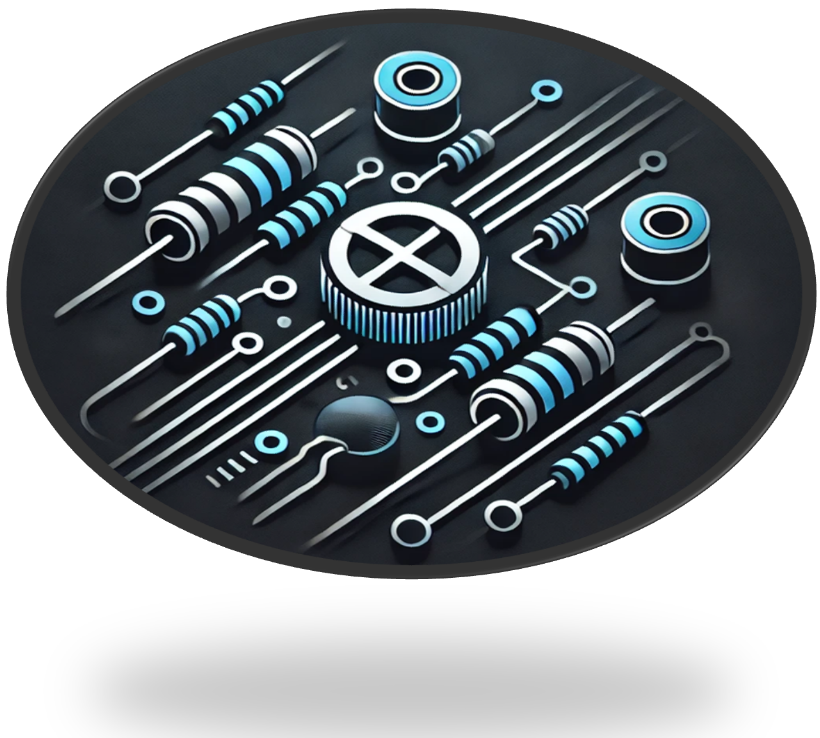
Ministry of Higher Education and Scientific Research
Al-Mustaqbal University

Computer Engineering Technologies Department



Lecturer: Zahraa Hazim

Electrical Engineering Fundamentals

Supplementary books:

1. **Fundamentals of Electric Circuits – Charles K. Alexander & Matthew N. O. Sadiku**
2. **Electrical Engineering: Principles and Applications – Allan R. Hambley**

Email: zahraa.hazim@uomus.edu.iq

SERIES DC CIRCUITS

A circuit consists of any number of elements joined at terminal points, providing at least one closed path through which charge can flow. The circuit of Fig. 2.1(a) has three elements joined at three terminal points (*a, b, and c) to provide a closed path for the current I.*

Two elements are in series if

1. **They have only one terminal in common (i.e., one lead of one is connected to only one lead of the other).**
2. **The common point between the two elements is not connected to another current-carrying element.**

If the circuit of Fig. 2.1(a) is modified such that a current-carrying resistor R_3 is introduced, as shown in Fig. 2.1(b), the resistors R_1 *and* R_2 are no longer in series due to a violation of number 2 of the above definition of series elements.

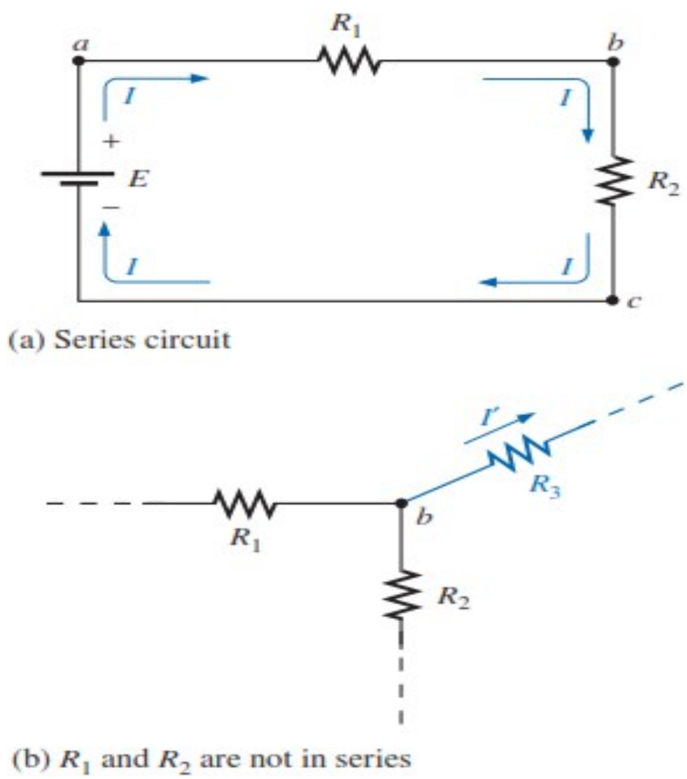


Fig.2.1

The total resistance of a series circuit is the sum of the resistance levels.

In general, to find the total resistance of *N resistors in series, the following* equation is applied:

$$R_T = R_1 + R_2 + R_3 + \cdots + R_N \quad \text{(ohms, } \Omega\text{)}$$

Once R_T is known, the current drawn from the source can be determined using Ohm's law, as follows:

$$I_s = \frac{E}{R_T} \quad \text{(amperes, A)}$$

The fact that the current is the same through each element of Fig. 2.1(a) permits a direct calculation of the voltage across each resistor using Ohm's law; that is,

$$V_1 = IR_1,\ V_2 = IR_2,\ V_3 = IR_3,\ \ldots,\ V_N = IR_N \quad \text{(volts, V)}$$

The total power delivered to a resistive circuit is equal to the total power dissipated by the resistive elements.

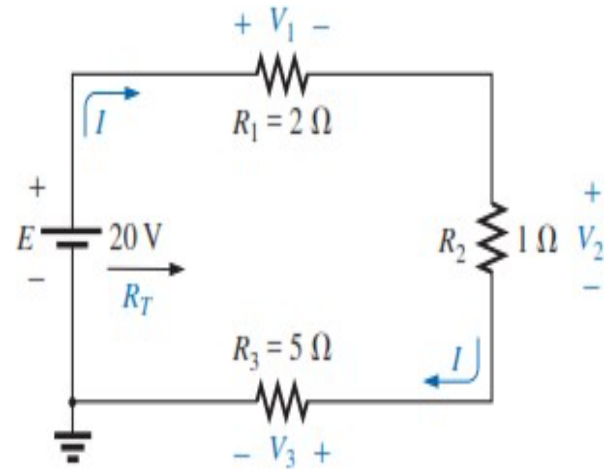
$$P_1 = V_1 I_1 = I_1^2 R_1 = \frac{V_1^2}{R_1} \quad \text{(watts, W)}$$

The power delivered by the source is

$$P_{del} = P_1 + P_2 + P_3 + \cdots + P_N$$

$$P_{del} = EI \quad \text{(watts, W)}$$

Example 2.1



a. Find the total resistance for the series circuit shown.

b. Calculate the source current *I*.

c. Determine the voltages *V*1, *V*2, and *V3*.

d. Calculate the power dissipated by *R1, R2* and *R3*.

e. Determine the power delivered by the source and compare it to the sum of the power levels of part (d).

Solution :

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

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

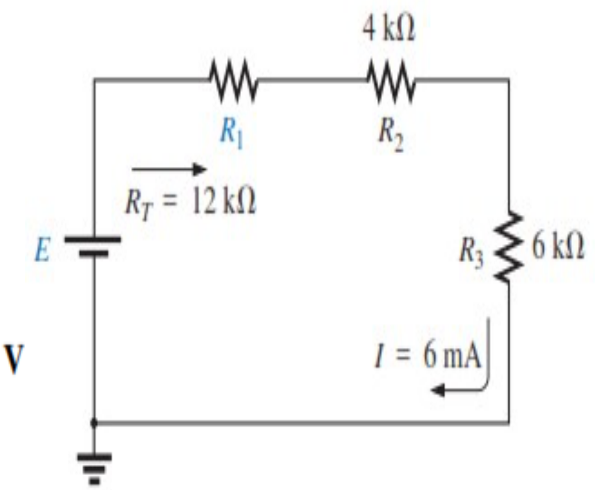
c. $V_1 = IR_1 = (2.5\ A)(2\ \Omega) = \mathbf{5\ V}$
$V_2 = IR_2 = (2.5\ A)(1\ \Omega) = \mathbf{2.5\ V}$
$V_3 = IR_3 = (2.5\ A)(5\ \Omega) = \mathbf{12.5\ V}$

d. $P_1 = V_1 I_1 = (5\ V)(2.5\ A) = \mathbf{12.5\ W}$
$P_2 = I_2^2 R_2 = (2.5\ A)^2(1\ \Omega) = \mathbf{6.25\ W}$
$P_3 = V_3^2/R_3 = (12.5\ V)^2/5\ \Omega = \mathbf{31.25\ W}$

e. $P_{del} = EI = (20\ V)(2.5\ A) = \mathbf{50\ W}$
$P_{del} = P_1 + P_2 + P_3$
$50\ W = 12.5\ W + 6.25\ W + 31.25\ W$
$50\ W = 50\ W$ (checks)

Example 2.2 **:** Given R_T and *I, calculate* R_1 and *E for the circuit shown.*

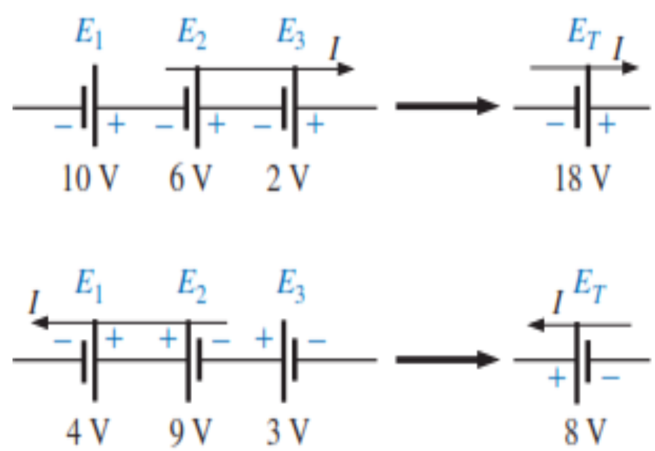
$$R_T = R_1 + R_2 + R_3$$
$$12\ \text{k}\Omega = R_1 + 4\ \text{k}\Omega + 6\ \text{k}\Omega$$
$$R_1 = 12\ \text{k}\Omega - 10\ \text{k}\Omega = \mathbf{2\ k\Omega}$$
$$E = IR_T = (6 \times 10^{-3}\ \text{A})(12 \times 10^{3}\ \Omega) = \mathbf{72\ V}$$



VOLTAGE SOURCES IN SERIES

$$E_T = E_1 + E_2 + E_3 = 10\ \text{V} + 6\ \text{V} + 2\ \text{V} = 18\ \text{V}$$

$$E_T = E_2 + E_3 - E_1 = 9\ \text{V} + 3\ \text{V} - 4\ \text{V} = 8\ \text{V}$$



Email: zahraa.hazim@uomus.edu.iq

KIRCHHOFF'S VOLTAGE LAW

Kirchhoff's voltage law ***(KVL) states that the algebraic sum of the potential rises and drops around a closed loop (or path) is zero.***

A **closed loop** is any continuous path that leaves a point in one direction and returns to that same point from another direction without leaving the circuit

$$\Sigma_{\circlearrowright} V = 0$$ (Kirchhoff's voltage law in symbolic form)

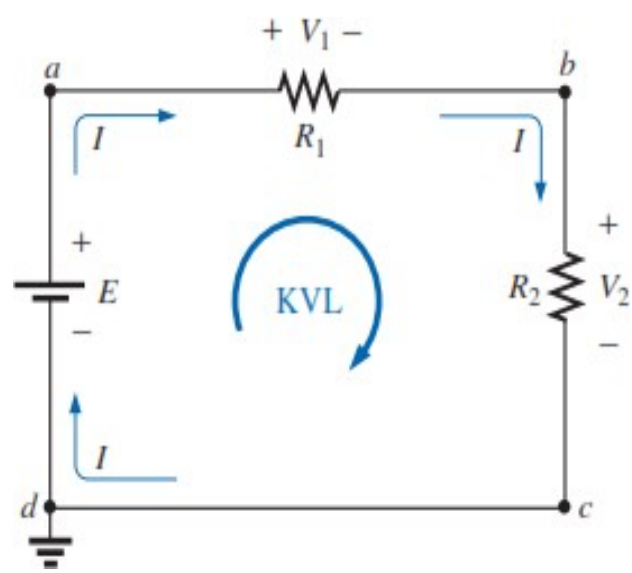
Kirchhoff's voltage law can also be stated in the following form:

$$\Sigma_{\circlearrowright} V_{\text{rises}} = \Sigma_{\circlearrowright} V_{\text{drops}}$$

$$\Sigma_{\circlearrowright} V = 0$$

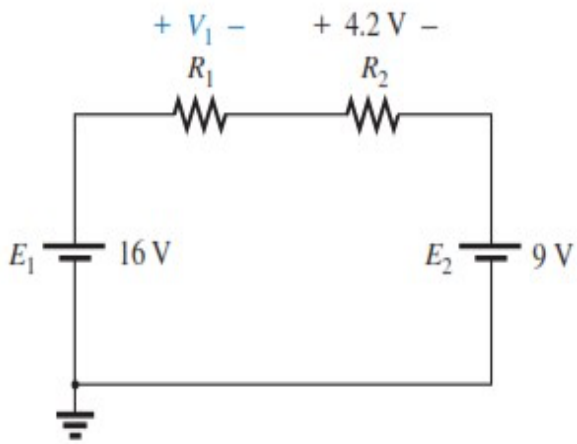
$$-E + V_2 + V_1 = 0$$

$$E = V_1 + V_2$$

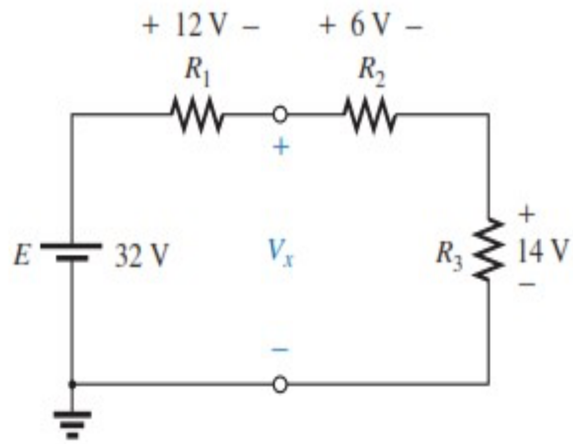


Email: zahraa.hazim@uomus.edu.iq

Example 2.3 : Determine the unknown voltages for the networks shown.



(a)



(b)

$$+E_1 - V_1 - V_2 - E_2 = 0$$

$$V_1 = E_1 - V_2 - E_2 = 16\,V - 4.2\,V - 9\,V$$
$$= 2.8\,V$$

$$+E - V_1 - V_x = 0$$

$$V_x = E - V_1 = 32\,V - 12\,V$$
$$= \mathbf{20\,V}$$

⇓ ⇓

Using the clockwise direction for the other loop involving R_2 *and* R_3 will result in:

$$+V_x - V_2 - V_3 = 0$$

$$V_x = V_2 + V_3 = 6\,V + 14\,V$$
$$= \mathbf{20\,V}$$

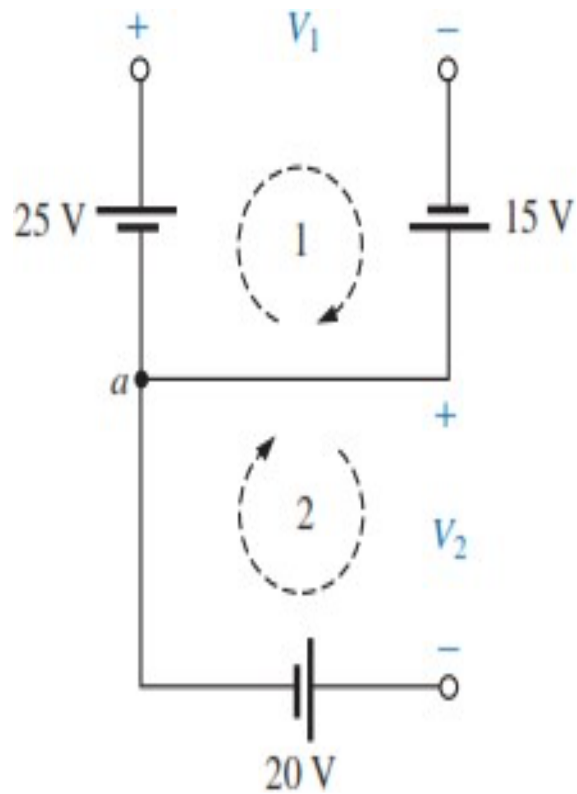
Email: zahraa.hazim@uomus.edu.iq

Example 2.4: Find V_1 and V_2 for the network shown.

For path 1, starting at point *a in a clockwise direction:*

$$+25\text{ V} - V_1 + 15\text{ V} = 0$$

$$\text{and} \quad V_1 = \mathbf{40\ V}$$



For path 2, starting at point *a in a clockwise direction:*

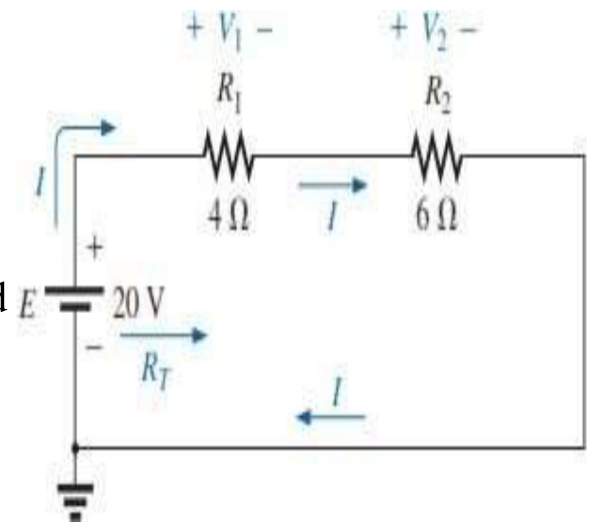
$$-V_2 - 20\text{ V} = 0$$

$$\text{and} \quad V_2 = \mathbf{-20\ V}$$

❖ The minus sign simply indicates that the actual polarities of the potential difference are opposite the assumed polarity indicated in figure.

Example 2.5: For the circuit shown.

a. Find R_T.
b. Find I.
c. Find V_T and V_1.
d. Find the power to the 4Ω and 6Ω resistors.
e. Find the power delivered by the battery, and compare it to that dissipated by the 4Ω and 6Ω resistors combined.
f. Verify Kirchhoff's voltage law (clockwise direction).



Solution:

a. $R_T = R_1 + R_2 = 4\ \Omega + 6\ \Omega = \mathbf{10\ \Omega}$

b. $I = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{10\ \Omega} = \mathbf{2\text{ A}}$

c. $V_1 = IR_1 = (2\text{ A})(4\ \Omega) = \mathbf{8\text{ V}}$
$V_2 = IR_2 = (2\text{ A})(6\ \Omega) = \mathbf{12\text{ V}}$

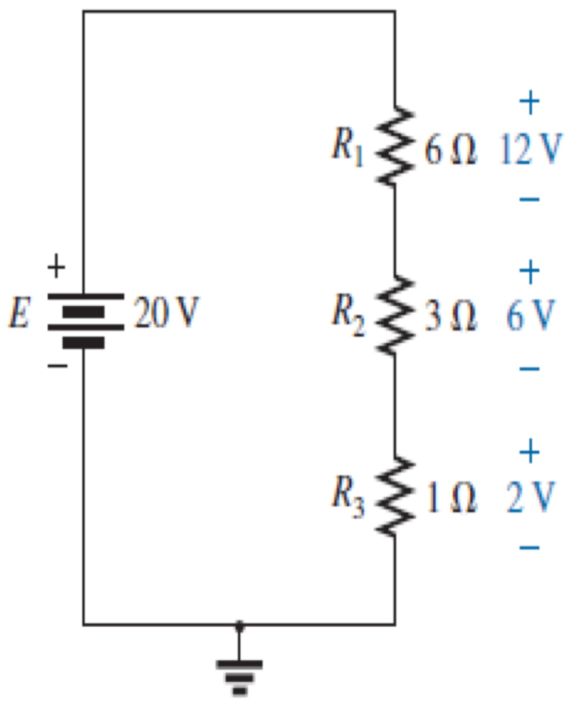
d. $P_{4\Omega} = \dfrac{V_1^2}{R_1} = \dfrac{(8\text{ V})^2}{4} = \dfrac{64}{4} = \mathbf{16\text{ W}}$
$P_{6\Omega} = I^2R_2 = (2\text{ A})^2(6\ \Omega) = (4)(6) = \mathbf{24\text{ W}}$

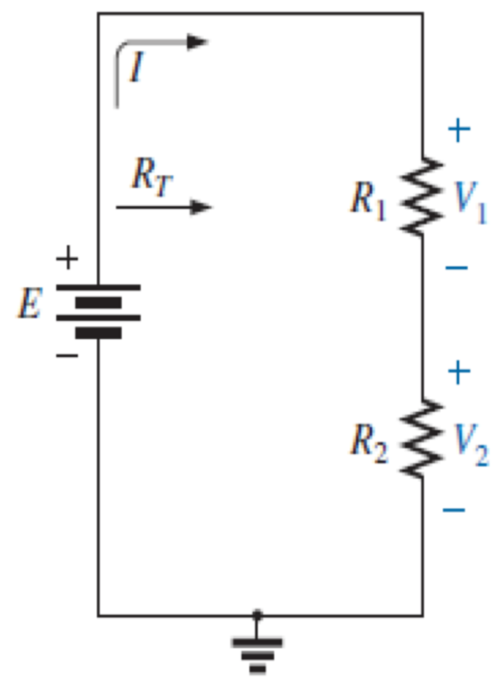
e. $P_E = EI = (20\text{ V})(2\text{ A}) = \mathbf{40\text{ W}}$
$P_E = P_{4\Omega} + P_{6\Omega}$
$40\text{ W} = 16\text{ W} + 24\text{ W}$
$40\text{ W} = 40\text{ W}$ (checks)

f. $\Sigma_{C} V = +E - V_1 - V_2 = 0$
$E = V_1 + V_2$
$20\text{ V} = 8\text{ V} + 12\text{ V}$
$20\text{ V} = 20\text{ V}$ (checks)

VOLTAGE DIVIDER RULE

In a series circuit, the voltage across the resistive elements will divide as the magnitude of the resistance levels.





$$R_T = R_1 + R_2$$

and $$I = \frac{E}{R_T}$$

Applying Ohm's law:

$$V_1 = IR_1 = \left(\frac{E}{R_T}\right)R_1 = \frac{R_1E}{R_T}$$

with $$V_2 = IR_2 = \left(\frac{E}{R_T}\right)R_2 = \frac{R_2E}{R_T}$$

$$V_x = \frac{R_xE}{R_T}$$ (voltage divider rule)

Example 2.6: Using the voltage divider rule, determine the voltages V_1 and V_3 for the series circuit shown.

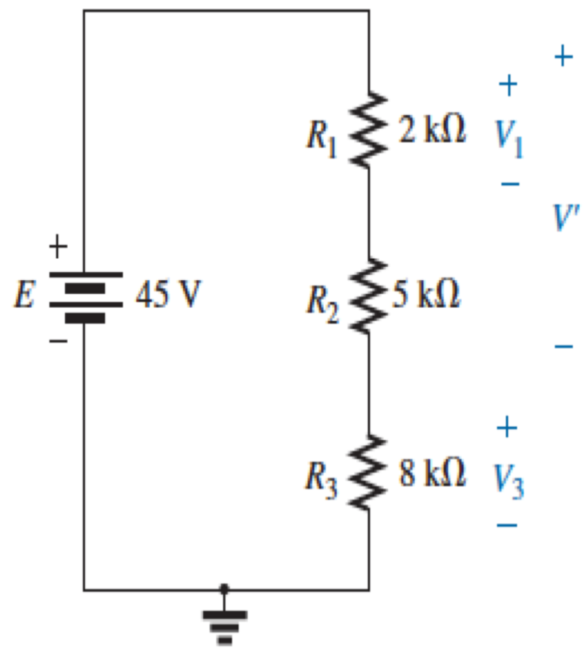
Solution:

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

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

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

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



The rule can be extended to the voltage across two or more series elements if the resistance is expanded to include the total resistance of the series elements that the voltage is to be found across (R'); *that is,*

$$V' = \frac{R'E}{R_T} \qquad \text{(volts)}$$

Email: zahraa.hazim@uomus.edu.iq

Example 2.7 Design the voltage divider shown such that $V_{R1} = 4V_{R2}$.

Solution:

The total resistance is defined by

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

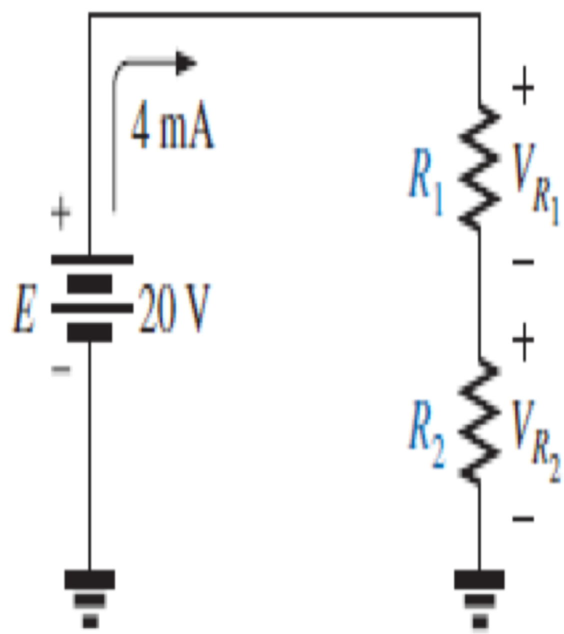
Since $V_{R_1} = 4V_{R_2}$,

$$R_1 = 4R_2$$

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

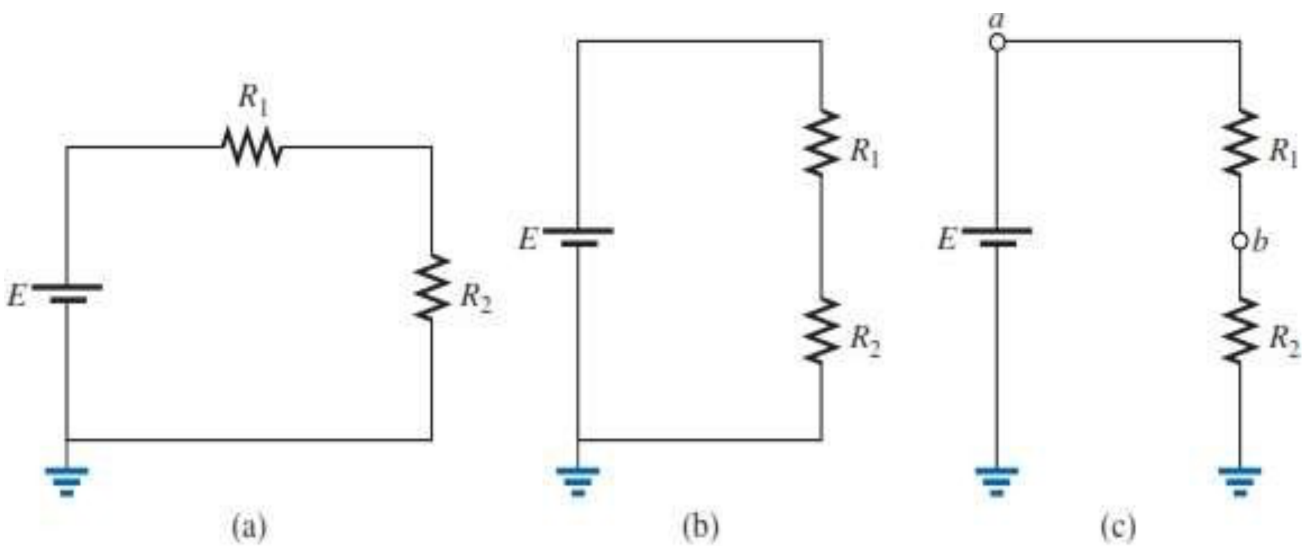
$$5R_2 = 5\ \text{k}\Omega$$
$$R_2 = \mathbf{1\ k\Omega}$$

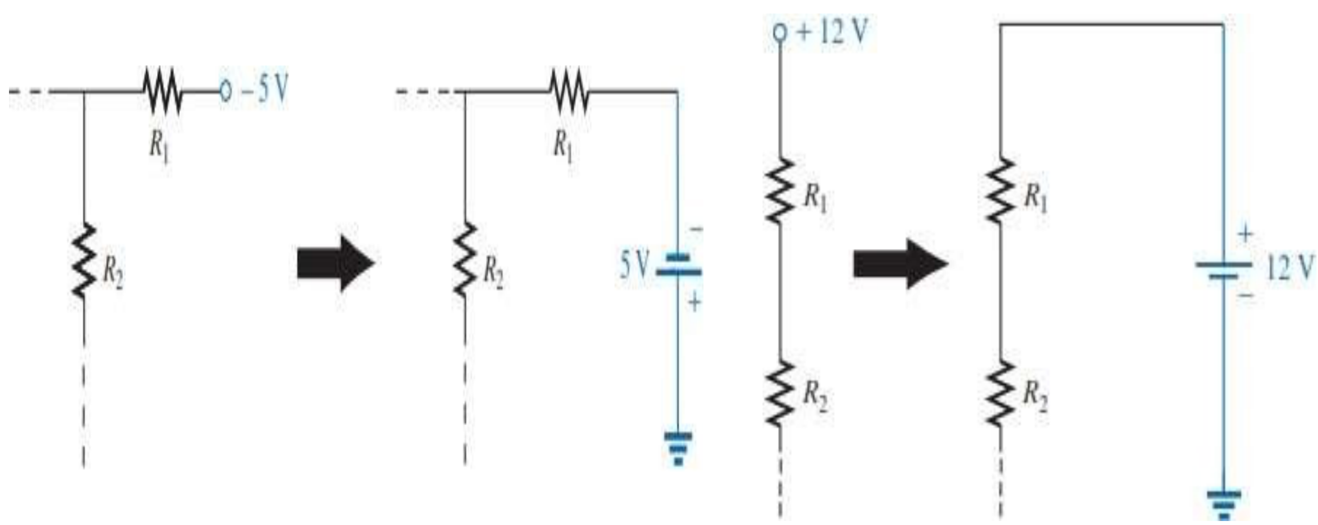
$$R_1 = 4R_2 = \mathbf{4\ k\Omega}$$



Email: zahraa.hazim@uomus.edu.iq

Voltage Sources and Ground

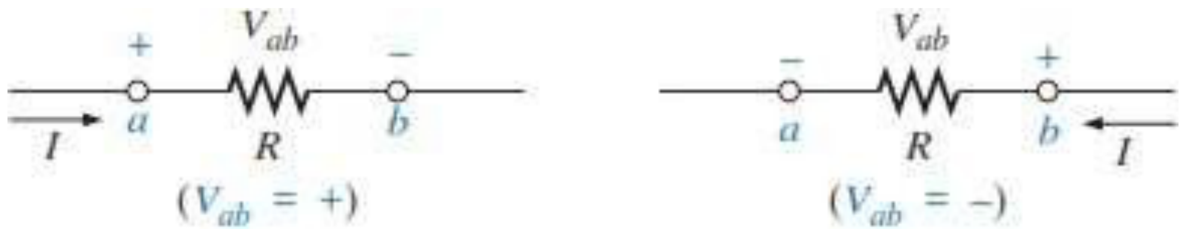




Email: zahraa.hazim@uomus.edu.iq

Double-Subscript Notation

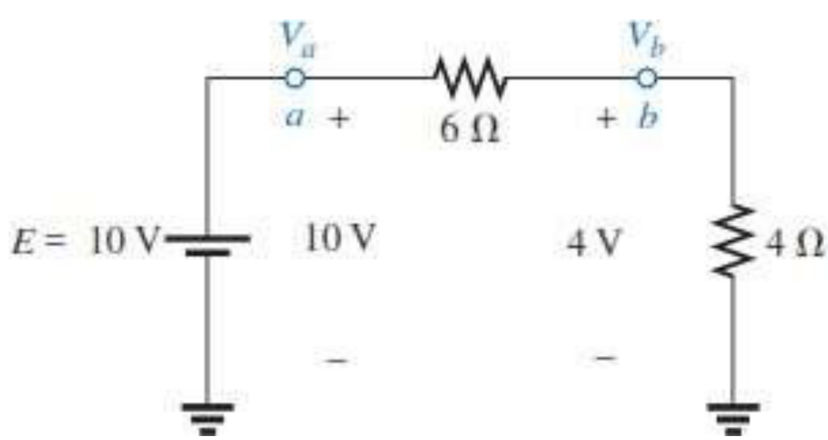
The two points that define the voltage across the resistor *R are denoted by a and b. Since a* is the first subscript for *Vab*, point *a must have a higher potential than* point *b if Vab* is to have a positive value. If, in fact, point *b is at a higher* potential than point *a, Vab* will have a negative value, as indicated in Figure.



Single-Subscript Notation

If point *b of the notation Vab* is specified as ground potential (zero volts), then a single-subscript notation can be employed that provides the voltage at a point with respect to ground.

$$V_{ab} = V_a - V_b$$

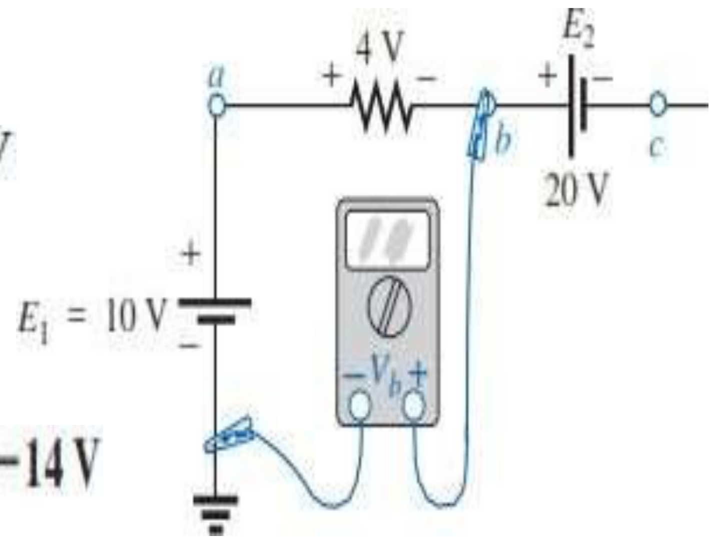


$$V_{ab} = V_a - V_b = 10\text{ V} - 4\text{ V}$$
$$= 6\text{ V}$$

Email: zahraa.hazim@uomus.edu.iq

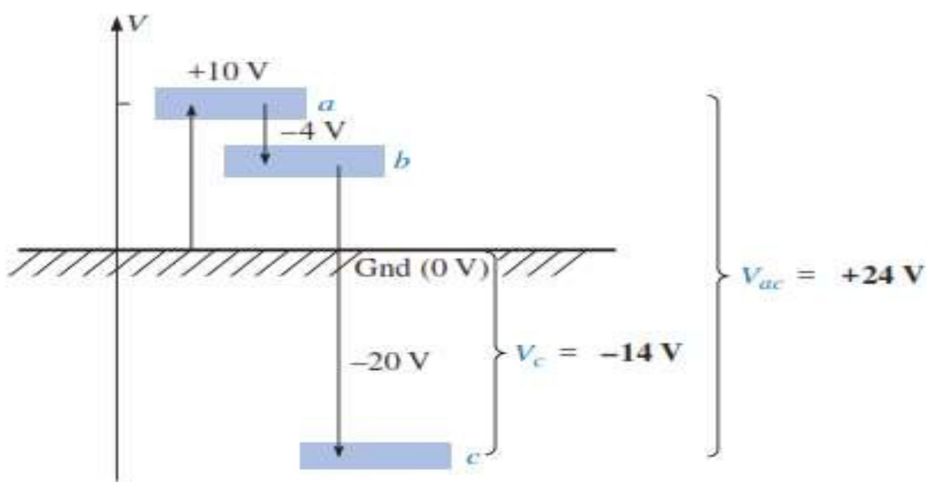
Example 2.8 Find the voltages *Vb*, *Vc*, and *Vac* for the network shown.

$$V_b = +10\text{ V} - 4\text{ V} = \mathbf{6\text{ V}}$$



$$V_c = V_b - 20\text{ V} = 6\text{ V} - 20\text{ V} = \mathbf{-14\text{ V}}$$

$$V_{ac} = V_a - V_c = 10\text{ V} - (-14\text{ V}) = \mathbf{24\text{ V}}$$



Email: zahraa.hazim@uomus.edu.iq

EXAMPLE 2.9 Determine *Vab*, *Vcb*, and *Vc* for the network shown.

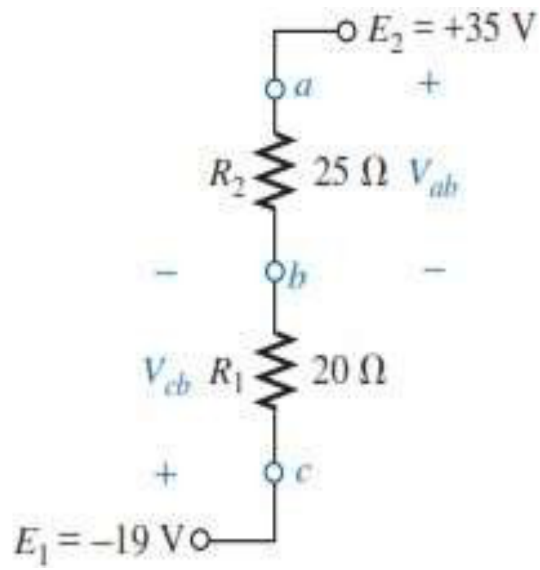
Note that there is a 54-V drop across the series resistors R_1 and R_2. The current can then be determined using Ohm's Law and the voltage levels as follows:

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

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

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

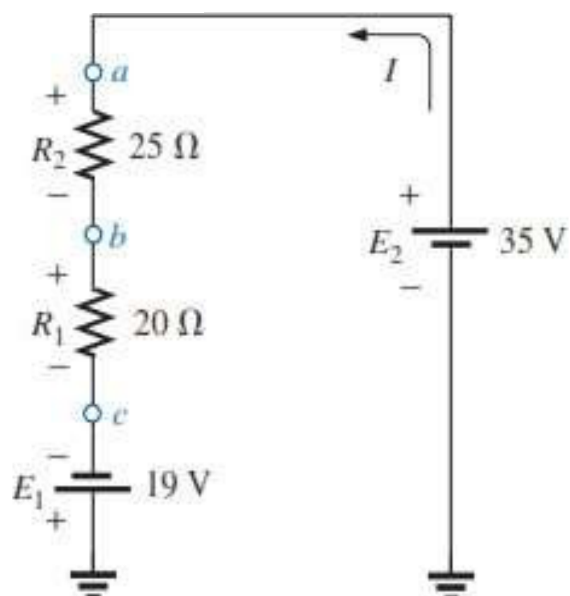
$$V_c = E_1 = \mathbf{-19\ V}$$



he other approach is to redraw the network as shown to clearly stablish the aiding effect of *E*1 and *E2* and then solve the esulting series circuit.

$$I = \frac{E_1 + E_2}{R_T} = \frac{19\text{ V} + 35\text{ V}}{45\ \Omega} = \frac{54\text{ V}}{45\ \Omega} = 1.2\text{ A}$$

$$V_{ab} = 30\text{ V} \qquad V_{cb} = -24\text{ V} \qquad V_c = -19\text{ V}$$

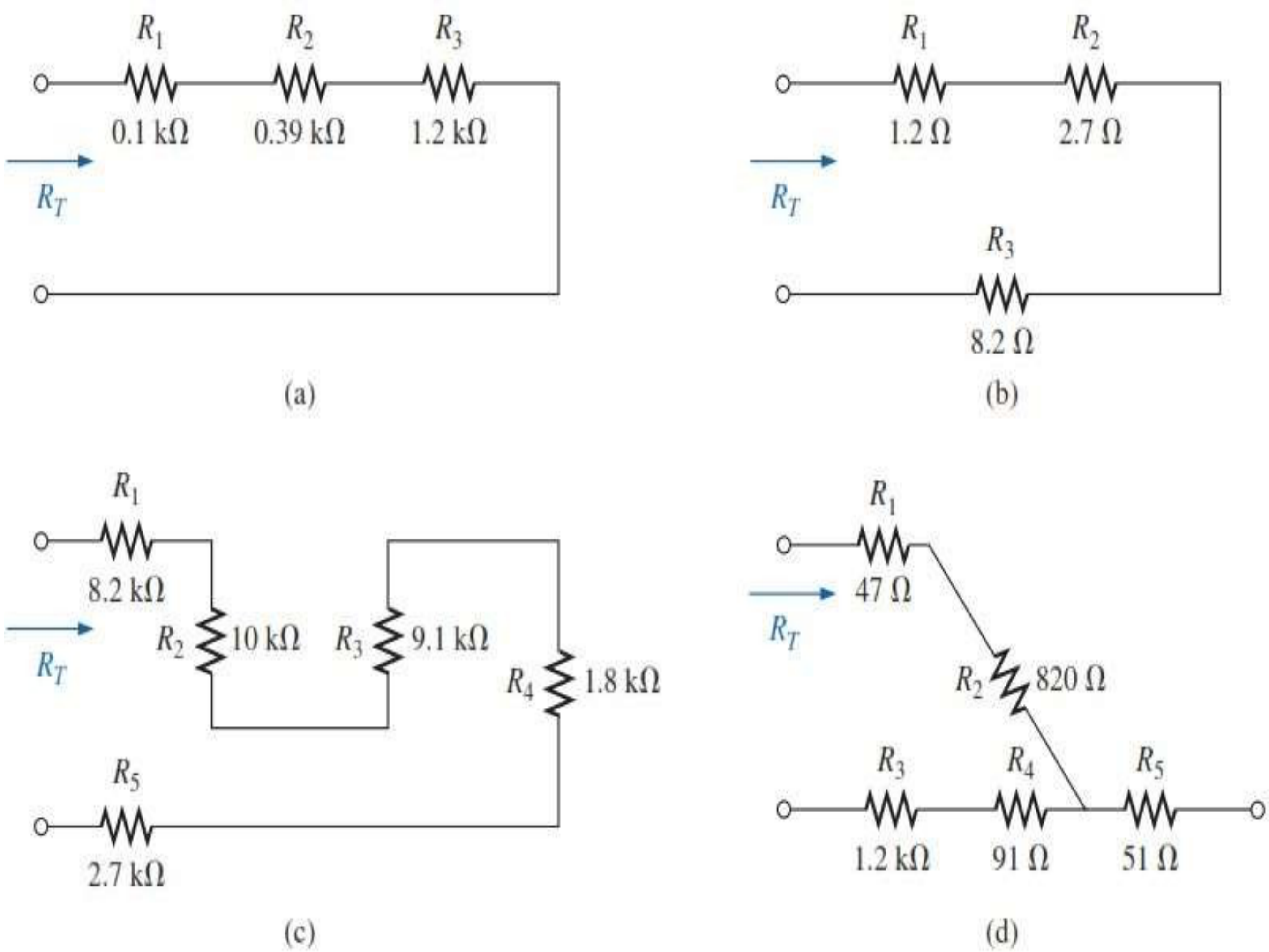


Email: zahraa.hazim@uomus.edu.iq

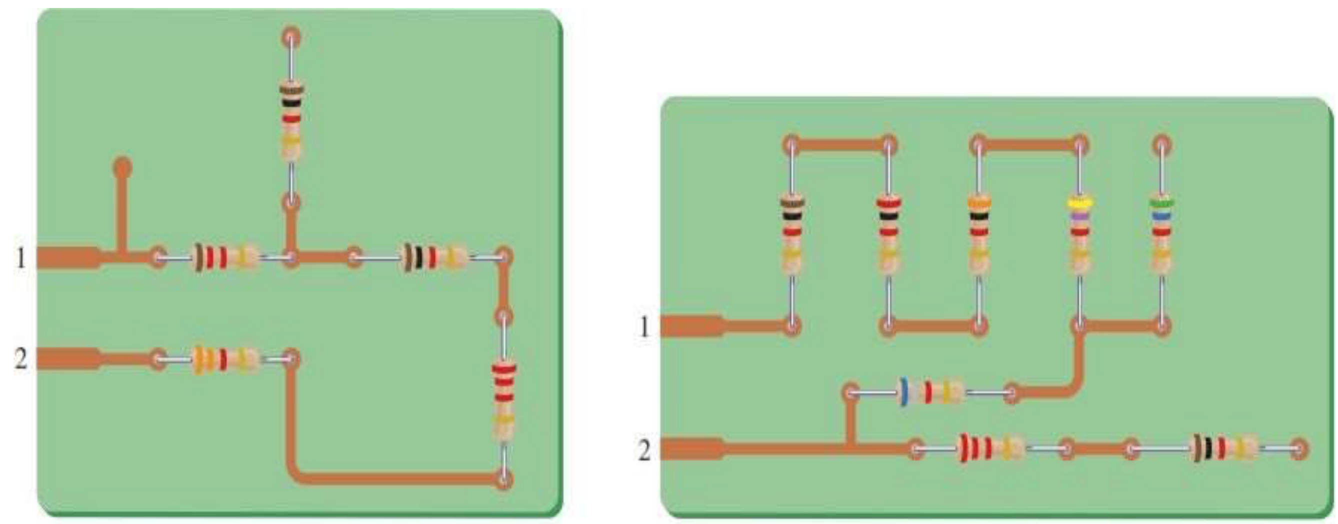
Problems

SECTION 5.2 Series Resistors

1. Find the total resistance R_T for each circuit shown.



2. For each circuit board in Fig., find the total resistance between connection tabs 1 &2.



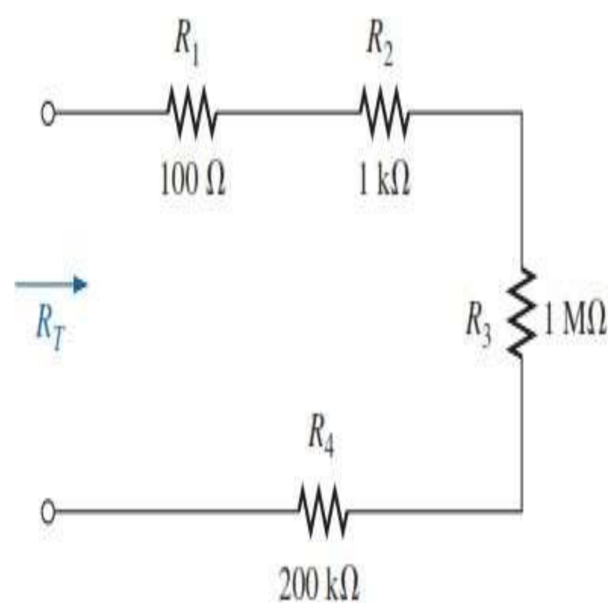
(a) (b)

3. For the circuit in Fig., composed of standard values:

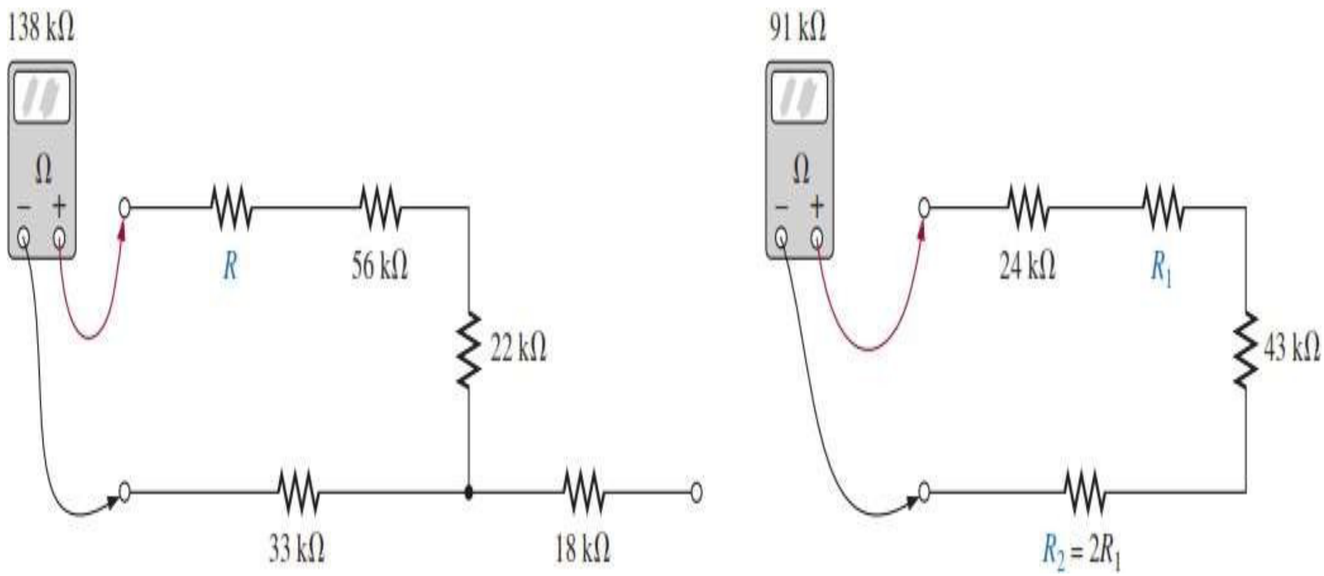
a. Which resistor will have the most impact On the total resistance?

b. On an approximate basis, which resistors can Be ignored when determining the total resistance?

c. Find the total resistance, and comment on Your results for parts (a) and (b).

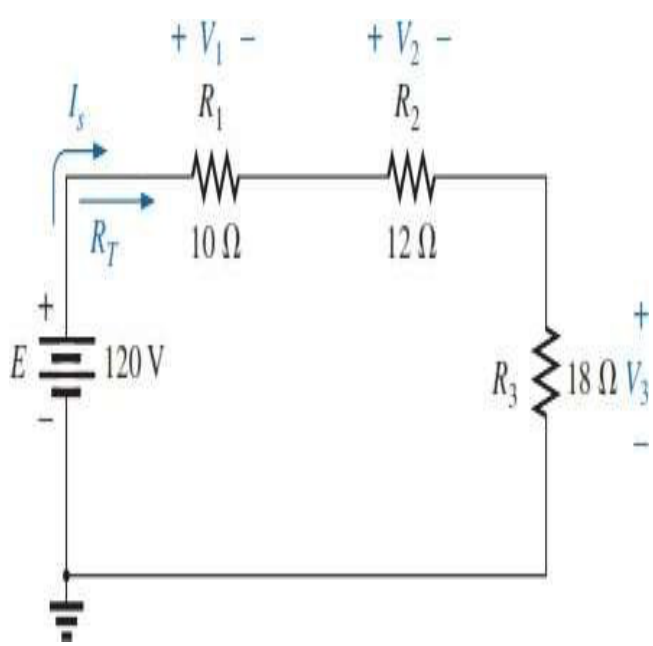


4. For each configuration in Fig., find the unknown resistors using the ohmmeter reading.



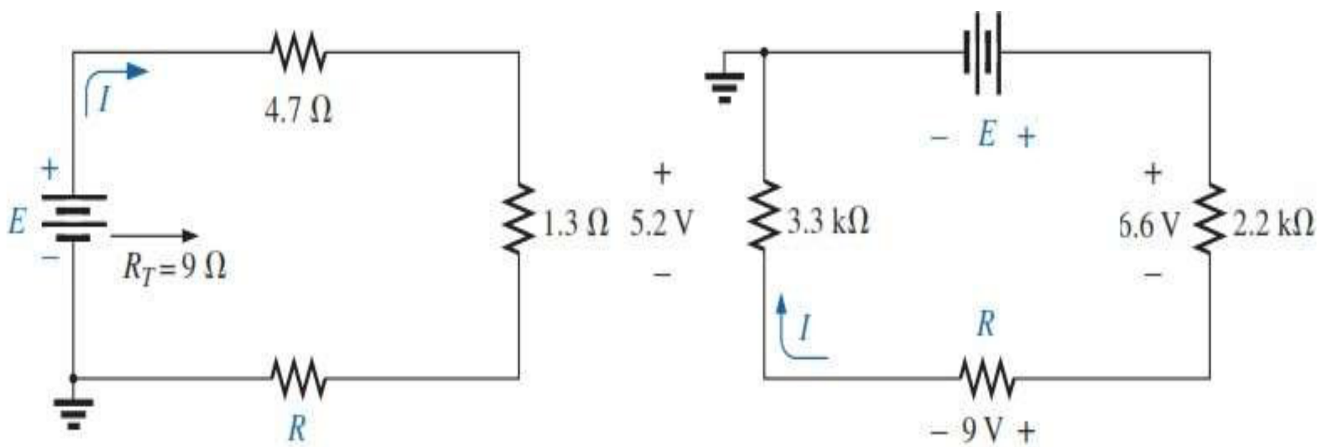
5. For the series configuration in Fig.:

a. Find the total resistance.
b. Calculate the current.
c. Find the voltage across each resistive element.



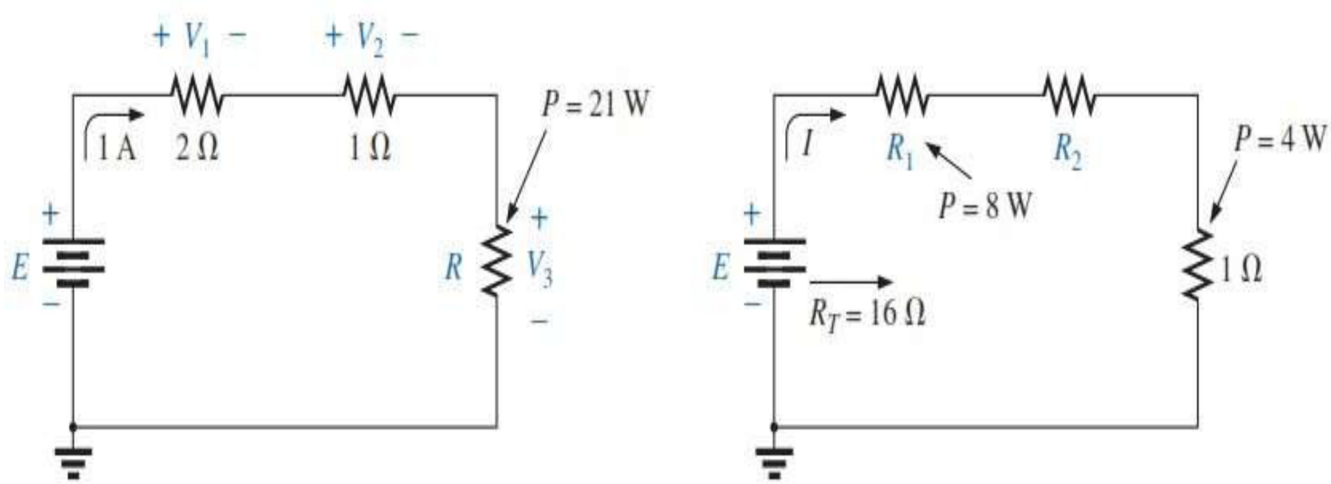
Email: zahraa.hazim@uomus.edu.iq

6. For each network in Fig, constructed of standard values, determine:
a. The current *I*. b. The source voltage *E*. c. The unknown resistance. d. The voltage across each element.



(a) (b)

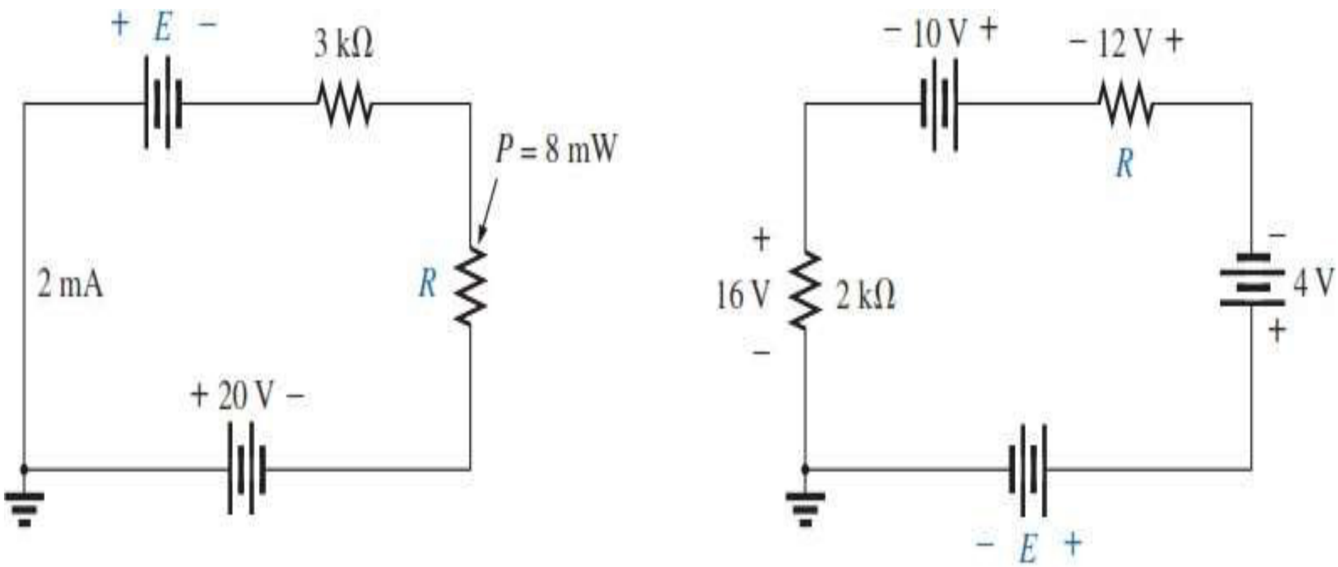
7. Find the unknown quantities for the circuits in Fig. using the information provided.



(a) (b)

Email: zahraa.hazim@uomus.edu.iq

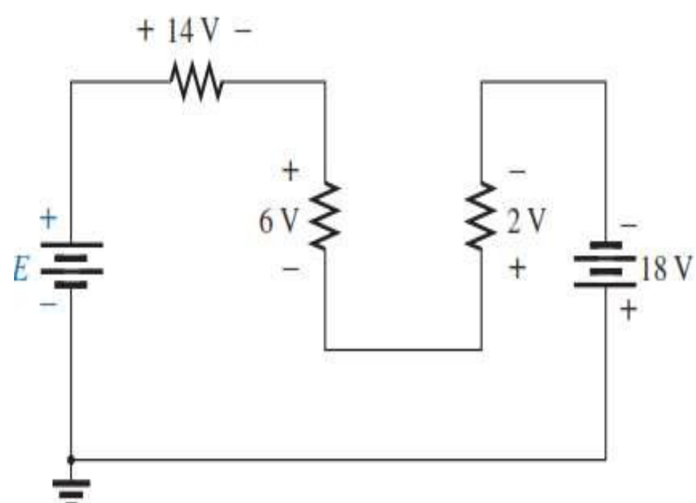
8. Find the unknown voltage source and resistor for the networks in Fig.First combine the series voltage sources into a single source. Indicate the direction of the resulting current.



(a) (b)

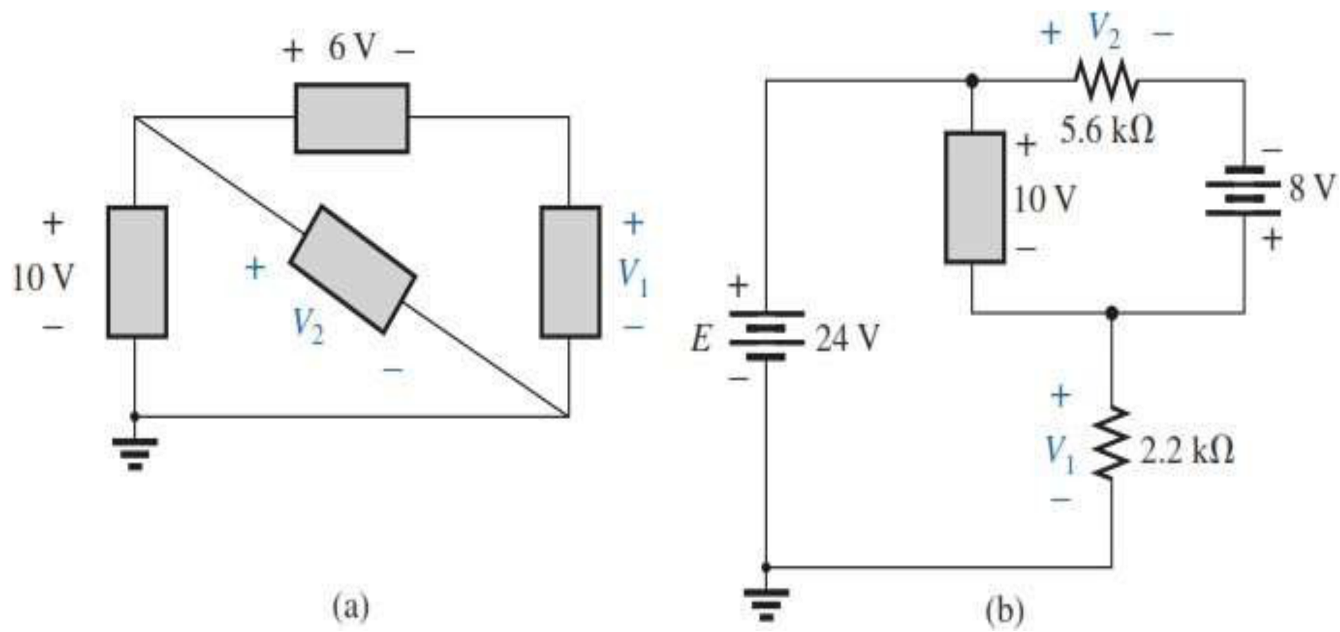
SECTION 5.6: Kirchhoff's Voltage Law

9. Using Kirchhoff's voltage law, find the unknown voltages for the circuit shown.

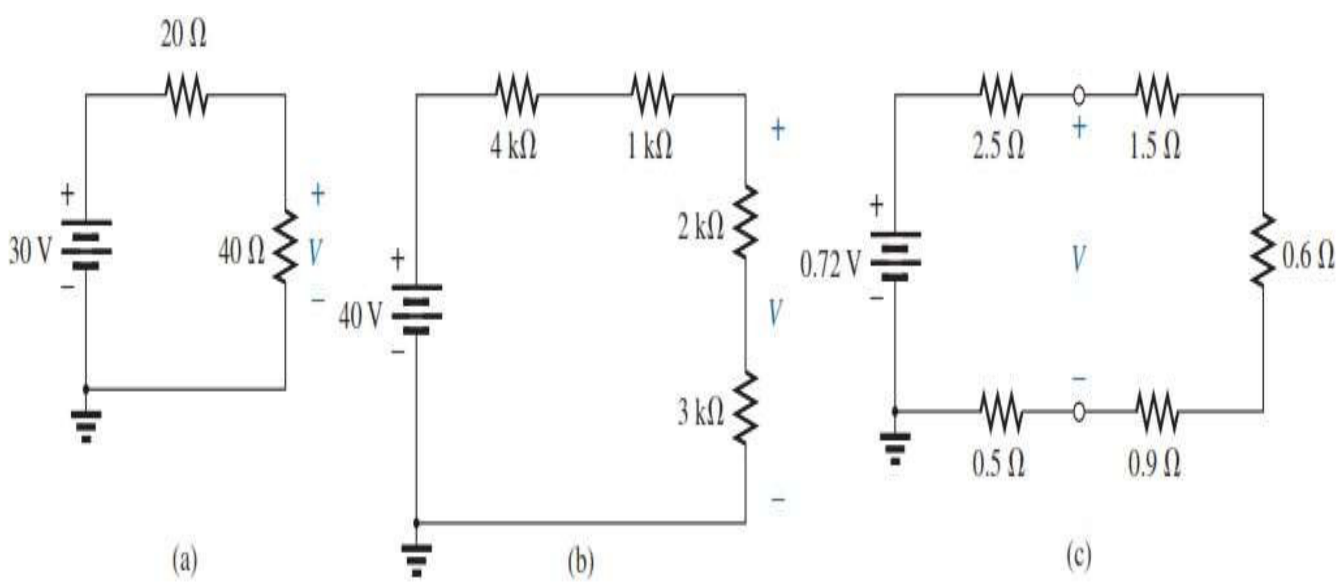


Email: zahraa.hazim@uomus.edu.iq

10. Using Kirchhoff's voltage law, determine the unknown voltages for the series circuits shown.



11. Using the voltage divider rule, find the indicated voltages in Fig.



Email: zahraa.hazim@uomus.edu.iq

Email: zahraa.hazim@uomus.edu.iq