Chapter 3: Sound waves

Sound waves

1. Sound travels at 340 m/s in air and 1500 m/s in water. A sound of 256 Hz is made under water. In the air,
   A) the frequency remains the same but the wavelength is shorter.
   B) the frequency is higher but the wavelength stays the same.
   C) the frequency is lower but the wavelength is longer.
   D) the frequency is lower and the wavelength is shorter.
   E) both the frequency and the wavelength remain the same.

2. The speed of sound in air at 0°C is 331 m/s. What is the speed of sound in air at –40°C?
   A) 241 m/s   B) 282 m/s   C) 306 m/s   D) 309 m/s   E) 379 m/s

3. The curve that represents the speed of sound in a gas plotted against the kelvin temperature is
   A) 1   B) 2   C) 3   D) 4   E) 5

4. A stationary ship generates a sound signal at the bow and has a receiver system at the stern of the ship 100 m away. The signal arriving at the stern travelling directly through the air and the signal reflected from the sea bottom arrive at the sensor at the same time. If the velocity of sound in air is 331 m/s and in water is 1435 m/s, calculate the depth of water below the ship.
   A) 434 m   B) 422 m   C) 217 m   D) 211 m   E) 192 m
5. A sound pulsar unit puts out short sound bursts at constant time intervals. This unit also has a receiver to listen to the time delay from an echo from any objects or walls. If the unit is positioned such that the echo time corresponds to the sound burst interval of 0.6 s, find the distance to the reflecting wall. (Velocity of sound in air = 331 m/s)
   A) 150 m  B) 50.0 m  C) 200 m  D) 100 m  E) None of the above

6. The sound intensity in front of a loudspeaker diaphragm vibrating at 2 kHz is 4.3 W/m², with an acoustic power output of 0.3 W. Calculate the diameter of the diaphragm.
   A) 3 cm  B) 9 cm  C) 15 cm  D) 30 cm  E) 60 cm

7. A train traveling at 90 km/h is blowing its whistle at 440 Hz as it crosses a level crossing. You are waiting at the crossing and hear the pitch of the whistle change as the train passes you. The sound you hear changes from a frequency of _____ to a frequency of _____. (Take the speed of sound to be 340 m/s.)
   A) 475 Hz; 410 Hz  D) 472 Hz; 408 Hz
   B) 410 Hz; 475 Hz  E) 598 Hz; 348 Hz
   C) 408 Hz; 472 Hz

8. Car A moves at speed \( v \) toward car B, which is at rest. The frequency of car A's horn is observed by car B to be \( f \). What is the frequency of car A's horn as heard by an observer in car B if car A is at rest and car B moves at speed \( v \) toward car A? (Assume there is no wind.)
   A) \( f \)  D) either greater than or less than \( f \)
   B) greater than \( f \)  E) \( 2f \)
   C) less than \( f \)

9. The frequency of a car horn is \( f \). What frequency is observed if both the car and the observer are at rest, but a wind is blowing toward the observer?
   A) \( f \)  B) greater than \( f \)  C) less than \( f \)  D) either greater or less than \( f \)
   E) far greater than \( f \), depending on how wind speed compares with the speed of sound

10. A passenger car traveling due east at 53.6 m/s passes a truck traveling due east at 13.4 m/s. After the car passes, the horn on the truck is blown at a frequency of 350 Hz. The speed of sound in air is 335 m/s. The frequency heard by the driver of the car is
    A) 290 Hz  B) 306 Hz  C) 314 Hz  D) 400 Hz  E) 434 Hz
11. A woman drives toward the face of a cliff at 26.8 m/s. She sounds a burst on her 500-Hz car horn and then listens for the echo. Assuming 313 m/s to be the speed of sound, the woman hears an echo frequency of

A) about 595 Hz  
B) about 545 Hz  
C) exactly 500 Hz

d) about 460 Hz  
e) exactly 1000 Hz

12. A sound source of frequency $f$ moves with constant velocity (less than the speed of sound) through a medium that is at rest. A stationary observer hears a sound whose frequency is appreciably different from $f$ because

A) the equation that relates velocity of propagation, frequency, and wavelength of a sound traveling through a medium does not apply in this situation.  
B) the sound wave travels through the medium with a velocity different from that which it would have if the source were at rest.  
C) the frequency of the source is changed because of its motion.  
D) the wavelength established in the medium is not the same as it would be if the source were at rest.  
e) interference effects set up a standing-wave pattern that alters the frequency.

13. A locomotive moving at a constant speed approaches and then passes a man standing at a crossing. The frequency of the locomotive's horn as the man hears it

A) gradually increases and then decreases.  
B) gradually decreases and then increases.  
C) abruptly changes as the locomotive passes.  
D) does not change at all.  
e) produces beats due to the Doppler effect.

14. A jet engine emits a whine of frequency 3000 Hz. When the engine is moving directly away from an observer at half the speed of sound, an observer hears a frequency of

A) 1000 Hz  
B) 1500 Hz  
C) 2000 Hz  
D) 4500 Hz  
e) 6000 Hz
15. The object shown in the figure is
A) traveling from 2 toward 4. D) traveling from 4 toward 2.
B) traveling from 3 toward 1. E) not in motion.
C) traveling from 1 toward 3.

16. The angle of the shock wave produced by a jet traveling at Mach 2 at an altitude of 3000 m (assume the speed of sound to be 340 m/s at this altitude) is approximately
A) 30º B) 40º C) 50º D) 60º E) 80º

17. A police car siren emits a sound at 600 Hz. If an observer moves toward the source at 50 km/hr, and the police car approaches the observer at 100 km/hr (all speeds relative to the road), calculate the siren frequency heard by the driver of the police car. (Assume the speed of sound in air = 343 m/s.)
A) 626 Hz B) 600 Hz C) 679 Hz D) 577 Hz E) 970 Hz

18. An observer is standing on the platform of a railway station. A train goes through the station without stopping. If the frequency of the train whistle decreases by a factor of 1.2 as it approaches and then passes him, calculate the speed of the train. (Assume the speed of sound in air = 343 m/s.)
A) 112 km/hr B) 31.2 km/hr C) 56.0 km/hr D) 62.0 km/hr E) 122 km/hr
19. Tuning fork A has a frequency of 440 Hz. When A and a second tuning fork B are struck simultaneously, four beats per second are heard. When a small mass is added to one of the tines of B, the two forks struck simultaneously produce two beats per second. The original frequency of tuning fork B was
   A) 448 Hz   B) 444 Hz   C) 438 Hz   D) 436 Hz   E) 432 Hz

20. The air columns in two identical pipes vibrate at frequencies of 150 Hz. The percentage of change needed in the length of one of the pipes to produce 3 beats per second is
   A) 1%   B) 2%   C) 3%   D) 4%   E) 5%

21. Two loudspeakers $S_1$ and $S_2$, 3.0 m apart, emit the same single-frequency tone in phase at the speakers. A listener L directly in front of speaker $S_1$ notices that the intensity is a minimum when she is 4.0 m from that speaker (see figure). What is the lowest frequency of the emitted tone? The speed of sound in air is 340 m/s.
   A) 85 Hz   B) 0.17 kHz   C) 0.26 kHz   D) 0.34 kHz   E) 0.51 kHz

22. Two loudspeakers $S_1$ and $S_2$, 3.0 m apart, emit the same single-frequency tone in phase at the speakers. A listener directly in front of speaker $S_1$ notices that the intensity is a minimum when she is 4.0 m from that speaker (see figure). The listener now walks
around speaker $S_1$ in an arc of a circle, staying 4.0 m from that speaker but increasing her distance from the other speaker. How far is she from speaker $S_2$ when she notices the first maximum in the sound intensity? The speed of sound in air is 340 m/s.
A) 4.5 m    B) 5.0 m    C) 5.5 m    D) 6.0 m    E) 6.5 m

23. Two whistles produce sounds with wavelengths 3.40 m and 3.30 m. What is the beat frequency produced? (The speed of sound is 340 m/s.)
A) 0.1 Hz    B) 1.0 Hz    C) 2.0 Hz    D) 3.0 Hz    E) 4.0 Hz

24. Middle C on a piano has a frequency of 262 Hz. Sometimes it is said that middle C is actually $2^8 = 256$ Hz, and tuning forks are made with this frequency. How many beats per second would be heard if such a tuning fork were sounded simultaneously with the middle C of a (well-tuned) piano?
A) 3    B) 6    C) 12    D) 4    E) 8

25. A violinist is tuning the A string on her violin by listening for beats when this note is played simultaneously with a tuning fork of frequency 440 Hz. She hears a beat frequency of 4 Hz. She notices that, when she increases the tension in the string slightly, the beat frequency decreases. What was the frequency of the mistuned A string?
A) 448 Hz    B) 444 Hz    C) 436 Hz    D) 432 Hz    E) 438 Hz

26. Two trumpet players are both playing a pitch with a frequency of 440 Hz, corresponding to the musical pitch A above middle C. However, one of the trumpet players is marching away from you so that you hear a beat frequency of 4 Hz from the two trumpets. With what speed is the departing trumpet player moving away from you? (The speed of sound in air is 340 m/s.)
A) 3.12 m/s    B) 3.09 m/s    C) 3.06 m/s    D) 3.00 m/s    E) 2.95 m/s

27. When a piano tuner strikes both the A above middle C on the piano and a 440 Hz tuning fork, he hears 4 beats each second. The frequency of the piano’s A is
A) 440 Hz    B) 444 Hz    C) 880 Hz    D) 436 Hz    E) either 436 Hz or 444 Hz
28. Two tones of equal amplitude but slightly different frequencies are emitted by a sound source. This gives rise to
A) standing waves.  
B) destructive interference.  
C) constructive interference.  
D) beats.  
E) amplification.

29. One source of sound is at A and another is at B. The two sources are in phase. The distance AB = 10.0 m. The frequency of the sound waves from both sources is 1000 Hz, and both have the same amplitude. The speed of sound in air is 330 m/s. A receiver is at point C, and AB is perpendicular to AC. The greatest distance AC for which the signal at C is a minimum is
A) 33.0 cm  
B) 152 m  
C) 330 m  
D) 303 m  
E) 100 m

30. Two speakers face each other at a distance of 1 m and are driven by a common audio oscillator. A first minimum in sound intensity is found 16.1 cm from the midpoint. If the velocity of sound is 330 m/s, find the frequency of the oscillator.
A) 256 Hz  
B) 1024 Hz  
C) 512 Hz  
D) 341 Hz  
E) 683 Hz

31. Of the sound sources shown, that which is vibrating with its first harmonic is
A) the whistle.  
B) the organ pipe.  
C) the vibrating string.  
D) the vibrating rod.  
E) None of these is correct.
32. Of the sound sources shown, that which is vibrating with its first harmonic is the
A) whistle.  D) vibrating rod.
B) organ pipe.  E) vibrating spring.
C) vibrating string.

33. When an organ pipe, which is closed at one end only, vibrates with a frequency that is
three times its fundamental (first harmonic) frequency,
A) the sound produced travels at three times its former speed.
B) the sound produced is its fifth harmonic.
C) beats are produced.
D) the sound produced has one-third its former wavelength.
E) the closed end is a displacement antinode.

34. The air in a closed organ pipe vibrates as shown. The length of the pipe is 3.0 m. The
frequency of vibration is 80 Hz. The speed of sound in the pipe is approximately
A) 80 m/s  B) 0.16 km/s  C) 0.24 km/s  D) 0.32 km/s  E) 0.96 km/s
35. A vibrating tuning fork of frequency 640 Hz is held above a tube filled with water. Assume the speed of sound to be 330 m/s. As the water level is lowered, consecutive maxima in intensity are observed at intervals of about
   A) 12.9 cm     B) 19.4 cm     C) 25.8 cm     D) 51.7 cm     E) 194 cm

36. A vibrating tuning fork of frequency 1080 Hz is held above a tube filled with water. Assume the speed of sound to be 330 m/s. As the water level is lowered, consecutive maxima in intensity are observed at intervals of about
   A) 7.65 cm     B) 15.3 cm     C) 23.0 cm     D) 30.6 cm     E) 53.6 cm

37. The air column in an organ pipe, which is closed at one end, is vibrating in such a way as to produce the second harmonic. A pressure node and displacement node, respectively, occur at
   A) 1 and 3.     B) 1 and 5.     C) 7 and 4.     D) 7 and 5.     E) 5 and 3.

38. In a pipe that is open at one end and closed at the other and that has a fundamental frequency of 256 Hz, which of the following frequencies cannot be produced?
   A) 768 Hz     D) 19.7 kHz
   B) 1.28 kHz     E) All of these can be produced.
   C) 5.12 kHz

39. The fundamental frequency of a pipe that has one end closed is 256 Hz. When both ends of the same pipe are opened, the fundamental frequency is
   A) 64.0 Hz     B) 128 Hz     C) 256 Hz     D) 512 Hz     E) 1.02 kHz
40. The standing waves in air in a pipe of length $L$ that is open at both ends have a speed $v$. The frequencies of the three lowest harmonics are
A) $v/L$, $2v/L$, and $3v/L$  
B) $v/2L$, $v/L$, and $3v/2L$  
C) $\lambda/2$, $\lambda$, and $3\lambda/2$  
D) $L/v$, $2L/v$, and $3L/v$  
E) $\lambda/3$, $2\lambda/3$, and $3\lambda/3$

41. The standing waves in air in a pipe of length $L$ that is open at one end and closed at the other have a speed $v$. The frequencies of the three lowest harmonics are
A) $v/4L$, $v/2L$, and $3v/4L$  
B) $v/2L$, $v/L$, and $3v/2L$  
C) $\lambda/4$, $\lambda/2$, and $3\lambda/4$  
D) $v/4L$, $3v/4L$, and $5v/4L$  
E) $\lambda/3$, $2\lambda/3$, and $3\lambda/3$

42. The human vocal tract can be thought of as a tube that is open at one end. If the length of this tube is 17 cm (about average for an adult male), what are the lowest two harmonics?
A) 500 Hz, 1500 Hz  
B) 500 Hz, 1000 Hz  
C) 1000 Hz, 2000 Hz  
D) 1000 Hz, 3000 Hz  
E) 1500 Hz, 2500 Hz

43. For a tube of length 57.0 cm that is open at both ends, what is the frequency of the fundamental mode? (The speed of sound in air is 340 m/s.) 
A) 149 Hz  
B) 447 Hz  
C) 596 Hz  
D) 298 Hz  
E) 746 Hz

44. A clarinet, which is essentially a tube that is open at one end, is properly tuned to concert A (440 Hz) indoors, where the temperature is 20ºC and the speed of sound is 340 m/s. The musician then takes the instrument to play an outdoor concert, where the temperature is 0ºC and the speed of sound is 331 m/s. What is the frequency of the A played on the cold clarinet? (Ignore any thermal changes in the body of the clarinet itself.) 
A) 417 Hz  
B) 428 Hz  
C) 434 Hz  
D) 445 Hz  
E) 451 Hz

45. Sound has a velocity of 335 m/s in air. For an air column that is closed at both ends to resonate to a frequency of 528 Hz, the length of the air column could be
A) 79.2 cm  
B) 55.5 cm  
C) 47.5 cm  
D) 31.7 cm  
E) 15.8 cm
46. The sound wave in an organ tube has a wavelength that is equal to the distance between
A) A and B.  D) the antinodes farthest apart.
B) A and C.  E) None of these is correct.
C) the nodes farthest apart.

47. The third harmonic of a tube closed at one end is 735 Hz. If the speed of sound in air is 335 m/s, the length of the tube must be
A) 11.6 cm  B) 22.9 cm  C) 34.1 cm  D) 45.7 cm  E) 57.3 cm

48. The ratio of the fundamental frequency (first harmonic) of an open pipe to that of a closed pipe of the same length is
A) 2:1  B) 7:8  C) 4:5  D) 3:2  E) 1:2

49. The wave function $y(x,t)$ for a standing wave on a string fixed at both ends is given by $y(x,t) = 0.080 \sin 6.0x \cos 600t$ where the units are SI. The amplitudes of the traveling wave that result in this standing wave are
A) 0.04 m  B) 0.08 m  C) 0.02 m  D) 0.16 m  E) impossible to tell given this information about the standing wave.
50. A vibrating tuning fork is held above a tube filled with water. The first two resonances occur when the water level is lowered by 14.2 cm and 44.2 cm from the top of the tube. If there is a small end correction that adds a small extra length ΔL to the effective length of the air column, calculate the frequency of the tuning fork. Assume the speed of sound to be 330 m/s.

A) 560 Hz  
B) 581 Hz  
C) 550 Hz  
D) 1100 Hz  
E) 1120 Hz

51. A vibrating tuning fork of 850 Hz is held above a tube filled with water. The first and third resonances occur when the water level is lowered by 8.8 cm and 47.6 cm from the top of the tube. If there is a small end correction that adds a small extra length ΔL to the effective length of the air column, calculate ΔL. Assume the speed of sound to be 330 m/s.

A) 0.2 cm  
B) 0.9 cm  
C) 0.4 cm  
D) 0.6 cm  
E) 1.1 cm

52. A vibrating tuning fork of 725 Hz is held above a tube filled with water. Successive resonances are heard when the water level is lowered by 11.5 cm and 34.5 cm from the top of the tube. Calculate a value for the speed of sound. (Hint: remember the small end correction ΔL at the top of the tube.)

A) 333 m/s  
B) 343 m/s  
C) 325 m/s  
D) 315 m/s  
E) 338 m/s

53. Two pipes closed at one end of length L₁ and L₂ are excited at their resonant frequencies. If the beat period is B Hz, then the velocity of sound is given by:

A) \( B_f \times L_1 \times L_2 / (4L_1 - 4L_2) \)  
B) \( 4 \times B_f \times L_1 \times L_2 / (4L_1 - 4L_2) \)  
C) \( 16 \times B_f \times L_1 \times L_2 / (4L_1 + 4L_2) \)  
D) \( 4 \times B_f \times L_1 \times L_2 / (L_1 - L_2) \)  
E) \( 4 \times B_f \times L_1 \times L_2 / (L_1 + L_2) \)

54. A guitar string of length 105 cm is in resonance with a tuning fork of frequency \( f \). Using the fret board the length of the string is shortened by 1.5 cm while keeping the tension in the string constant. Now a beat frequency of 10 Hz is heard between the string and the tuning fork. What is the frequency of the tuning fork?

A) 230 Hz  
B) 1380 Hz  
C) 345 Hz  
D) 690 Hz  
E) None of the above

55. What is the third harmonic of an open-both-ends organ pipe of length 1.5 m? Assume the speed of sound to be 340 m/s.

A) 229 Hz  
B) 340 Hz  
C) 457 Hz  
D) 686 Hz  
E) None of the above

56. A piano tuner hears a beat every 0.33 seconds when he hits a note and compares it to his reference tone at 163 Hz. What is the lowest possible frequency of the piano note?

A) 44.9 Hz  
B) 166.0 Hz  
C) 162.7 Hz  
D) 163.3 Hz  
E) 160.0 Hz

57. Two identical loudspeakers are driven in phase by the same amplifier. The speakers are positioned a distance of 3.2 m apart. A person stands 4.1 m away from one speaker and
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4.8 m away from the other. Calculate the second lowest frequency that results in destructive interference at the point where the person is standing. Assume the speed of sound to be 340 m/s.
A) 245 Hz     B) 735 Hz     C) 1225 Hz     D) 490 Hz     E) 1470 Hz

58. A pipe produces successive harmonics at 300 Hz and 350 Hz. Calculate the length of the pipe and state whether it is closed at one end or not. Assume the speed of sound to be 340 m/s.
A) 1.7 m closed one end
B) 3.4 m open both ends
C) 4.0 m closed one end
D) 8.0 m closed one end
E) 4.0 m open both ends

59. The reason we can tell the difference between a trumpet and a clarinet when they both play the same pitch is that they have
A) the same overtones.     D) different waveforms.
B) the same harmonics.     E) harmonic syntheses.
C) different fundamental frequencies.

60. An examination of this frequency spectrum allows you to conclude that
A) the odd harmonics 1 through 19 are present in the composite wave.
B) the even harmonics 2 through 20 are present in the composite wave.
C) the amplitudes of the component waves are equal.
D) the wave form is a simple sinusoid.
E) None of these is correct.

61. In any wave motion, dependence of velocity on wavelength is called
A) polarization  B) diffraction  C) deviation  D) scattering  E) dispersion
# Answers

1) A  
2) C  
3) B  
4) D  
5) D  
6) D  
7) A  
8) C  
9) A  
10) B  
11) A  
12) D  
13) C  
14) C  
15) C  
16) A  
17) B  
18) A  
19) B  
20) B  
21) B  
22) B  
23) D  
24) B  
25) C  
26) A  
27) E  
28) D  
29) D  
30) C  
31) E  
32) A  
33) D  
34) D  
35) C  
36) B  
37) D  
38) C  
39) B  
40) B  
41) D  
42) A  
43) D  
44) B  
45) D  
46) D  
47) C  
48) A  
49) A  
50) C  
51) B  
52) A  
53) D  
54) D  
55) B  
56) E  
57) B  
58) B  
59) D  
60) A  
61) E