Contents:

Short Circuits

A short circuit, or "short," is a path of zero resistance. A component is said to be *short-circuited*, or "shorted out," when there is a short circuit connected in parallel with it. Figure 4.38 shows current I entering the junction where a short circuit is connected in parallel with a resistor. By the current-divider rule, the current in the resistor is

$$I_R = I\frac{0}{R+0} = 0$$

Similarly, the current in the short circuit is

$$I_{SS} = I\frac{R}{R+0} = I$$

We conclude that *no* current flows in a short-circuited component, and that *all* current is diverted through the path that shorts it.

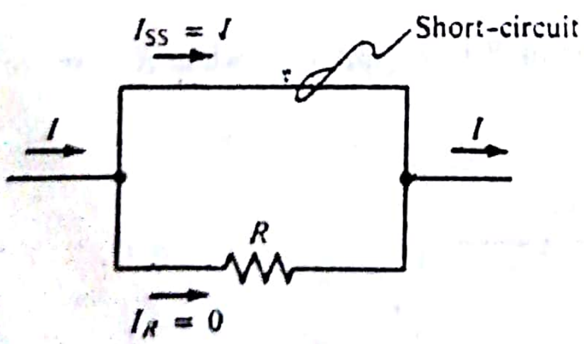
The total equivalent resistance of a short-circuited resistor is

$$R_T = \frac{R(0)}{R+0} = \frac{0}{R} = 0\ \Omega$$

It follows that the total equivalent resistance of any number of parallel resistors is zero if any one of them is short-circuited. Since the resistance of a short circuit or of a short-circuited network is zero, the voltage across it must always be zero:

$$V = IR = I(0) = 0$$

An (ideal) switch is a device that produces a short circuit between its terminals when it is closed and an open circuit when it is opened.



$$\frac{I(0)}{R+0}$$

FIGURE 4.38 A short circuit has zero resistance. When a component is short-circuited, all current is diverted through the path that shorts it.

Example 4.20 (Analysis)

Find the total current I_T and the voltage across the 120-Ω resistor in Figure 4.39 when

(a) the switch is open
(b) the switch is closed

SOLUTION

(a) When the switch is open, the circuit consists of three series-connected resistors.

$$R_T = 80 + 120 + 300 = 500\ \Omega$$

$$I_T = \frac{E}{R_T} = \frac{80\ \text{V}}{500\ \Omega} = 0.16\ \text{A}$$

The voltage across the 120-Ω resistor is then

$$V = I_T R = (0.16\ \text{A})(120\ \Omega) = 19.2\ \text{V}$$

(b) When the switch is closed, the 120-Ω resistor is shorted out. The equivalent resistance of the shorted combination is therefore 0 Ω, and the total resistance of the series circuit becomes

$$R_T = 80 + 300 = 380\ \Omega$$

Then

$$I_T = \frac{80\ \text{V}}{380\ \Omega} = 0.2105\ \text{A}$$

The voltage across the 120-Ω resistor is 0 V because it is shorted. ■

Drill Exercise 4.20

Find the voltage across the 80-Ω resistor in Figure 4.39 when the switch is (a) open; (b) closed.

ANSWER: (a) 12.8 V; (b) 16.84 V. □

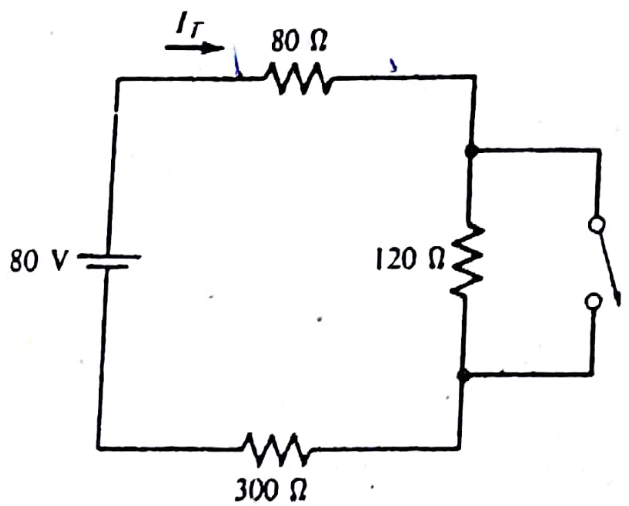


FIGURE 4.39 (Example 4.20)

Example 4.22 (Design)

The circuit shown in Figure 4.41 is to be used to test the 15-V source by drawing three different values of current from it as the switch is put in the three positions shown. The test currents corresponding to the three switch positions are to be as follows:

$$\begin{aligned} \text{position 1:} \quad I &= 10 \text{ mA} \\ \text{position 2:} \quad I &= 30 \text{ mA} \\ \text{position 3:} \quad I &= 150 \text{ mA} \end{aligned}$$

Assuming that the ammeter has zero resistance, design the circuit. (Find the resistor values.)

SOLUTION When the switch is in position 1, the total resistance in series with the source is $R_1 + R_2 + R_3$. Therefore, we must have

$$\frac{15 \text{ V}}{R_1 + R_2 + R_3} = 10 \text{ mA}$$

or

$$R_1 + R_2 + R_3 = \frac{15 \text{ V}}{10 \text{ mA}} = 1.5 \text{ k}\Omega$$

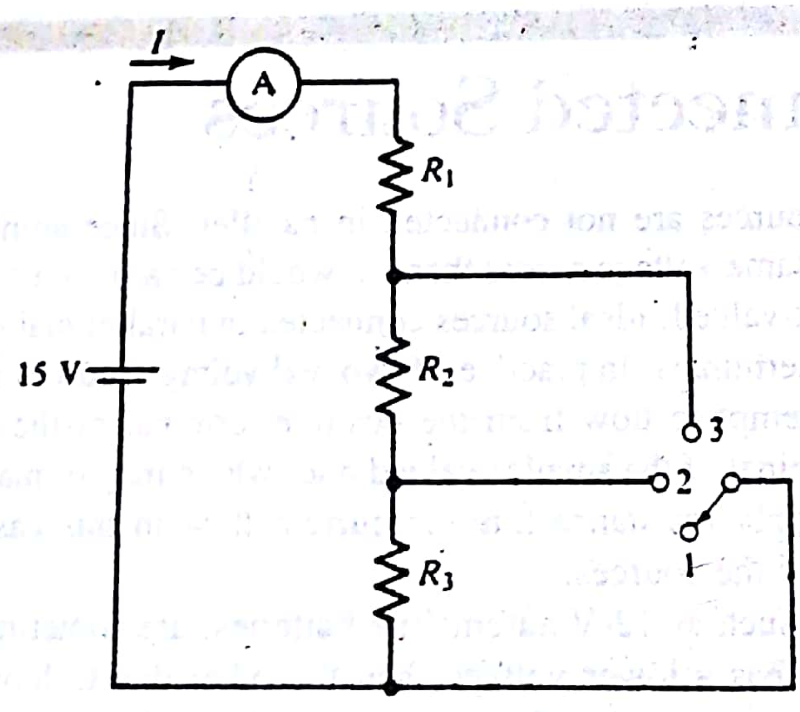


FIGURE 4.41 (Example 4.22)

When the switch is in position 2, R_3 is shorted out, so the total series resistance becomes $R_1 + R_2$. Thus,

$$\frac{15\text{ V}}{R_1 + R_2} = 30\text{ mA}$$

or

$$R_1 + R_2 = \frac{15\text{ V}}{30\text{ mA}} = 500\ \Omega$$

When the switch is in position 3, both R_2 and R_3 are shorted out, and the resistance in series with the source is R_1. Therefore,

$$\frac{15\text{ V}}{R_1} = 150\text{ mA}$$

or

$$R_1 = \frac{15\text{ V}}{150\text{ mA}} = 100\ \Omega$$

Then

$$R_1 + R_2 = 500\ \Omega \Rightarrow R_2 = 500\ \Omega - 100\ \Omega = 400\ \Omega$$

and

$$R_1 + R_2 + R_3 = 1500\ \Omega \Rightarrow R_3 = 1500\ \Omega - 500\ \Omega = 1\text{ k}\Omega$$

Drill Exercise 4.22

Repeat Example 4.22 assuming that the ammeter has resistance 50 Ω.

ANSWER: $R_1 = 50\ \Omega$; $R_2 = 400\ \Omega$; $R_3 = 1\text{ k}\Omega$. □

Parallel Connected Current Sources

Example 4.23 (Analysis)

Find the voltage V_{ab} across the 33-Ω resistor in Figure 4.43(a).

SOLUTION The 2.5-A and 0.5-A current sources both produce current from a to b in the resistor, while the 1.9-A current source produces current from b to a. Therefore, the resultant current is

$$2.5 + 0.5 - 1.9 = 1.1 \text{ A}$$

Since the sum of the currents flowing from a to b is greater than that flowing from b to a, the resultant source produces current from a to b, as shown in Figure 4.23(b). Thus, V_{ab} is positive, and

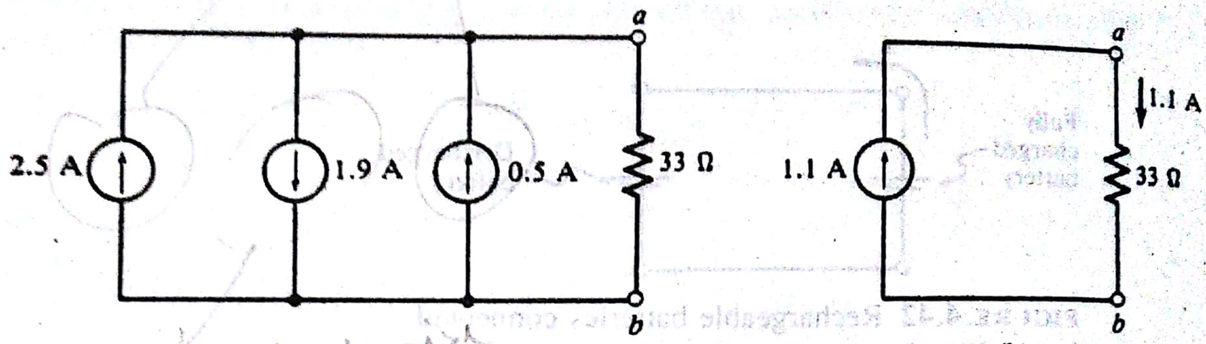
$$V_{ab} = (1.1 \text{ A})(33 \ \Omega) = 36.3 \text{ V}$$

Drill Exercise 4.23

Repeat Example 4.23 if the direction of the 2.5-A current source is reversed.

ANSWER: -128.7 V. □

clockwise



Anti clockwise

(a) (b)

FIGURE 4.43 (Example 4.23)