Problems

[Unless stated otherwise, assume $T = 20°C$ and $v_{sound} = 343\,m/s$ in air.]

12–1 Characteristics of Sound

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 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?
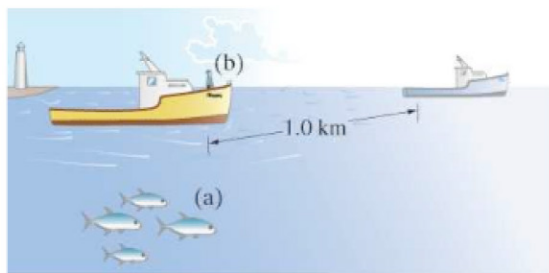

FIGURE 12–33 Problem 4.

5. (II) A stone is dropped from the top of a cliff. The splash it makes when striking the water below is heard 3.5 s later. How high is the cliff?

6. (II) A person, with his ear to the ground, sees a huge stone strike the concrete pavement. A moment later two sounds are heard from the impact: one travels in the air and the other in the concrete, and they are 1.1 s apart. How far away did the impact occur? See Table 12–1.

7. (II) Calculate the percent error made over one mile of distance by the "5-second rule" for estimating the distance from a lightning strike if the temperature is (a) 30°C, and (b) 10°C.

12–2 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 $2.0 \times 10^{-6}\,W/m^2$?

10. (II) If two firecrackers produce a sound level of 95 dB when fired simultaneously at a certain place, what will be the sound level if only one is exploded? [*Hint*: Add intensities, not dB's.]

11. (II) A person standing a certain distance from an airplane with four equally noisy jet engines is experiencing a sound level bordering on pain, 120 dB. What sound level would this person experience if the captain shut down all but one engine? [*Hint*: Add intensities, not dB's.]

12. (II) A cassette player is said to have a signal-to-noise ratio of 58 dB, whereas for a CD player it is 95 dB. What is the ratio of intensities of the signal and the background noise for each device?

13. (II) (a) Estimate the power output of sound from a person speaking in normal conversation. Use Table 12–2. Assume the sound spreads roughly uniformly over a sphere centered on the mouth. (b) How many people would it take to produce a total sound output of 100 W of ordinary conversation? [*Hint*: Add intensities, not dB's.]

14. (II) A 50-dB sound wave strikes an eardrum whose area is $5.0 \times 10^{-5}\,m^2$. (a) How much energy is absorbed by the eardrum per second? (b) At this rate, how long would it take your eardrum to receive a total energy of 1.0 J?

15. (II) Expensive amplifier A is rated at 250 W, while the more modest amplifier B is rated at 40 W. (a) Estimate the sound level in decibels you would expect at a point 3.5 m from a loudspeaker connected in turn to each amp. (b) Will the expensive amp sound twice as loud as the cheaper one?

16. (II) At a rock concert, a dB meter registered 130 dB when placed 2.8 m in front of a loudspeaker on the stage. (a) What was the power output of the speaker, assuming uniform spherical spreading of the sound and neglecting absorption in the air? (b) How far away would the sound level be a somewhat reasonable 90 dB?

17. (II) Human beings can typically detect a difference in sound level of 2.0 dB. What is the ratio of the amplitudes of two sounds whose levels differ by this amount? [*Hint*: See Section 11–9.]

18. (II) If the amplitude of a sound wave is tripled, (a) by what factor will the intensity increase? (b) By how many dB will the sound level increase?

* **19.** (II) Two sound waves have equal displacement amplitudes, but one has twice the frequency of the other. What is the ratio of their intensities?

* **20.** (II) What would be the sound level (in dB) of a sound wave in air that corresponds to a displacement amplitude of vibrating air molecules of 0.13 mm at 300 Hz?

* 12–3 Loudness

* **21.** (I) A 6000-Hz tone must have what sound level to seem as loud as a 100-Hz tone that has a 50-dB sound level? (See Fig. 12–6.)

* **22.** (I) What are the lowest and highest frequencies that an ear can detect when the sound level is 30 dB? (See Fig. 12–6.)

* **23.** (II) Your auditory system can accommodate a huge range of sound levels. What is the ratio of highest to lowest intensity at (a) 100 Hz, (b) 5000 Hz? (See Fig. 12–6.)

12–4 Sources of Sound: Strings and Air Columns

24. (I) The A string on a violin has a fundamental frequency of 440 Hz. The length of the vibrating portion is 32 cm, and it has a mass of 0.35 g. Under what tension must the string be placed?