BEFORE, you learned
• Sound waves are produced by vibrations
• Frequency determines the pitch of a sound
• Amplitude is a measure of the height of a wave crest

NOW, you will learn
• How the intensity of a wave affects its loudness
• How sound intensity can be controlled
• How loudness can affect hearing

KEY CONCEPT
Intensity determines loudness.

THINK ABOUT
What makes a sound louder?
A drum player has to play softly at some times and loudly at others. Think about what the drummer must do to produce each type of sound. If you could watch the drummer in the photograph in action, what would you see? How would the drummer change the way he moves the drumsticks to make a loud, crashing sound? What might he do to make a very soft sound?

Intensity depends on the amplitude of a sound wave.
Earlier you read that all waves carry energy. The more energy a sound wave carries, the more intense it is and the louder it will sound to listeners. The intensity of a sound is the amount of energy its sound wave has. A unit called the decibel (dB) is used to measure sound intensity. The faint rustling of tree leaves on a quiet summer day can hardly be heard. Some of the softest sounds measure less than 10 decibels. On the other hand, the noise from a jet taking off or the volume of a TV set turned all the way up can hurt your ears. Very loud sounds measure more than 100 decibels. Remember that amplitude is related to wave energy. The greater the amplitude, the more intensity a sound wave has and the louder the sound will be.

VOCABULARY
intensity p. 532
decibel p. 532
amplification p. 535
acoustics p. 535

OUTLINE
Make an outline for this heading. Remember to include main ideas and details.
1. Main idea
   A. Supporting idea
      1. Detail
      2. Detail
   B. Supporting idea

CHECK YOUR READING
How is energy related to loudness?
The drummer varies the loudness of a sound by varying the energy with which he hits the drum. Loudness is also affected by the distance between the source and the listener.

Have you ever wondered why sound gradually dies out over distance? Think about someone walking away from you with a radio. When the radio is close, the radio seems loud. As the person walks away, the sound grows fainter and fainter. Sound waves travel in all directions from their source. As the waves travel farther from the radio, their energy is spread out over a greater area. This means that their intensity is decreased. The sound waves with lower intensities are heard as quieter sounds.

Other forces can take energy away from sound waves, too. Forces can act within the medium of a sound wave to decrease the intensity of the waves. This effect on sound is probably a good thing. Imagine what the world would be like if every sound wave continued forever!

---

**INVESTIGATE Loudness**

**How is amplitude related to loudness?**

**PROCEDURE**

1. Cut a notch in the middle of both ends of the cardboard. Stretch the rubber band around the cardboard so that it fits into the notches as shown.

2. Mark lines on the cardboard at one and four centimeters away from the rubber band.

3. Slide the pencils under the rubber band at each end.

4. Pull the rubber band to the one-centimeter line and let it go so that it vibrates with a low amplitude. Notice the sound it makes. Pull the rubber band to the four-centimeter line and let it go again. This time the amplitude is higher. Notice the sound it makes this time.

**WHAT DO YOU THINK?**

- How did the loudness of the sounds compare?
- How is amplitude related to loudness?

**CHALLENGE** Using what you learned from experimenting with the rubber band, explain why swinging a drumstick harder on a drum would make a louder sound than swinging a drumstick lightly.

---

**SKILL FOCUS**

Observing

**MATERIALS**

- piece of cardboard
- scissors
- large rubber band
- 2 pencils
- ruler

**TIME**

15 minutes
534
Unit 4: Waves, Sound, and Light

The intensity of sound can be controlled.

Over time and distance, a sound wave gets weaker and weaker until the sound becomes undetectable. The pitch, however, does not typically change as the sound grows weaker. In other words, even as the amplitude decreases, the frequency stays the same.

Sometimes it is desirable to change sound intensity without changing the pitch and quality of a sound. We can do this by adding energy to or taking energy away from a sound wave. As you have already seen, intensity is the amount of energy in a sound wave. Changing the intensity of a sound wave changes its amplitude.

Sound intensity can be controlled in many ways. Mufflers on cars and trucks reduce engine noise. Have you ever heard a car with a broken muffler? You were probably surprised at how loud it was. Burning fuel in an engine produces hot gases that expand and make a very loud noise. A muffler is designed to absorb some of the energy of the sound waves and so decrease their amplitude. As a result, the intensity of the sound you hear is much lower than it would be without the muffler.

How could you change the intensity of a sound without changing the pitch?
Amplification

In addition to being reduced, as they are in a muffler, sound waves can be amplified. The word *amplify* may remind you of *amplitude*, the measure of the height of a wave’s crest. These words are related. To amplify something means to make it bigger. **Amplification** is the increasing of the strength of an electrical signal. It is often used to increase the intensity of a sound wave.

When you listen to a stereo, you experience the effects of amplification. Sound input to the stereo is in the form of weak electrical signals from a microphone. Transistors in an electronic circuit amplify the signals. The electrical signals are converted into vibrations in a coil in your stereo’s speaker. The coil is attached to a cone, which also vibrates and sends out sound waves. You can control the intensity of the sound waves by adjusting your stereo’s volume.

Acoustics

The scientific study of sound is called **acoustics** (uh-KOO-stihks). Acoustics involves both how sound is produced and how it is received and heard by humans and animals.

Acoustics also refers to the way sound waves behave inside a space. Experts called acoustical engineers help design buildings to reduce unwanted echoes. An echo is simply a reflected sound wave. To control sound intensity, engineers design walls and ceilings with acoustical tiles. The shapes and surfaces of acoustical tiles are designed to absorb or redirect some of the energy of sound waves.

**COMPARE AND CONTRAST** Imagine sound waves reflecting off the surfaces in the two photographs above. How do the reflections differ?
Intense sound can damage hearing.

When a train screeches to a stop in a subway station, the sound of the squealing brakes echoes off the tunnel walls. Without thinking about it, you cover your ears with your hands. This response helps protect your ears from possible damage.

In the first section of this chapter, you read about the main parts of the human ear. The part of the inner ear called the cochlea is lined with special cells called hair cells. As you have seen, these cells are necessary for hearing.

The hair cells are extremely sensitive. This sensitivity makes hearing possible, but it also makes the cells easy to damage. Continual exposure to sounds of 90 dB or louder can damage or destroy the cells. This is one reason why being exposed to very loud noises, especially for more than a short time, is harmful to hearing.

Using earplugs can prevent damage from too much exposure to high-intensity sounds such as amplified music. The intensity at a rock concert is between 85 and 120 dB. Ear protection can also protect the hearing of employees in factories and other noisy work sites. In the United States, there are laws that require employers to reduce sounds at work sites to below 90 dB or to provide workers with ear protection.

Even a brief, one-time exposure to an extremely loud noise can destroy hair cells. Noises above 130 dB are especially dangerous. Noises above 140 dB are even painful. It is best to avoid such noises altogether. If you find yourself exposed suddenly to such a noise, covering your ears with your hands may be the best protection.