(Fig. 18–5 and Chapter opening photo) becomes so hot it glows; only a few percent of the energy is transformed into visible light, and the rest, over 90%, into thermal energy. Lightbulb filaments and heating elements (Fig. 18–16) in household appliances have resistances typically of a few ohms to a few hundred ohms.

Electric energy is transformed into thermal energy or light in such devices, and there are many collisions between the moving electrons and the atoms of the wire. In each collision, part of the electron's kinetic energy is transferred to the atom with which it collides. As a result, the kinetic energy of the wire's atoms increases and hence the temperature of the wire element increases. The increased thermal energy can be transferred as heat by conduction and convection to the air in a heater or to food in a pan, by radiation to bread in a toaster, or radiated as light.

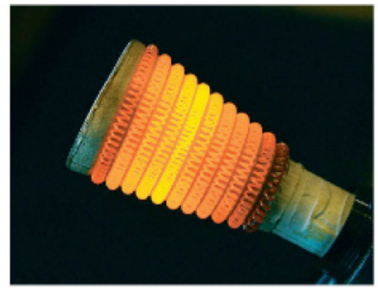

FIGURE 18–16 Coiled heating element of an electric space heater glows because of energy transformed by electric current.

To find the power transformed by an electric device, recall that the energy transformed when a charge Q moves through a potential difference V is QV (Eq. 17–3). Then the power P, which is the rate energy is transformed, is

$$P = \frac{\text{energy transformed}}{\text{time}} = \frac{QV}{t}.$$

The charge that flows per second, Q/t, is simply the electric current I. Thus we have

$$P = IV. \qquad \textbf{(18–5)}$$

Electric power (general)

This general relation gives us the power transformed by any device, where I is the current passing through it and V is the potential difference across it. It also gives the power delivered by a source such as a battery. The SI unit of electric power is the same as for any kind of power, the **watt** ($1\text{ W} = 1\text{ J/s}$).

The rate of energy transformation in a resistance R can be written in two other ways, starting with the general relation $P = IV$ and substituting in $V = IR$:

$$P = IV = I(IR) = I^2R \qquad \textbf{(18–6a)}$$

$$P = IV = \left(\frac{V}{R}\right)V = \frac{V^2}{R}. \qquad \textbf{(18–6b)}$$

Electric power (in resistance R)

Equations 18–6a and b apply only to resistors, whereas Eq. 18–5, $P = IV$, applies to any device, including a resistor.

EXAMPLE 18–8 **Headlights.** Calculate the resistance of a 40-W automobile headlight designed for 12 V (Fig. 18–17).

APPROACH We are given the power and the potential difference across the headlight, so we solve Eq. 18–6b for R.

SOLUTION Given $P = 40\text{ W}$ and $V = 12\text{ V}$, and solving Eq. 18–6b for R, we obtain

$$R = \frac{V^2}{P} = \frac{(12\text{ V})^2}{(40\text{ W})} = 3.6\ \Omega.$$

NOTE This is the resistance when the bulb is burning brightly at 40 W. When the bulb is cold, the resistance is much lower, as we saw in Eq. 18–4. Since the current is high when the resistance is low, lightbulbs burn out most often when first turned on.

PHYSICS APPLIED

Why lightbulbs burn out when first turned on

FIGURE 18–17 Example 18–8.