SECTION 3

Electrical Calculations

A German school teacher named Georg Ohm wondered how electric current, voltage, and resistance are related.

What You Will Learn

- Use Ohm's law to calculate voltage, current, and resistance.
- Calculate electric power.
- Determine the electrical energy used by a device.

Vocabulary

electric power

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Connecting Current, Voltage, and Resistance

Ohm (1789–1854) studied the resistances of materials. He measured the current that resulted from different voltages applied to a piece of metal wire. The graph on the left in **Figure 1** is similar to the graph of his results.

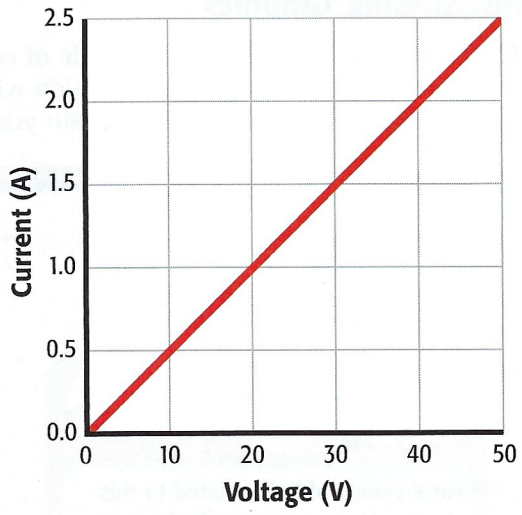
Ohm's Law

Ohm found that the ratio of voltage (V) to current (I) is a constant for each material. This ratio is the resistance (R) of the material. When the voltage is expressed in volts (V) and the current is in amperes (A), the resistance is in ohms (Ω). The equation below is often called *Ohm's law* because of Ohm's work.

$$R = \frac{V}{I}, \text{ or } V = I \times R$$

As the resistance goes up, the current goes down. And as the resistance decreases, the current increases. The second graph in **Figure 1** shows this relationship. Notice that if you multiply the current and the resistance for any point, you get 16 V.

Current Versus Voltage



Current Versus Resistance at Constant Voltage

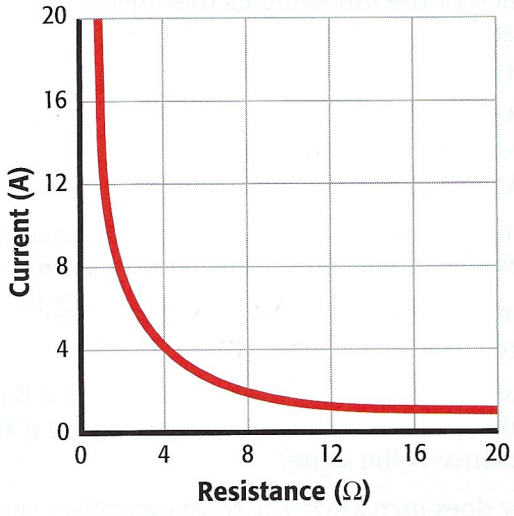


Figure 1 *The relationship between current and voltage is different from the relationship between current and resistance.*

MATH FOCUS

Using Ohm's Law What is the voltage if the current is 2 A and the resistance is 12 Ω?

Step 1: Write the equation for voltage.

$$V = I \times R$$

Step 2: Replace the current and resistance with the measurements given in the problem, and solve.

$$V = 2 \text{ A} \times 12 \ \Omega$$

$$V = 24 \text{ V}$$

Now It's Your Turn

1. Find the voltage if the current is 0.2 A and the resistance is 2 Ω.
2. The resistance of an object is 4 Ω. If the current in the object is 9 A, what voltage must be used?
3. An object has a resistance of 20 Ω. Calculate the voltage needed to produce a current of 0.5 A.

Electric Power

The rate at which electrical energy is changed into other forms of energy is **electric power.** The unit for power is the watt (W), and the symbol for power is the letter *P*. Electric power is expressed in watts when the voltage is in volts and the current is in amperes. Electric power is calculated by using the following equation:

power = *voltage* × *current*, or $P = V \times I$

electric power the rate at which electrical energy is converted into other forms of energy

Watt: The Unit of Power

If you have ever changed a light bulb, you probably know about watts. Light bulbs, such as the ones in **Figure 2,** have labels such as "60 W," "75 W," or "120 W." As electrical energy is supplied to a light bulb, the light bulb glows. As power increases, the bulb burns brighter because more electrical energy is converted into light energy. The higher power rating of a 120 W bulb tells you that it burns brighter than a 60 W bulb.

Another common unit of power is the kilowatt (kW). One kilowatt is equal to 1,000 W. Kilowatts are used to express high values of power, such as the power needed to heat a house.

Reading Check **What are two common units for electric power?** (*See the Appendix for answers to Reading Checks.*)

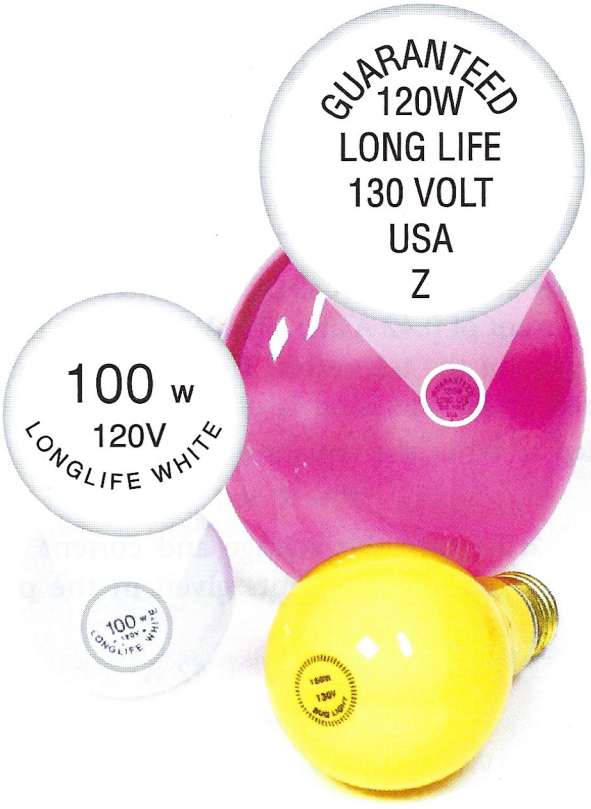


Figure 2 *These light bulbs have different wattages, so they use different amounts of electric power.*

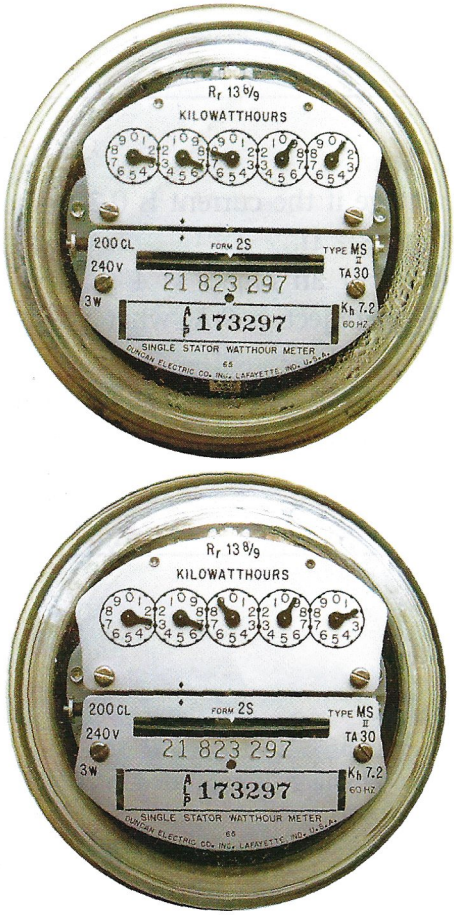


Figure 3 *These photographs were taken 10 days apart. According to the dials on the meter, 101 kWh of energy were used.*

Measuring Electrical Energy

Electric power companies sell electrical energy to homes and businesses. Such companies determine how much a home or business has to pay based on power and time. For example, the amount of electrical energy used in a home depends on the power of the electrical devices in the house and the length of time that those devices are on. The equation for electrical energy is as follows:

$$\textit{electrical energy} = \textit{power} \times \textit{time}, \text{ or } E = P \times t$$

Measuring Household Energy Use

Different amounts of electrical energy are used each day in a home. Electric companies usually calculate electrical energy by multiplying the power in kilowatts by the time in hours. The unit of electrical energy is usually kilowatt-hours (kWh). If 2,000 W (2 kW) of power are used for 3 h, then 6 kWh of energy were used.

Electric power companies use meters, such as the one in **Figure 3,** to determine how many kilowatt-hours of energy are used by a household. These meters are often outside of buildings so that someone from the power company can read them.

Reading Check **What unit of measurement is usually used to express electrical energy?**

MATH FOCUS

Power and Energy A small television set draws a current of 0.42 A at 120 V. What is the power rating for the television? How much energy is used if the television is on for 3 h?

Step 1: Write the equation for power.

$$P = V \times I$$

Step 2: Replace the voltage and current with the measurements given in the problem, and solve.

$$P = 120 \text{ V} \times 0.42 \text{ A}$$

$$P = 50.4 \text{ W, or } 0.0504 \text{ kW}$$

Step 3: Write the equation for electrical energy.

$$E = P \times t$$

Step 4: Replace the power and time with the measurements given in the problem, and solve.

$$E = 0.0504 \text{ kW} \times 3 \text{ h}$$

$$E = 0.1512 \text{ kWh}$$

Now It's Your Turn

1. A computer monitor draws 1.2 A at a voltage of 120 V. What is the power rating of the monitor?
2. A light bulb draws a 0.5 A current at a voltage of 120 V. What is the power rating of the light bulb?
3. How much electrical energy does a 100 W light bulb use if it is left on for 24 h?

How to Save Energy

Every appliance uses energy. But a fan, such as the one in **Figure 4,** could actually help you save energy. If you use a fan, you can run an air conditioner less. Replacing items that have high power ratings with items that have lower ratings is another way to save energy. Turning off lights when they are not in use will also help.

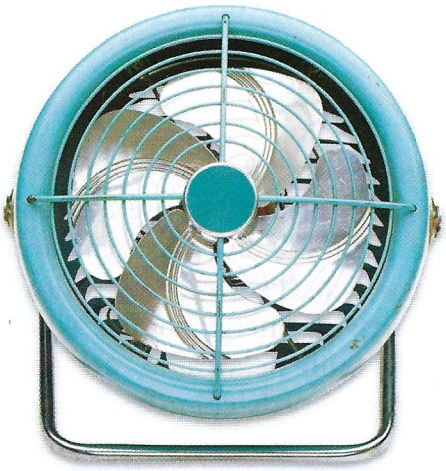


Figure 4 *Using a fan to stay cool and using a small toaster instead of a larger toaster oven are ways to save energy.*

SCHOOL to HOME

Saving Energy

WRITING SKILL With a parent, identify the power rating for each light in your home and estimate how long each light is on during a day. In your **science journal,** determine how much electrical energy each light uses per day. Then, describe two ways to save energy with the lights.

ACTIVITY

SECTION Review

Summary

- Ohm's law describes the relationship between current, resistance, and voltage.
- Electric power is the rate at which electrical energy is changed into other forms of energy.
- Electrical energy is electric power multiplied by time. It is usually expressed in kilowatt-hours.

Using Key Terms

1. In your own words, write a definition for the term *electric power.*

Understanding Key Ideas

2. Which of the following is Ohm's law?
   - **a.** $E = P \times t$
   - **b.** $I = V \times R$
   - **c.** $P = V \times I$
   - **d.** $V = I \times R$
3. Circuit A has twice the resistance of circuit B. The voltage is the same in each circuit. Which circuit has the higher current?

Math Skills

4. Use Ohm's law to find the voltage needed to make a current of 3 A in a resistance of 9 Ω.
5. How much electrical energy does a 40 W light bulb use if it is left on for 12 h?

Critical Thinking

6. **Applying Concepts** Explain why increasing the voltage applied to a wire can have the same effect on the current in the wire that decreasing the resistance of the wire does.
7. **Identifying Relationships** Using the equations in this section, develop an equation to find electrical energy from time, current, and resistance.