SECTION 2

Sound Intensity and Resonance

SECTION OBJECTIVES

- **Calculate the intensity of sound waves.**
- **Relate intensity, decibel level, and perceived loudness.**
- **Explain why resonance occurs.**

SOUND INTENSITY

When a piano player strikes a piano key, a hammer inside the piano strikes a wire and causes it to vibrate, as shown in **Figure 8.** The wire's vibrations are then transferred to the piano's soundboard. As the soundboard vibrates, it exerts a force on air molecules around it, causing the air molecules to move. Because this force is exerted through displacement of the soundboard, the soundboard does work on the air. Thus, as the soundboard vibrates back and forth, its kinetic energy is converted into sound waves. This is one reason that the vibration of the soundboard gradually dies out.

Intensity is the rate of energy flow through a given area

As described in Section 1, sound waves traveling in air are longitudinal waves. As the sound waves travel outward from the source, energy is transferred from one air molecule to the next. The rate at which this energy is transferred through a unit area of the plane wave is called the **intensity** of the wave. Because power, P, is defined as the rate of energy transfer, intensity can also be described in terms of power.

intensity

the rate at which energy flows through a unit area perpendicular to the direction of wave motion

$$\text{intensity} = \frac{\Delta E/\Delta t}{\text{area}} = \frac{P}{\text{area}}$$

The SI unit for power is the watt. Thus, intensity has units of watts per square meter (W/m^2). In a spherical wave, energy propagates equally in all directions; no one direction is preferred over any other. In this case, the power emitted by the source (P) is distributed over a spherical surface (area $= 4\pi r^2$), assuming that there is no absorption in the medium.

Figure 8
As a piano wire vibrates, it transfers energy to the piano's soundboard, which in turn transfers energy into the air in the form of sound.

INTENSITY OF A SPHERICAL WAVE

$$\text{intensity} = \frac{P}{4\pi r^2}$$

$$\textbf{intensity} = \frac{\textbf{(power)}}{\mathbf{(4\pi)(distance\ from\ the\ source)^2}}$$

This equation shows that the intensity of a sound wave decreases as the distance from the source (r) increases. This occurs because the same amount of energy is spread over a larger area.