R_4}{R_{b2}+R_4} = 2\ \Omega$$

$$R_T = R_1 + R_a = 3\ \Omega + 2\ \Omega = 5\ \Omega$$

$$I_1 = \frac{E}{R_T} = \frac{20\ \text{V}}{5\ \Omega} = \mathbf{4\ A}$$

$$V_a = \frac{R_a}{R_T}E = \frac{2\ \Omega}{5\ \Omega}\times 20\ \text{V} = \mathbf{8\ V}$$

$$I_2 = \frac{V_a}{R_{b2}} = \frac{8\ \text{V}}{6\ \Omega} = \mathbf{1.333\ A}$$

$$V_b = I_2R_b = 1.333\ \text{A}\times 3\ \Omega \cong \mathbf{4\ V}$$

$$I_3 = \frac{V_b}{R_3} = \frac{I_2}{2} = \frac{1.333\ \text{A}}{2} = \mathbf{0.667\ A}$$

Problem 10 [Ch 7] Determine the unknown voltage (V) and current (I) for the following network.

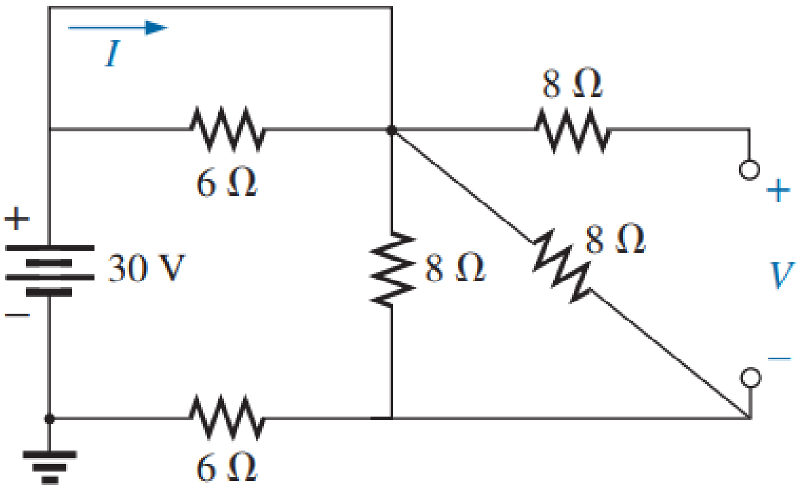
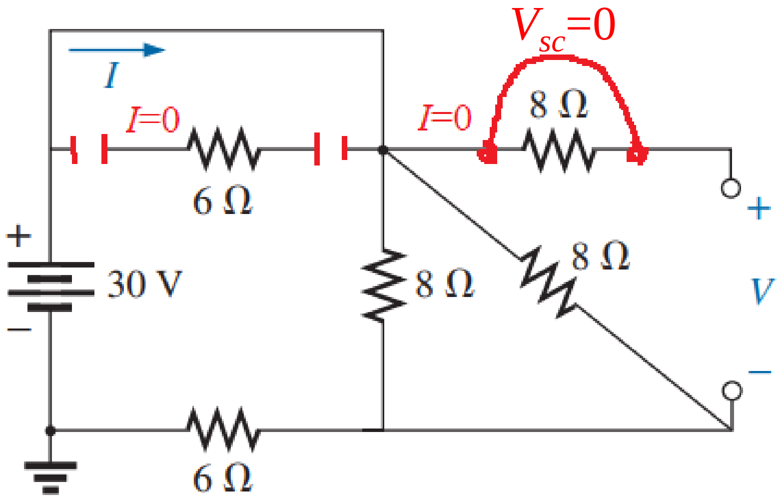
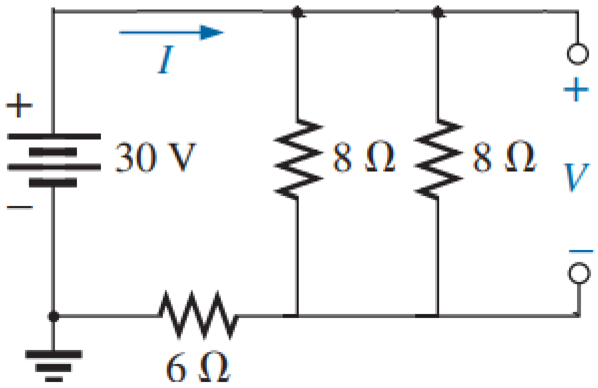
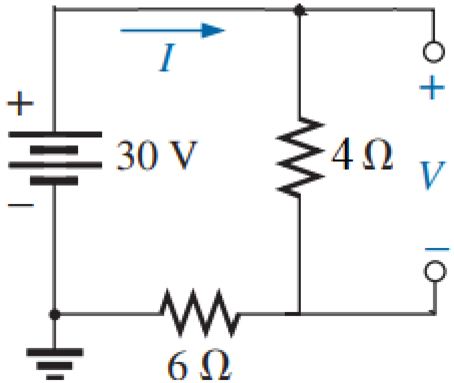


FIG. 7.78 *Problem 18.*





$$R_{8//8} = \frac{8\ \Omega}{2} = 4\ \Omega$$



$$I = \frac{30\ \text{V}}{4\ \Omega + 6\ \Omega} = \mathbf{3\ A}$$

$$V = 3\ \text{A} \times 4\ \Omega = \mathbf{12\ V}$$

Problem 26 For the ladder network in Fig. 7.86: ***a***. Determine R_T. ***b***. Calculate I. ***c***. Find I_8. d. Power consumed by R_6 resistance. e. Power delivered by the 2 V supply.

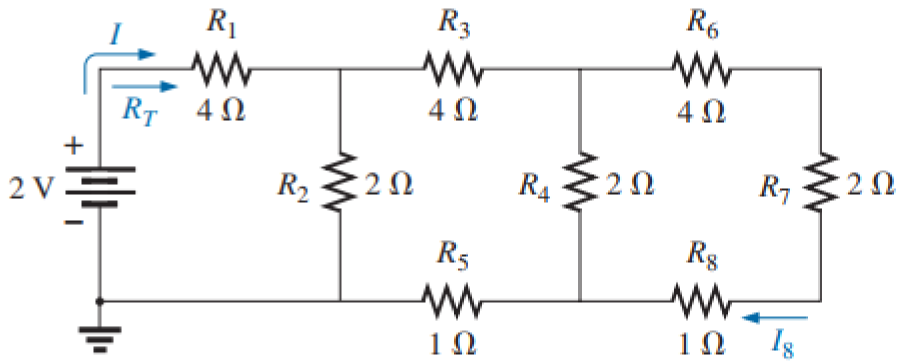
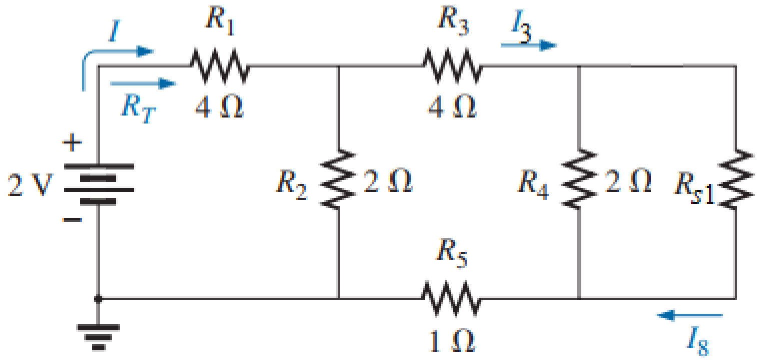
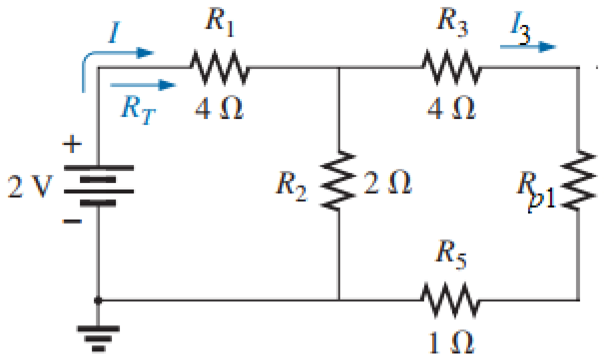


FIG. 7.86 *Problem 26.*

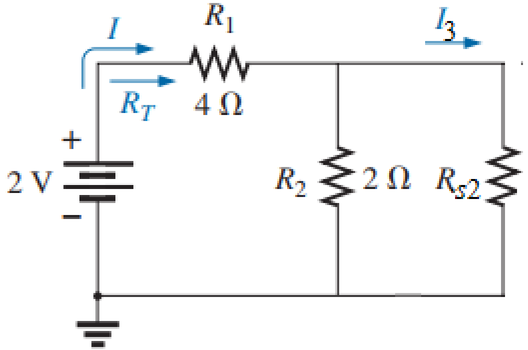
$$R_{s1} = R_6 + R_7 + R_8 = 7\ \Omega$$



$$R_{p1} = \frac{R_{s1}R_4}{R_{s1} + R_4} = 1.56\ \Omega$$



$$R_{s2} = R_3 + R_{p1} + R_5 = 6.56\ \Omega$$



$$R_{p2} = \frac{R_{s2}R_2}{R_{s2} + R_2} = 1.53\ \Omega$$

$$R_T = R_{p2} + R_1 = \mathbf{5.53\ \Omega}$$

$$I = \frac{E}{R_T} = \frac{20\,\text{V}}{5.53\ \Omega} = \mathbf{361.66\,mA}$$

$$I_3 = \frac{R_2}{R_2 + R_{s2}} I = \mathbf{84.50\,mA}$$

$$I_8 = \frac{R_4}{R_4 + R_{s1}} I_3 = \mathbf{18.78\,mA}$$

$$P_6 = I_8^2 R_6 = (18.78 \times 10^{-3})^2 \times 4\Omega$$
$$= \mathbf{1.41\,mW}$$

$$P_E = EI = (2\,\text{V}) \times (361.66 \times 10^{-3})$$
$$= \mathbf{723.32\,mW}$$

Problem 28. [Ch. 7] For the multiple ladder configuration in Fig. 7.88:

a. Determine I. **b.** Calculate I_4. **c.** Find I_6. **d.** Find I_{10}.

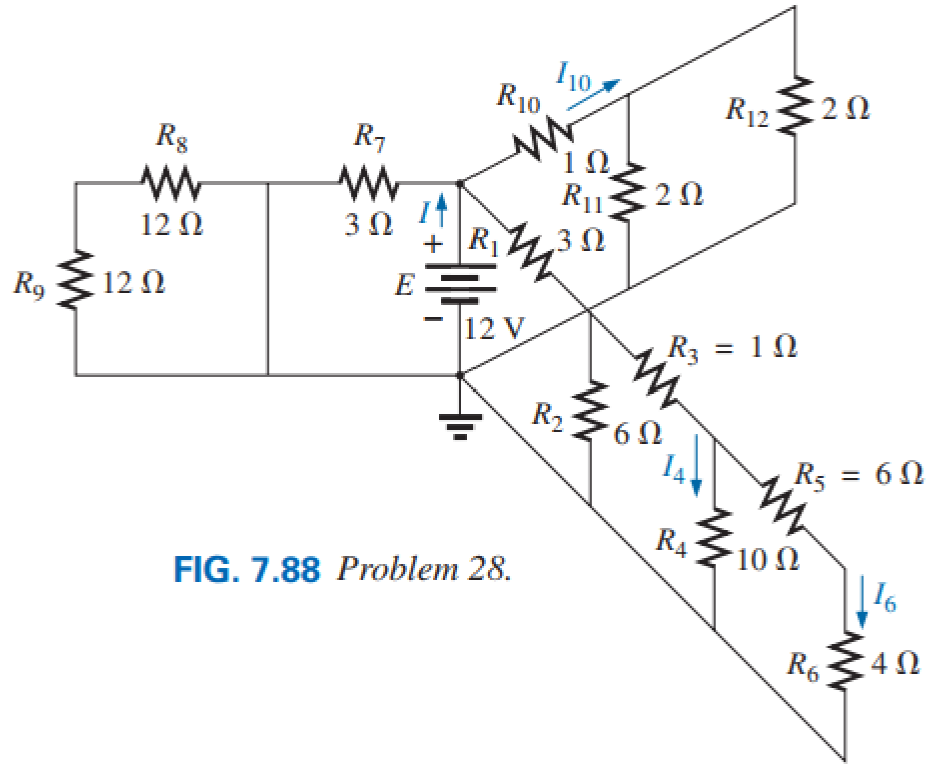


FIG. 7.88 *Problem 28.*

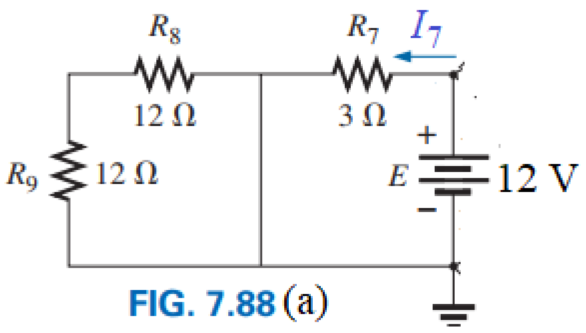


FIG. 7.88 (a)

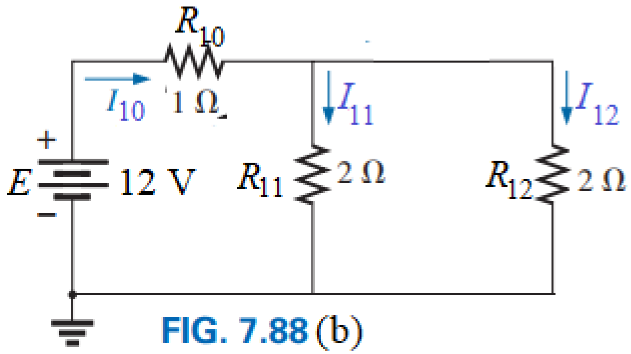


FIG. 7.88 (b)

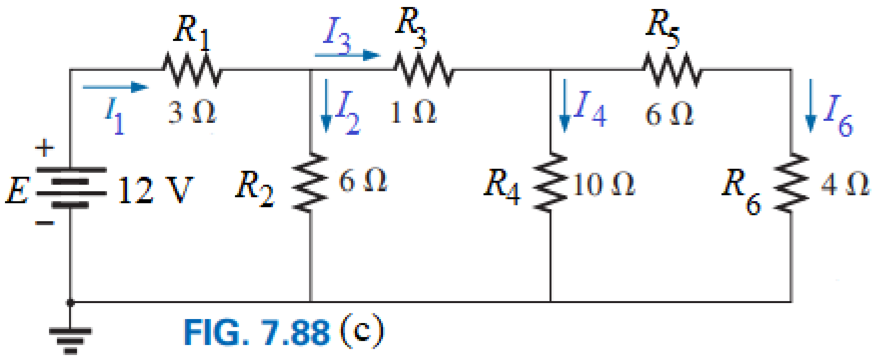


FIG. 7.88 (c)