SECTION 3

Interactions of Sound Waves

Have you ever heard of a sea canary? It's not a bird! It's a whale! Beluga whales are sometimes called sea canaries because of the many different sounds they make.

What You Will Learn

- Explain how echoes are made, and describe their use in locating objects.
- List examples of constructive and destructive interference of sound waves.
- Explain what resonance is.

Vocabulary

echo
echolocation
interference
sonic boom
standing wave
resonance

READING STRATEGY

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

Dolphins, beluga whales, and many other animals that live in the sea use sound to communicate. Beluga whales also rely on reflected sound waves to find fish, crabs, and shrimp to eat. In this section, you will learn about reflection and other interactions of sound waves. You will also learn how bats, dolphins, and whales use sound to find food.

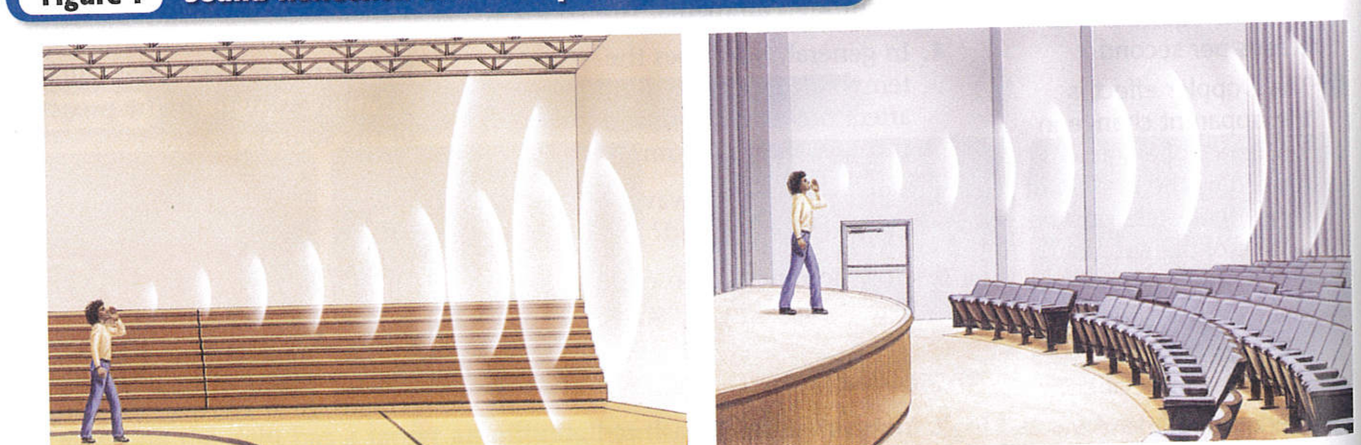
Reflection of Sound Waves

Reflection is the bouncing back of a wave after it strikes a barrier. You're probably already familiar with a reflected sound wave, otherwise known as an **echo.** The strength of a reflected sound wave depends on the reflecting surface. Sound waves reflect best off smooth, hard surfaces. Look at **Figure 1.** A shout in an empty gymnasium can produce an echo, but a shout in an auditorium usually does not.

The difference is that the walls of an auditorium are usually designed so that they absorb sound. If sound waves hit a flat, hard surface, they will reflect back. Reflection of sound waves doesn't matter much in a gymnasium. But you don't want to hear echoes while listening to a musical performance!

echo a reflected sound wave

Figure 1 Sound Reflection and Absorption



Sound waves easily reflect off the smooth, hard walls of a gymnasium. For this reason, you hear an echo.

In well-designed auditoriums, echoes are reduced by soft materials that absorb sound waves and by irregular shapes that scatter sound waves.

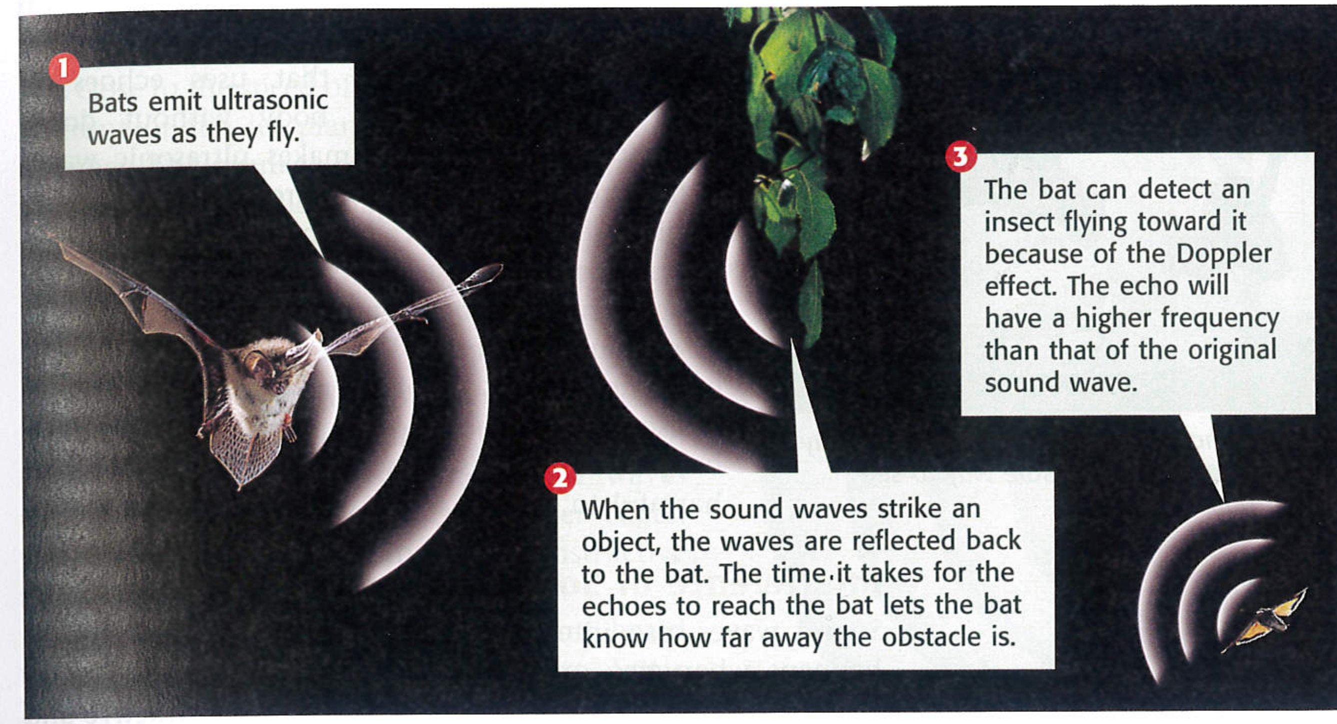


Figure 2 *Bats use echolocation to navigate around barriers and to find insects to eat.*

Echolocation

Beluga whales use echoes to find food. The use of reflected sound waves to find objects is called **echolocation.** Other animals—such as dolphins, bats, and some kinds of birds—also use echolocation to hunt food and to find objects in their paths. **Figure 2** shows how echolocation works. Animals that use echolocation can tell how far away something is based on how long it takes sound waves to echo back to their ears. Some animals, such as bats, also make use of the Doppler effect to tell if another moving object, such as an insect, is moving toward it or away from it.

echolocation the process of using reflected sound waves to find objects; used by animals such as bats

Reading Check **How is echolocation useful to some animals?** (*See the Appendix for answers to Reading Checks.*)

Echolocation Technology

People use echoes to locate objects underwater by using sonar (which stands for sound navigation and ranging). *Sonar* is a type of electronic echolocation. **Figure 3** shows how sonar works. Ultrasonic waves are used because their short wavelengths give more details about the objects they reflect off. Sonar can also help navigators on ships avoid icebergs and can help oceanographers map the ocean floor.

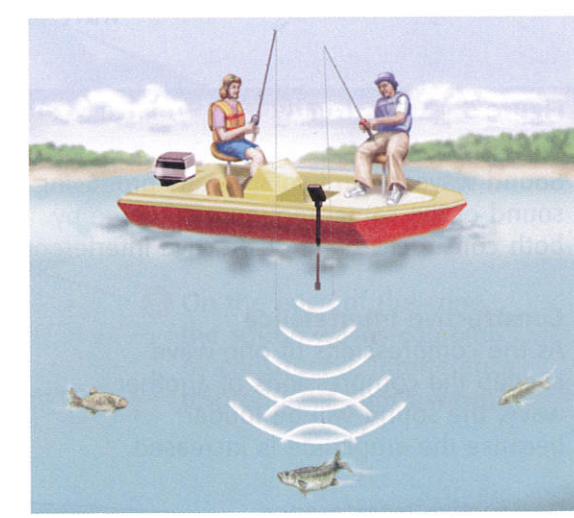


Figure 3 *A fish finder sends ultrasonic waves down into the water. The time it takes for the echo to return helps determine the location of the fish.*

Figure 4 *Images created by ultrasonography are fuzzy, but they are a safe way to see inside a patient's body.*

Ultrasonography

Ultrasonography (UHL truh soh NAHG ruh fee) is a medical procedure that uses echoes to "see" inside a patient's body without doing surgery. A special device makes ultrasonic waves with a frequency that can be from 1 million to 10 million hertz, which reflect off the patient's internal organs. These echoes are then changed into images that can be seen on a television screen, as shown in **Figure 4.** Ultrasonography is used to examine kidneys, gallbladders, and other organs. It is also used to check the development of an unborn baby in a mother's body. Ultrasonic waves are less harmful to human tissue than X rays are.

Interference of Sound Waves

interference the combination of two or more waves that results in a single wave

sonic boom the explosive sound heard when a shock wave from an object traveling faster than the speed of sound reaches a person's ears

Sound waves also interact through interference. **Interference** happens when two or more waves overlap. **Figure 5** shows how two sound waves can combine by both constructive and destructive interference.

Orchestras and bands make use of constructive interference when several instruments of the same kind play the same notes. Interference of the sound waves causes the combined amplitude to increase, resulting in a louder sound. But destructive interference may keep some members of the audience from hearing the concert well. In certain places in an auditorium, sound waves reflecting off the walls interfere destructively with the sound waves from the stage.

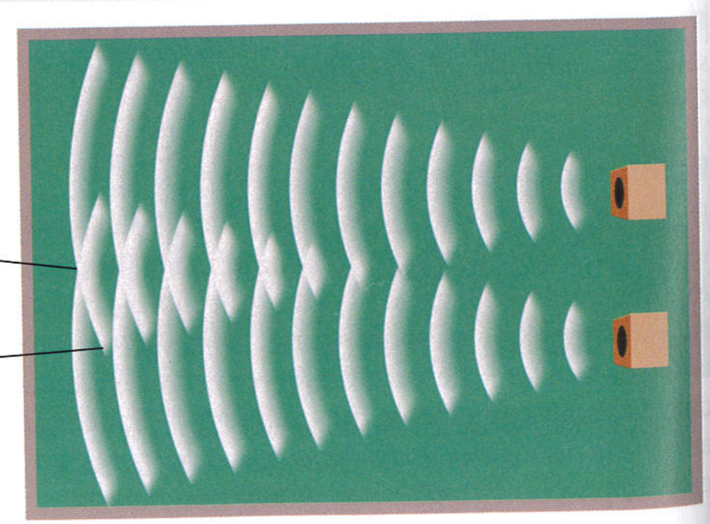
Reading Check What are the two kinds of sound wave interference?

Figure 5 Constructive and Destructive Interference

Sound waves from two speakers producing sound of the same frequency combine by both constructive and destructive interference.

Constructive Interference
As the compressions of one wave overlap the compressions of another wave, the sound will be louder because the amplitude is increased.

Destructive Interference
As the compressions of one wave overlap the rarefactions of another wave, the sound will be softer because the amplitude is decreased.



Interference and the Sound Barrier

As the source of a sound—such as a jet plane—gets close to the speed of sound, the sound waves in front of the jet plane get closer and closer together. The result is constructive interference. **Figure 6** shows what happens as a jet plane reaches the speed of sound.

For the jet in **Figure 6** to go faster than the speed of sound, the jet must overcome the pressure of the compressed sound waves. **Figure 7** shows what happens as soon as the jet reaches supersonic speeds—speeds faster than the speed of sound. At these speeds, the sound waves trail off behind the jet. At their outer edges, the sound waves combine by constructive interference to form a *shock wave.*

A **sonic boom** is the explosive sound heard when a shock wave reaches your ears. Sonic booms can be so loud that they can hurt your ears and break windows. They can even make the ground shake as it does during an earthquake.

Figure 6 *When a jet plane reaches the speed of sound, the sound waves in front of the jet combine by constructive interference. The result is a high-density compression that is called the sound barrier.*

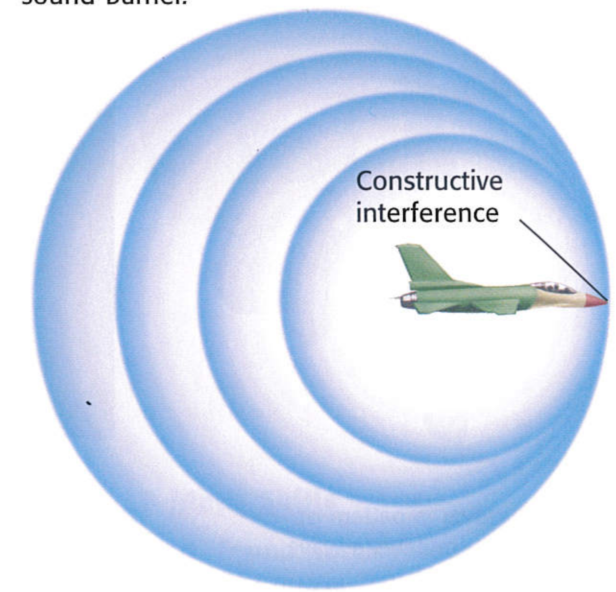
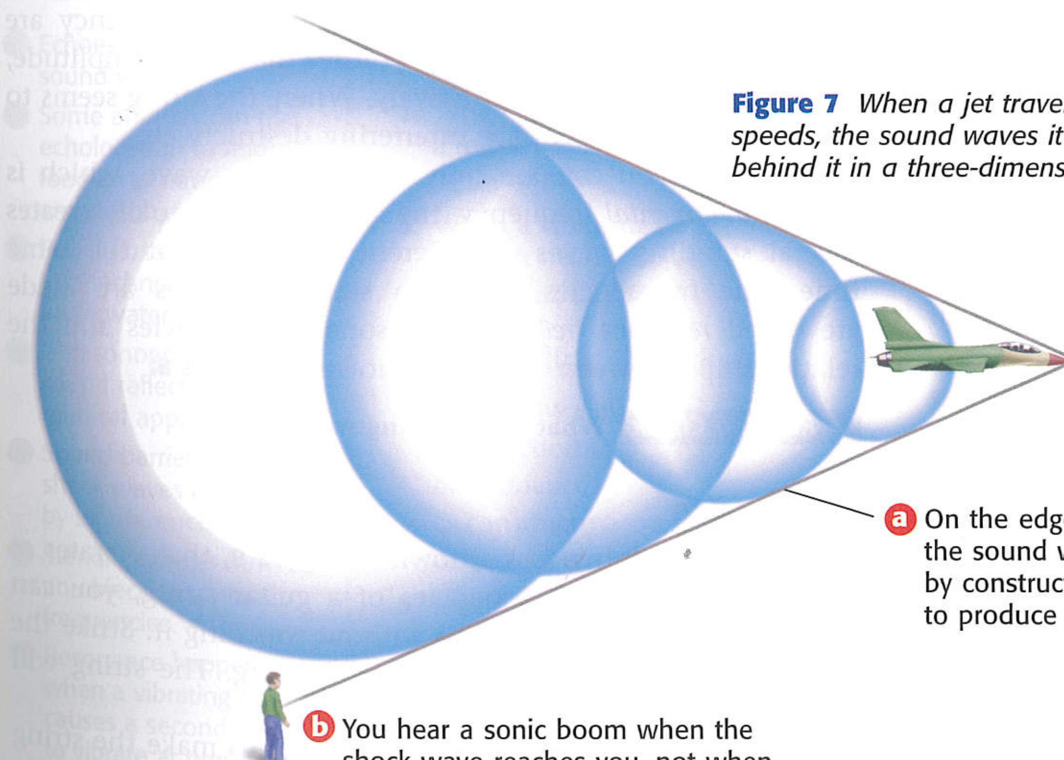


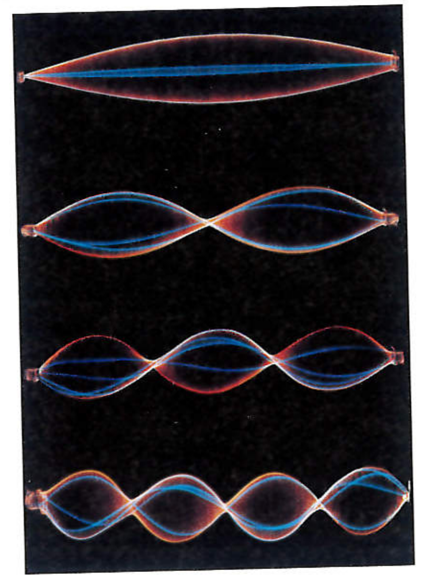
Figure 7 *When a jet travels at supersonic speeds, the sound waves it creates spread out behind it in a three-dimensional cone shape.*



a On the edge of the cone, the sound waves combine by constructive interference to produce a shock wave.

b You hear a sonic boom when the shock wave reaches you, not when the jet breaks the sound barrier.

Figure 8 Resonant Frequencies of a Plucked String



The lowest resonant frequency is called the *fundamental.*

Higher resonant frequencies are called *overtones*. The first overtone is twice the frequency of the fundamental.

The second overtone is 3 times the fundamental.

The third overtone is 4 times the fundamental.

standing wave a pattern of vibration that simulates a wave that is standing still

resonance a phenomenon that occurs when two objects naturally vibrate at the same frequency; the sound produced by one object causes the other object to vibrate

Interference and Standing Waves

When you play a guitar, you can make some pleasing sounds, and you might even play a tune. But have you ever watched a guitar string after you've plucked it? You may have noticed that the string vibrates as a standing wave. A **standing wave** is a pattern of vibration that looks like a wave that is standing still. Waves and reflected waves of the same frequency are going through the string. Where you see maximum amplitude, waves are interfering constructively. Where the string seems to be standing still, waves are interfering destructively.

Although you can see only one standing wave, which is at the *fundamental* frequency, the guitar string actually creates several standing waves of different frequencies at the same time. The frequencies at which standing waves are made are called *resonant frequencies*. Resonant frequencies and the relationships between them are shown in **Figure 8.**

Reading Check What is a standing wave?

Resonance

If you have a tuning fork, shown in **Figure 9,** that vibrates at one of the resonant frequencies of a guitar string, you can make the string make a sound without touching it. Strike the tuning fork, and hold it close to the string. The string will start to vibrate and produce a sound.

Using the vibrations of the tuning fork to make the string vibrate is an example of resonance. **Resonance** happens when an object vibrating at or near a resonant frequency of a second object causes the second object to vibrate.

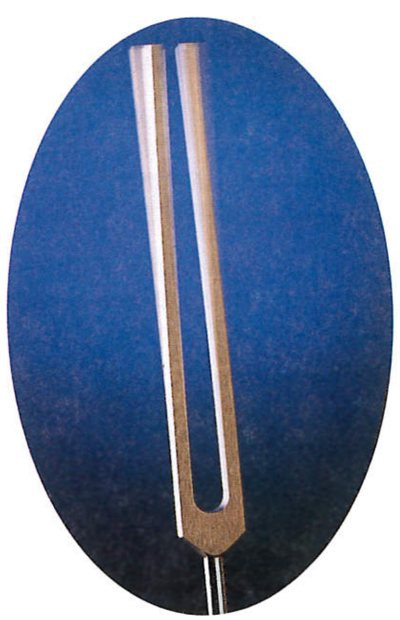


Figure 9 *When struck, a tuning fork can make another object vibrate if they both have the same resonant frequency.*

Resonance in Musical Instruments

Musical instruments use resonance to make sound. In wind instruments, vibrations are caused by blowing air into the mouthpiece. The vibrations make a sound, which is amplified when it forms a standing wave inside the instrument.

String instruments also resonate when they are played. An acoustic guitar, such as the one shown in **Figure 10,** has a hollow body. When the strings vibrate, sound waves enter the body of the guitar. Standing waves form inside the body of the guitar, and the sound is amplified.

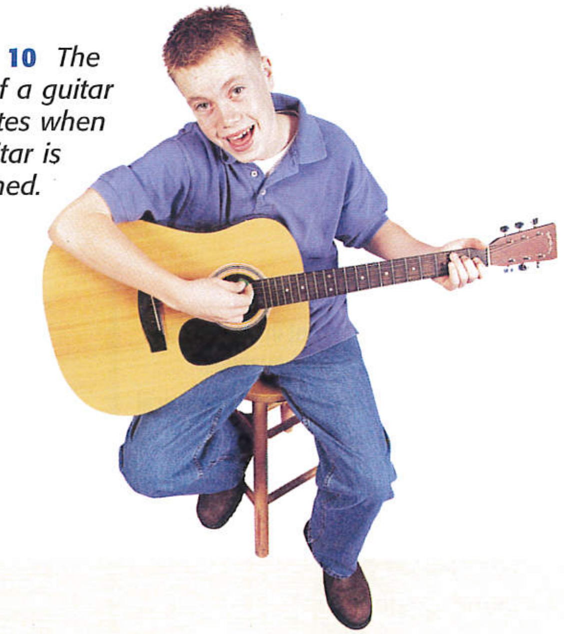


Figure 10 *The body of a guitar resonates when the guitar is strummed.*

SECTION Review

Summary

- Echoes are reflected sound waves.
- Some animals can use echolocation to find food or to navigate around objects.
- People use echolocation technology in many underwater applications.
- Ultrasonography uses sound reflection for medical applications.
- Sound barriers and shock waves are created by interference.
- Standing waves form at an object's resonant frequencies.
- Resonance happens when a vibrating object causes a second object to vibrate at one of its resonant frequencies.

Using Key Terms

1. Use the following terms in the same sentence: *echo* and *echolocation.*

Complete each of the following sentences by choosing the correct term from the word bank.

interference	standing wave
sonic boom	resonance

2. When you pluck a string on a musical instrument, a(n) ____ forms.
3. When a vibrating object causes a nearby object to vibrate, ____ results.

Understanding Key Ideas

4. What causes an echo?
   a. reflection
   b. resonance
   c. constructive interference
   d. destructive interference
5. Describe a place in which you would expect to hear echoes.
6. How do bats use echoes to find insects to eat?
7. Give one example each of constructive and destructive interference of sound waves.

Math Skills

8. Sound travels through air at 343 m/s at 20°C. A bat emits an ultrasonic squeak and hears the echo 0.05 s later. How far away was the object that reflected it? (Hint: Remember that the sound must travel *to* the object and *back to* the bat.)

Critical Thinking

9. **Applying Concepts** Your friend is playing a song on a piano. Whenever your friend hits a certain key, the lamp on top of the piano rattles. Explain why the lamp rattles.
10. **Making Comparisons** Compare sonar and ultrasonography in locating objects.