University of Diyala
College of Engineering
Department of Materials

Fundamentals of Electric Circuits

Lecture 1Seven

Prepared by:

Asst. Lecturer Ali Nadhim Jbarah

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2-11 Short and Open Circuits

When two points of circuit are connected together by a thick metallic wire (Fig. 1), they are said to be *short-circuited.* Since 'short' has practically zero resistance, it gives rise to two important facts:

(*i*) No voltage can exist across it because $V = IR = I \times 0 = 0$

(*ii*) Current through it (called short-circuit current) is very large (theoretically, infinity)

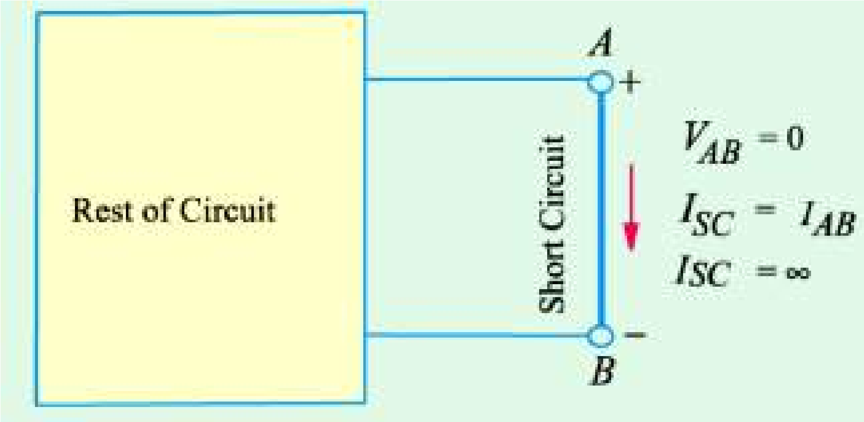


Fig. 1

Two points are said to be open-circuited when there is no direct connection between them (Fig. 2). Obviously, an 'open' represents a break in the continuity of the circuit. Due to this break

(*i*) Resistance between the two points is infinite.

(*ii*) There is no flow of current between the two points.

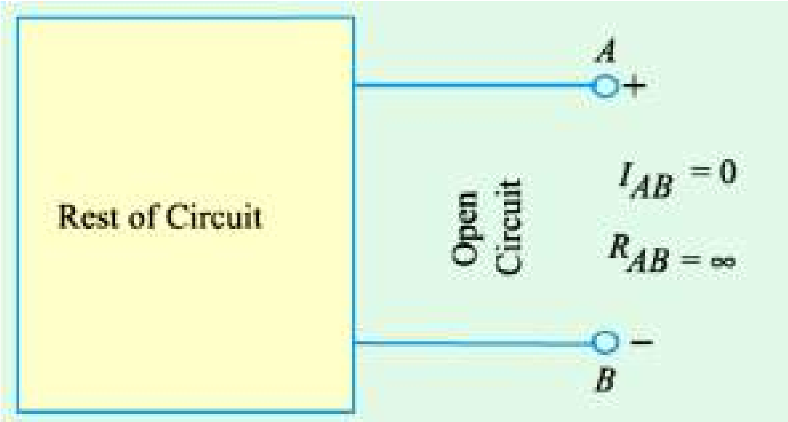


Fig. 2.

2-12 'Shorts' in a Series Circuit

Since a dead (or solid) short has almost zero resistance, it causes the problem of excessive current which, in turn, causes power dissipation to increase many times and circuit components to burn out.

In Fig. 3 (*a*) is shown a normal series circuit where

$$V = 12\ \text{V},\ R = R_1 + R_2 + R_3 = 6\ \Omega$$

$$I = V/R = 12/6 = 2\ \text{A},\ P = I^2R = 22 \times 6 = 24\ \text{W}$$

In Fig. 3 (*b*), 3Ω resistor has been shorted out by a resistanceless copper wire so that $R_{CD} = 0$. Now, total circuit resistance $R = 1 + 2 + 0 = 3\ \Omega$. Hence, $I = 12/3 = 4$ A and $P = 4^2 \times 3 = 48$ W.

Fig. 3 (*c*) shows the situation where both 2 Ω and 3 Ω resistors have been shorted out of the circuit. In this case,

$$R = 1\ \Omega,\ I = 12/1 = 12\ \text{A and } P = 12^2 \times 1 = 144\ \text{W}$$

Because of this excessive current (6 times the normal value), connecting wires and other circuit components can become hot enough to ignite and burn out.

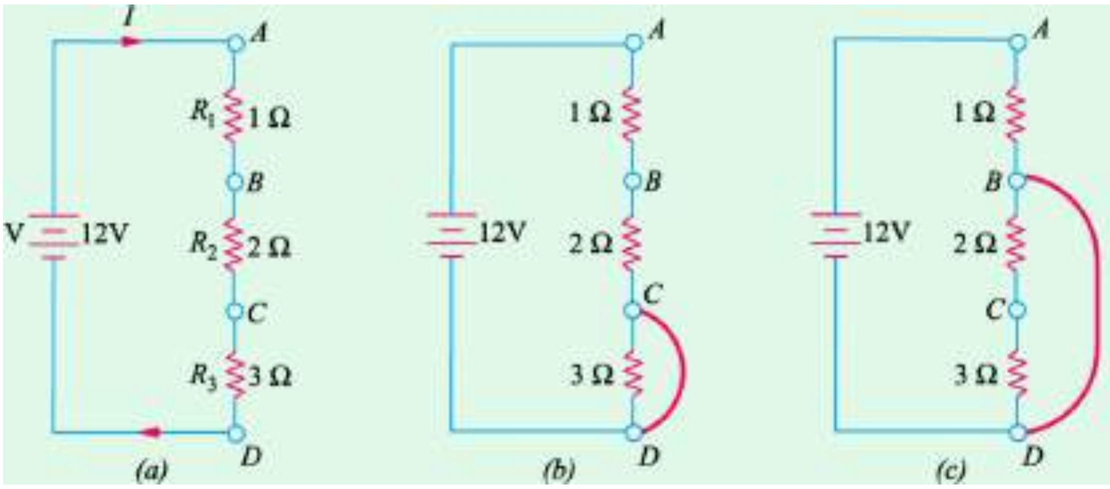


Fig. 3

2-10 'Opens' in a Series Circuit

In a normal series circuit like the one shown in Fig. 4 (*a*), there exists a current flow and the voltage drops across different resistors are proportional to their resistances. If the circuit becomes 'open' anywhere, following two effects are produced:

(*i*) Since 'open' offers infinite resistance, circuit current becomes zero. Consequently, there is no voltage drop across R_1 and R_2.

(*ii*) *Whole of the applied voltage* (*i.e. 100 V in this case*) *is felt across the 'open' i.e. across terminals A and B* [Fig. 4 (*b*)].

The reason for this is that R_1 and R_2 become negligible as compared to the infinite resistance of the 'open' which has practicallly whole of the applied voltage dropped across it. Hence, voltmeter in Fig. 4 (*b*) will read nearly 100 *V i.e.* the supply voltage.

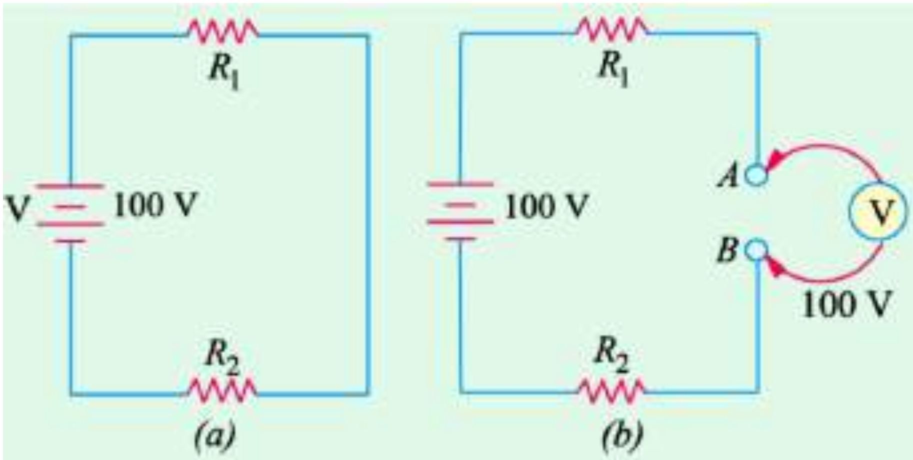


Fig. 4

2-11 'Opens' in a Parallel Circuit

Since an 'open' offers infinite resistance, there would be no current in that part of the circuit where it occurs. In a parallel circuit, an 'open' can occur either in the main line or in any parallel branch. As shown in Fig. 5 (*a*), an open in the main line prevents flow of current *to* ***all branches***.

Hence, neither of the two bulbs glows. However, full applied voltage (*i.e.* 220 V in this case) ***is available across the open***.

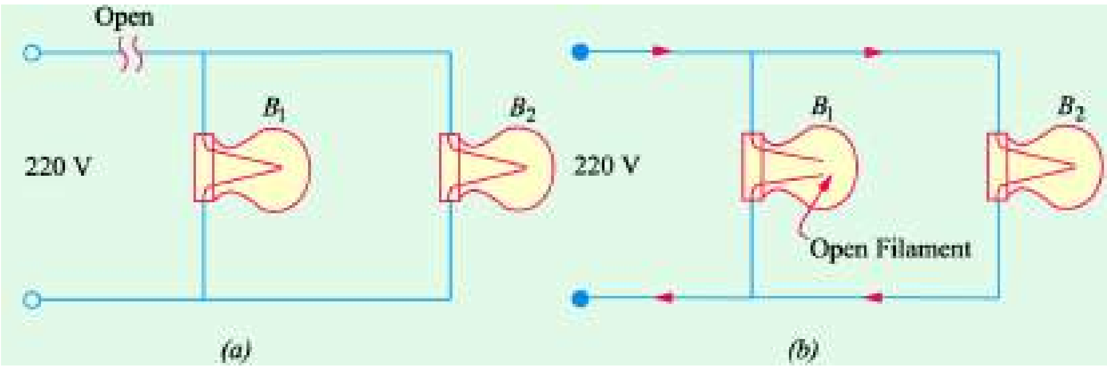


Fig. 5

In this Fig. 5 (b), 'open' has occurred in branch circuits of B_1. Since there is no current in this branch, B_1 will not glow. However, as the other bulb remains connected across the voltage supply, it would keep operating normality.

It may be noted that if a voltmeter is connected across the open bulb, it will read full supply voltage of 220 V.

2-12 'Shorts' in Parallel Circuits

Suppose a 'short' is placed across R_3 (Fig. 6). It becomes directly connected across the battery and draws almost infinite current because not only its own resistance but that of the connecting wires AC and BD is negligible. Due to this excessive current, the wires may get hot enough to burn out unless the circuit is protected by a fuse. Fig. 6

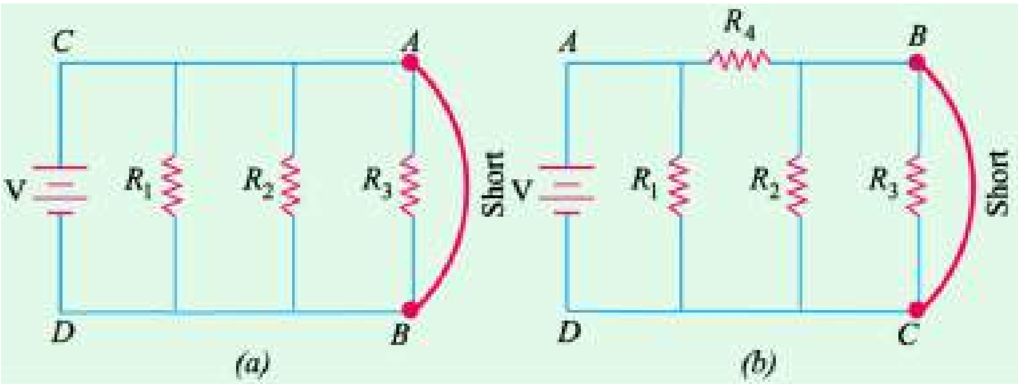


Fig. 6

Following points about the circuit of Fig. 6 (*a*) are worth noting.

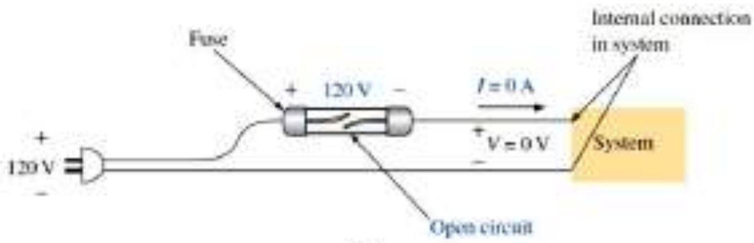
1. Not only is R_3 short-circuited but both R_1 and R_2 are also shorted out *i.e.* ***short across one branch means short across all branches***.

2. There is no current in shorted resistors. If there were three bulbs, they will not glow.

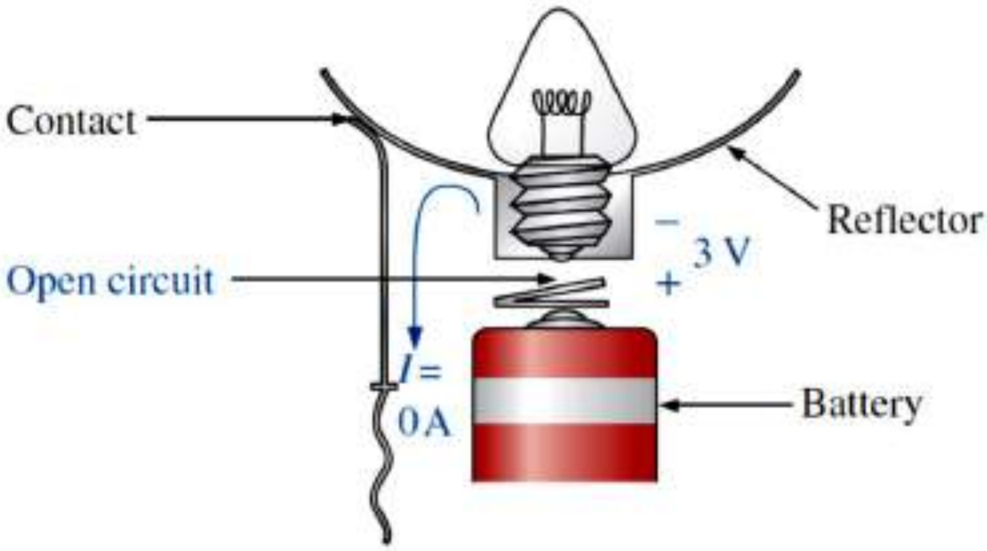
3. The shorted components are not damaged, For example, if we had three bulbs in Fig. 6 (*a*), they would glow again when circuit is restored to normal conditions by removing the short-circuited.

It may, however, be noted from Fig. 6 (*b*) that a short-circuit across R_3 may short out R_2 but not R_1 since it is protected by R_4.

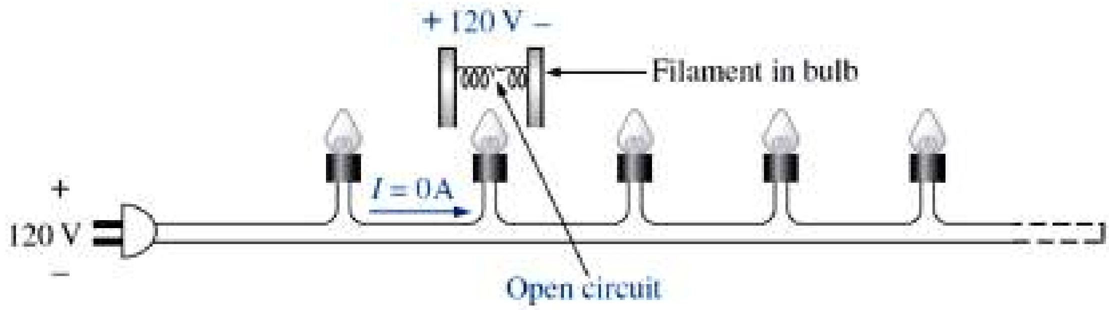
Examples of open circuits



(a)

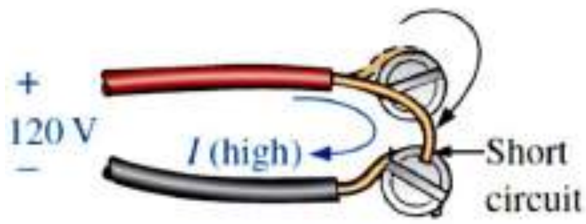


(b)

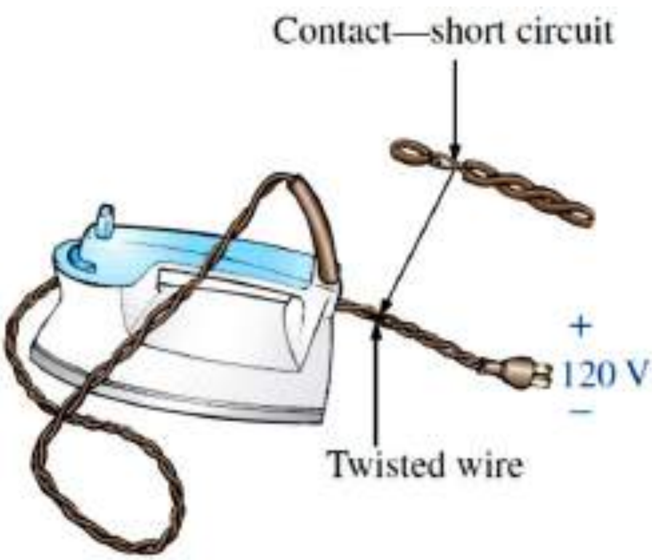


(c)

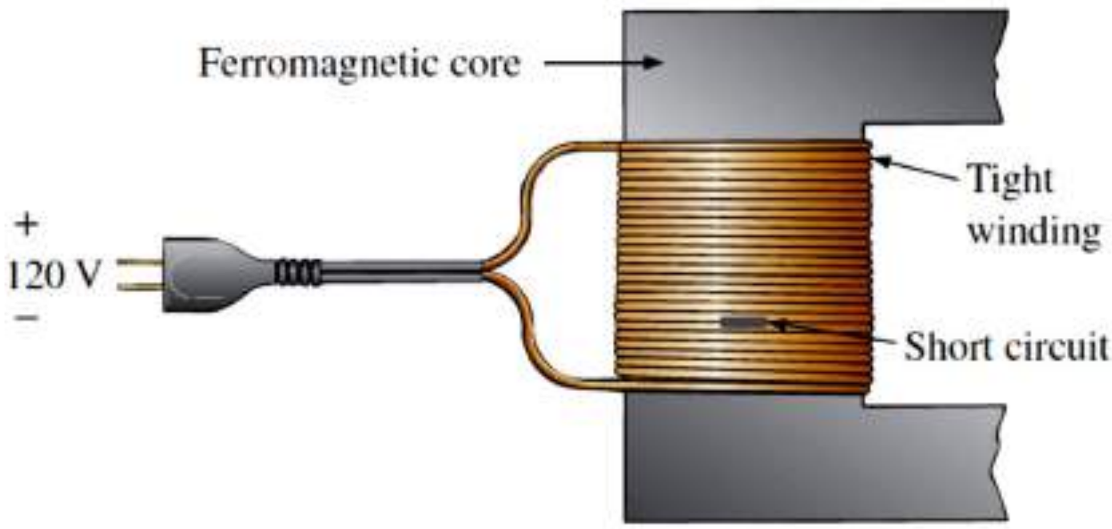
Examples of short circuits



(a)



(b)



(c)

Example 1: *Determine voltage V_{ab} for the network in Fig. 7.*

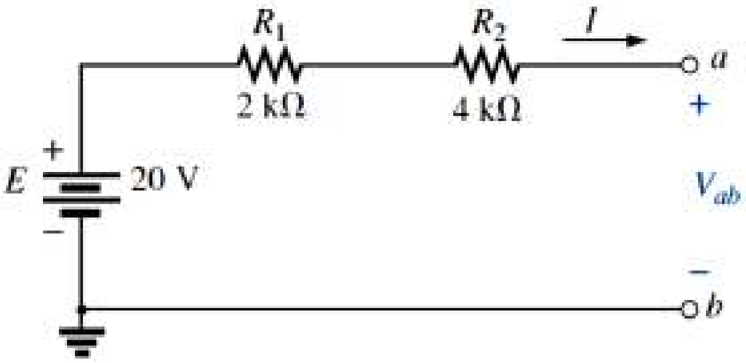


Fig.7

Solution: The open circuit requires that I be zero amperes. The voltage drop across both resistors is therefore zero volts since $V = IR = (0)R = 0$ V. Applying Kirchhoff's voltage law around the closed loop,

$$V_{ab} = E = \mathbf{20\ V}$$

Example 2: Determine voltages V_{ab} and V_{cd} for the network in Fig. 8.

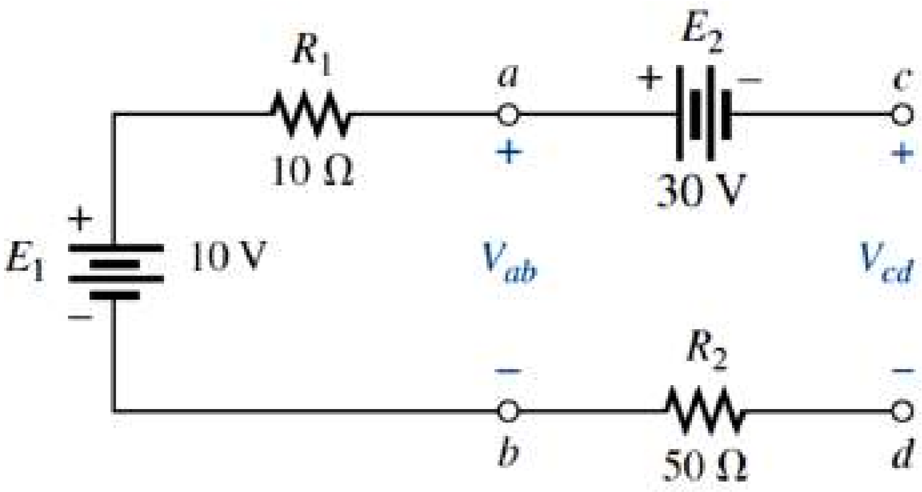


Fig. 8

Solution: The current through the system is zero amperes due to the open circuit, resulting in a 0 V drop across each resistor. Both resistors can therefore be replaced by short circuits, as shown in Fig. 2.31. Voltage V_{ab} is then directly across the 10 V battery, and

$$V_{ab} = E_1 = \mathbf{10\ V}$$

Voltage V_{cd} requires an application of Kirchhoff's voltage law:

$$+E_1 - E_2 - V_{cd} = 0$$

or
$$V_{cd} = E_1 - E_2 = 10\ \text{V} - 30\ \text{V} = \mathbf{-20\ V}$$

The negative sign in the solution indicates that the actual voltage V_{cd} has the opposite polarity of that appearing in Fig. 8.

Example 3: *Determine V and I for the network in Fig. 9 if resistor R_2 is shorted out.*

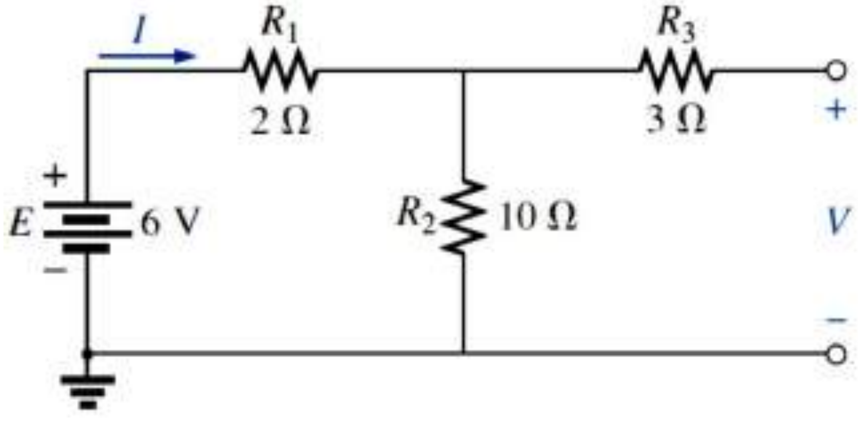


Fig. 9

Solution: The redrawn network appears in Fig. 10.. The current through the 3Ω resistor is zero due to the open circuit, causing all the current *I* to pass through the jumper. Since $V_{3\Omega} = IR = (0)R = 0$ V, the voltage *V* is directly across the short, and

$$V = \mathbf{0\ V}$$

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

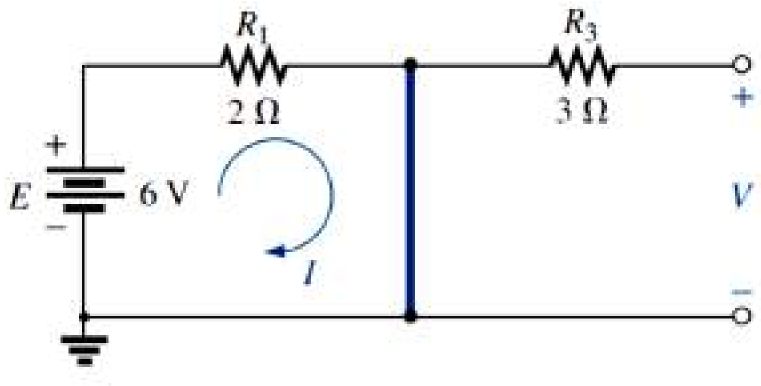


Fig. 10

Example 4: For the configuration in Fig. 11:

a. Find the currents I_2, I_6, and I_8.

b. Find the voltages V_4 and V_8.

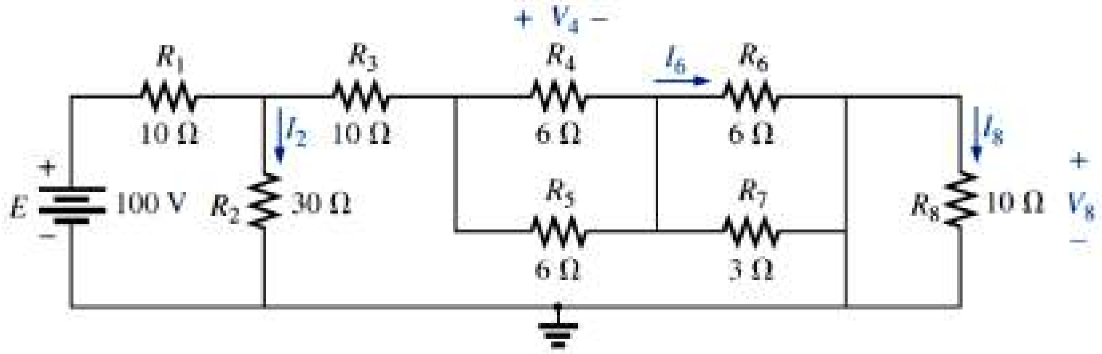


Fig. 11

Example 5: For the network in Fig. 12:

a. Determine R_T by combining resistive elements.

b. Find V_1 and V_4.

c. Calculate I_3 (with direction).

d. Determine I_s

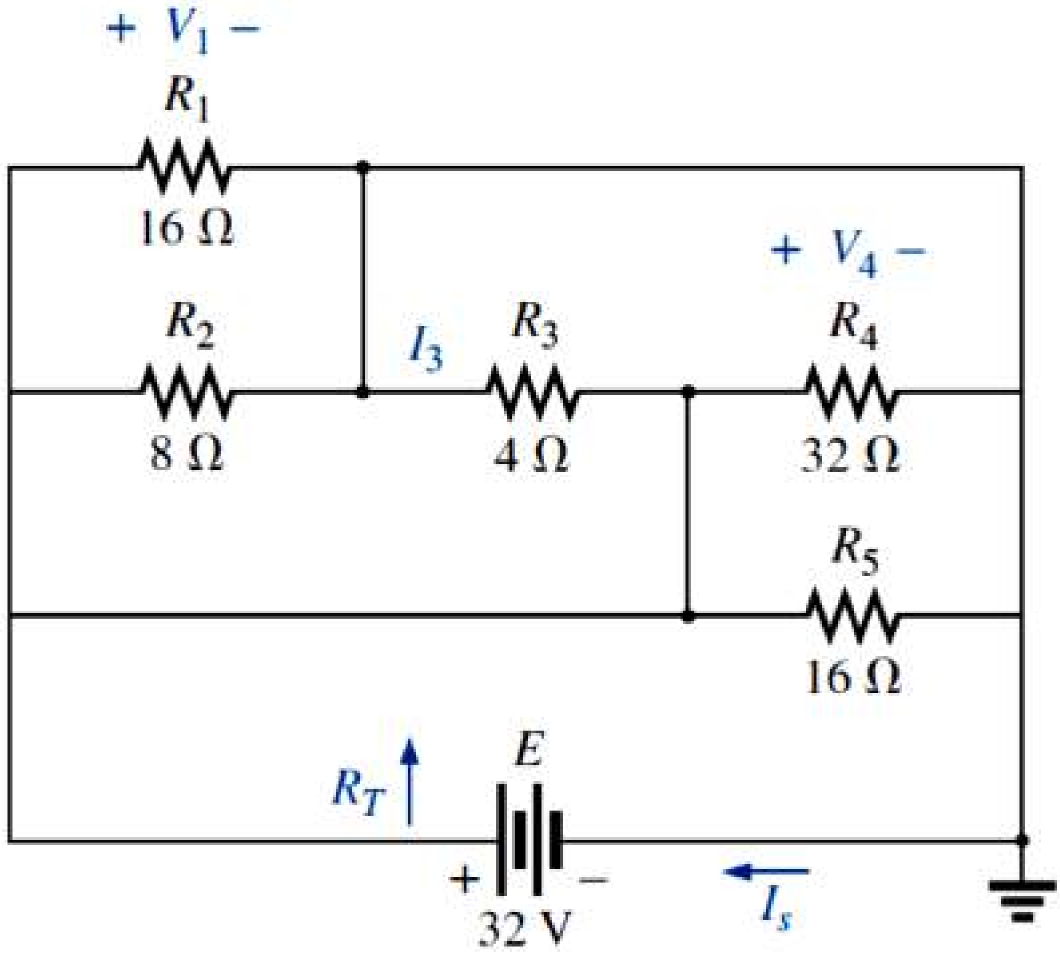


Fig. 12