

## Circuits and Circuit Elements

**Problem A****RESISTORS IN SERIES****PROBLEM**

A particular electronic-code lock provides over 500 billion combinations. Moreover, it can sustain an electric shock of  $1.25 \times 10^5$  V. Suppose this potential difference is applied across a series connection of the following resistors: 11.10 k $\Omega$ , 34.0 k $\Omega$  and 215 k $\Omega$ . What is the equivalent resistance for the circuit? What current would pass through the resistors?

**SOLUTION****1. DEFINE**

**Given:**

$$R_1 = 11.0 \text{ k}\Omega = 11.0 \times 10^3 \Omega$$

$$R_2 = 34.0 \text{ k}\Omega = 34.0 \times 10^3 \Omega$$

$$R_3 = 215 \text{ k}\Omega = 215 \times 10^3 \Omega$$

$$\Delta V = 1.25 \times 10^5 \text{ V}$$

**Unknown:**  $R_{eq} = ?$       $I = ?$

**2. PLAN**     **Choose the equation(s) or situation:** Because the resistors are in series, the equivalent resistance can be calculated from the equation for resistors in series.

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

The equation relating potential difference, current, and resistance can be used to calculate the current.

$$\Delta V = IR_{eq}$$

**Rearrange the equation(s) to isolate the unknown(s):**

$$I = \frac{\Delta V}{R_{eq}}$$

**3. CALCULATE**     **Substitute the values into the equation(s) and solve:**

$$R_{eq} = (11.0 \times 10^3 \Omega + 34.0 \times 10^3 \Omega + 215 \times 10^3 \Omega)$$

$$R_{eq} = 2.60 \times 10^5 \Omega$$

$$I = \frac{(1.25 \times 10^5 \text{ V})}{(2.60 \times 10^5 \Omega)} = 0.481 \text{ A}$$

**4. EVALUATE**     For resistors connected in series, the equivalent resistance should be greater than the largest resistance in the circuit.

$$2.60 \times 10^5 \Omega > 2.15 \times 10^5 \Omega$$

**ADDITIONAL PRACTICE**

- The Large Optics Diamond Turning Machine at the Lawrence Livermore National Lab in California can cut a human hair lengthwise 3000 times! That would produce pieces with a cross-sectional area of  $10^{-7}$  mm<sup>2</sup>. A 1.0 m long

silver wire with this cross-sectional area would have a resistance of  $160\text{ k}\Omega$ . Consider three pieces of silver wire connected in series. If their lengths are 2.0 m, 3.0 m, and 7.5 m, and the resistance of each wire is proportional to its length, what is the equivalent resistance of the connection?

- Most of the  $43 \times 10^3\text{ kg}$  of gold that sank with the British ship *HMS Laurentis* in 1917 has been recovered. If this gold were drawn into a wire long enough to wrap around Earth's equator five times, its electrical resistance would be about  $5.0 \times 10^8\ \Omega$ . Consider three resistors with resistances that are exactly  $1/3$ ,  $2/7$ , and  $1/5$  the resistance of the gold wire. What equivalent resistance would be produced by connecting all three resistors in series?
- A 3 mm thick steel wire that stretches for 5531 km has a resistance of about  $82\text{ k}\Omega$ . If you connect in series three resistors with the values  $16\text{ k}\Omega$ ,  $22\text{ k}\Omega$ , and  $32\text{ k}\Omega$ , what value must the fourth resistor have for the equivalent resistance to equal  $82\text{ k}\Omega$ ?
- The largest operating wind generator in the world has a rotor diameter of almost 100 m. This generator can deliver 3.2 MW of power. Suppose you connect a  $3.0\text{ k}\Omega$  resistor, a  $4.0\text{ k}\Omega$  resistor, and a  $5.0\text{ k}\Omega$  resistor in series. What potential difference must be applied across these resistors in order to dissipate power equal to 1.00 percent of the power provided by the generator? What is the current through the resistors? (Hint: Recall the relation between potential difference, resistance, and power.)
- The resistance of loudspeakers varies with the frequency of the sound they produce. For example, one type of speaker has a minimum resistance of  $4.5\ \Omega$  at low frequencies and  $4.0\ \Omega$  at ultra-low frequencies, and it has a peak resistance of  $16\ \Omega$  at a high frequency. Consider a set of resistors with resistances equal to  $4.5\ \Omega$ ,  $4.0\ \Omega$ , and  $16.0\ \Omega$ . What values of the equivalent resistance can be obtained by connecting any two of them in different series connections?
- Standard household potential difference in the United States is  $1.20 \times 10^2\text{ V}$ . However, many electric companies allow the residential potential difference to increase up to 138 V at night. Suppose a  $2.20 \times 10^2\ \Omega$  resistor is connected to a constant potential difference. A second resistor is provided in an alternate circuit so that when the potential difference rises to 138 V, the second resistor connects in series with the first resistor. This changes the resistance so that the current in the circuit is unchanged. What is the value of the second resistor?
- The towers of the Golden Gate Bridge, in San Francisco, California, are about 227 m tall. The supporting cables of the bridge are about 90 cm thick. A steel cable with a length of 227 m and a thickness of 90 cm would have a resistance of  $3.60 \times 10^{-5}\ \Omega$ . If a  $3.60 \times 10^{-5}\ \Omega$  resistor is connected in series with an  $8.4 \times 10^{-6}\ \Omega$  resistor, what power would be dissipated in the resistors by a 280 A current? (Hint: Recall the relation between current, resistance, and power.)