# Physics SOUND

## Questions

1. What is the evidence that sound travels as a wave?
2. What is the evidence that sound is a form of energy?
3. Children sometimes play with a homemade "telephone" by attaching a string to the bottoms of two paper cups. When the string is stretched and a child speaks into one cup, the sound can be heard at the other cup (Fig. 12–29). Explain clearly how the sound wave travels from one cup to the other.
4. When a sound wave passes from air into water, do you expect the frequency or wavelength to change?

## Problems

1. (I) A hiker determines the length of a lake by listening for the echo of her shout reflected by a cliff at the far end of the lake. She hears the echo 2.0 s after shouting. Estimate the length of the lake.
2. (I) A sailor strikes the side of his ship just below the waterline. He hears the echo of the sound reflected from the ocean floor directly below 2.5 s later. How deep is the ocean at this point? Assume the speed of sound in seawater is $1560\,\text{m/s}$ (Table 12–1) and does not vary significantly with depth.
3. (I) (*a*) Calculate the wavelengths in air at 20°C for sounds in the maximum range of human hearing, 20 Hz to 20,000 Hz. (*b*) What is the wavelength of a 10-MHz ultrasonic wave?
4. (II) An ocean fishing boat is drifting just above a school of tuna on a foggy day. Without warning, an engine backfire occurs on another boat 1.0 km away (Fig. 12–33). How much time elapses before the backfire is heard (*a*) by the fish, and (*b*) by the fishermen?

### Intensity of Sound; Decibels

8. (I) What is the intensity of a sound at the pain level of 120 dB? Compare it to that of a whisper at 20 dB.
9. (I) What is the sound level of a sound whose intensity is $2.0\times10^{-6}\ \text{W/m}^2$?

## Answers to Questions

1. Sound exhibits several phenomena that give evidence that it is a wave. The phenomenon of interference is a wave phenomenon, and sound produces interference (such as beats). The phenomenon of diffraction is a wave phenomenon, and sound can be diffracted (such as sound being heard around corners). Refraction is a wave phenomenon, and sound exhibits refraction when passing obliquely from one medium to another.

2. Evidence that sound is a form of energy is found in the fact that sound can do work. A sound wave created in one location can cause the mechanical vibration of an object at a different location. For example, sound can set eardrums in motion, make windows rattle, or shatter a glass.

3. The child speaking into a cup creates sound waves which cause the bottom of the cup to vibrate. Since the string is tightly attached to the bottom of the cup, the vibrations of the cup are transmitted to longitudinal waves in the string. These longitudinal waves travel down the string, and cause the bottom of the receiver cup to vibrate. This relatively large vibrating surface moves the adjacent air, and generates sound waves from the bottom of the cup, traveling up into the cup. These waves are incident on the receiver's ear, and they hear the sound from the speaker.

4. If the frequency were to change, the two media could not stay in contact with each other. If one medium vibrates with a certain frequency, and the other medium vibrates with a different frequency, then particles from the two media initially in contact could not stay in contact with each other. But particles must be in contact in order for the wave to be transmitted from one medium to the other, and so the frequency does not change. Since the wave speed changes in passing from air into water, and the frequency does not change, we expect the wavelength to change. The wave travels about four times faster in water, so we expect the wavelength in water to be about four times longer than it is in air.

## Answers to Problems

1. The round trip time for sound is 2.0 seconds, so the time for sound to travel the length of the lake is 1.0 seconds. Use the time and the speed of sound to determine the length of the lake.

$$d = vt = (343\,\text{m/s})(1.0\text{ s}) = 343\text{ m} \approx \boxed{3.4\times10^{2}\,\text{m}}$$

2. The round trip time for sound is 2.5 seconds, so the time for sound to travel the length of the lake is 1.25 seconds. Use the time and the speed of sound in water to determine the depth of the lake.

$$d = vt = (1560\,\text{m/s})(1.25\text{ s}) = 1950\text{ m} = \boxed{2.0\times10^{3}\,\text{m}}$$

3. (*a*) $\lambda_{20\text{ Hz}} = \dfrac{v}{f} = \dfrac{343\,\text{m/s}}{20\text{ Hz}} = \boxed{17\text{ m}}$ $\lambda_{20\text{ kHz}} = \dfrac{v}{f} = \dfrac{343\,\text{m/s}}{2.0\times10^{4}\,\text{Hz}} = \boxed{1.7\times10^{-2}\,\text{m}}$

So the range is from 17 cm to 17 m.

(*b*) $\lambda = \dfrac{v}{f} = \dfrac{343\,\text{m/s}}{10\times10^{6}\,\text{Hz}} = \boxed{3.4\times10^{-5}\,\text{m}}$

4. (*a*) For the fish, the speed of sound in seawater must be used.

$$d = vt \;\rightarrow\; t = \frac{d}{v} = \frac{1.0\times10^{3}\text{ m}}{1560\,\text{m/s}} = \boxed{0.64\text{ s}}$$

(*b*) For the fishermen, the speed of sound in air must be used.

$$d = vt \;\rightarrow\; t = \frac{d}{v} = \frac{1.0\times10^{3}\text{ m}}{343\,\text{m/s}} = \boxed{2.9\text{ s}}$$

8. $120\text{ dB} = 10\log\dfrac{I_{120}}{I_0} \;\rightarrow\; I_{120} = 10^{12} I_0 = 10^{12}\left(1.0\times10^{-12}\,\text{W/m}^2\right) = \boxed{1.0\,\text{W/m}^2}$

$20\text{ dB} = 10\log\dfrac{I_{20}}{I_0} \;\rightarrow\; I_{20} = 10^{2} I_0 = 10^{2}\left(1.0\times10^{-12}\,\text{W/m}^2\right) = \boxed{1.0\times10^{-10}\,\text{W/m}^2}$

The pain level is $10^{10}$ times more intense than the whisper.

9. $\beta = 10\log\dfrac{I}{I_0} = 10\log\dfrac{2.0\times10^{-6}\,\text{W/m}^2}{1.0\times10^{-12}\,\text{W/m}^2} = \boxed{63\text{ dB}}$