CHAPTER 17

Sound Waves

- Sound waves
- Interference of sound waves
- Intensity & level
- Resonance in tubes
- Doppler effect

*If the speed of sound in air is not given in the problem, take it as 343 m/s.*

1. A pipe has two consecutive resonant frequencies of 600 Hz and 1000 Hz. One end of the pipe is closed. What is the fundamental frequency of the pipe? (Ans: 200 Hz)

2. Two identical loudspeakers, facing each other, are in phase and each has a frequency of 85 Hz. A man initially at the midpoint between the two loudspeakers moves slowly toward one of them until he hears the first minimum in sound. How far did he move? [The speed of sound in air = 340 m/s] (Ans: 1.0 m)

3. If it were possible for a man to move with the speed of sound directly toward a stationary whistle emitting a sound of frequency $f$, what frequency would he hear? (Ans: $2f$)

4. Two speakers $S_1$ and $S_2$ are placed on the y-axis as shown in figure 1. The speakers are in phase and emit identical sound waves with a given frequency. An observer, standing at point A, hears a sound of maximum intensity. As the observer moves along a straight line parallel to the y-axis and reaches point B, he hears the first minimum of sound intensity. What is the frequency of sound emitted by the speakers? (Ans: 121 Hz)

5. A stationary train passenger hears a frequency of 520 Hz as a train approaches a bell on a trackside safety gate. After the train passes the gate, the passenger hears a frequency of 480 Hz for the bell sound. What is the speed of the train? (Ans: 13.7 m/s)

6. The intensity of a certain sound wave is 6 mW/cm². If its sound level is raised by 10 decibels, what is the new intensity? (Ans: 60 mW/cm²)

7. If the speed of sound is 340 m/s, what are the two lowest resonance frequencies of a 0.5-m organ pipe, closed at one end? (Ans: 170 and 510 Hz)

8. In figure 2, two speakers are driven by the same generator and are a distance of 1.0 m apart. The speakers emit sound waves at a frequency of 686 Hz that are in phase. A listener starts at A and moves toward B. What will be the distance from A of the first point at which he will observe constructive interference? (Ans: 0.25 m)

9. A standing wave is set up in an air-filled tube that is closed at one end. The standing wave has two nodes and the frequency of oscillation is 230 Hz. What is the length of the tube? (Ans: 1.1 m)

10. The average output power of a speaker is 550 W. The sound level that reaches to a detector is 105 dB, how far is the detector from the source? (Ans: 37 m)
11. A stationary policeman sends a sound wave of frequency 550 Hz towards a car approaching him. The reflected frequency detected by the policeman is 620 Hz. What is the speed of the car? (Ans: 20 m/s)

12. A 2.5-m long tube, open at both ends, is filled with a gas. The frequency of a certain harmonic is 500 Hz and the frequency of the next harmonic is 600 Hz. What is the speed of sound in the tube? (Ans: 500 m/s)

13. The intensity of a sound wave, of frequency 360 Hz, is $1.6 \times 10^{-6}$ W/m². If the speed of sound in air is 343 m/s, what is the displacement amplitude of the air molecules oscillation caused by this wave? ($\rho_{air} = 1.21$ kg/m³). (Ans: $3.88 \times 10^{-8}$ m)

14. A person is listening to sounds from two different sources simultaneously. One source has sound level of 80 dB, while the other has 90 dB. What combined sound level will the person hear? (Ans: 90.4 dB)

15. Two trucks are heading straight toward each other with the same speed $V$. The horn of one truck, with frequency $f_s = 3000$ Hz, is blowing, and is heard to have a frequency of 3200 Hz by the people in the other truck. Find $V$ if the speed of sound is 340 m/s. (Ans: 11 m/s)

16. Sound waves of frequency 340 Hz are sent into the top of a vertical tube containing water, as shown in the figure 3. If standing waves are produced, as shown, what is the height level of the water? [speed of sound in air = 340 m/s] (Ans: 35 cm)

17. A man strikes one end of a long steel pipe of length $L$, filled with water, by a hammer. A detector attached to the other end of the pipe receives two sounds signals, one from the wave that travels through the pipe and the other from the wave that travels through the water. If the time difference between the two wave signals is 0.02 s, what is the length of the pipe? [speeds of sound in steel and water are $v_s = 5940$ m/s and $v_w = 1480$ m/s, respectively] (Ans: 39 m)

18. The intensity of a sound wave is $10^{-7}$ W/m² at a distance of 30.0 m from a speaker emitting sound waves at a frequency of $2.0 \times 10^3$ Hz. What is the sound level at a distance of 50.0 m from the speaker? (Ans: 46 dB)

19. A truck emits sound with frequency 620 Hz. A person is riding a bike that moves at a speed of 3.0 m/s and is following the truck. If the person hears a frequency of 560 Hz, how fast is the truck moving? (Ans: 40 m/s)

20. A pipe open at both ends has a fundamental frequency of 400 Hz. What will be the fundamental frequency if the pipe is closed at one end? [speed of sound in air = 340 m/s] (Ans: 200 Hz)

21. The sound level of a certain sound source is increased by 40 dB. By what factor is the displacement amplitude increased? (Ans: 100)

22. A stationary person hears a frequency of 800 Hz of an ambulance siren moving at a speed of 60 m/s towards him. What frequency will he hear when the ambulance is moving away from him with the same speed. [speed of sound in air = 340 m/s] (Ans: 560 Hz)

23. Two speakers are separated by a distance of 3.6 m. A listener is standing in front of one speaker at a distance of 6 m, as shown in figure 4. The transmitted sound waves by both speakers are in phase and are in the audible range. What is lowest frequency at which a listener will hear a minimum intensity? [speed of sound in air = 340 m/s] (Ans: 170 Hz)

24. The maximum pressure amplitude $\Delta P_m$ that the human ear can tolerate is about 30 N/m². If the maximum displacement $S_m$ is $1.3 \times 10^{-5}$ m, find the frequency of the corresponding sound. [$\rho = 1.2$ kg/m³, speed of sound = 340 m/s] (Ans: 900 Hz)
25. Two speakers face each other and emit sound waves in air with a frequency of 500 Hz, as shown in figure 5. The phase difference between the sound waves emitted by the two speakers at point \( A \) is 2.35 radians. What is the distance between \( A \) and \( S_2 \)? (Ans: 0.756 m)

26. A police car is moving at a speed of 30 m/s. Its siren emits a sound at frequency of 600 Hz. As the car approaches a large wall, what is the frequency of the sound heard by the driver of the police car? (Ans: 716 Hz)

27. In a liquid having density \( 1.30 \times 10^3 \) kg/m\(^3\), longitudinal waves with frequency 400 Hz are found to have a wavelength of 8.0 m. Calculate the bulk modulus of the liquid. (Ans: \( 1.33 \times 10^{10} \) Pa)

28. An ambulance emits sound of frequency 300 Hz and is moving with a speed of 45.0 m/s away from a moving car. If the car is moving towards the ambulance with a speed of 15.0 m/s, what frequency does a person in the car hear? (Ans: 277 Hz)

29. The frequency of the fundamental mode of a sound wave in a 30.0-cm long tube closed at one end is 256 Hz. When the tube length is shortened to 12.0-cm, what is the new fundamental frequency? (Ans: 640 Hz)

30. In figure 6, two speakers, \( A \) and \( B \), are driven by the same oscillator at a frequency of 170 Hz and face each other at a distance of 2.0 m. What is the number of minima along the line joining the sources? [Consider only the nodes between the sources, and take the speed of sound = 340 m/s] (Ans: 2)

31. The intensity of sound wave \( A \) is 800 times that of sound wave \( B \) at a fixed point from both sources. If the sound level of sound wave \( A \) is 110 dB, what is the sound level of wave \( B \)? (Ans: 81 dB)

32. In figure 7, two small identical speakers are connected (in phase) to the same source. The speakers are 4.10 m apart and at ear level. An observer stands at \( X \), 8.00 m in front of one speaker. In the frequency range 200 Hz-500 Hz, what frequency will result in the most intense sound? (Ans: 346 Hz)

33. Two transmitters, \( S_1 \) and \( S_2 \), shown in figure 8, emit identical sound waves of wavelength \( \lambda \). The transmitters are separated by a distance \( \lambda/2 \). Consider a big circle of radius \( R \) with its center halfway between these transmitters. How many interference maxima are there on this big circle? (Ans: 2)

34. Organ pipe \( A \), with both ends open, has a fundamental frequency of 340 Hz and length 0.4 m. The third harmonic of organ pipe \( B \), with one end open, has the same frequency as the second harmonic of pipe \( A \). How long is pipe \( B \)? (Ans: 0.3 m)

35. If an observer’s distance from a point source is doubled, what will be the change in sound level? (Ans: decrease by 6 dB)

36. In an air pipe, closed at one end, the three successive resonance frequencies are 425 Hz, 595 Hz, and 765 Hz. If the speed of sound in air is 340 m/s, what is the length of the pipe? (Ans: 1.0 m)

37. A sinusoidal sound wave is described by the displacement \( S(x,t) = (2.00 \times 10^{-4}) \cos \left( 1.25 x - 1850 t \right) \), where \( x \) is in meters and \( t \) is seconds. What is the pressure amplitude of this wave if it is traveling in a material with a bulk modulus of \( 2.10 \times 10^9 \) N/m\(^2\)? (Ans: 52.5 Pa)

38. Two sound waves, from two different sources with the same frequency, 540 Hz, travel in the same direction at 344 m/s. The sources are in phase. What is the phase difference between the waves at a point that is 4.40 m from one source and 4.00 m from the other source? (Ans: 3.95 rad)

39. Two point sources \( S_1 \) and \( S_2 \) are placed on the \( y \)-axis as shown in figure 9. The two sources are in phase and emit identical sound waves with frequency 860 Hz. An observer starts at point \( A \) and moves to point \( B \) along a straight line parallel to the \( y \)-axis. How many points of maximum intensity (constructive interference) will he observe? [speed of sound in air = 344 m/s] (Ans: 5)
40. A sound source located at the origin emits sound with an average power of 0.04 W. Two detectors are located on the positive x-axis. Detector A is at \( x = 3.0 \) m and detector B is at \( x = 5.0 \) m. What is the difference in sound level between A and B? (Ans: 4.4 dB)

41. A tube 1.5 m long is closed at one end. A stretched wire is placed near the open end, see figure 11. The wire is 0.33 m long and has a mass of 9.8 g. It is fixed at both ends and vibrates in its fundamental mode. By resonance, it sets the air column in the tube into oscillation at that column's fundamental frequency. Find the tension in the wire. (Ans: 42 N)

42. If the distance from a source of sound increases by 1 meter, the sound level is decreased by 2 dB. Assume the loudspeaker that is emitting this sound emits sound in all directions. What is the original distance from the sound source? (Ans: 3.86 m)

43. An ambulance siren emits a sound of frequency 1.60 kHz. A person running with a speed of 2.50 m/s hears a frequency of 1.70 kHz as the ambulance approaches him from the back. How fast is the ambulance moving? [speed of sound is 340 m/s] (Ans: 22.4 m/s)

44. Two speakers are driven by a common oscillator and face each other at a distance of 1.500 m. A man is standing at 0.700 m from one of the speakers along the line joining the two speakers. What is the highest frequency of the oscillator, within the audible range (20.0 Hz to 20.0 kHz), so that the man hears a minimum sound? [speed of sound = 343 m/s] (Ans: 18.9 kHz)

45. A stationary device generates sound waves of unknown frequency. An observer hears a frequency of 825 Hz as he approaches the device with a speed of 16 m/s. He hears a frequency of 750 Hz as he moves away from the device with the same speed. Find the speed of sound from the above information. (Ans: 336 m/s)

46. Two identical speakers, facing each other are driven by a common oscillator of frequency 600 Hz. A man, at the midpoint between the speakers, starts moving toward one of them. He reaches the first minimum sound when he is 1.0 m from one of the speakers. Find the distance between the speakers. (Ans: 2.3 m)

47. The form of a sound wave travelling through air is \( S(x,t) = S_m \cos (kx + 3000t + \phi) \), where \( x \) is in meters and \( t \) in seconds. What is the shortest time interval that any air molecule takes along the path to move between displacements \( S = +S_m/3 \) and \( S = -S_m/3 \)? (Ans: 0.23 ms)

48. A tuning fork with a frequency of 510 Hz is placed at the open end of an air column that is closed at the other end. What is the shortest length of the air column that will resonate with the tuning fork? The speed of sound in air is 345 m/s. (Ans: 17 cm)

49. Two sound sources are driven by the same generator and emit sound waves with frequency 688 Hz. An observer is at a point on the line joining the two sources, and is at a point of destructive interference. What is the shortest distance the observer should walk on the line joining the sources to move to a point of constructive interference? [speed of sound in air is 344 m/s] (Ans: 0.125 m)

50. Two small identical speakers are connected to the same sinusoidal source, as shown in figure 13. At a distance 40.0 m in front of one speaker, the sound intensity is minimum at two consecutive frequencies 4500 Hz and 7500 Hz. What is the distance X between the speakers? (Ans: 3.0 m)

51. A point source emits sound waves which are reflected from a metal plate with air in between, as shown in figure 14. Standing waves are produced in between the source and the plate. If the points R, S and T are three successive nodes, what is the frequency of the wave? [speed of sound in air is 342 m/s] (Ans: 114 Hz)
52. A completely destructive interference has been found at location C that is 3.0 m from wave source A and 4.2 m from wave source B (see figure 15). If the two sources A and B are in phase, what is the maximum wavelength of the waves? (Ans: 2.4 m)

53. A point source emits 30 W of sound. A small microphone, with an area of 0.75 cm², is placed 10 m from the point source. What power does the microphone receive? (Ans: 1.8 μW)

54. A sound wave of 50.0 cm wavelength enters the tube shown in figure 16 at the source end. What must be the smallest radius (r) (other than zero) such that a maximum sound will be heard at the detector end? (Ans: 43.8 cm)

55. A tube open at both ends has a fundamental frequency of 76.0 Hz. What is the third harmonic frequency of this tube if one end is closed? (Ans: 114 Hz)

56. Two small identical speakers A and B are connected (in phase) to the same source, as shown in figure 17. A man starts walking from speaker A toward speaker B. He hears the second minimum sound at point P which is 3 m from speaker A and 9 m from speaker B. What is the wavelength of the emitted sound wave? (Ans: 4 m)

57. Two sound waves have equal displacement amplitudes, but one has twice the frequency of the other. What is the ratio of their intensities? (Ans: 4)

58. In figure 18, the two observers at A and B are hearing the sound emitted by the point source S. What is the time difference between hearing the sound at the two locations? [speed of sound = 345 m/s] (Ans: 0.315 s)

59. Two loudspeakers, S1 and S2, emit sound waves of identical wavelength and amplitude. They are situated as shown in figure 19. The two speakers are in phase. A listener starts walking from point D toward S2 along a line perpendicular to the line joining S1 and S2. How many times will he hear a minimum in sound intensity as he moves from D to S2? (Ans: 4)

60. A pipe is closed at one end and open at the other, and has a length of 0.500 m. The pipe is filled with air. What is the resonant frequency corresponding to the mode shown in figure 20? [Use 344 m/s as the speed of sound in air] (Ans: 860 Hz)

61. Two cars A and B are traveling toward each other. The speed of car A is half the speed of car B. Car A sounds a horn at frequency 400 Hz and the other car B hears the horn at frequency 500 Hz. What is the speed of car B? [Use 344 m/s as the speed of sound in air] (Ans: 52.9 m/s)

62. Two sound waves, one in air and one in water, are of equal intensity. What is the ratio of the pressure amplitude of the wave in water to that of the wave in air? \(\frac{v_{\text{water}}}{\rho_{\text{water}}} = 1482 \text{ m/s}, \ \rho_{\text{water}} = 10^3 \text{ kg/m}^3, \ v_{\text{air}} = 343 \text{ m/s}, \ \rho_{\text{air}} = 1.21 \text{ kg/m}^3\) (Ans: 59.8)

63. A train passes a train station at a constant speed of 40 m/s. The train whistle emits sound with a frequency of 320 Hz. An observer at the station hears a frequency \(f_1\) while the train is approaching and a frequency \(f_2\) while the train is moving away from the station. What change in frequency \((f_1 - f_2)\) does the observer notice? (Ans: 76 Hz)

64. A group of students, in a class room, produce a sound level of 53 dB. A single student speaking normally produces a sound level of 40 dB. How many students are in the room? Assume that each student speaks at the same level as did the single person. (Ans: 20)

65. At a location that is 3.00 m from sound source A and 4.20 m from sound source B, constructive interference occurs. Source A and source B are in phase. What is the lowest frequency of the waves? (Ans: 286 Hz)
66. Water in a vertical well is at a depth of 12.4 m. What is the lowest resonant frequency of this well? The speed of sound in the well is 348 m/s. (Ans: 7.00 Hz)

67. The sound from a single source can reach point O by two different paths. One path has a length of 20.0 m and the second path has a length of 21.0 m. The sound destructively interferes at point O. What is the minimum frequency of the source if the speed of sound is 340 m/s? (Ans: 170 Hz)

68. A pipe, open at both ends, resonates in its second harmonic with a frequency of 1200 Hz. In this situation, what is the distance between two consecutive antinodes? (Ans: 14.3 cm)

69. A truck moving at 36 m/s passed a police car moving at 45 m/s in the opposite directions. If the frequency of the siren of the police car is 500 Hz, what is the frequency of the police siren as heard by an observer in the truck after the police car passed the truck. (Ans: 396 Hz)

70. A police car, moving at 20.0 m/s, emits a sound wave with a frequency of 300 Hz. Find the wavelength of the sound wave in front of the car (see figure 22). [Take the speed of sound in air to be 340 m/s] (Ans: 1.07 m)

71. During a typical workday of eight hours, the average sound intensity arriving at a human ear is 18 \( \mu \)W/m\(^2\). If the area of the human ear through which the sound passes is 2.1 cm\(^2\), what is the total energy entering each ear during the workday? (Ans: 110 \( \mu \)J)

72. A tuning fork with a frequency of 512 Hz is placed near the top of the tube shown in figure 23. The water level is lowered, by opening the valve, so that the length \( L \) slowly increases from an initial value of 20.0 cm. Determine the next value of \( L \) that corresponds to a resonance. (Ans: 50.2 cm)

73. A sound source emitting sound with a frequency of 400 Hz is placed at the entrance of a tube, to which is attached a moving piston, as shown in figure 25. How many resonances can be heard as the piston is moved to the other end, which is a distance of 1.00 m from the entrance? Take the speed of sound to be 344 m/s. (Ans: 2)

74. Two cars are traveling toward each other, each with a speed of 9.00 m/s. One car sounds a horn that emits sound with a frequency of 396 Hz. What frequency do the passengers of the other car? (Ans: 417 Hz)

75. The pressure in a travelling sound wave is given by the equation: \( \Delta p = (1.00) \sin \pi [0.900x - 315t] \) (SI units). Find the sound level of the wave (Take the density of air to be \( \rho_{\text{air}} = 1.21 \text{ kg/m}^3 \)). (Ans: 90.7 dB)

76. An ambulance and a truck are approaching each other with speeds of 50.0 m/s and 30.0 m/s, respectively. The ambulance emits sound waves at a frequency of 0.150 MHz. Find the wavelength of the sound waves reflected back to the ambulance. (The speed of sound in air is 340 m/s) (Ans: 0.141 cm)

77. Two speakers (S\(_1\), S\(_2\)), emitting sound waves of frequency 340 Hz and separated by a distance of 3.0 m, are driven by the same oscillator, as shown in figure 27. A listener starts walking from point A to S\(_2\) along the line that joins A and S\(_2\). How many points of destructive interference will he observe? Speed of sound in air = 340 m/s. (Ans: 4)
Conceptual Problems

1. Which of the following statements is correct?
   A. The pressure of sound wave is not in phase with the displacement.
   B. The speed of sound in water is less than in air.
   C. Sound waves are transverse waves.
   D. For a string fixed at both ends, the speed of waves on the string decreases when its linear density decreases.
   E. Waves on a stretched string are longitudinal waves.

2. Which of the following statements is correct?
   A. For spherical sound waves, the displacement amplitude decreases linearly with increasing distance from the source.
   B. Sound waves are transverse.
   C. For the Doppler effect, the observed frequency is always less than the actual frequency of the source.
   D. The power of sound emitted is always inversely proportional to the distance from the source.
   E. The intensity of sound waves is independent of the distance from the source.

3. Sound waves are not:
   A. transverse waves.
   B. pressure waves.
   C. compression waves.
   D. longitudinal waves.
   E. mechanical waves.

4. A car emitting a sound wave at a certain frequency moves along an x-axis (figure 10 a). The car moves directly toward detector A and directly away from detector B. The superimposed three plots of figure 10 b indicate the displacement function $s(x)$ at some time $t$ of the sound wave as measured by detector A, by detector B, and by someone in C. Which plot corresponds to which measurement?
   A. 1 to A, 2 to B, 3 to C
   B. 1 to A, 3 to B, 2 to C
   C. 2 to A, 1 to B, 3 to C
   D. 2 to A, 3 to B, 1 to C
   E. 3 to A, 2 to B, 1 to C

5. Fully destructive interference between two sinusoidal waves of the same frequency and amplitude occurs only if they:
   A. travel in the same direction and are 180° out of phase.
   B. travel in opposite directions and are 90° out of phase.
   C. travel in opposite directions and are in phase.
   D. travel in the same direction and are 90° out of phase.
   E. travel in the same direction and are in phase.

6. A sound wave travels from air to water, then:
   A. its speed increases.
   B. its frequency increases.
   C. its speed decreases.
   D. its frequency decreases.
   E. its wavelength will remain unchanged.
7. Consider a sound source $S$ and a sound detector $D$. Which of the following situations may result in the detector observing the same frequency as that of the source?
   A. $S$ moves toward $D$ and $D$ moves away from $S$ with the same speed.
   B. $S$ moves toward $D$ and $D$ moves toward $S$ with the same speed.
   C. Both $S$ and $D$ move away from each other with the same speed.
   D. $S$ is stationary and $D$ moves away from $S$.
   E. $D$ is stationary and $S$ moves away from $D$.

8. Two pipes have the same length $L$. Pipe B open at one end and closed at the other, while pipe A open both ends. Which harmonic of pipe B matches the second harmonic of pipe A?
   A. Never match.
   B. The fourth.
   C. The second.
   D. The fundamental.
   E. One needs to know the exact length.

9. During a time equal to the period of a certain vibrating fork, the emitted sound wave travels a distance of
   A. one wavelength
   B. two wavelengths
   C. a quarter of a wavelength
   D. half a wavelength
   E. four wavelengths

10. A tube of length $L$ is open at both ends. The second harmonic frequency of this tube is $F$. The tube is then closed at one end, and its length is adjusted so that its fundamental frequency is equal to $F$. What is the new length?
    A) $L/4$
    B) $L/2$
    C) $2L$
    D) $4L$
    E) $L$

11. Sound waves
    A. are mechanical waves.
    B. are matter waves.
    C. are transverse waves.
    D. travel at the same speed in all media.
    E. are electromagnetic waves.

12. Figure 12 shows four situations in which a moving source of sound $S$ and a detector $D$ are either moving or stationary. The arrows indicate the directions of motion. The speeds $\nu$ of the source and the detector are the same. Detector 3 is stationary. Rank the situations according to the frequency at the detector, highest to lowest.
    A) 4, 3, 2, 1
    B) 1, 2, 3, 4
    C) 1, 3, 2, 4
    D) 4, 1, 2, 3
    E) 4, 2, 3, 1
13. A pipe, with one end open and the other closed, is operating at one of its resonant frequencies. The open and closed ends are respectively:
   A. pressure minimum, displacement minimum
   B. pressure minimum, pressure minimum
   C. displacement maximum, pressure minimum
   D. displacement minimum, displacement minimum
   E. pressure maximum, pressure maximum

14. Which one of the following statements is TRUE?
   A. If two sound waves have the same intensity level (in decibels), they must have the same intensity.
   B. If two different sound waves have the same displacement amplitude, then they must have the same intensity level (in decibels).
   C. If the intensity level (in decibels) of sound A is twice the intensity level of sound B, then the intensity of A is twice the intensity of B.
   D. If two different sound waves have the same displacement amplitude, then they must have the same intensity.
   E. If the intensity of sound A is twice the intensity of sound B, then the intensity level (in decibels) of A is twice the intensity level of B.

15. Two small identical speakers are connected (in phase) to the same source, as shown in figure 21. The speakers are 2.0 m apart. An observer stands at X, 3.0 m in front of one speaker. The sound he hears will be minimum if the wavelength is:
   A. 1.2 m
   B. 3.7 m
   C. 7.6 m
   D. 2.9 m
   E. 0.60 m

16. Pipe Y (open at both ends) is 7 cm long, and pipe X (open at one end) is 5 cm long. The ratio of their fundamental frequencies $f_{1X}/f_{1Y}$ is:
   A. 0.7
   B. 1.7
   C. 0.2
   D. 1.3
   E. 0.5

17. If the intensity of a sound wave traveling in air with constant frequency is doubled, then
   A. the wave speed remains the same.
   B. the displacement amplitude remains the same.
   C. the displacement amplitude is doubled.
   D. the sound level is doubled.
   E. the displacement amplitude is halved.

18. A tube open at both ends has length $L_A$. A tube open only at one end has length $L_B$. If the two tubes have the same fundamental frequency, then
   A. $L_A = 2L_B$
   B. $L_A = L_B/2$
   C. $L_A = L_B/4$
   D. $L_A = L_B$
   E. $L_A = 4L_B$
19. A block, with a speaker attached to it, is connected to a spring and oscillates on a frictionless table between points A and B, as shown in figure 24. The speaker emits sound that is received by a person. The closest point of the block to the person is A, the farthest point is B, and O is the equilibrium point of the spring. What position of the speaker corresponds to the highest frequency observed by the person?

A. Point O travelling to the right.
B. Point O travelling to the left.
C. Point A.
D. Point B.
E. The frequency is the same everywhere.

20. Two identical sound sources emit sound waves of wavelength $\lambda$, and are separated by a distance $d$. What is the lowest non-zero value of $d$ for which constructive interference occurs everywhere along the line that passes through the two sources? Consider only points which do not lie between the two sources.

A. $\lambda$
B. $\lambda/4$
C. $2\lambda$
D. $\lambda/2$
E. $4\lambda$

21. A standing sound wave in a pipe has five nodes and five antinodes. Find the harmonic number $n$ for this standing wave.

A. 9
B. 8
C. 7
D. 12
E. 10

22. Figure 26 shows two point sources $S_1$ and $S_2$, which are in phase and emit identical waves of wavelength $\lambda$. Initially, the sources are at equal distances from point P. Then $S_1$ is moved directly toward P by a distance equal to $\lambda/4$ and $S_2$ is moved directly away from P by a distance equal to $\lambda/4$. Now the waves at P:

A. Are exactly out of phase.
B. Are exactly in phase.
C. Have some intermediate phase.
D. Have path difference equal to $\lambda/4$.
E. Have phase difference equal to $\pi/4$.

23. A sound wave is travelling in air. The intensity and frequency of the wave are both doubled. What is the ratio of the new pressure amplitude to the initial pressure amplitude?

A) $\sqrt{2}$
B) $1/\sqrt{2}$
C) 1
D) 2
E) 1/2