13.7 Resistance in Circuits

Have you ever noticed that when you recharge your cellphone, MP3 player, or laptop computer, the adaptor gets warm? The warmth is caused by the resistance experienced by the electric current flowing through the adapter.

Electrical resistance is the opposition to the movement of electrons as they flow through a circuit. The symbol for resistance is *R*. The unit for resistance is the ohm (Ω). To better understand the concept of resistance, imagine that you are kicking a soccer ball. If the ball is on a smooth, hard surface like pavement, the ball will roll easily. If the ball is on a rough surface like tall grass, you would have to kick the ball much harder just to make it roll.

In the same way, when electrons flow through a material that has many "bumps" along its path, there will be more resistance than if the material is "smooth." For example, insulators tend to minimize the amount of electron flow, so the internal resistance of an insulator is quite high. Conversely, a conductor like copper has a very low internal resistance. This is why electrons flow so easily in copper wire.

electrical resistance (*R*) the ability of a material to oppose the flow of electric current; measured in ohms (Ω)

DID YOU **KNOW?**

Internal Resistance in Everyday Materials

Many devices that you use every day use materials with high internal resistance. For example, a toaster consists of nichrome wires, which have a high internal resistance. The electrical energy through the wires gets converted into light (the red glow) and thermal energy. It is the thermal energy that toasts bread.

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Factors that Affect Resistance

All materials have some internal resistance. The greater the resistance, the lower the current, and the warmer the material becomes when current flows through it. This happens because, as the electrons move through the material, they bump into the atoms that make up the material. In the process, electrical energy is converted into thermal energy.

Internal resistance depends on many factors. We will look at four of these factors: type of material, cross-sectional area, length, and temperature.

Type of Material

The ability of a material to conduct electricity is determined by how freely electrons can move within the material. Copper is used in circuits because it is an excellent conductor. It has a low electrical resistance. Silver is a better conductor because its resistance is even lower. Silver, however, is an expensive material and is not suitable for low-cost electrical devices.

Cross-Sectional Area

When you cut through a wire, you can see its cross-section more easily. The diameter of the cross-section gives you a sense of how thick the wire is. Thicker wires have less internal resistance than thinner ones. Electrons flowing through a thicker wire have more room to move freely (Figure 1). This is similar to what happens with water in a pipe. The greater the diameter of a pipe, the greater the water flow will be.

Figure 1 The wire at the left has a smaller diameter cross-section than the wire at the right. The thinner wire will have more internal resistance than the thicker wire.

Length

As you increase the length of a wire, its internal resistance increases. This happens because electrons have to travel through more material. You can see how this applies if you examine extension cords.

The longer the extension cord, the more resistance it has, and the warmer it will get while being used. This can be dangerous because the cord can overheat and potentially cause a fire. Manufacturers of extension cords can avoid this hazard by using a larger-diameter wire, which lowers the electrical resistance.

Temperature

As you have learned, resistance increases when electrons bump into atoms as they move through a material. When a wire gets warmer, the atoms that make up the wire gain energy and vibrate faster. The increased vibration results in more collisions between the atoms and the free-flowing electrons in the current. Since greater vibrations cause more collisions, resistance increases with temperature.

Measuring Resistance

Just as current and voltage are useful quantities to measure when troubleshooting a circuit, so is resistance. An **ohmmeter** is the device designed to measure resistance. The circuit diagram symbol for an ohmmeter is shown in Figure 2(a).

As with a voltmeter, an ohmmeter must be connected in parallel with a load (Figure 2(b)). However, you do not power up the circuit to measure resistance. The reason is that the ohmmeter is powered and provides an electric current through the load.

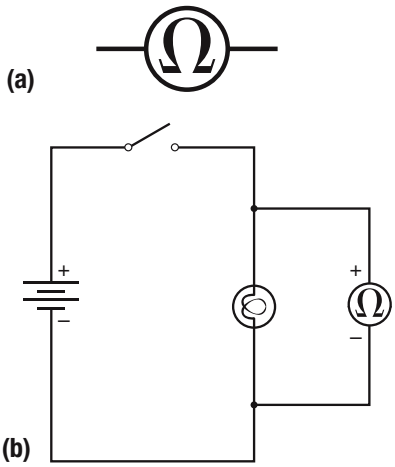

Figure 2 (a) The circuit diagram symbol for an ohmmeter (b) An ohmmeter measures the electrical resistance across a load. It is placed in parallel with the load.

ohmmeter a device used to measure resistance

Resistors in Circuits

You may have a lamp at home with three brightness settings. Or you may have a dimmer switch on the wall that allows you to control the brightness of the light. This is possible because these devices contain resistors. A **resistor** is an electrical device that reduces the current in a circuit. There are many different types of resistors (Figure 3). For example, lightweight carbon resistors are commonly used in electronics; heavier ceramic resistors are used in larger circuits. Dimmer switches and the volume controls on a stereo amplifier are another type of resistor called variable resistors. A variable resistor allows you to change the resistance in a circuit. For example, by turning a dimmer switch, you can dim the light in a room. Figure 4 shows the circuit diagram symbol for a resistor.

resistor a device that reduces the flow of electric current

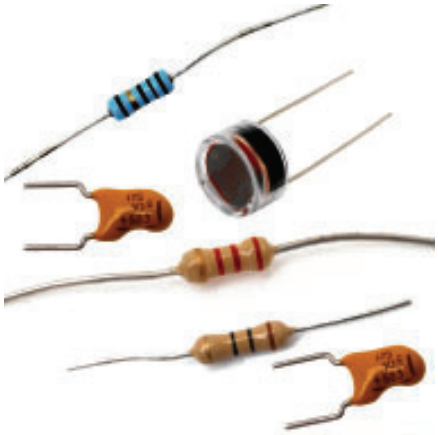

Figure 3 A variety of resistors

Figure 4 The circuit diagram symbol for a resistor

TRY THIS MEASURING RESISTANCE WITH AN OHMMETER

SKILLS: Performing, Observing, Communicating

SKILLS HANDBOOK 2.D.

You can test the resistance of a resistor with an ohmmeter. In this activity, you will use an ohmmeter to test resistance in a variety of resistors.

Equipment and Materials: **resistors of different types and resistances; ohmmeter with leads**

1. Design a table in which to record your observations.
2. Record the resistance of one of the resistors in your table. The resistance is usually printed on the resistor. If not, your teacher will provide you with the value.
3. Connect the ohmmeter with one lead on one side of the resistor and the other lead on the opposite side. Record the resistance in ohms.
4. Repeat steps 2 and 3 using another resistor.

A. How did the rated resistance compare with the measured value? K/U T/I

B. Predict what would happen to the resistance if you reversed the position of the leads. Test your prediction. T/I

IN SUMMARY

- Electrical resistance is the opposition to the flow of electrons.
- The internal resistance of a wire increases by decreasing its cross-sectional area, lengthening the wire, and increasing its temperature.
- All materials have some internal resistance. Materials that have less resistance are usually used as conductors.
- Resistance causes electrical devices to warm up when a circuit is functioning.
- Resistance is measured in units of ohms (Ω) using a meter called an ohmmeter.
- Resistors are electrical devices that affect the electric current in a circuit.
- Ohmmeters are connected in parallel with a load when measuring resistance. The circuit must be turned off to measure the resistance.

CHECK YOUR LEARNING

1. Have you had an experience that relates to the reading about resistors? How did the reading help you understand your experience? C
2. In science, we measure quantities and use symbols to represent quantities. We also assign measurement units. Copy and complete Table 1 in your notebook. K/U

Table 1 Internal Resistance

Electrical quantity	Electrical quantity symbol	Unit of measurement	Unit of measurement symbol
resistance			

3. Which material would you expect to have greater resistance, plastic or silver? Explain your choice. K/U
4. Draw a circuit diagram that shows a two-cell battery in series with a switch and two lamps in parallel. Include an ohmmeter correctly connected to one of the lamps. K/U C
5. Identify a situation in which you would want to have a high resistance and a situation in which you would want to have a low resistance. A
6. What effect would the following changes have on a conductor's resistance? In each situation, explain why the change occurs. T/I
   (a) decreasing the diameter of a conductor
   (b) placing an extension cord outside in the winter
   (c) plugging two identical extension cords together to make it longer
   (d) changing from a copper conductor to a silver conductor
7. An extension cord that you would use for a lamp is much thinner than an extension cord recommended for use with large appliances. If you plugged in a refrigerator using a lamp extension cord, the plastic coating of the cord could melt and perhaps start a fire. Why does this occur? How can this hazard be prevented? K/U A