

4. Explain how the distance to a lightning bolt (Fig. CQ14.4) can be determined by counting the seconds between the flash and the sound of thunder.



Figure CQ14.4

5. Secret agents in the movies always want to get to a secure phone with a voice scrambler. How do these devices work?
6. Why does a vibrating guitar string sound louder when placed on the instrument than it would if allowed to vibrate in the air while off the instrument?

7. You are driving toward the base of a cliff and you honk your horn. (a) Is there a Doppler shift of the sound when you hear the echo? If so, is it like a moving source or moving observer? (b) What if the reflection occurs not from a cliff, but from the forward edge of a huge alien spacecraft moving toward you as you drive?
8. The radar systems used by police to detect speeders are sensitive to the Doppler shift of a pulse of radio waves. Discuss how this sensitivity can be used to measure the speed of a car.
9. An archer shoots an arrow from a bow. Does the string of the bow exhibit standing waves after the arrow leaves? If so, and if the bow is perfectly symmetric so that the arrow leaves from the center of the string, what harmonics are excited?
10. A soft drink bottle resonates as air is blown across its top. What happens to the resonant frequency as the level of fluid in the bottle decreases?
11. An airplane mechanic notices that the sound from a twin-engine aircraft varies rapidly in loudness when both engines are running. What could be causing this variation from loud to soft?

PROBLEMS

WebAssign The problems in this chapter may be assigned online in Enhanced WebAssign.

1. denotes straightforward problem; 2. denotes intermediate problem; 3. denotes challenging problem
1. denotes full solution available in *Student Solutions Manual/Study Guide*
1. denotes problems most often assigned in Enhanced WebAssign

BIO denotes biomedical problems

GP denotes guided problems

M denotes Master It tutorial available in Enhanced WebAssign

Q/C denotes asking for quantitative and conceptual reasoning

S denotes symbolic reasoning problem

W denotes Watch It video solution available in Enhanced WebAssign

14.2 Characteristics of Sound Waves

14.3 The Speed of Sound

Note: Unless otherwise specified, assume the speed of sound in air is 343 m/s, its value at an air temperature of 20.0°C. At any other Celsius temperature T_C , the speed of sound in air is described by Equation 14.4:

$$v = 331 \sqrt{1 + \frac{T_C}{273}}$$

where v is in m/s and T is in °C. Use Table 14.1 to find speeds of sound in other media.

1. **Q/C** Suppose you hear a clap of thunder 16.2 s after seeing the associated lightning stroke. The speed of light in air is 3.00×10^8 m/s. (a) How far are you from the lightning stroke? (b) Do you need to know the value of the speed of light to answer? Explain.
2. Earthquakes at fault lines in Earth's crust create seismic waves, which are longitudinal (P-waves) or transverse (S-waves). The P-waves have a speed of about 7 km/s. Estimate the average bulk modulus of Earth's crust given that the density of rock is about 2500 kg/m³.
3. On a hot summer day, the temperature of air in Arizona reaches 114°F. What is the speed of sound in air at this temperature?
4. **BIO** A dolphin located in seawater at a temperature of 25°C emits a sound directed toward the bottom of the ocean 150 m below. How much time passes before it hears an echo?
5. A group of hikers hears an echo 3.00 s after shouting. How far away is the mountain that reflected the sound wave?
6. **BIO** The range of human hearing extends from approximately 20 Hz to 20 000 Hz. Find the wavelengths of these extremes at a temperature of 27°C.

7. A sound wave propagating in air has a frequency of 4.00 kHz. Calculate the change in wavelength when the wave, initially traveling in a region where $T = 27.0^\circ\text{C}$, enters a region where $T = 10.0^\circ\text{C}$.

8. A stone is dropped from rest into a well. The sound of the splash is heard exactly 2.00 s later. Find the depth of the well if the air temperature is 10.0°C .

9. **QC** A hammer strikes one end of a thick steel rail of length 8.50 m. A microphone located at the opposite end of the rail detects two pulses of sound, one that travels through the air and a longitudinal wave that travels through the rail. (a) Which pulse reaches the microphone first? (b) Find the separation in time between the arrivals of the two pulses.

14.4 Energy and Intensity of Sound Waves

14.5 Spherical and Plane Waves

10. **QC** The intensity level produced by a jet airplane at a certain location is 150 dB. (a) Calculate the intensity of the sound wave generated by the jet at the given location. (b) Compare the answer to part (a) to the threshold of pain and explain why employees directing jet airplanes at airports must wear hearing protection equipment.

11. **W** One of the loudest sounds in recent history was that made by the explosion of Krakatoa on August 26–27, 1883. According to barometric measurements, the sound had a decibel level of 180 dB at a distance of 161 km. Assuming the intensity falls off as the inverse of the distance squared, what was the decibel level on Rodriguez Island, 4 800 km away?

12. A sound wave from a siren has an intensity of 100.0 W/m^2 at a certain point, and a second sound wave from a nearby ambulance has an intensity level 10 dB greater than the siren's sound wave at the same point. What is the intensity level of the sound wave due to the ambulance?

13. **BIO** A person wears a hearing aid that uniformly increases the intensity level of all audible frequencies of sound by 30.0 dB. The hearing aid picks up sound having a frequency of 250 Hz at an intensity of $3.0 \times 10^{-11} \text{ W/m}^2$. What is the intensity delivered to the eardrum?

14. **BIO** The area of a typical eardrum is about $5.0 \times 10^{-5} \text{ m}^2$. Calculate the sound power (the energy per second) incident on an eardrum at (a) the threshold of hearing and (b) the threshold of pain.

15. **BIO** The toadfish makes use of resonance in a closed tube to produce very loud sounds. The tube is its swim bladder, used as an amplifier. The sound level of this creature has been measured as high as 100 dB. (a) Calculate the intensity of the sound wave emitted. (b) What is the intensity level if three of these toadfish try to make a sound at the same time?

16. **GP** A trumpet creates a sound intensity level of $1.15 \times 10^2 \text{ dB}$ at a distance of 1.00 m. (a) What is the sound intensity of a trumpet at this distance? (b) What is the sound intensity of five trumpets at this distance? (c) Find the

sound intensity of five trumpets at the location of the first row of an audience, 8.00 m away, assuming, for simplicity, the sound energy propagates uniformly in all directions. (d) Calculate the decibel level of the five trumpets in the first row. (e) If the trumpets are being played in an outdoor auditorium, how far away, in theory, can their combined sound be heard? (f) In practice such a sound could not be heard once the listener was 2–3 km away. Why can't the sound be heard at the distance found in part (e) *Hint*: In a very quiet room the ambient sound intensity level is about 30 dB.

17. There is evidence that elephants communicate via infrasound, generating rumbling vocalizations as low as 14 Hz that can travel up to 10 km. The intensity level of these sounds can reach 103 dB, measured a distance of 5.0 m from the source. Determine the intensity level of the infrasound 10 km from the source, assuming the sound energy radiates uniformly in all directions.

18. A family ice show is held at an enclosed arena. The skaters perform to music playing at a level of 80.0 dB. This intensity level is too loud for your baby, who yells at 75.0 dB. (a) What total sound intensity engulfs you? (b) What is the combined sound level?

19. **M** A train sounds its horn as it approaches an intersection. The horn can just be heard at a level of 50 dB by an observer 10 km away. (a) What is the average power generated by the horn? (b) What intensity level of the horn's sound is observed by someone waiting at an intersection 50 m from the train? Treat the horn as a point source and neglect any absorption of sound by the air.

20. An outside loudspeaker (considered a small source) emits sound waves with a power output of 100 W. (a) Find the intensity 10.0 m from the source. (b) Find the intensity level in decibels at that distance. (c) At what distance would you experience the sound at the threshold of pain, 120 dB?

21. **S** Show that the difference in decibel levels β_1 and β_2 of a sound source is related to the ratio of its distances r_1 and r_2 from the receivers by the formula

$$\beta_2 - \beta_1 = 20 \log\left(\frac{r_1}{r_2}\right)$$

22. A skyrocket explodes 100 m above the ground (Fig. P14.22). Three observers are spaced 100 m apart, with the first (A) directly under the explosion. (a) What

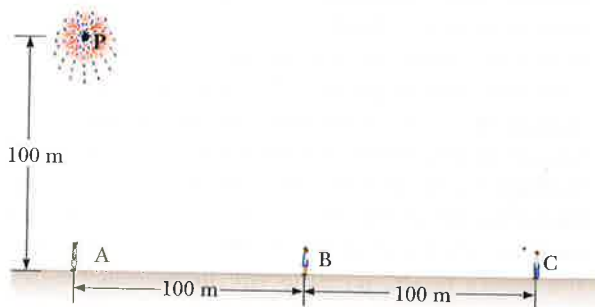


Figure P14.22

is the ratio of the sound intensity heard by observer A to that heard by observer B? (b) What is the ratio of the intensity heard by observer A to that heard by observer C?

14.6 The Doppler Effect

23. A commuter train passes a passenger platform at a constant speed of 40.0 m/s. The train horn is sounded at its characteristic frequency of 320 Hz. (a) What overall change in frequency is detected by a person on the platform as the train moves from approaching to receding? (b) What wavelength is detected by a person on the platform as the train approaches?
24. An airplane traveling at half the speed of sound emits a sound of frequency 5.00 kHz. At what frequency does a stationary listener hear the sound (a) as the plane approaches? (b) After it passes?
25. **W** Two trains on separate tracks move toward each other. Train 1 has a speed of 130 km/h; train 2, a speed of 90.0 km/h. Train 2 blows its horn, emitting a frequency of 500 Hz. What is the frequency heard by the engineer on train 1?
26. At rest, a car's horn sounds the note A (440 Hz). The horn is sounded while the car is moving down the street. A bicyclist moving in the same direction with one-third the car's speed hears a frequency of 415 Hz. (a) Is the cyclist ahead of or behind the car? (b) What is the speed of the car?
27. An alert physics student stands beside the tracks as a train rolls slowly past. He notes that the frequency of the train whistle is 465 Hz when the train is approaching him and 441 Hz when the train is receding from him. Using these frequencies, he calculates the speed of the train. What value does he find?
28. **BIO Q.C** A bat flying at 5.00 m/s is chasing an insect flying in the same direction. If the bat emits a 40.0-kHz chirp and receives back an echo at 40.4 kHz, (a) what is the speed of the insect? (b) Will the bat be able to catch the insect? Explain.
29. A tuning fork vibrating at 512 Hz falls from rest and accelerates at 9.80 m/s^2 . How far below the point of release is the tuning fork when waves of frequency 485 Hz reach the release point?
30. **BIO** Expectant parents are thrilled to hear their unborn baby's heartbeat, revealed by an ultrasonic motion detector. Suppose the fetus's ventricular wall moves in simple harmonic motion with amplitude 1.80 mm and frequency 115 beats per minute. The motion detector in contact with the mother's abdomen produces sound at precisely 2 MHz, which travels through tissue at 1.50 km/s. (a) Find the maximum linear speed of the heart wall. (b) Find the maximum frequency at which sound arrives at the wall of the baby's heart. (c) Find the maximum frequency at which reflected sound is received by the motion detector. (By electronically "listening" for echoes at a

frequency different from the broadcast frequency, the motion detector can produce beeps of audible sound in synchrony with the fetal heartbeat.)

31. **M** A supersonic jet traveling at Mach 3.00 at an altitude of $h = 20\,000 \text{ m}$ is directly over a person at time $t = 0$ as shown in Figure P14.31. Assume the average speed of sound in air is 335 m/s over the path of the sound. (a) At what time will the person encounter the shock wave due to the sound emitted at $t = 0$? (b) Where will the plane be when this shock wave is heard?

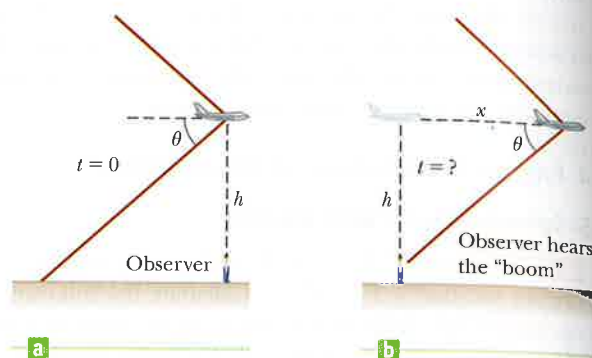


Figure P14.31

32. **GP** A yellow submarine traveling horizontally at 11.0 m/s uses sonar with a frequency of $5.27 \times 10^3 \text{ Hz}$. A red submarine is in front of the yellow submarine and moving 3.00 m/s relative to the water in the same direction. A crewman in the red submarine observes sound waves ("pings") from the yellow submarine. Take the speed of sound in seawater as 1 533 m/s. (a) Write Equation 14.12. (b) Which submarine is the source of the sound? (c) Which submarine carries the observer? (d) Does the motion of the observer's submarine increase or decrease the time between the pressure maxima of the incoming sound waves? How does that affect the observed period? The observed frequency? (e) Should the sign of v_0 be positive or negative? (f) Does the motion of the source submarine increase or decrease the time observed between the pressure maxima? How does this motion affect the observed period? The observed frequency? (g) What sign should be chosen for v_s ? (h) Substitute the appropriate numbers and obtain the frequency observed by the crewman on the red submarine.

14.7 Interference of Sound Waves

33. Two small speakers are driven by a common oscillator at $8.00 \times 10^2 \text{ Hz}$. The speakers face each other and are separated by 1.25 m. Locate the points along a line joining the two speakers where relative minima would be expected. (Use $v = 343 \text{ m/s}$.)
34. The acoustical system shown in Figure P14.34 is driven by a speaker emitting sound of frequency 756 Hz. (a) If constructive interference occurs at a particular instant, by what minimum amount should the path length in the upper U-shaped tube be increased so

that destructive interference occurs instead? (b) What minimum increase in the original length of the upper tube will again result in constructive interference?

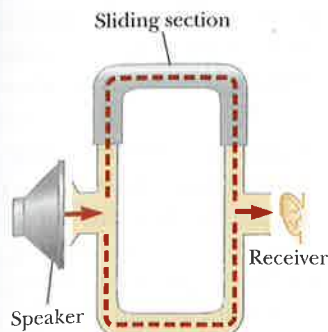


Figure P14.34

35. The ship in Figure P14.35 travels along a straight line parallel to the shore and a distance $d = 600$ m from it. The ship's radio receives simultaneous signals of the same frequency from antennas A and B , separated by a distance $L = 800$ m. The signals interfere constructively at point C , which is equidistant from A and B . The signal goes through the first minimum at point D , which is directly outward from the shore from point B . Determine the wavelength of the radio waves.

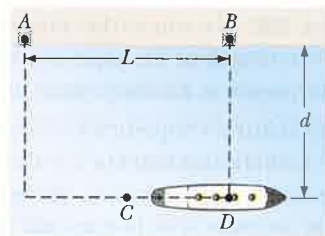


Figure P14.35

36. Two loudspeakers are placed above and below each other, as in Figure P14.36 and driven by the same source at a frequency of 4.50×10^2 Hz. An observer is in front of the speakers (to the right) at point O , at the same distance from each speaker. What minimum vertical distance upward should the top speaker be moved to create destructive interference at point O ?

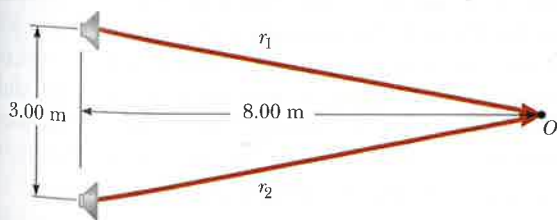


Figure P14.36

37. A pair of speakers separated by a distance $d = 0.700$ m are driven by the same oscillator at a frequency of 686 Hz. An observer originally positioned at one of the speakers begins to walk along a line perpendicular

to the line joining the speakers as in Figure P14.37. (a) How far must the observer walk before reaching a relative maximum in intensity? (b) How far will the observer be from the speaker when the first relative minimum is detected in the intensity?

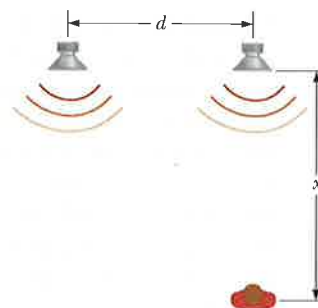


Figure P14.37

14.8 Standing Waves

38. A steel wire in a piano has a length of 0.700 m and a mass of 4.300×10^{-3} kg. To what tension must this wire be stretched so that the fundamental vibration corresponds to middle C ($f_C = 261.6$ Hz on the chromatic musical scale)?
39. **W** A stretched string fixed at each end has a mass of 40.0 g and a length of 8.00 m. The tension in the string is 49.0 N. (a) Determine the positions of the nodes and antinodes for the third harmonic. (b) What is the vibration frequency for this harmonic?
40. How far, and in what direction, should a cellist move her finger to adjust a string's tone from an out-of-tune 449 Hz to an in-tune 440 Hz? The string is 68.0 cm long, and the finger is 20.0 cm from the nut for the 449-Hz tone.
41. A stretched string of length L is observed to vibrate in five equal segments when driven by a 630-Hz oscillator. What oscillator frequency will set up a standing wave so that the string vibrates in three segments?
42. Two pieces of steel wire with identical cross sections have lengths of L and $2L$. The wires are each fixed at both ends and stretched so that the tension in the longer wire is four times greater than in the shorter wire. If the fundamental frequency in the shorter wire is 60 Hz, what is the frequency of the second harmonic in the longer wire?
43. A steel wire with mass 25.0 g and length 1.35 m is strung on a bass so that the distance from the nut to the bridge is 1.10 m. (a) Compute the linear density of the string. (b) What velocity wave on the string will produce the desired fundamental frequency of the E_1 string, 41.2 Hz? (c) Calculate the tension required to obtain the proper frequency. (d) Calculate the wavelength of the string's vibration. (e) What is the wavelength of the sound produced in air? (Assume the speed of sound in air is 343 m/s.)
44. **S** A standing wave is set up in a string of variable length and tension by a vibrator of variable frequency. Both ends of the string are fixed. When the vibrator has a frequency f_A , in a string of length L_A and under tension T_A , n_A antinodes are set up in the string. (a) Write an expression for the frequency f_A of a standing wave in terms of the number n_A , length L_A , tension

T_A , and linear density μ_A . (b) If the length of the string is doubled to $L_B = 2L_A$, what frequency f_B (written as a multiple of f_A) will result in the same number of antinodes? Assume the tension and linear density are unchanged. *Hint:* Make a ratio of expressions for f_B and f_A . (c) If the frequency and length are held constant, what tension T_B will produce $n_A + 1$ antinodes? (d) If the frequency is tripled and the length of the string is halved, by what factor should the tension be changed so that twice as many antinodes are produced?

45. A 12.0-kg object hangs in equilibrium from a string with total length of $L = 5.00$ m and linear mass density of $\mu = 0.00100$ kg/m. The string is wrapped around two light, frictionless pulleys that are separated by the distance $d = 2.00$ m (Fig. P14.45a). (a) Determine the tension in the string. (b) At what frequency must the string between the pulleys vibrate in order to form the standing-wave pattern shown in Figure P14.45b?

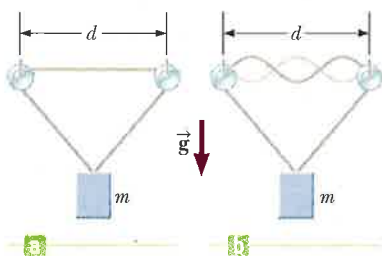


Figure P14.45

46. **M** In the arrangement shown in Figure P14.46, an object of mass $m = 5.0$ kg hangs from a cord around a light pulley. The length of the cord between point P and the pulley is $L = 2.0$ m. (a) When the vibrator is set to a frequency of 150 Hz, a standing wave with six loops is formed. What must be the linear mass density of the cord? (b) How many loops (if any) will result if m is changed to 45 kg? (c) How many loops (if any) will result if m is changed to 10 kg?

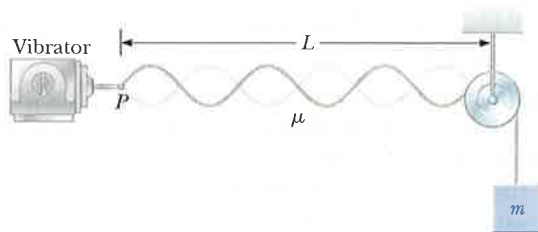


Figure P14.46

47. **BIO** A 60.00-cm guitar string under a tension of 50.000 N has a mass per unit length of 0.10000 g/cm. What is the highest resonant frequency that can be heard by a person capable of hearing frequencies up to 20000 Hz?

14.9 Forced Vibrations and Resonance

48. Standing-wave vibrations are set up in a crystal goblet with four nodes and four antinodes equally spaced around the 20.0-cm circumference of its rim. If transverse waves move around the glass at 900 m/s, an opera singer would

have to produce a high harmonic with what frequency in order to shatter the glass with a resonant vibration?

14.10 Standing Waves in Air Columns

49. The windpipe of a typical whooping crane is about 5.0 ft. long. What is the lowest resonant frequency of this pipe, assuming it is closed at one end? Assume a temperature of 37°C.
50. The overall length of a piccolo is 32.0 cm. The resonating air column vibrates as in a pipe that is open at both ends. (a) Find the frequency of the lowest note a piccolo can play. (b) Opening holes in the side effectively shortens the length of the resonant column. If the highest note a piccolo can sound is 4000 Hz, find the distance between adjacent antinodes for this mode of vibration.
51. **BIO W** The human ear canal is about 2.8 cm long. If it is regarded as a tube that is open at one end and closed at the eardrum, what is the fundamental frequency around which we would expect hearing to be most sensitive?
52. **Q.C** A tunnel under a river is 2.00 km long. (a) At what frequencies can the air in the tunnel resonate? (b) Explain whether it would be good to make a rule against blowing your car horn when you are in the tunnel.
53. **M** A pipe open at both ends has a fundamental frequency of 300 Hz when the temperature is 0°C. (a) What is the length of the pipe? (b) What is the fundamental frequency at a temperature of 30.0°C?
54. Two adjacent natural frequencies of an organ pipe are found to be 550 Hz and 650 Hz. (a) Calculate the fundamental frequency of the pipe. (b) Is the pipe open at both ends or open at only one end? (c) What is the length of the pipe?

14.11 Beats

55. In certain ranges of a piano keyboard, more than one string is tuned to the same note to provide extra loudness. For example, the note at 1.10×10^2 Hz has two strings at this frequency. If one string slips from its normal tension of 6.00×10^2 N to 5.40×10^2 N, what beat frequency is heard when the hammer strikes the two strings simultaneously?
56. The G string on a violin has a fundamental frequency of 196 Hz. It is 30.0 cm long and has a mass of 0.500 g. While this string is sounding, a nearby violinist effectively shortens the G string on her identical violin (by sliding her finger down the string) until a beat frequency of 2.00 Hz is heard between the two strings. When that occurs, what is the effective length of her string?
57. Two train whistles have identical frequencies of 1.80×10^2 Hz. When one train is at rest in the station and the other is moving nearby, a commuter standing on the station platform hears beats with a frequency of 2.00 beats/s when the whistles operate together. What are the two possible speeds and directions that the moving train can have?

58. Two pipes of equal length are each open at one end. Each has a fundamental frequency of 480 Hz at 300 K. In one pipe the air temperature is increased to 305 K. If the two pipes are sounded together, what beat frequency results?

59. A student holds a tuning fork oscillating at 256 Hz. He walks toward a wall at a constant speed of 1.33 m/s. (a) What beat frequency does he observe between the tuning fork and its echo? (b) How fast must he walk away from the wall to observe a beat frequency of 5.00 Hz?

14.13 The Ear

60. **BIO** If a human ear canal can be thought of as resembling an organ pipe, closed at one end, that resonates at a fundamental frequency of 3 000 Hz, what is the length of the canal? Use a normal body temperature of 37°C for your determination of the speed of sound in the canal.

61. **BIO** Some studies suggest that the upper frequency limit of hearing is determined by the diameter of the eardrum. The wavelength of the sound wave and the diameter of the eardrum are approximately equal at this upper limit. If the relationship holds exactly, what is the diameter of the eardrum of a person capable of hearing 20 000 Hz? (Assume a body temperature of 37.0°C.)

Additional Problems

62. A typical sound level for a buzzing mosquito is 40 dB, and that of a vacuum cleaner is approximately 70 dB. Approximately how many buzzing mosquitoes will produce a sound intensity equal to that of a vacuum cleaner?

63. Assume a 150-W loudspeaker broadcasts sound equally in all directions and produces sound with a level of 103 dB at a distance of 1.60 m from its center. (a) Find its sound power output. If a salesperson claims the speaker is rated at 150 W, he is referring to the maximum electrical power input to the speaker. (b) Find the efficiency of the speaker, that is, the fraction of input power that is converted into useful output power.

64. Two small loudspeakers emit sound waves of different frequencies equally in all directions. Speaker A has an output of 1.00 mW, and speaker B has an output of 1.50 mW. Determine the sound level (in decibels) at point C in Figure P14.64 assuming (a) only speaker A emits sound, (b) only speaker B emits sound, and (c) both speakers emit sound.

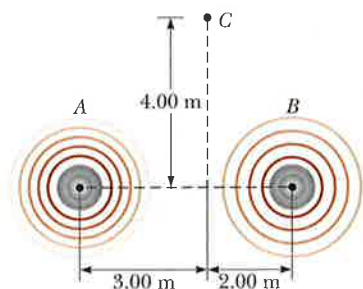


Figure P14.64

65. An interstate highway has been built through a neighborhood in a city. In the afternoon, the sound level in an apartment in the neighborhood is 80.0 dB as 100 cars pass outside the window every minute. Late at night, the traffic flow is only five cars per minute. What is the average late-night sound level?

66. A student uses an audio oscillator of adjustable frequency to measure the depth of a water well. He reports hearing two successive resonances at 52.0 Hz and 60.0 Hz. How deep is the well?

67. A stereo speaker is placed between two observers who are 36 m apart, along the line connecting them. If one observer records an intensity level of 60 dB, and the other records an intensity level of 80 dB, how far is the speaker from each observer?

68. **M** Two ships are moving along a line due east (Fig. P14.68). The trailing vessel has a speed relative to a land-based observation point of $v_1 = 64.0$ km/h, and the leading ship has a speed of $v_2 = 45.0$ km/h relative to that point. The two ships are in a region of the ocean where the current is moving uniformly due west at $v_{\text{current}} = 10.0$ km/h. The trailing ship transmits a sonar signal at a frequency of 1 200.0 Hz through the water. What frequency is monitored by the leading ship?



Figure P14.68

69. A quartz watch contains a crystal oscillator in the form of a block of quartz that vibrates by contracting and expanding. Two opposite faces of the block, 7.05 mm apart, are antinodes, moving alternately toward and away from each other. The plane halfway between these two faces is a node of the vibration. The speed of sound in quartz is 3.70×10^3 m/s. Find the frequency of the vibration. An oscillating electric voltage accompanies the mechanical oscillation, so the quartz is described as *piezoelectric*. An electric circuit feeds in energy to maintain the oscillation and also counts the voltage pulses to keep time.

70. A flowerpot is knocked off a window ledge from a height $d = 20.0$ m above the sidewalk as shown in Figure P14.70. It falls toward an unsuspecting man of height $h = 1.75$ m who is standing below. Assume the man below requires 0.300 s to respond to a warning. How close to the sidewalk can the flowerpot fall before it is too late for a warning shouted from the window to reach the man in time?

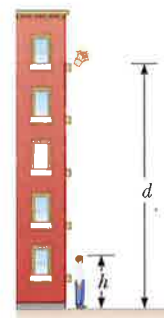


Figure P14.70

71. On a workday, the average decibel level of a busy street is 70 dB, with 100 cars passing

a given point every minute. If the number of cars is reduced to 25 every minute on a weekend, what is the decibel level of the street?

72. A flute is designed so that it plays a frequency of 261.6 Hz, middle C, when all the holes are covered and the temperature is 20.0°C . (a) Consider the flute to be a pipe open at both ends and find its length, assuming the middle-C frequency is the fundamental frequency. (b) A second player, nearby in a colder room, also attempts to play middle C on an identical flute. A beat frequency of 3.00 beats/s is heard. What is the temperature of the room?
73. A block with a speaker bolted to it is connected to a spring having spring constant $k = 20.0 \text{ N/m}$, as shown in Figure P14.73. The total mass of the block and speaker is 5.00 kg, and the amplitude of the unit's motion is 0.500 m. If the speaker emits sound waves of frequency 440 Hz, determine the (a) lowest and (b) highest frequencies heard by the person to the right of the speaker.

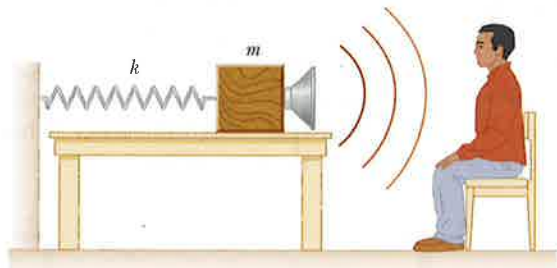


Figure P14.73

74. A student stands several meters in front of a smooth reflecting wall, holding a board on which a wire is fixed at each end. The wire, vibrating in its third harmonic, is 75.0 cm long, has a mass of 2.25 g, and is under a tension of 400 N. A second student, moving toward the wall, hears 8.30 beats per second. What is the speed of the student approaching the wall?
75. By proper excitation, it is possible to produce both longitudinal and transverse waves in a long metal rod. In a particular case, the rod is 150 cm long and 0.200 cm in radius and has a mass of 50.9 g. Young's modulus for the material is $6.80 \times 10^{10} \text{ Pa}$. Determine the required tension in the rod so that the ratio of the speed of longitudinal waves to the speed of transverse waves is 8.
76. A 0.500-m-long brass pipe open at both ends has a fundamental frequency of 350 Hz. (a) Determine the temperature of the air in the pipe. (b) If the temperature is increased by 20.0°C , what is the new fundamental frequency of the pipe? Be sure to include the effects of temperature on both the speed of sound in air and the length of the pipe.