Answer to Essential Question 18.3: If path A has a larger resistance then path B we would expect the current in path A to be smaller than that in path B, much as we might expect more skiers to choose trail B if it is an easier trail than trail A. The blanket statement about this is – **current prefers the path of least resistance**.

18-4 Power, the Cost of Electricity, and AC Circuits

A typical light bulb has two numbers on it. One is the power, in watts, and the other is the voltage, which is typically 120 V in North America, matching something about the voltage you obtain from a typical household electrical outlet. With these numbers you can determine the current through the bulb and the resistance of the bulb. Let's understand how this is done.

A change in electrical potential energy is given by the equation $\Delta U = q\,\Delta V$. Power is the time rate of change of energy. If we divide electrical potential energy by time we get:

$$P = \frac{\Delta U}{t} = \frac{q\,\Delta V}{t} = \frac{q}{t}\Delta V = I\,\Delta V \ .$$

Using Ohm's Law, $\Delta V = IR$, we can write the power equation in three ways:

$$P = I\,\Delta V = I^2 R = \frac{(\Delta V)^2}{R} \ .$$ (Equation 18.5: **Electrical power**)

EXAMPLE 18.4A – Calculating resistance

(a) What is the resistance of a bulb stamped with "100 W, 120 V?"
(b) What is the resistance of a bulb stamped with "40 W, 120 V?"
(c) If you pick up such a light bulb and measure its resistance when the bulb is not lit, the measured value is much less than what you calculate in parts (a) or (b). Why is this?

SOLUTION

(a) We can re-arrange one form of the power equation to solve for resistance of the 100 W bulb:

$$R = \frac{(\Delta V)^2}{P} = \frac{120 \text{ volts} \times 120 \text{ volts}}{100 \text{ W}} = \frac{120 \text{ volts} \times 120 \text{ volts}}{(10 \times 10) \text{ W}} = 12 \times 12\,\Omega = 144\,\Omega \, .$$

(b) The resistance of the 40 W bulb can be found in a similar way:

$$R = \frac{(\Delta V)^2}{P} = \frac{120 \text{ volts} \times 120 \text{ volts}}{40 \text{ W}} = (120 \times 3.0)\,\Omega = 360\,\Omega \, .$$

(c) What we calculated above is the resistance of a bulb when the bulb has 120 volts across it. This is when it glows brightly because the filament is a few thousand kelvin. If you measure the resistance when the bulb is off, with the filament at room temperature, the resistance is much less because of the temperature dependence of resistance. As we discussed earlier, resistance generally increases as temperature increases. This is what is going on with the bulbs.

Related End-of-Chapter Exercises: 20, 28.

The Cost of Electricity

On your electric bill you are charged about 20 cents for every kilowatt-hour of electricity you used in a month. What kind of unit is the kilowatt-hour?

$$1\text{ kW} - \text{hour} = 1000\text{ W} \times 3600\text{ s} = 3.6 \times 10^{6}\text{ J}.$$

The kilowatt-hour is a unit of energy. Note that you are charged only about 20 cents for each 3.6 million joules of energy delivered to your residence. To find the total cost associated with running a particular device, you do the following multiplication:

$$(\text{Number of hours it is on}) \times (\text{power rating in kW}) \times (\text{cost per kW-hr})$$ (Eq. 18.6: **Electricity cost**)

The power rating of a device is generally stamped on it. Clock radios and televisions usually show this on the back or the bottom, either on a sticker or printed directly on the device.

EXAMPLE 18.4B – The cost of watching television (the electrical cost, that is)

In a typical American household the television set is on for three hours a day. If the power company charges 20 cents for each kW-hr, what is the daily cost of having the TV on for that length of time if the TV's power rating is 300 W?

SOLUTION

First, let's convert the TV's power rating to kW by dividing by 1000, to get 0.30 kW. Then let's simply apply equation 18.6. The daily cost is:

$$(3\text{ hr}) \times (0.30\text{ kW}) \times (20\text{ cents/kW-hr}) = 18\text{ cents}.$$

This is amazingly cheap, particularly compared to what it costs to go to the movies.

Related End-of-Chapter Exercises: 48 – 50.

AC Circuits

In many situations we can treat an electrical outlet, in North America, as acting like a 120-volt battery (in Europe it would be like a 220-volt battery). In reality, however, the voltage signal in North America is a sine wave that oscillates between +170 volts and –170 volts with a frequency of 60 Hz (60 cycles/s), as in Figure 18.9. For a sine wave it turns out that the root mean square value of the voltage is the peak value divided by $\sqrt{2}$. This is where the 120 V comes from, it is the root-mean-square value of the voltage signal.

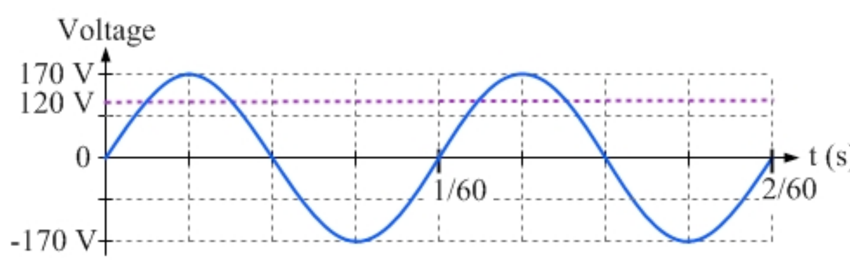

Figure 18.9: The voltage signal from an electrical outlet in North America.

When connected to a wall socket, an incandescent light bulb flickers, but it does so at a rate much faster than is observable to us. The average power dissipated in the light bulb, however, is the root-mean-square voltage multiplied by the root-mean-square current.

Essential Question 18.4: When connected to a wall socket, an incandescent light bulb flickers at a frequency that is not 60 Hz. At what frequency does it flicker? Why?