Therefore, $$I = -\frac{7}{162} = -0.0432 \text{ A}$$

As the current is negative, the actual current direction is opposite to the direction of the current assumed.

Voltage across the 10Ω resistor, $V_{10\Omega} = -0.0432 \times 10 = -0.432$ V.

1.5 RESISTORS IN SERIES CIRCUITS

In a series circuit, all the components are connected in such a way that there exists only one closed path through which the current can flow. The same current flows through all the components connected in series. If a series circuit consists of only pure resistors, then it is called a series resistor circuit. The voltage across each resistor can be determined by Ohm's law.

For example, consider the series circuit shown in Fig. 1.12. It consists of resistors, R_1, R_2 and R_3 connected in series with a voltage source, V_s, across them. Due to this voltage source, a current, I, flows through the circuit.

The total, or equivalent, resistance of the circuit can be expressed as

$$R_{eq} = R_1 + R_2 + R_3$$

Applying KVL to the circuit, we get

$$V_s = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3 = I(R_1 + R_2 + R_3) = IR_{eq}$$

Therefore, $$I = \frac{V_s}{R_{eq}}$$

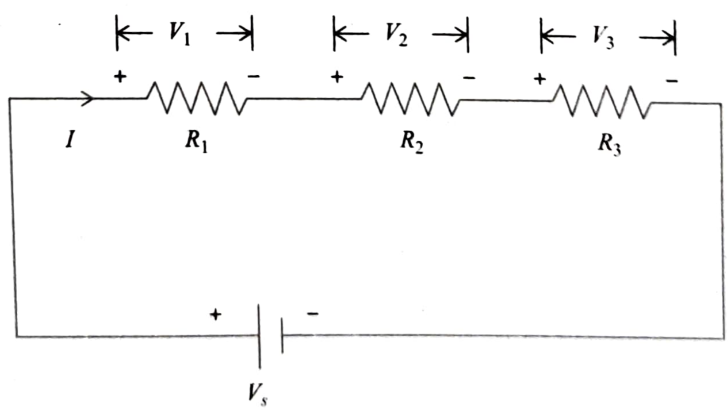


FIG. 1.12 Resistors in series

Thus, the current in the series circuit is determined by the voltage and its equivalent resistance.

The equivalent resistance in a series circuit is equal to the sum of all resistors connected in series. Suppose if n number of fixed resistors are connected in series, then

$$R_{eq} = R_1 + R_2 + R_3 + \dots\dots\dots + R_n.$$

When all resistors have equal values, then $R_{eq} = nR$.

Application of Series Resistor Circuits

Resistors are connected in series in order to increase the total resistance of the circuit and thus to limit the flow of the current. For a fixed source voltage, V_s, if the flow of current is limited by adding resistors in series, then it will result in the division of voltages across the resistors.

This can be illustrated with an example. Look at the circuit shown in Fig. 1.13(a), which consists of only one resistor, R, connected in series with a voltage source, V_s. The resultant current in the circuit is denoted as I.

The total resistance of this circuit is $R_T = R$

From Ohm's law, $V_s = IR$

Hence, $$I = \frac{V_s}{R}$$

If one more resistor R is added in series with the existing resistor, R, as shown in Fig. 1.13(b), then the equivalent resistance, R_{eq}, of the circuit increases. Thus,

$$R_{eq} = R + R = 2R$$

The increase in resistance from R to $2R$ limits the flow of the current as,

$$I = \frac{V_s}{2R}$$

The voltage across each resistor is

$$V_R = I \times R = \frac{V_s}{2R} \times R = \frac{V_s}{2}$$

Hence, it is inferred that as a result of addition of resistors in series, there will be a corresponding drop of voltage across each resistor.

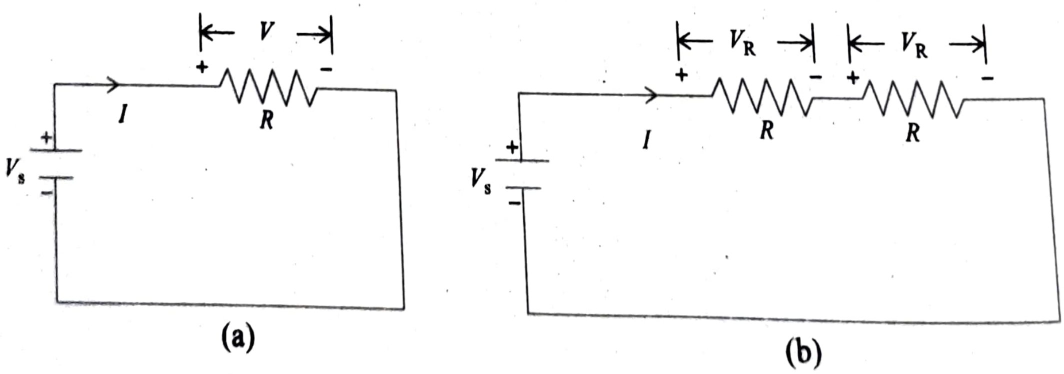


FIG. 1.13 Series resistor circuits

Effects of Resistors Connected in Series

1. The current remains the same through all the elements connected in series.
2. Voltage division occurs across the elements connected in series.
3. The voltage across different elements connected in series depends on its resistance value and the circuit current.
4. If n resistors are connected in series, then $R_{eq} = R_1 + R_2 + R_3 + ... + R_n$.
5. If n resistors of equal values are connected in series, then $R_{eq} = nR$.

6. Resistances, voltages and powers are additive in a series circuit.
7. The voltage applied is equal to the sum of voltage drops across different elements.

Limitations of Series Circuits

1. If there is a discontinuity or break in any part of the circuit, no current will flow through any element of the circuit.
2. As the voltage gets divided by the addition of elements, the series circuit is not practical for supplying power in the household and industrial applications.
3. It is also not practical to connect the devices having different current ratings in series.

Example 1.11 Determine the current and voltage across each resistor of the circuit shown in Fig. E1.11(a).

Solution

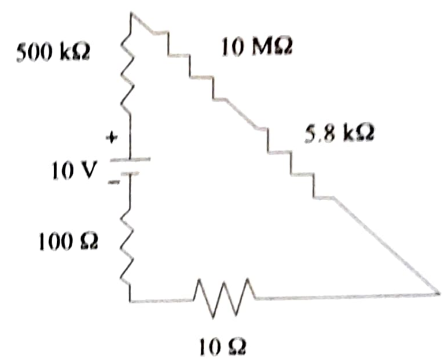


FIG. E1.11(a)

Let us assume that the direction of current, I, is clockwise as marked by dashed lines in Fig. E1.11(b). As the polarities of the resistors are not given along the traverse direction, positive sign is arbitrarily assumed to the side which encounters the current first, and negative sign on the other side.

Applying KVL to this circuit, we get

$$10\times10^6 I + 5.8\times10^3 I + 10I + 100I - 10 + 500\times10^3 I = 0$$

$$\text{or } 10\times10^6 I + 5.8\times10^3 I + 10I + 100I + 500\times10^3 I = 10$$

Therefore, $$I = \frac{10}{10505910} = 9.518\times10^{-7}\text{ A}$$

As this is a series circuit, the same current flows through all the resistors.

Applying Ohm's law to each resistor, we get

$$V_{10\text{M}\Omega} = IR_{10\text{M}\Omega} = 9.518\times10^{-7}\times10\times10^6 = 9.518\text{V}$$

$$V_{5.8\text{k}\Omega} = IR_{5.8\text{k}\Omega} = 9.518\times10^{-7}\times5.8\times10^3 = 5.52\text{mV}$$

$$V_{10\Omega} = IR_{10\Omega} = 9.518\times10^{-7}\times10 = 9.518\,\mu\text{V}$$

$$V_{100\Omega} = IR_{100\Omega} = 9.518\times10^{-7}\times100 = 9.518\times10^{-5}\text{ V}$$

$$V_{500\text{k}\Omega} = IR_{500\text{k}\Omega} = 9.518\times10^{-7}\times500\times10^3 = 0.4759\text{ V}$$

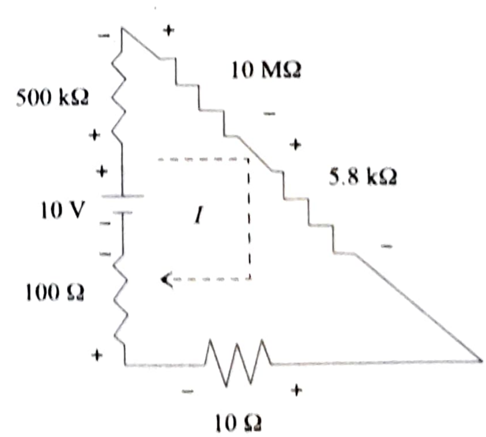


FIG. E1.11(b)

In order to prove KVL, if we add all the voltage drops across each resistor, it should be equal to the supply voltage.

$$V_{10\text{M}\Omega} + V_{5.8\text{k}\Omega} + V_{10\Omega} + V_{100\Omega} + V_{500\text{k}\Omega}$$

$$= 9.518 + 5.52\times10^{-3} + 9.518\times10^{-6} + 9.518\times10^{-5} + 0.4759 = 10\text{V}$$

Example 1.12 A 10 V power supply having an internal resistance of 30 Ω is connec series with two resistors of values 100 Ω and R_x. Find the value of R_x if the current th the circuit is 1 mA.

Solution

The circuit with the given data can be drawn as shown in Fig. E1.12.

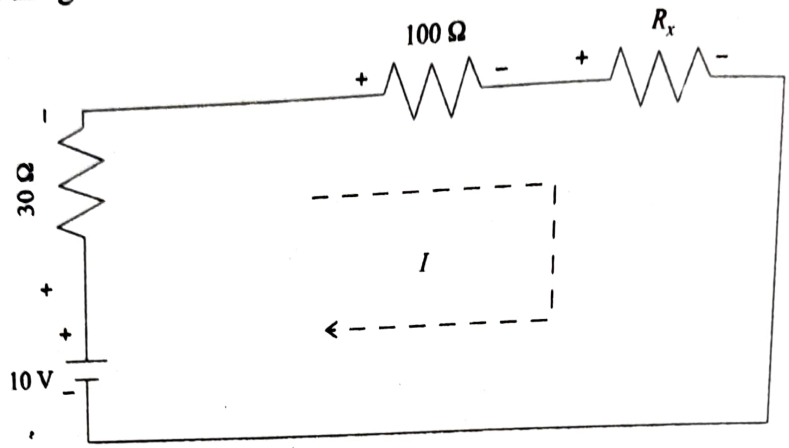


FIG. E1.12

As the circuit is in series form, same current flows through all the resistors. Applying KV to this circuit for the assumed current direction, we have

$$100I + R_x I + 30I = 10$$

$$(130 + R_x) \times 1 \times 10^{-3} = 10$$

Therefore, $R_x = 9870\Omega$

Example 1.13 For the circuit shown in Fig. E1.13(a), find the voltage across x and y.

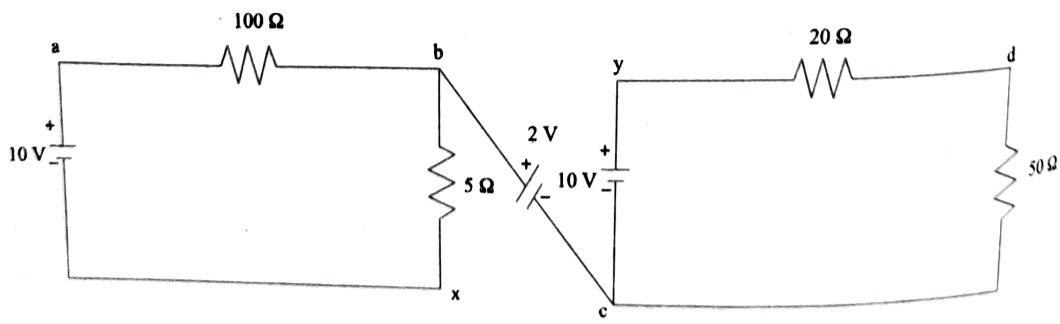


FIG. E1.13(a)

Solution

To simplify the analysis the given circuit can be redrawn as shown in Fig. E1.13(b).

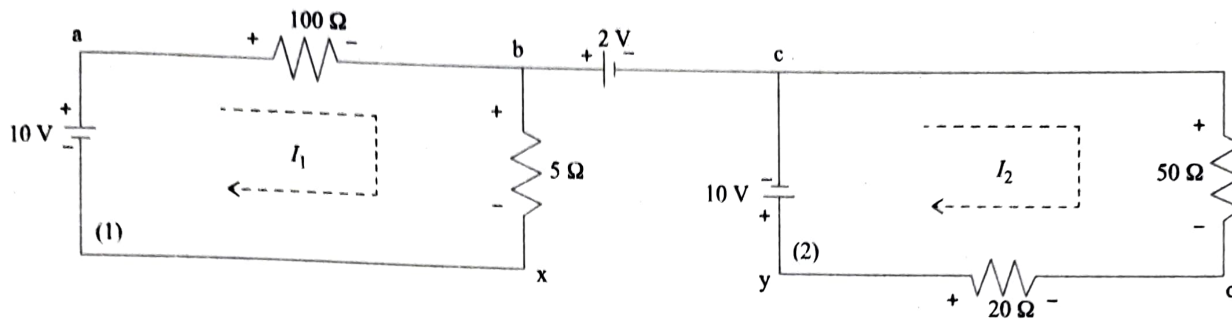


FIG. E1.13(b)

The clockwise traverse current direction and polarities across resistors are assumed arbitrarily. It is noticed that two series loops, 1 (abxa) and 2 (cdyc), share a common voltage source, 2 V, and the currents that flow through them are I_1 and I_2, respectively. Hence, the components shared between the nodes 'x' and 'y' can be drawn as shown in Fig. E1.13(c). Applying KVL for the nodes 'x' and 'y' in the assumed traverse direction, we have

$$2-10+V_{yx}-5I_1=0$$

$$V_{yx}=8+5I_1$$

The only current flowing through the 5 Ω resistor is due to the current, I_1 in loop-1. From the current direction of I_1 through the 5 Ω resistor in Fig. E1.13(b), it is found that the direction of current is opposite to the traverse direction shown in Fig. E1.13(c). So, a negative sign is assigned to $5I_1$ in the KVL equation.

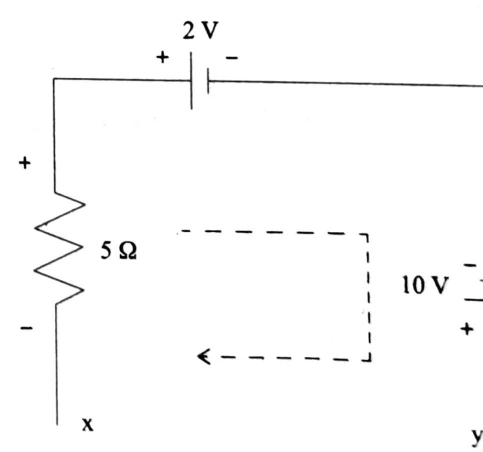


FIG. E1.13(c)

Applying KVL for loop-1 shown in Fig. E1.13(b), we get

$$100I_1+5I_1=10$$

$$I_1=0.095\,\text{A}$$

Therefore, $\quad V_{yx}=8+5\times 0.095=8.476\,\text{V}$

and $\quad V_{xy}=-V_{yx}=-8.476\,\text{V}$

Example 1.14 For the circuit shown in Fig. E1.14, if $v_2=20\,\text{V}$, find the current, I.

Solution

Given $v_2=20\,\text{V}$. Applying KVL in the clockwise traverse current direction as shown in Fig. E1.14, we get

$$20I+25-10v_2=0$$

$$20I=-25+10\times 20$$

$$I=\frac{175}{20}=8.75\,\text{A}$$

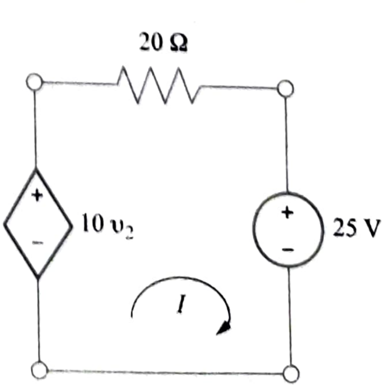


FIG. E1.14

1.6 RESISTORS IN PARALLEL CIRCUITS

A circuit is called parallel circuit if all the components in that circuit are connected in such a way that there exists, more than one path or branch through which the circuit current can flow. As the current has to flow through more than one branch, the current gets divided in a parallel circuit. But the net voltage remains the same across all the branches connected in parallel.

Consider a simple circuit consisting of two resistors connected in parallel as shown in Fig. 1.14(a). If a voltage, V_s, is applied to node 'a' the circuit, then current, I, is divided into I_1 and I_2.

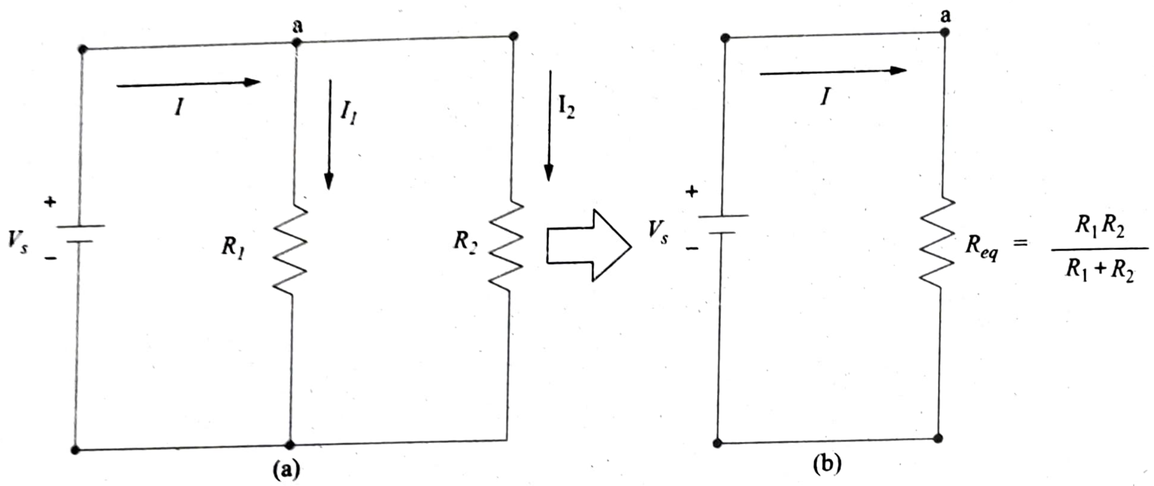


FIG. 1.14 (a) Two resistors in parallel, (b) Its equivalent

Applying KCL to the node 'a', we get

$$I = I_1 + I_2$$

We also know from Ohm's law that

$$I_1 R_1 = I_2 R_2 = V_s$$

i.e., $$I_1 = \frac{V_s}{R_1} \text{ and } I_2 = \frac{V_s}{R_2}$$

Therefore, $$I = \frac{V_s}{R_1} + \frac{V_s}{R_2}$$

$$V_s = \frac{I}{\left(\frac{1}{R_1} + \frac{1}{R_2}\right)} = I\left(\frac{R_1 R_2}{R_1 + R_2}\right) = IR_{eq}$$

Thus, as shown in Fig. 1.14(b), two parallel resistors, R_1 and R_2, can be replaced with their equivalent single resistance, $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$.

Consider another parallel circuit consisting of three resistors, R_1, R_2 and R_3, connected in parallel with a voltage source as shown in Fig. 1.15.

The circuit consists of nodes 'a' and 'b'. If a DC voltage V_s is applied across these nodes, the current, I, gets divided in the node 'a' as I_1, I_2 and I_3.

Applying KCL at the node 'a', we have

$$I = I_1 + I_2 + I_3$$

According to Ohm's law, $V_1 = I_1 R_1$.

Therefore, $I_1 = \dfrac{V_1}{R_1}$

Similarly, $V_2 = I_2 R_2$, i.e., $I_2 = \dfrac{V_2}{R_2}$

and $V_3 = I_3 R_3$, i.e., $I_3 = \dfrac{V_3}{R_3}$

Hence, $I = \dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3}$

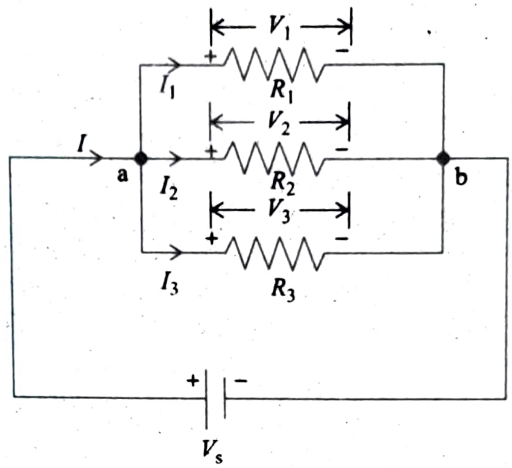


FIG. 1.15 Three resistors in parallel

As the net voltage remains the same across all the branches connected in parallel,

$$V_1 = V_2 = V_3 = V_s$$

Hence,
$$I = \frac{V_s}{R_1} + \frac{V_s}{R_2} + \frac{V_s}{R_3}$$
$$= \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) V_s$$
$$= \frac{1}{R_{eq}} \times V_s$$

where $\dfrac{1}{R_{eq}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Since conductance, $G = \dfrac{1}{R}$ the above equation for parallel circuit equivalent resistance can be written in terms of conductance as,

$$G_{eq} = G_1 + G_2 + G_3$$

If n fixed resistors are connected in parallel, then

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

and
$$G_{eq} = G_1 + G_2 + \cdots + G_n$$

When all resistors have the same value, then $R_{eq} = \dfrac{R}{n}$ and $G_{eq} = nG$

Effects of Resistors Connected in Parallel

1. The voltage remains same across all the elements connected in parallel.
2. The current gets divided in a parallel circuit.

3. The flow of current through each element connected in parallel depends on its resistance value and the voltage across it.
4. The equivalent resistance of a parallel circuit can be calculated by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n}$$

5. If n resistors all having equal resistance values are connected in parallel, then the equivalent resistance of the circuit is $R_{eq} = \frac{R}{n}$.
6. Branch currents, conductances and powers are additive in a parallel circuit.

Advantages of Parallel Circuits

1. If there is a discontinuity, or break, in any one branch, the current still flows in the other branches of the parallel circuit.
2. Electrical appliances having same voltage rating but different power or current rating can be connected in parallel. This is the reason for using parallel circuits in all household and industrial wirings and for connecting the electrical appliances and equipment.

Example 1.15 Find the current delivered by the source for the network shown in Fig. E1.15(a) using the network reduction techniques.

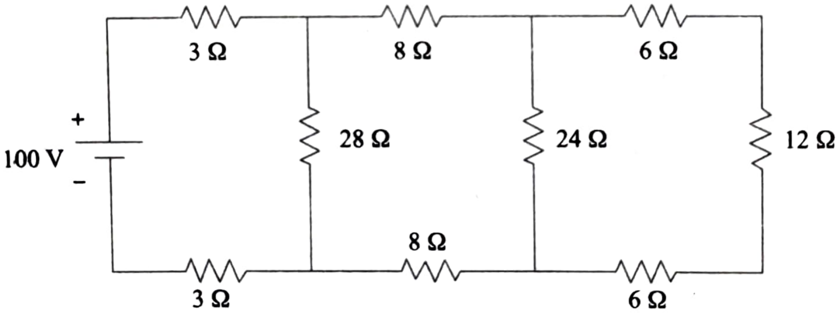


FIG. E1.15(a)

Solution

It is convenient to analyze the given circuit in its simplified form using network reduction techniques. Network reduction has to be applied systematically, starting from the output end of the circuit and progressively followed to the input. Inspecting the given circuit, it is noticed that the output end consists of a series combination of three resistors 6Ω, 12Ω and 6Ω, which can be replaced by a single equivalent resistor as shown in Fig. E1.15(b).

$$R_{eq} = 6 + 12 + 6 = 24\Omega$$

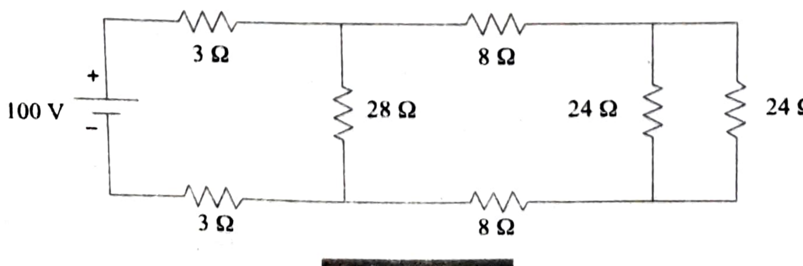


FIG. E1.15(b)

The parallel combination of two $24\,\Omega$ resistors shown in Fig. E1.15(b) can be replaced by its equivalent $\frac{24 \times 24}{24 + 24}\Omega = 12\,\Omega$, as shown in Fig. E1.15(c).

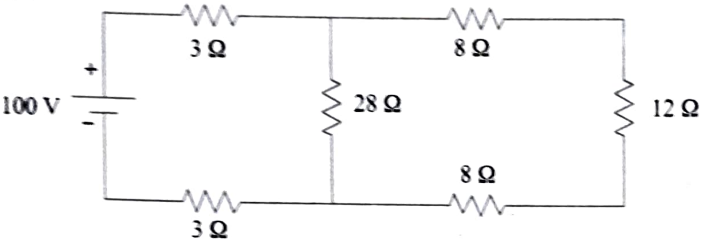


FIG. E1.15(c)

The series combination of resistors $8\,\Omega$, $12\,\Omega$ and $8\,\Omega$ in Fig. E1.15(c) can be replaced by its equivalent $(8{+}12{+}8)\,\Omega = 28\,\Omega$, as shown in Fig. E1.15(d).

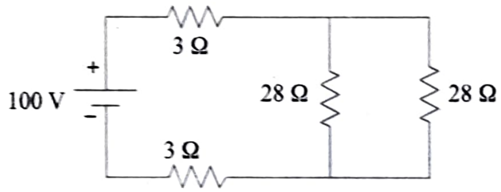


FIG E1.15(d)

The parallel combination of two resistors of $28\,\Omega$ each in Fig. E1.15(d) can be replaced by $\frac{28 \times 28}{28 + 28}\Omega = 14\,\Omega$ as shown in Fig. E1.15(e).

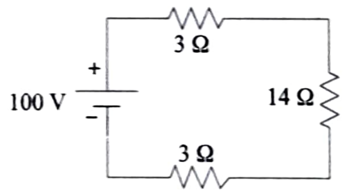


FIG. E1.15(e)

Finally, the series combination of $3\,\Omega$, $14\,\Omega$ and $3\,\Omega$ in Fig. E1.15(e), can be replaced by $(3 + 14 + 3)\,\Omega = 20\,\Omega$, as shown in Fig. E1.15(f).

Therefore, according to Ohm's law, the total current delivered by the source,

$$I = \frac{100}{20} = 5\,\text{A}$$

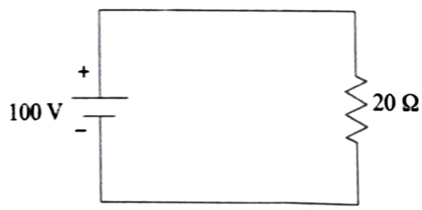
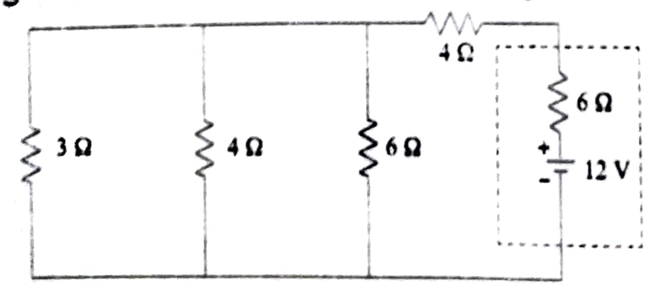


FIG. E1.15(f)

Example 1.16 A circuit consists of three resistors of $3\,\Omega$, $4\,\Omega$ and $6\,\Omega$ in parallel and fourth resistor of $4\,\Omega$ in series. A battery of 12 V having an internal resistance of $6\,\Omega$ is connected across the circuit. Find the total current in the circuit and terminal voltage across the battery.

Solution

The circuit with the given data can be drawn as shown in Fig. E1.16(a).



(a)

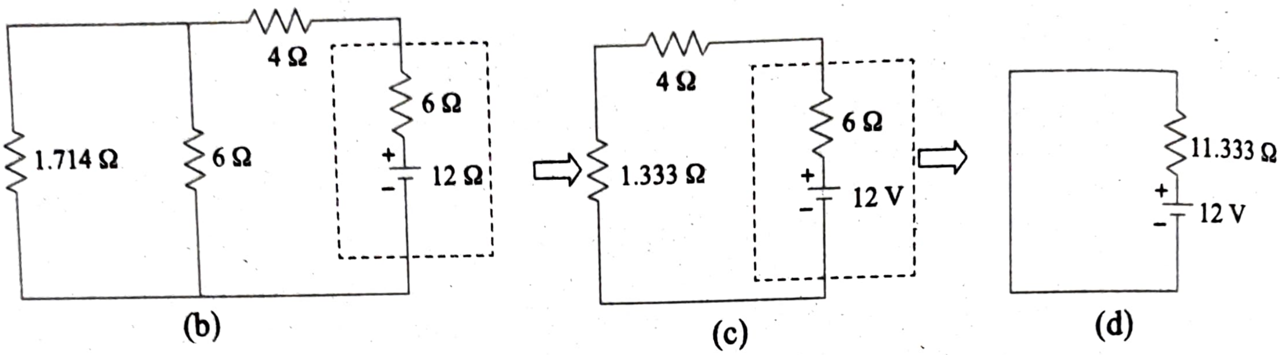


FIG. E1.16

It is convenient to analyze the given circuit in its simplified form using network reduction techniques. Network reduction has to be applied systematically, starting from the output end (load) of the circuit and progressively followed to the input (source).

Starting the analysis from the load, the parallel combination of two resistors, 3Ω and 4Ω, can be replaced by a single equivalent resistor, $\frac{1}{R_{eq}}=\frac{1}{R_1}+\frac{1}{R_2}$, i.e., $R_{eq}=R_{3\Omega}\,||\,R_{4\Omega}=\frac{3\times 4}{3+4}=1.714\Omega$ as shown in Fig. E1.16(b).

The parallel combination of the resistors, 1.714Ω and 6Ω, is replaced by its equivalent resistor, $R_{eq}=R_{1.714\Omega}\,||\,R_{6\Omega}=\frac{1.714\times 6}{1.714+6}=1.333\Omega$, as shown in Fig. E1.16(c).

Finally, the series combination of the resistors, 1.333 Ω, 4Ω and 6Ω, can be replaced by $R_{eq}=1.333+4+6=11.333\,\Omega$, as shown in Fig. E1.16(d).

According to Ohm's law, the current flowing in the circuit,

$$I=\frac{12}{11.333}=1.0589\,\text{A}$$

The terminal voltage across the battery is the difference between the battery voltage and voltage drop in the internal resistor.

$$V_{Terminal}=V-V_{6\Omega}$$

According to Ohm's law, the voltage drop across 6Ω resistor,

$$V_{6\Omega}=IR_{6\Omega}=1.0589\times 6=6.353\,\text{V}$$

Therefore, $V_{Terminal}=12-6.353=5.647\,\text{V}$

Example 1.17 Equivalent resistance of two wires is measured as 150 Ω when connected in series and 100/3 Ω when connected in parallel. Calculate their individual resistance values.

Solution

Total resistance when connected in series $=150\Omega$

i.e.., $R_1+R_2=150$

Total resistance when connected in parallel $=\frac{100}{3}\Omega$

i.e., $$\frac{R_1R_2}{R_1+R_2}=\frac{100}{3}$$

Substituting the value of R_1+R_2 in the above equation, we get

$$\frac{R_1R_2}{150}=\frac{100}{3}$$

$$R_1R_2=5000$$

or $$R_1=\frac{5000}{R_2}$$

Substituting the above equation in $R_1+R_2=150$, we get

Thus, $$\frac{5000}{R_2}+R_2=150$$

or, $$R_2^2-150R_2+5000=0$$

As this equation is in quadratic form ($ax^2+bx+c=0$), the solution $\left(x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}\right)$ can be obtained as,

$$R_2=\frac{-(-150)\pm\sqrt{150^2-4\times1\times5000}}{2\times1}$$

$$R_2=100\Omega \text{ (or) } 50\Omega$$

Substituting these values of R_2 in $R_1=\frac{5000}{R_2}$, we get

$$R_1=50\Omega \text{ (or) } 100\Omega$$

Example 1.18 For the circuit shown in Fig. E1.18(a), find the equivalent resistance between the terminals A and B.

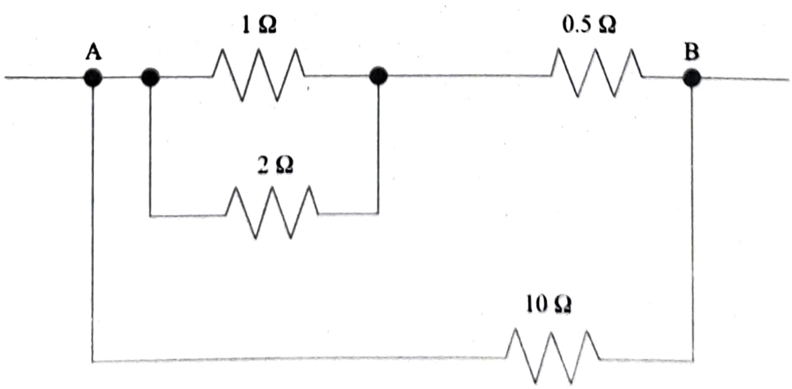


FIG. E1.18(a)

Solution

It is convenient to analyze the given circuit in its simplified form using network reduction. Inspecting the circuit, it can be noticed that it consists of two parallel resistors 1 Ω and 2 Ω as shown by dashed lines in Fig. E1.18(b).

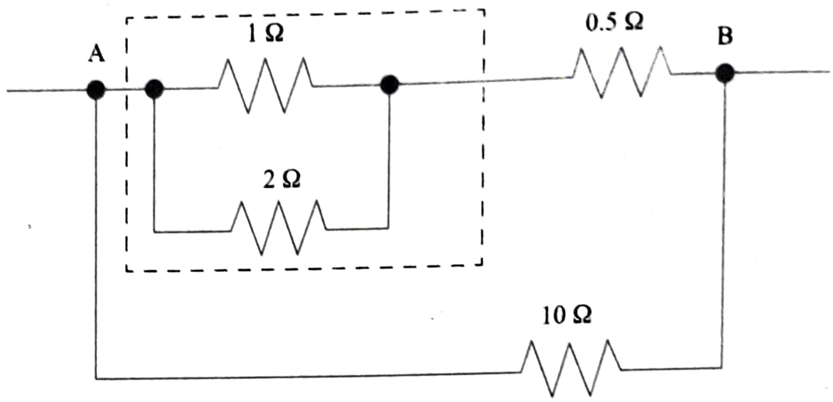


FIG. E1.18(b)

This parallel combination of two resistors can be reduced by replacing them with a single equivalent resistor using the relationship $R_{eq} = \dfrac{R_1 R_2}{R_1 + R_s}$

$$R_{eq} = \frac{1 \times 2}{1 + 2} = \frac{2}{3}\,\Omega.$$

The circuit in the reduced form is shown in Fig. E1.18(c).

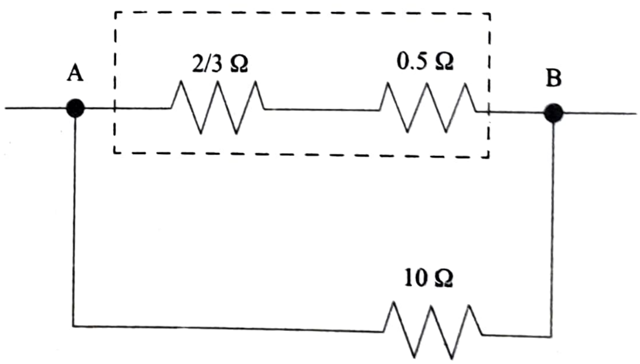


FIG. E1.18(c)

It consists of two resistors $\dfrac{2}{3}\,\Omega$ and $0.5\,\Omega$ in series. These resistors can be reduced into a single equivalent resistor using the relationship, $R_{eq} = R_1 + R_2$

$$R_{eq} = \frac{2}{3} + 0.5 = \frac{7}{6}\,\Omega$$

The circuit in the reduced form is shown in Fig. E1.18(d).

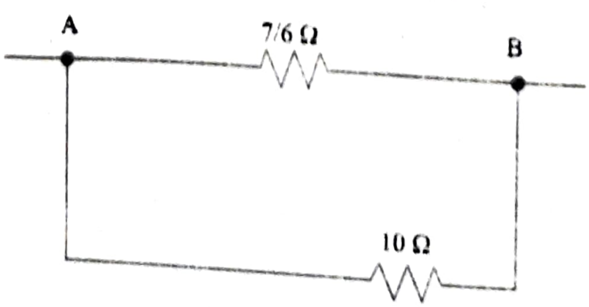


FIG. E1.18(d)

Between the terminals A and B, as there exists a parallel combination of two resistors 7/6 Ω and 10 Ω, the equivalent resistance is

$$R_{AB} = \frac{\frac{7}{6}\times 10}{\frac{7}{6}+10} = \frac{70}{67} = 1.045\ \Omega$$

Example 1.19 For the circuit shown in Fig. E1.19(a), find the equivalent resistance between points C and D.

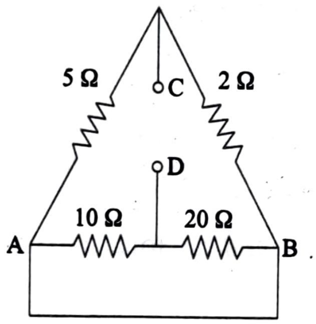


FIG. E1.19(a)

Solution

The given circuit of Fig. E1.19(a) can be redrawn as shown in Fig. E1.19(b).

Inspecting the circuit, it can be noticed that there exist two sets of parallel resistors 5 Ω ||2 Ω and 10 Ω||20 Ω as shown by dotted lines in Fig. E1.19(b). Replacing the parallel resistors by their equivalent resistances we get the network as shown in Fig. E1.19(c).

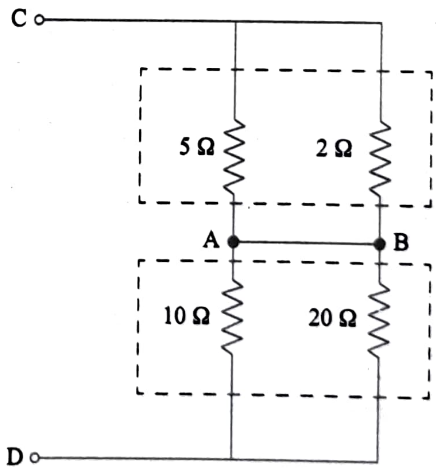


FIG. E1.19(b)

$$R_{5\Omega\|2\Omega} = \frac{5\times 2}{5+2} = 1.429\Omega$$

$$R_{10\Omega\|20\Omega} = \frac{10\times 20}{10+20} = 6.667\Omega$$

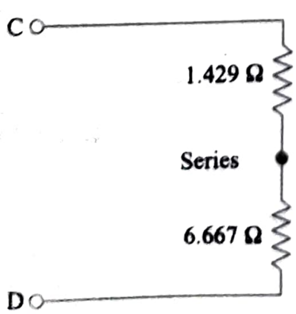


FIG. E1.19(c)

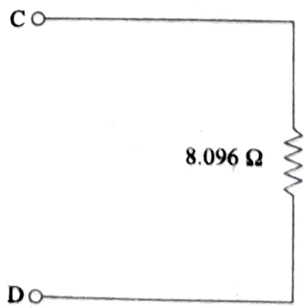


FIG. E1.19(d)

Now, the series combination of two resistors 1429 Ω and 6.667 Ω can be replaced by its equivalent circuit as shown in Fig. E1.19(d).

$$R_{eq} = 1.429 + 6.667\,\Omega$$
$$= 8.096\,\Omega$$

Therefore, $R_{CD} = 8.096\,\Omega$

Example 1.20 The current through a resistor is measured as 0.5 A when it is placed across a 12 V supply. Calculate the value of load resistance that has to be connected in parallel to increase the load current to 1 A.

Solution

Given $V_s = 12\,\text{V}$, $I_1 = 0.5\text{A}$, and $R_1 = \dfrac{12}{0.5} = 24\,\Omega$.

The required load current $I_L = 1\text{A}$, and the total current $I = I_1 + I_L = 0.5 + 1 = 1.5$ A.

Therefore, the required total circuit resistance, $R_{eq} = \dfrac{V_s}{I} = \dfrac{12}{1.5} = 8\,\Omega$.

The equation for parallel circuit equivalent resistance is given as

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_L}$$

$$\frac{1}{8} = \frac{1}{24} + \frac{1}{R_L}$$

$$\frac{1}{R_L} = \frac{1}{8} - \frac{1}{24} = 0.125 - 0.042$$

$$\frac{1}{R_L} = 0.083$$

Therefore, $R_L = 12.048\,\Omega$

Example 1.21 Two resistors, 3 Ω and 5 Ω, are connected in series. Calculate the value of the resistor that has to be connected in parallel with the 5 Ω so that the total circuit resistance becomes 7.5 Ω.

Solution

Given: $R_{5\Omega}$ and R_x are connected in parallel, total resistance $R_T = 7.5\,\Omega$ and series resistance $R_s = 3\,\Omega$.

The equation for the parallel combination of two resistors is

$$R_p = \frac{R_{5\Omega} R_x}{R_{5\Omega} + R_x} = \frac{5R_x}{5 + R_x}$$

$$R_T = R_p + R_s$$

$$7.5 = \frac{5R_x}{5+R_x} + 3$$

$$5R_x = 4.5(5+R_x)$$

$$= 22.5 + 4.5R_x$$

$$R_x = \frac{22.5}{0.5} = 45\,\Omega$$

Example 1.22 For the circuit shown in Fig. E1.22(a), find the unknown voltages, V_1 and V_2, across the resistors.

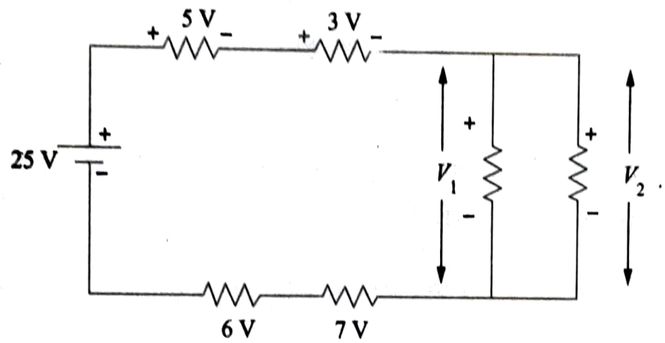


FIG. E1.22(a)

Solution

The voltage drops across parallel branches remain equal. Therefore, $V_1 = V_2$.
Assuming clockwise current traversal direction as shown in Fig. E1.22(b) and applying KVL with respect to loop current, I_1, we get

$$5 + 3 + V_1 + 7 + 6 - 25 = 0$$

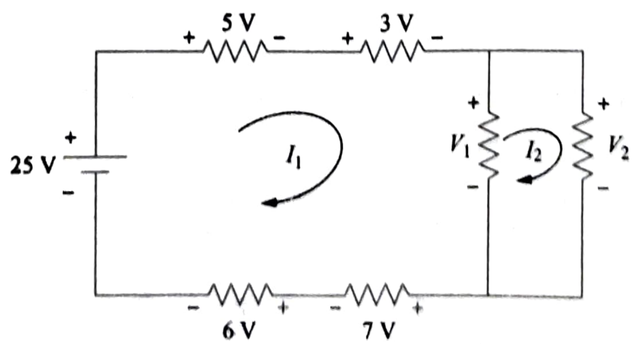


FIG. E1.22(b)

$$25 = 5 + 3 + V_1 + 7 + 6$$

$$V_1 = 25 - 21$$

$$V_1 = 4\,\text{V}$$

$$V_2 = V_1 = 4\,\text{V}$$

Example 1.23 For the circuit shown in Fig. E1.23(a), find the values of I and R.

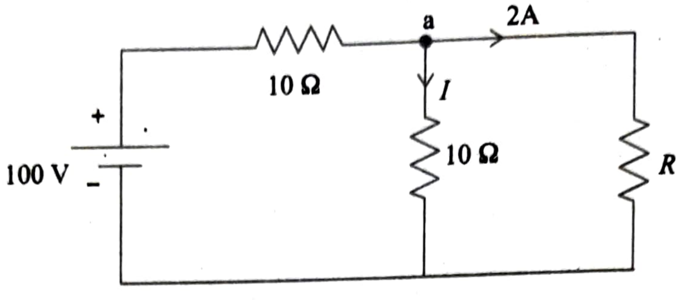


FIG. E1.23(a)

Solution

Assuming clockwise traversal current direction for I_T in the middle loop as shown in Fig. E1.23(b), and applying KCL at node 'a', we get

$$I_T = I + 2$$

Applying KVL for the middle loop, we get

$$100 = 10I_T + 10I$$

Substituting the equation of I_T in the above equation, we get

$$100 = 10(I + 2) + 10I$$

$$20I = 80$$

$$I = 4\text{A}$$

Since 10Ω and R are in parallel,

$$V_{10\Omega} = V_R$$

$$10 \times 4 = 2 \times R$$

$$R = 20\Omega$$

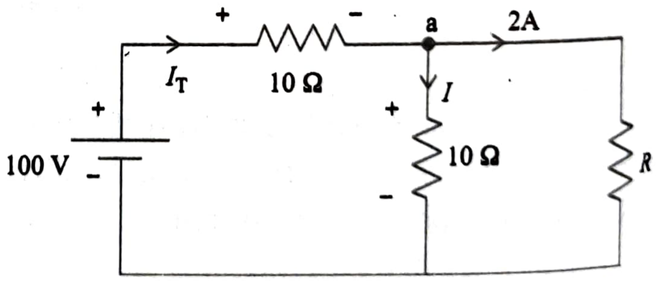


FIG. E1.23(b)

Example 1.24 Find the value of V_s in the network shown in Fig. E1.24(a).

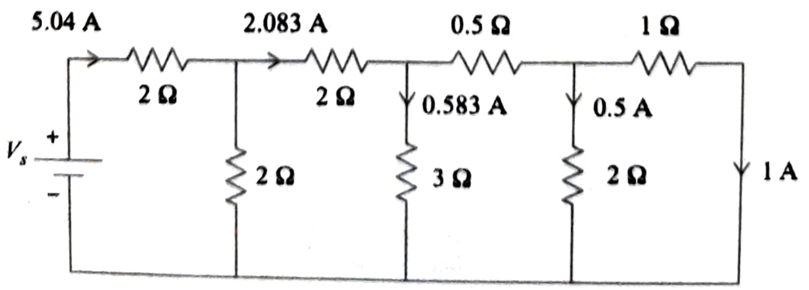


FIG. E1.24(a)

Solution

The given circuit can be redrawn as shown in Fig. E1.24(b).

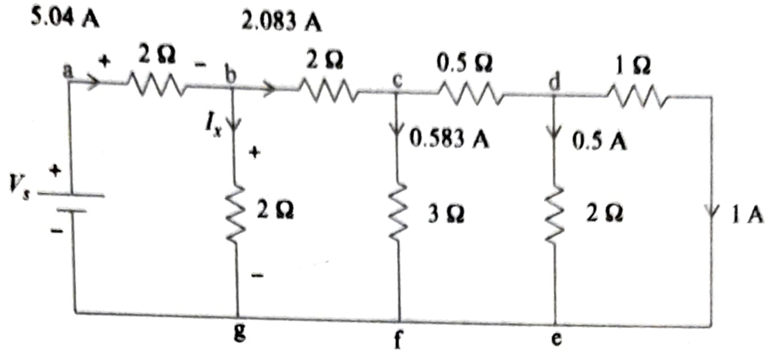


FIG. E1.24(b)

Applying KCL to node 'b', we get

$$I_x = 5.04 - 2.083 = 2.957\ \text{A}$$

Applying KVL to the loop 'abga', we get

$$2 \times 5.04 + 2 \times I_x - V_s = 0$$

$$V_s = 10.08 + 2 \times 2.957 = 15.99\ \text{V}$$

Example 1.25 Obtain the potential difference, V_{BA}, in the circuit shown in Fig. E1.25 using Kirchhoff's laws.

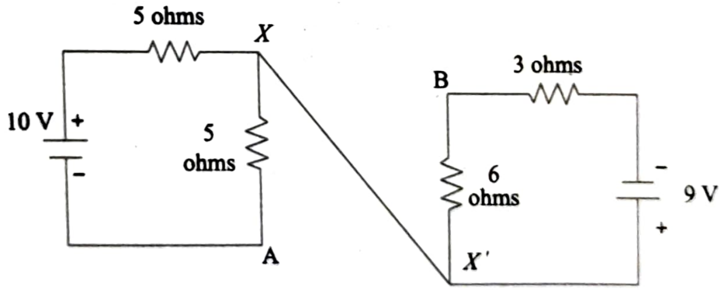


FIG. E1.25(a)

Solution

As the nodes X and X′ shown in Fig. E1.25(a) do not have any element connected in between, they can be simply shorted to a single node X and the circuit can be redrawn as shown in Fig. E1.25(b).

Now the circuit consists of two loops—one with current, I_1, and the other with current, I_2. Assuming the current direction to be clockwise, and applying KVL for the first loop, we get

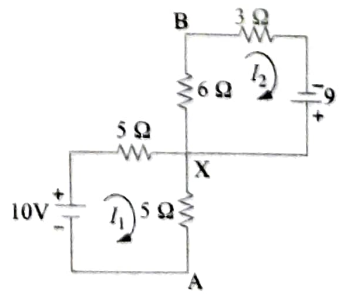


FIG. E1.25(b)

$$(5 + 5)I_1 = 10$$

or, $$I_1 = 1\ \text{A}$$