EXERCISES

Conceptual Questions

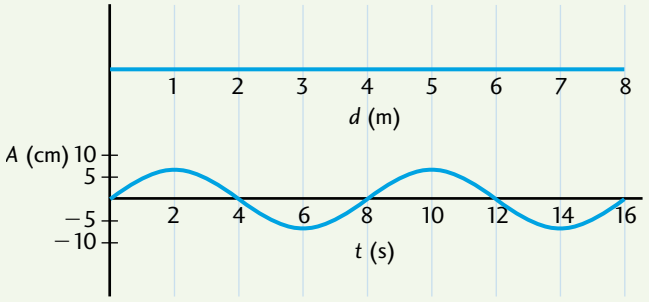
1. Why can't sound be a transverse wave when moving through air?
2. If all sound is produced by vibrating objects, do all vibrating objects produce sound?
3. If the speed of sound is 332 m/s, does a particle of air necessarily move at this speed?
4. Describe what causes the air to vibrate for common, everyday sounds.
5. As ice melts, what happens to the speed of sound passing through it?
6. If light travels forever in space, why does sound die off in air?
7. When a person inhales helium, his or her voice sounds high. There is a gas, SF_6, which, if inhaled, causes the voice to sound low. Explain how this effect occurs. (SF_6 gas is heavier than air, so it's not a good idea to try inhaling it because it will fill up your lungs and cause some breathing problems.)
8. Does a music note of frequency 440 Hz have the same wavelength in water as it does in air?
9. If you are in the water, what do you have to do to hear a beaver slap its tail twice? (Note: The beaver slapped its tail only once.)
10. How is the wavelength of sound affected as the temperature decreases?
11. How can air create a barrier that is "solid" enough to stop planes from penetrating?
12. When you snap a towel, a reasonably sharp "crack" is heard. For one brief moment, the end of the towel is moving at greater than the speed of sound. What causes the "crack"?
13. Can you tell how far away a plane is by observing it, then hearing the sound?
14. Does a pilot singing very loudly in a plane travelling at Mach 2 form a sound barrier in the cockpit? Can he hear his own singing?
15. Is 0 dB an absolute or a relative value?
16. Is it possible to have sounds with an intensity level of -1 dB?
17. In the Doppler effect, the assumption is that air is stationary. What complications arise if this isn't true?
18. When a racing car passes you, do you hear the Doppler effect if you also are moving but not as fast? Does the direction you are moving in make a difference to the sound you hear?
19. If you are moving in the same direction and with the same speed as an object generating a siren sound, will you hear the Doppler effect?
20. Account for the different shapes of ears of various animals to the role hearing plays in their lives.
21. If sound travels faster in solids than in air, why does wax buildup in the ear cause hearing problems?
22. Why is listening to Walkmans more harmful than listening to monster sound systems even though the power output of the monster systems is 50 times greater than that of the Walkman?

Problems

13.1 Introduction to Wave Theory

23. Use Fig. 13.42 to find
    a) the wavelength.
    b) the period.
    c) the amplitude.
    d) the peak-to-peak value (crest to trough).
    e) the frequency.

Fig. 13.42 For this problem, note that there are two different scales used (d(m) and t(s)).



24. A tuning fork's tines vibrate 250 times in 2.0 s. Find
    a) the frequency of vibration.
    b) the period of vibration.

25. There are six classes in one day. If all the classes take 6.5 hours each day, find the
    a) frequency of the classes occurring each day.
    b) period of the classes.

26. The frequency of a note is 440 Hz. Find the wavelength of the sound given that the speed of sound is
    a) 332 m/s. b) 350 m/s. c) 1225 km/h.

27. The frequency of a tuning fork is 1000 Hz. If the wavelength is 35 cm, find the speed of sound in
    a) m/s. b) km/h.

28. Gravity waves are still being searched for by astrophysicists. These waves travel at the speed of light ($c = 3.0 \times 10^8$ m/s). If the expected frequency is about 1600 Hz and the size of a football field is 250 m, how many football fields long is the wavelength of a gravity wave?

29. If $\frac{\lambda}{4}$ is 0.85 m and the frequency is 125 Hz, find
    a) the wavelength.
    b) the period of the wave.
    c) the velocity of the wave.

30. Find the period and velocity for the following frequencies if the wavelength is 0.50 m:
    a) 0.30 Hz b) 400 s^{-1}
    c) 30 cycles/s d) 5.0 kHz
    e) 102.1 MHz

31. Find the frequency and velocity given that the wavelength is 75 cm for the following periods:
    a) 0.020 s b) 15.0 ms
    c) 2.0 min d) 0.6 h

32. You are shouting in a monotone voice with a frequency of 440 Hz. Your friend is 300 m away. If the speed of sound is 344 m/s, how many wavelengths occur between you and your friend?

13.2 The Transmission and Speed of Sound

33. Calculate the time it would take for sound to travel through 2000 m of the following substances, given the velocity of sound through the substance:
    a) Helium (972 m/s)
    b) Water (1450 m/s)
    c) Steel (5130 m/s)
    d) Glass (4700 m/s)

34. Calculate the wavelength in the following substances if the frequency is 1000 s^{-1} and the speed of sound in the medium is given:
    a) Lead (1230 m/s)
    b) Hydrogen (1267 m/s)
    c) Water (5250 km/h)
    d) Air (1234 km/h)

35. Calculate the speed of sound in air for the following temperatures :
    a) 0°C b) 25°C
    c) 30°C d) −15°C

36. What is the wavelength of the sound produced by a bat if the frequency of the sound is 90 kHz on a night when the air temperature is 22°C?

37. How far away is a storm if you hear the sound of thunder 7.0 s after the lightning flash on a day when the air temperature is 31°C?

38. Determine the depth of water if an echo using sonar returns in 870 ms and the speed of sound in water is 5300 km/h.

39. If it takes 0.8 s for your voice to be heard at a distance of 272 m, what is the temperature of the air?

40. If you stand on top of a hill overlooking a lake and shout, how long is the lake if an echo is heard 2.0 s later on a day when the air temperature is 21°C?

41. The air temperature is 20°C. You are swimming underwater when you hear a boat noise. Then, 3.5 s later, you hear a crash. If the speed of sound in water is 1450 m/s, how long after the crash does your friend on the dock beside you hear the crash?

42. On a hot summer night (32°C), you are listening to a rock group in a stadium 350 m away. A friend of yours is sitting in an air-conditioned house across the country, listening to the broadcast on the radio. If the signal travels 30 000 km up to a satellite that retransmits it, who hears the concert first ($c = 3.0 \times 10^8$ m/s)?

43. How many times more wavelengths occur in air than in water for an air temperature of 10°C if the speed of sound in water is 5220 km/h and the frequency of sound is 500 Hz?

13.3 Mach Number and the Sound Barrier

44. Calculate the Mach number for the following speeds of sound. State whether the speed is subsonic or supersonic. Assume the speed of sound in air to be 332 m/s:
    a) 664 m/s
    b) 306 m/s
    c) 140 km/h
    d) 7171 km/h

45. Calculate the Mach number for sound, given the temperature and the speed:
    a) 332 m/s at 30°C
    b) 340 m/s at −10°C
    c) 6000 km/h at 13°C
    d) 6000 km/h at −13°C

46. How far has a plane travelled from the point at which you hear the sound of a sonic boom if the plane is travelling at Mach 2.2 at an altitude of 8000 m and the average air temperature for the sound is 15°C? It took 3.40 s to hear the sonic boom.

47. Assume you visit a world where the atmosphere is made of hydrogen (the planet is massive and holds onto this gas). Your spacecraft can fly at Mach 20 on Earth, as measured by sound at 5°C. On this planet, what is your Mach number if the speed of sound in hydrogen is 1 267 m/s?

48. What is the Mach number for a shuttle if it starts re-entry after travelling around Earth in 1.495 h at an orbital radius of 6.73×10^6 m? Assume that the air temperature is −30°C.

13.4 Sound Intensity

49. Given a sound intensity of 6.0×10^{-6} W/m^2, find the intensity at the following distances from the source:
    a) The distance from the source doubles.
    b) The distance from the source quadruples.
    c) The distance from the source is halved.
    d) The distance from the source decreases by a third.

50. At close proximity, rustling leaves have a sound intensity of about 1.2×10^{-11} W/m^2. At what distance is the sound at the threshold of hearing (1.0×10^{-12} W/m^2)?

51. If the surface area that sound travels through is 5.5 m^2 and the source produces a sound power of 3.0×10^{-3} W, find the intensity of the sound at the surface.

52. If the sound intensity drops to 4.8×10^{-5} W/m^2 in Problem 51,
    a) what area does the sound intercept?
    b) what is the ratio of sound intensities?
    c) how much farther has the sound travelled?

53. Find the logs of the following values:
    a) 100 b) 1000 c) 0.01
    d) 3.5×10^{-4} e) 5.67×10^{6}
    f) 1 g) 0

54. Given the log value, find the ratio $\left(\frac{I_2}{I_1}\right)$ that, when logged, produces the given quantity (take antilogs):
    a) 2 b) 6 c) -2
    d) -6 e) 3.5 f) 0.35

55. Knowing $\beta = 10 \log \frac{I_2}{I_1}$, how many times larger or smaller is I_2 compared to I_1 given that $\beta =$
    a) 1? b) 4? c) -1?
    d) -3? e) 2.5? f) 0.5?

56. How many times greater in intensity is the threshold of pain (120 dB) than
    a) normal conversation (60 dB)?
    b) a whisper (20 dB)?
    c) a rock concert (110 dB)?
    d) 30 m from a freight train (75 dB)?

57. At one point in the room, the sound intensity is 3.5×10^{-6} W/m^2. If you move twice the distance away, find
    a) the sound intensity at the new distance.
    b) the decibel difference between the intensities.

58. A hearing aid increases the sound intensity level, thereby allowing a person to hear better. For the following decibel increases, by how much does the intensity of sound increase?
    a) 30 dB b) 22 dB c) 18.9 dB

59. A refrigerator lightbulb uses 25 W of power. A jack hammer produces a sound intensity of 110 dB. How many jack hammers would you need so that the sound power could light one lightbulb, assuming 100% conversion of sound energy?

60. A rock concert produces sounds at 120 dB, measured 2.0 m away. How far back should you be in order to listen to the music at 100 dB?

61. A person has a threshold of hearing of 5 dB. Another person has a threshold of hearing of 25 dB. Which person has better hearing and by how much?

62. You and your friend have bought stereo systems. Your stereo has a signal-to-noise ratio of 50 dB, your friend's stereo has a signal-to-noise ratio of 60 dB. Who has the better system and by what factor?

63. If you could add the intensities of conversations between two people (65 dB), how many of them would you need to duplicate the sound intensity of a rock concert (120 dB)?

13.5 Doppler Effect

64. A siren emits a sound at 1700 Hz. Assume a speed of sound of 332 m/s. What frequency would a stationary observer hear if the car with the siren is travelling at
    a) 25 m/s toward the observer?
    b) 25 m/s away from the observer?
    c) 140 km/h toward the observer?

65. Repeat Problem 64, assuming an air temperature of 30°C.

66. How fast is a car moving and in what direction if the frequency of its horn drops from 900 Hz to 875 Hz, as heard by a stationary listener? The air temperature is 0°C.

67. As a racing car zooms by you, its pitch decreases by 20%. If the speed of sound is 345 m/s, how fast is the car travelling?

68. The sound of a racing car has its pitch decrease by 10%. If the temperature of the air is 22°C, how fast is the car travelling?

69. Two people hear the 1700 Hz siren of an ambulance. One person is in front and the other person is behind the ambulance. If the ambulance is travelling at 120 km/h, what is the difference in frequencies heard by the two people? Assume the speed of sound to be 333 m/s.

70. Refer to Fig 13.31. Find the apparent frequency a person moving at 30 m/s hears if she is moving
    a) toward a stationary siren with frequency 1800 Hz.
    b) away from a stationary siren with frequency 1800 Hz.

71. Repeat Problem 70 for a siren moving at 30 m/s and a stationary listener.