SERIES - PARALLEL NETWORKS

Reduce and return approach

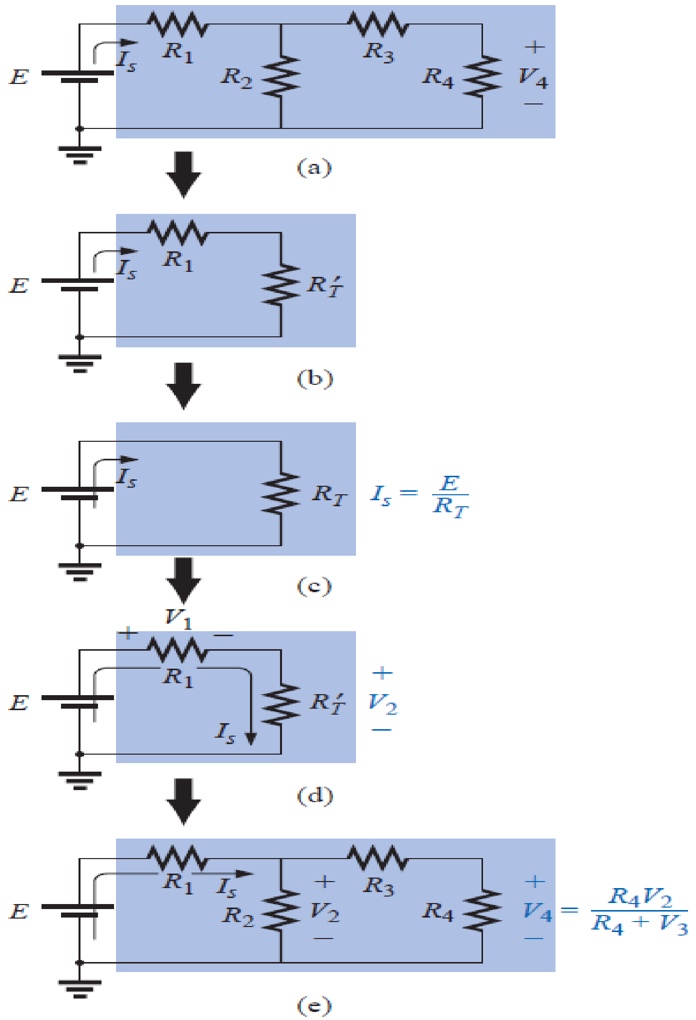


FIG. 7.1
Introducing the reduce and return approach.

Block diagram approach

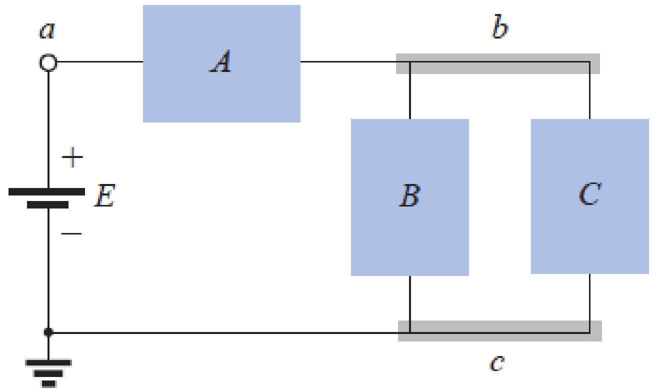


FIG. 7.2
Introducing the block diagram approach.

In Fig. 7.2, blocks B and C are in parallel (points b and c in common), and the voltage source E is in series with block A (point a in common). The parallel combination of B and C is also in series with A and the voltage source E due to the common points b and c, respectively.

PROBLEM SOLVING

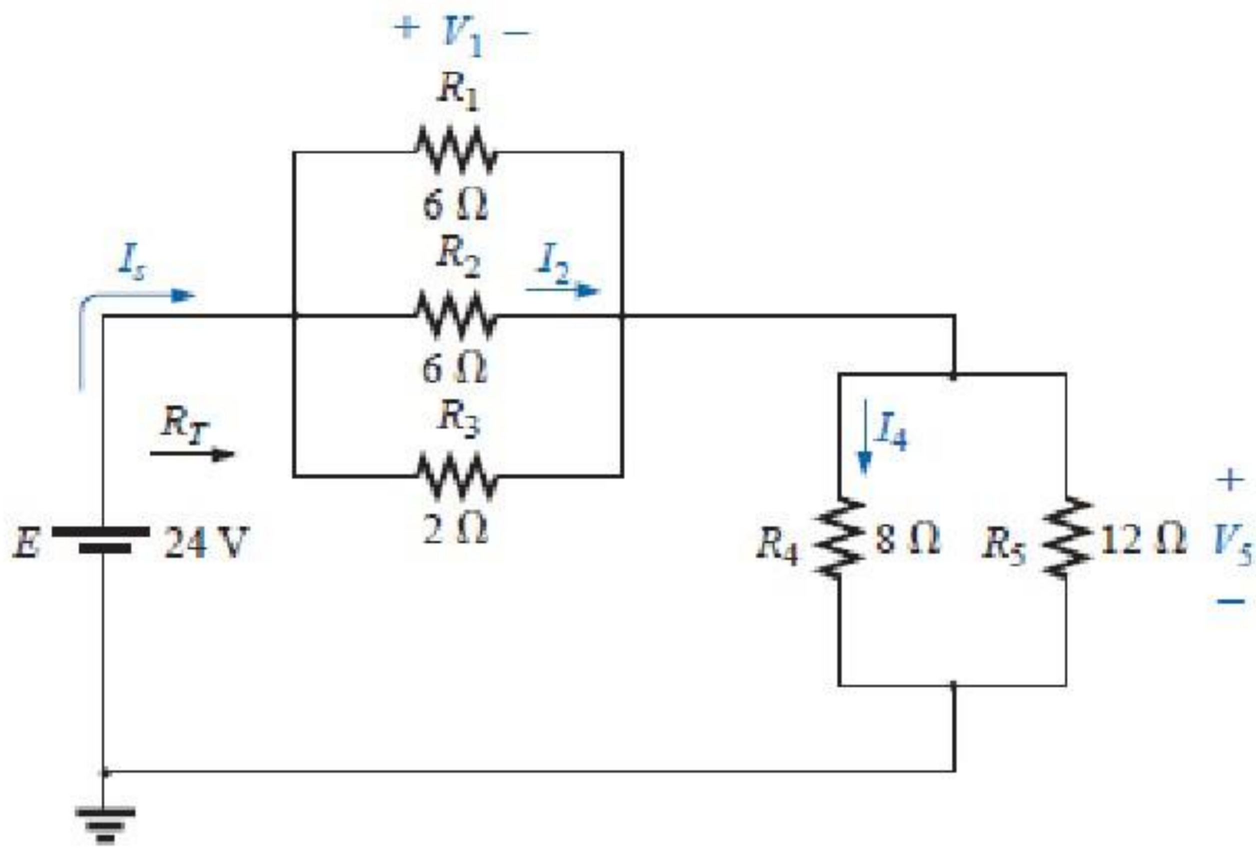
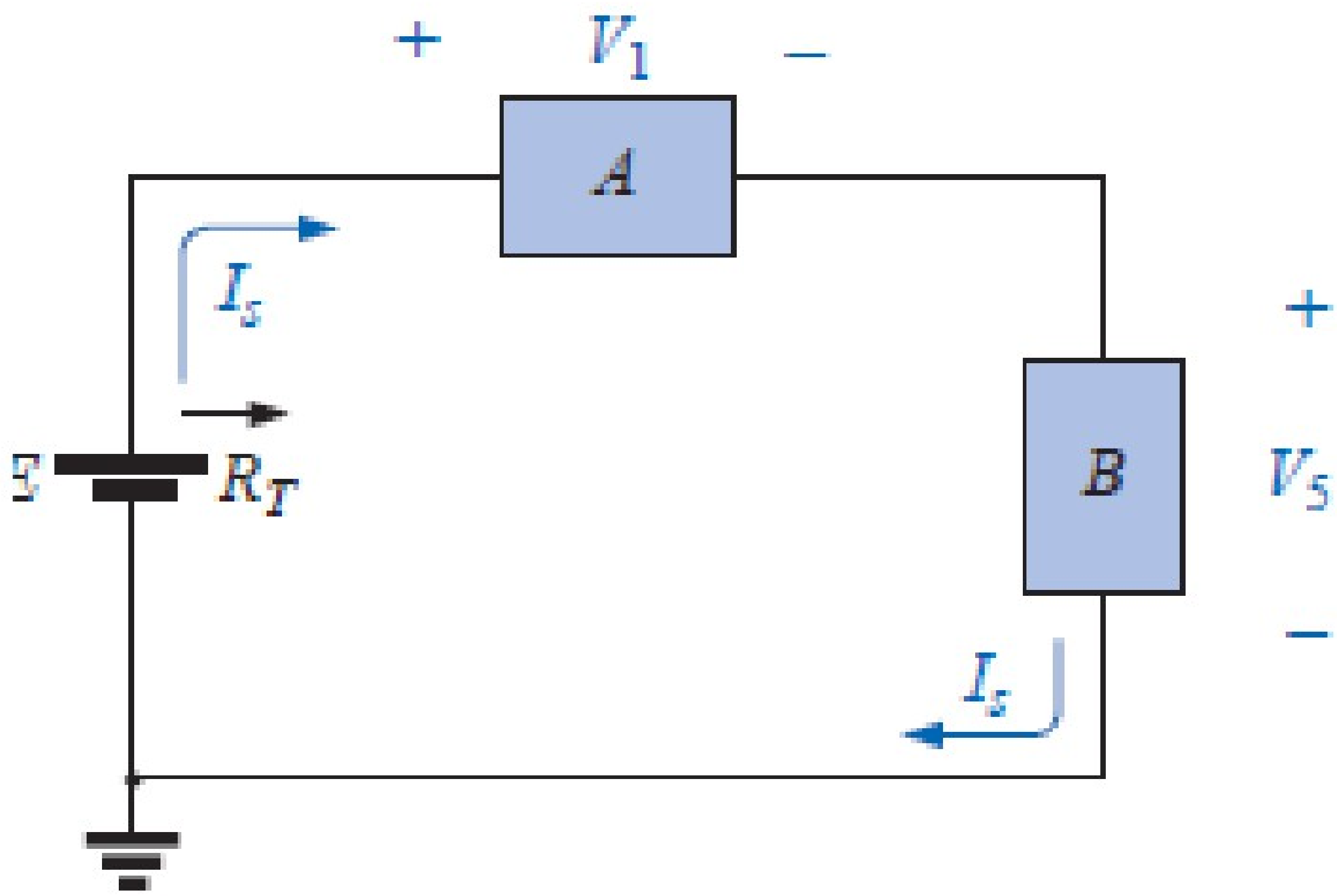


FIG. 7.13

Find the indicated currents and voltages for the network of Fig. 7.13



+
V1
–
A
Is
E
RT
B
+
V5
–
Is

SOLUTION

$$R_{1\|2} = \frac{R}{N} = \frac{6\ \Omega}{2} = 3\ \Omega$$

$$R_A = R_{1\|2\|3} = \frac{(3\ \Omega)(2\ \Omega)}{3\ \Omega + 2\ \Omega} = \frac{6\ \Omega}{5} = 1.2\ \Omega$$

$$R_B = R_{4\|5} = \frac{(8\ \Omega)(12\ \Omega)}{8\ \Omega + 12\ \Omega} = \frac{96\ \Omega}{20} = 4.8\ \Omega$$

The reduced form of Fig. 7.13 will then appear as shown in Fig. 7.15, and

$$R_T = R_{1\|2\|3} + R_{4\|5} = 1.2\ \Omega + 4.8\ \Omega = \mathbf{6\ \Omega}$$

$$I_s = \frac{E}{R_T} = \frac{24\ \text{V}}{6\ \Omega} = \mathbf{4\ A}$$

with

$$V_1 = I_s R_{1\|2\|3} = (4\ \text{A})(1.2\ \Omega) = \mathbf{4.8\ V}$$

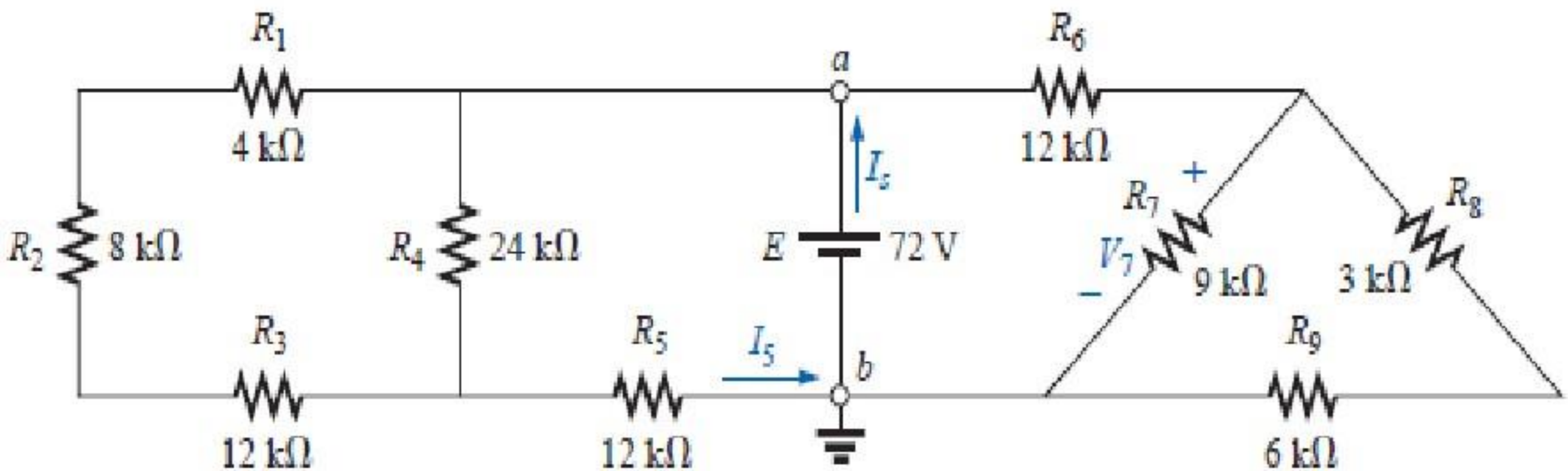
$$V_5 = I_s R_{4\|5} = (4\ \text{A})(4.8\ \Omega) = \mathbf{19.2\ V}$$

Applying Ohm's law,

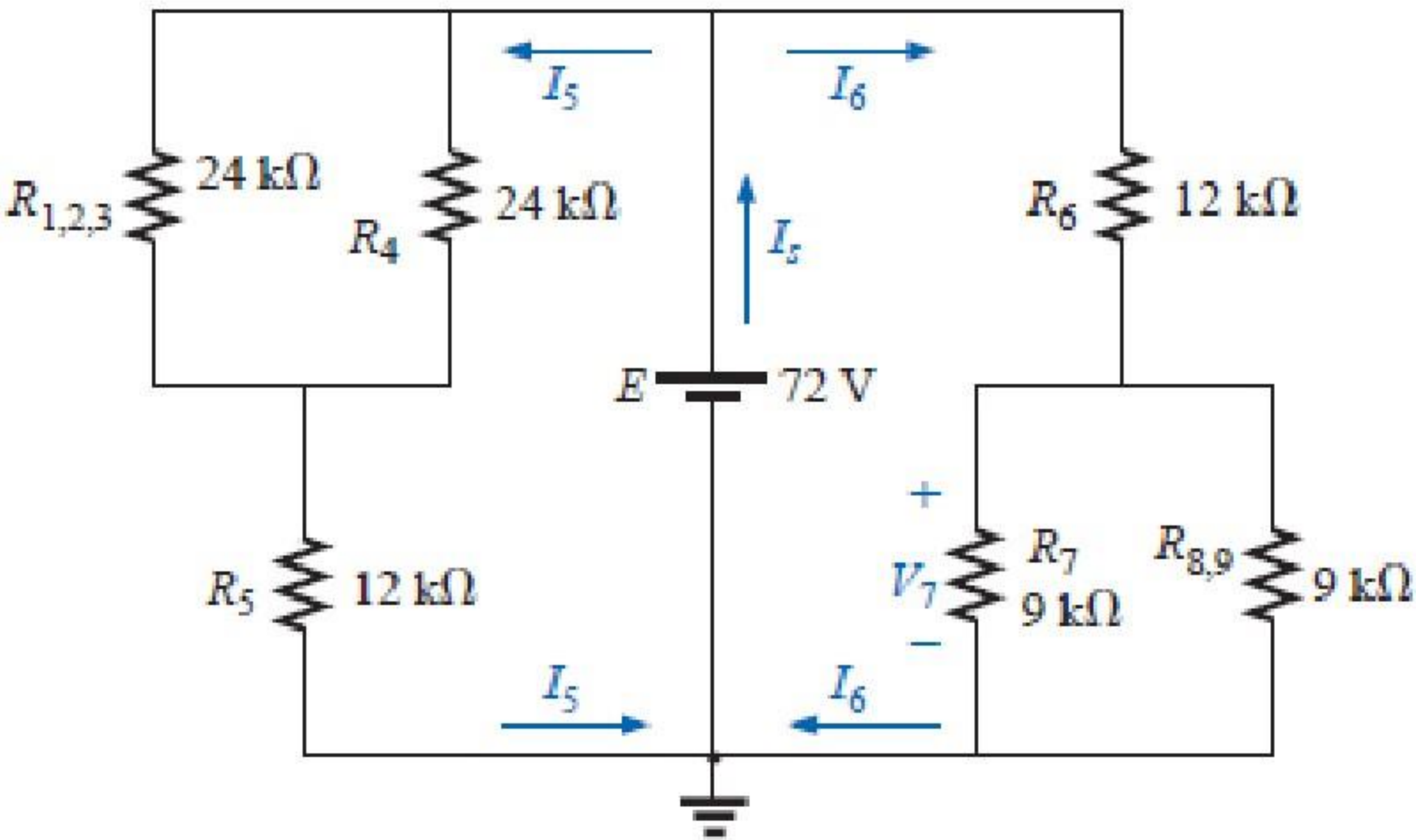
$$I_4 = \frac{V_5}{R_4} = \frac{19.2\ \text{V}}{8\ \Omega} = \mathbf{2.4\ A}$$

$$I_2 = \frac{V_2}{R_2} = \frac{V_1}{R_2} = \frac{4.8\ \text{V}}{6\ \Omega} = \mathbf{0.8\ A}$$

PROBLEM SOLVING



Calculate the indicated currents and voltage of the following network.



I_5
I_6
$R_{1,2,3}$
24 kΩ
24 kΩ
R_4
I_s
R_6
12 kΩ
E
72 V
+
R_7
$R_{8,9}$
V_7
9 kΩ
9 kΩ
–
R_5
12 kΩ
I_5
I_6

SOLUTION

$$I_5 = \frac{E}{R_{(1,2,3)\|4} + R_5} = \frac{72\text{ V}}{12\text{ k}\Omega + 12\text{ k}\Omega} = \frac{72\text{ V}}{24\text{ k}\Omega} = \mathbf{3\text{ mA}}$$

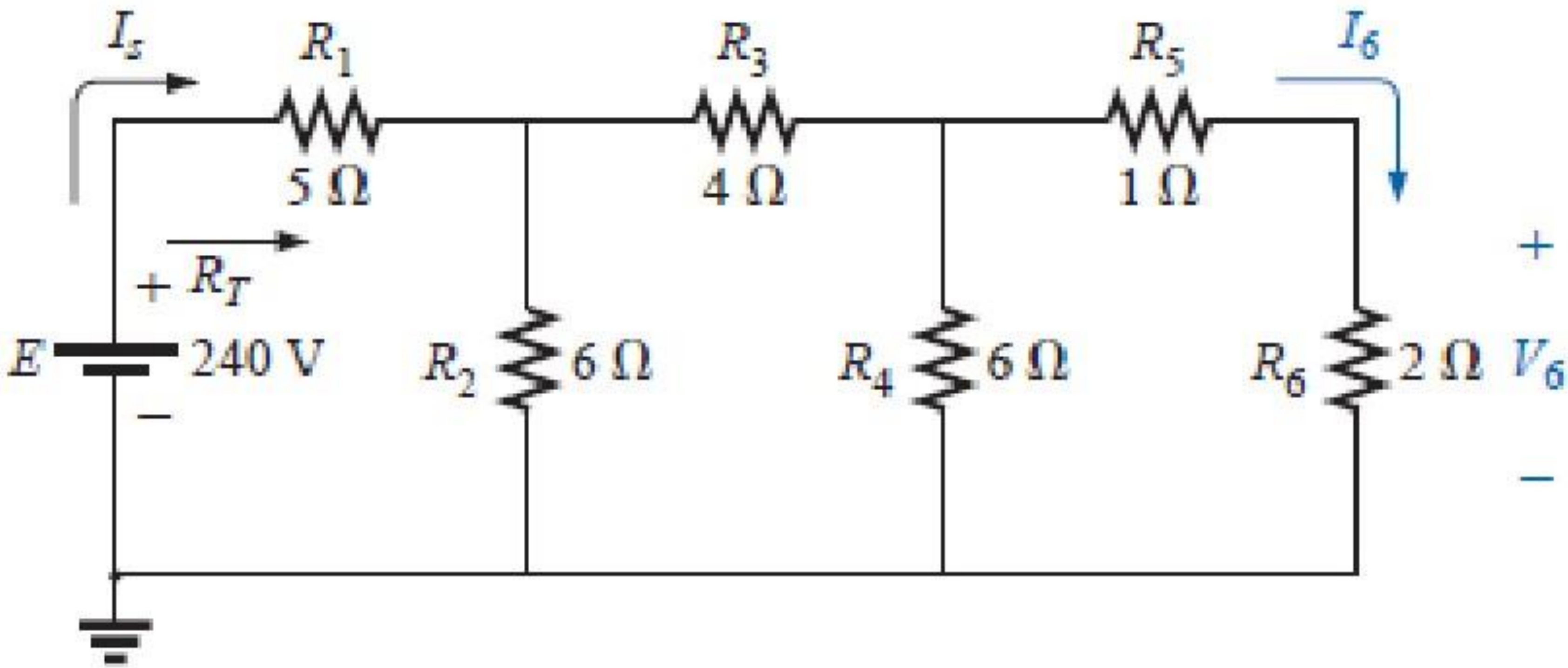
with

$$V_7 = \frac{R_{7\|(8,9)}E}{R_{7\|(8,9)} + R_6} = \frac{(4.5\text{ k}\Omega)(72\text{ V})}{4.5\text{ k}\Omega + 12\text{ k}\Omega} = \frac{324\text{ V}}{16.5} = \mathbf{19.6\text{ V}}$$

$$I_6 = \frac{V_7}{R_{7\|(8,9)}} = \frac{19.6\text{ V}}{4.5\text{ k}\Omega} = \mathbf{4.35\text{ mA}}$$

and $$I_s = I_5 + I_6 = 3\text{ mA} + 4.35\text{ mA} = \mathbf{7.35\text{ mA}}$$

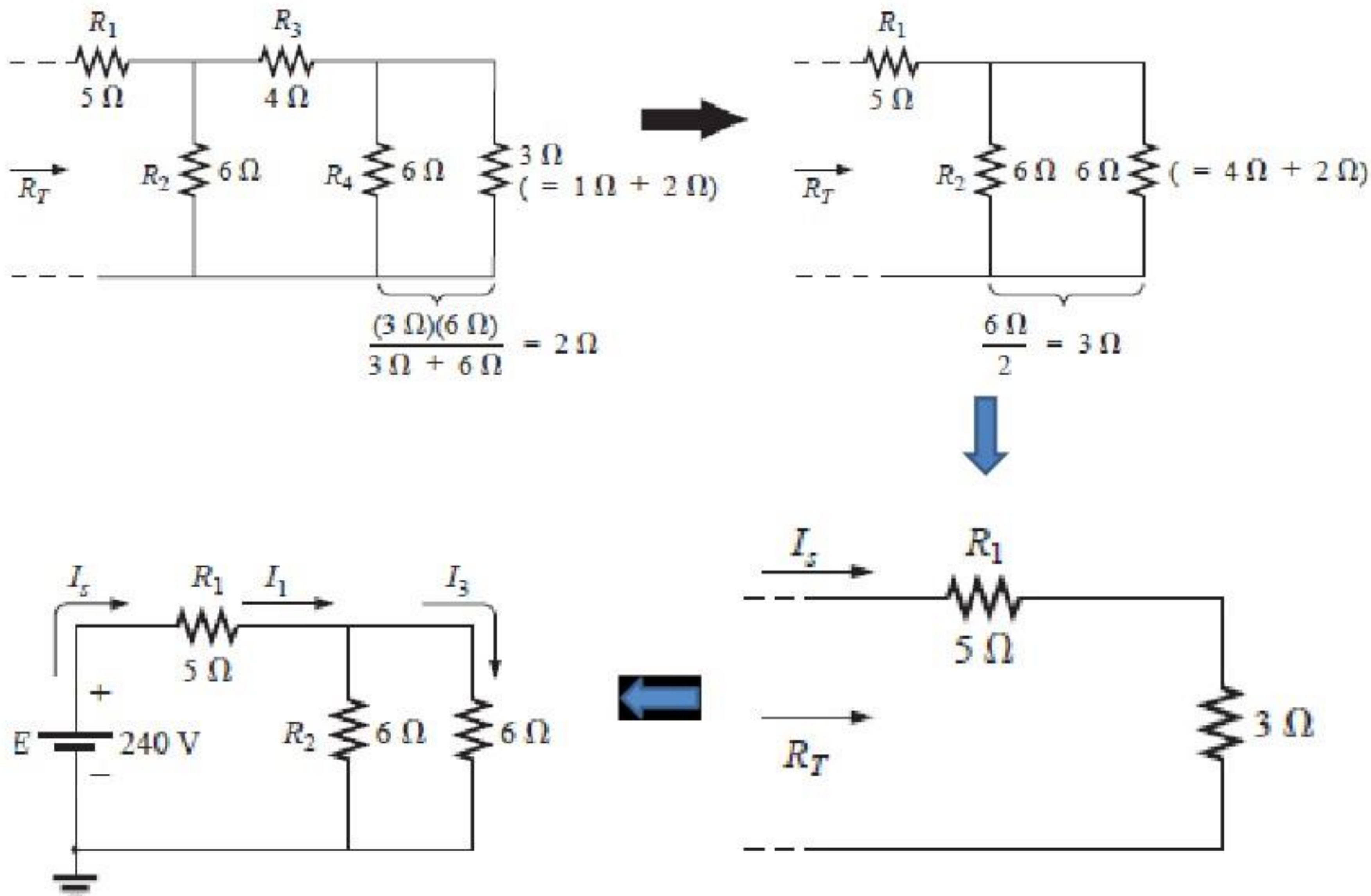
LADDER NETWORKS



I_s
R_1
5 Ω
R_3
4 Ω
R_5
1 Ω
I_6
R_T
E
240 V
R_2
6 Ω
R_4
6 Ω
R_6
2 Ω
V_6

SOLVING APPROACH

- Calculate the total resistance
- Calculate the resulting source current
- Work back through the ladder


R1
5 Ω
R3
4 Ω
RT
R2
6 Ω
R4
6 Ω
3 Ω
(= 1 Ω + 2 Ω)
(3 Ω)(6 Ω) / (3 Ω + 6 Ω) = 2 Ω
R1
5 Ω
RT
R2
6 Ω
6 Ω
(= 4 Ω + 2 Ω)
6 Ω / 2 = 3 Ω
Is
R1
5 Ω
RT
3 Ω
Is
R1
I1
I3
5 Ω
+
E
240 V
−
R2
6 Ω
6 Ω

PROBLEM SOLVING

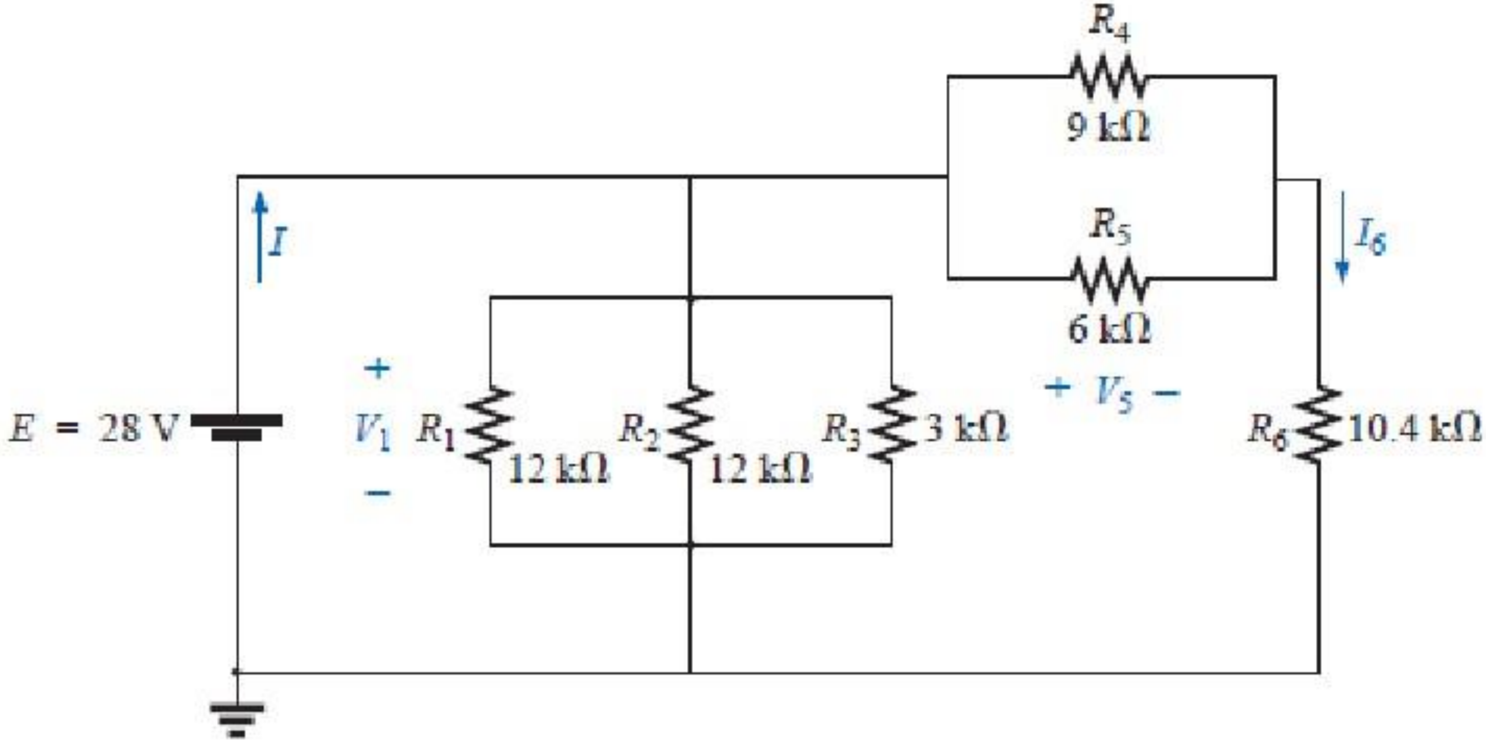


FIG. 7.73

For the network of Fig. 7.73:

a. Find the currents I and I_6.

b. Find the voltages V_1 and V_5.

c. Find the power delivered to the 6-kΩ resistor.

SOLUTION

a. $R_T = (R_1 \| R_2 \| R_3) \| (R_6 + R_4 \| R_5)$
$= (12\text{ k}\Omega \| 12\text{ k}\Omega \| 3\text{ k}\Omega) \| (10.4\text{ k}\Omega + 9\text{ k}\Omega \| 6\text{ k}\Omega)$
$= (6\text{ k}\Omega \| 3\text{ k}\Omega) \| (10.4\text{ k}\Omega + 3.6\text{ k}\Omega)$
$= 2\text{ k}\Omega \| 14\text{ k}\Omega = 1.75\text{ k}\Omega$

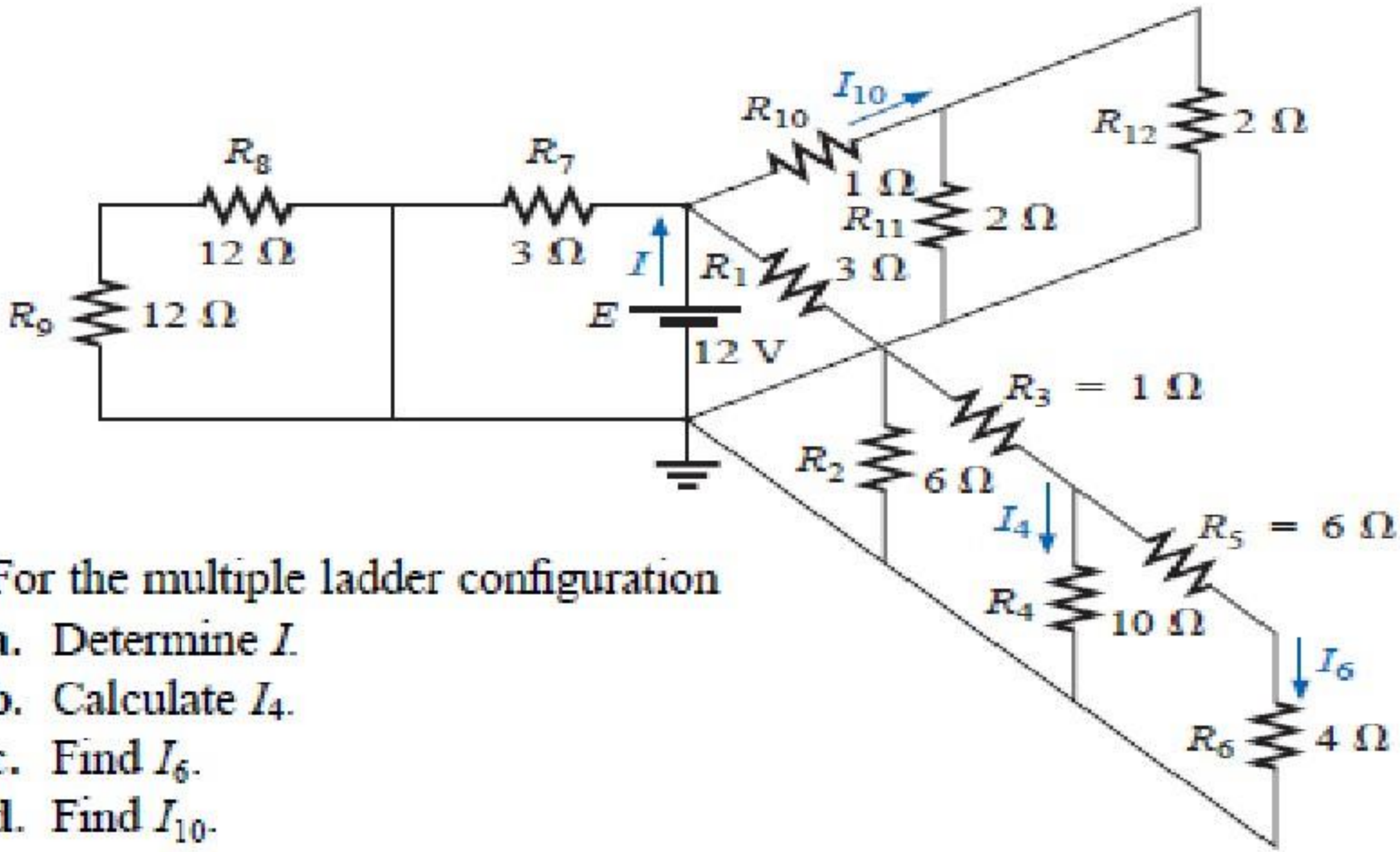
$$I_s = \frac{E}{R_T} = \frac{28\text{ V}}{1.75\text{ k}\Omega} = \mathbf{16\text{ mA}}, \quad I_2 = \frac{E}{R_2} = \frac{28\text{ V}}{12\text{ k}\Omega} = \mathbf{2.33\text{ mA}}$$

$R' = R_1 \| R_2 \| R_3 = 2\text{ k}\Omega$
$R'' = R_6 + R_4 \| R_5 = 14\text{ k}\Omega$

$$I_6 = \frac{R'(I_s)}{R' + R''} = \frac{2\text{ k}\Omega(16\text{ mA})}{2\text{ k}\Omega + 14\text{ k}\Omega} = \mathbf{2\text{ mA}}$$

b. $V_1 = E = \mathbf{28\text{ V}}$
$R' = R_4 \| R_5 = 6\text{ k}\Omega \| 9\text{ k}\Omega = 3.6\text{ k}\Omega$
$V_5 = I_6 R' = (2\text{ mA})(3.6\text{ k}\Omega) = \mathbf{7.2\text{ V}}$

PROBLEM SOLVING



For the multiple ladder configuration

a. Determine I.

b. Calculate I_4.

c. Find I_6.

d. Find I_{10}.

SOLUTION

a. $R_{10} + R_{11} \parallel R_{12} = 1\ \Omega + 2\ \Omega \parallel 2\ \Omega = 2\ \Omega$

$R_4 \parallel (R_5 + R_6) = 10\ \Omega \parallel 10\ \Omega = 5\ \Omega$

$R_1 + R_2 \parallel (R_3 + 5\ \Omega) = 3\ \Omega + 6\ \Omega \parallel 6\ \Omega = 6\ \Omega$

$R_T = 2\ \Omega \parallel 3\ \Omega \parallel 6\ \Omega = 2\ \Omega \parallel 2\ \Omega = 1\ \Omega$

$I = 12\ \text{V}/1\ \Omega = \mathbf{12\ A}$

b. $I_1 = 12\ \text{V}/6\ \Omega = 2\ \text{A}$

$$I_3 = \frac{6\,\Omega(2\ \text{A})}{6\,\Omega + 6\,\Omega} = 1\ \text{A}$$

$$I_4 = \frac{1\ \text{A}}{2} = \mathbf{0.5\ A}$$

c. $I_6 = I_4 = \mathbf{0.5\ A}$

d. $$I_{10} = \frac{12\ \text{A}}{2} = \mathbf{6\ A}$$

Voltage divider supply

Unloaded

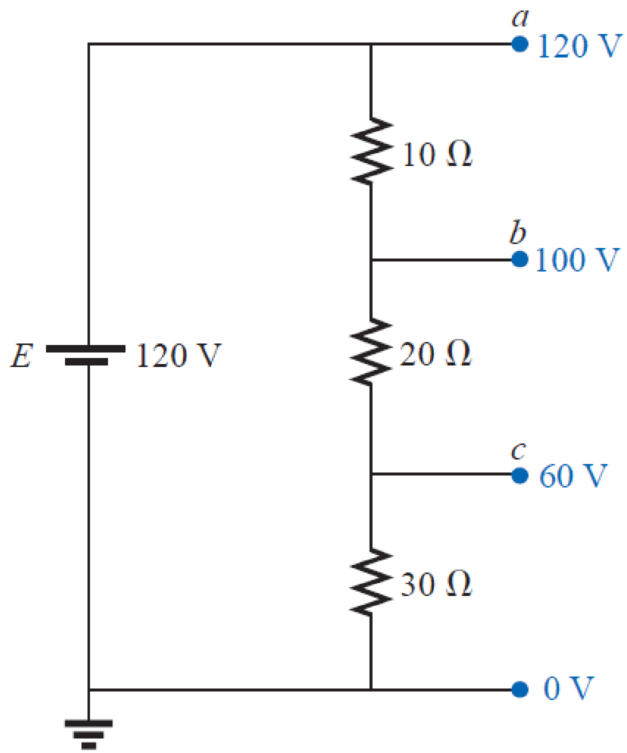


FIG. 7.34
Voltage divider supply.

Voltage divider supply

Loaded

Voltage-divider supply

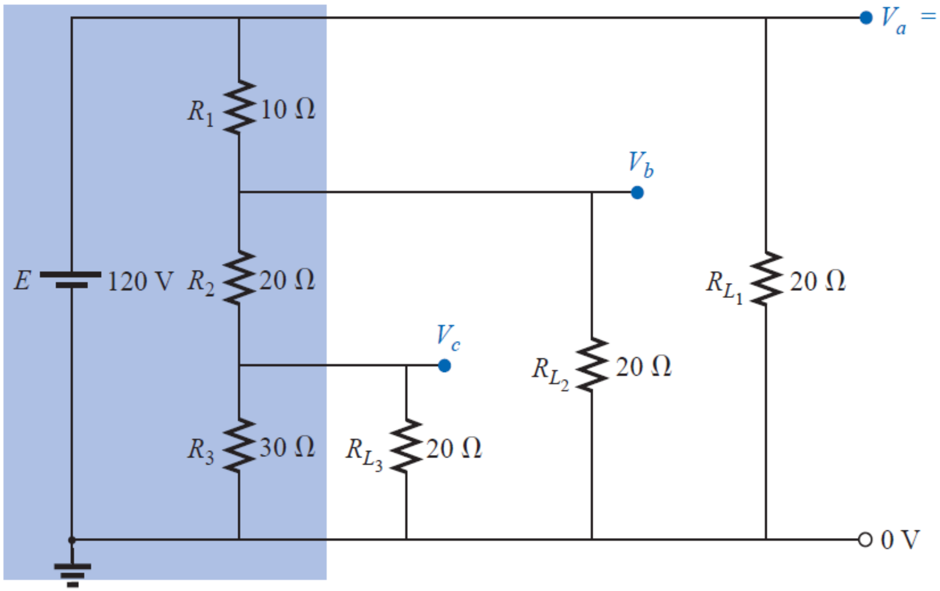


FIG. 7.35

The voltage V_a is unaffected by the load R_{L_1} since the load is in parallel with the supply voltage E. The result is $V_a = 120$ V, which is the same as the no-load level. To determine V_b, we must first note that R_3 and R_{L_3} are in parallel and $R'_3 = R_3 \| R_{L_3} = 30\ \Omega \| 20\ \Omega = 12\ \Omega$. The parallel combination $R'_2 = (R_2 + R'_3) \| R_{L_2} = (20\ \Omega + 12\ \Omega) \| 20\ \Omega = 32\ \Omega \| 20\ \Omega = 12.31\ \Omega$. Applying the voltage divider rule gives

$$V_b = \frac{(12.31\ \Omega)(120\ \text{V})}{12.31\ \Omega + 10\ \Omega} = 66.21\ \text{V}$$

versus 100 V under no-load conditions.

The voltage V_c is

$$V_c = \frac{(12\ \Omega)(66.21\ \text{V})}{12\ \Omega + 20\ \Omega} = 24.83\ \text{V}$$

versus 60 V under no-load conditions.

The effect of load resistors close in value to the resistor employed in the voltage divider network is, therefore, to decrease significantly some of the terminal voltages.

PRACTICE PROBLEMS

BOYLESTAD

- TOPIC: 7.1, 7.2, 7.3
- Associated Exercise Problems