**Sound and Music Review**

From <http://www.physicsclassroom.com/reviews/sound/soundprint.cfm>

**Part A: TRUE/FALSE**

1. Which of the following statements are **TRUE** of sound waves? Identify all that apply.

1. A sound wave is a mechanical wave.
2. A sound wave is a means of transporting energy without transporting matter.
3. Sound can travel through a vacuum.
4. A sound wave is a pressure wave; they can be thought of as fluctuations in pressure with respect to time.
5. A sound wave is a transverse wave.
6. To hear the sound of a tuning fork, the tines of the fork must move air from the fork to one's ear.
7. Most (but not all) sound waves are created by a vibrating object of some type.
8. To be heard, a sound wave must cause a relatively large displacement of air (for instance, at least a cm or more) around an observer's ear.

2. Which of the following statements are **TRUE** of sound intensity and decibel levels? Identify all that apply.

1. The intensity of a sound wave has units of Watts/meter.
2. When a sound wave is said to be intense, it means that the particles are vibrating back and forth at a high frequency.
3. Intense sounds are characterized by particles of the medium vibrating back and forth with a relatively large amplitude.
4. Intense sounds are usually perceived as loud sounds.
5. The ability of an observer to hear a sound wave depends solely upon the intensity of the sound wave.
6. From the least intense to the most intense, humans have a rather narrow range of intensity over which sound waves can be heard.
7. The intensity of sound that corresponds to the threshold of pain is one trillion times more intense than the sound that corresponds to the threshold of hearing.
8. Two sounds which have a ratio of decibel ratings equal to 2.0. This means that the second sound is twice as intense as the first sound.
9. Sound A is 20 times more intense than sound B. So if Sound B is rated at 30 dB, then sound A is rated at 50 dB.
10. Sound C is 1000 times more intense than sound D. So if sound D is rated at 80 dB, sound C is rated at 110 dB.
11. A machine produces a sound which is rated at 60 dB. If two of the machines were used at the same time, the decibel rating would be 120 dB.
12. Intensity of a sound at a given location varies directly with the distance from that location to the source of the sound.
13. If the distance from the source of sound is doubled then the intensity of the sound will be quadrupled.
14. If the distance from the source of sound tripled, then the intensity of the sound will be increased by a factor of 6.

3. Which of the following statements are **TRUE** of the speed of sound? Identify all that apply.

1. The speed of a sound wave depends upon its frequency and its wavelength.
2. In general, sound waves travel fastest in solids and slowest in gases.
3. Sound waves travel fastest in solids (compared to liquids and gases) because solids are more dense.
4. The fastest which sound can move is when it is moving through a vacuum.
5. If all other factors are equal, a sound wave will travel fastest in the most dense materials.
6. A highly elastic material has a strong tendency to return to its original shape if stressed, stretched, plucked or somehow disturbed.
7. A more rigid material such as steel has a higher elasticity and therefore sound tends to move through it at high speeds.
8. The speed of sound moving through air is largely dependent upon the frequency and intensity of the sound wave.
9. A loud shout will move faster through air than a faint whisper.
10. Sound waves would travel faster on a warm day than a cool day.
11. The speed of a sound wave would be dependent solely upon the properties of the medium through which it moves.
12. A shout in a canyon produces an echo off a cliff located 127 m away. If the echo is heard 0.720 seconds after the shout, then the speed of sound through the canyon is 176 m/s.
13. The speed of a wave within a guitar string varies inversely with the tension in the string.
14. The speed of a wave within a guitar string varies inversely with the mass per unit length of the string.
15. The speed of a wave within a guitar string will be doubled if the tension of the string is doubled.
16. An increase in the tension of a guitar string by a factor of four will increase the speed of a wave in the string by a factor of two.
17. An increase in the linear mass density of a guitar string by a factor of four will increase the speed of a wave in the string by a factor of two.

4. Which of the following statements are **TRUE** of the frequency of sound and the perception of pitch? Identify all that apply.

1. A high-pitched sound has a low wavelength.
2. A low-pitched sound is a sound whose pressure fluctuations occur with a low period.
3. If an object vibrates at a relatively high frequency, then the pitch of the sound will be low.
4. The frequency of a sound will not necessarily be the same as the frequency of the vibrating object since sound speed will be altered as the sound is transmitted from the object to the air and ultimately to your ear.
5. Two different guitar strings are used to produce a sound. The strings are identical in terms of material, thickness and the tension to which they are pulled. Yet string A is shorter than string B. Therefore, string A will produce a lower pitch.
6. Both low- and high-pitched sounds will travel through air at the same speed.
7. Doubling the frequency of a sound wave will halve the wavelength but not alter the speed of the wave.
8. Tripling the frequency of a sound wave will decrease the wavelength by a factor of 6 and alter the speed of the wave.
9. Humans can pretty much hear a low-frequency sound as easily as a high-frequency sound.
10. Ultrasound waves are those sound waves with frequencies less than 20 Hz.

5. Which of the following statements are **TRUE** of standing wave patterns? Identify all that apply.

1. A standing wave pattern is formed as a result of the interference of two or more waves.
2. When a standing wave pattern is established, there are portions of the medium which are not disturbed.
3. A standing wave is really not a wave at all; it is a pattern resulting from the interference of two or more waves that are traveling through the same medium.
4. A standing wave pattern is a regular and repeating vibrational pattern established within a medium; it is always characterized by the presence of nodes and antinodes.
5. An antinode on a standing wave pattern is a point which is stationary; it does not undergo any displacement from its rest position.
6. For every node on a standing wave pattern, there is a corresponding antinode; there are always the same number of each.
7. When a standing wave pattern is established in a medium, there are alternating nodes and antinodes, equally spaced apart across the medium.

6. Which of the following statements are **TRUE** of the concept of resonance? Identify all that apply.

1. A musical instrument can play any frequency imaginable.
2. All musical instruments have a natural frequency or set of natural frequencies at which they will vibrate; each frequency corresponds to a unique standing wave pattern.
3. The result of two objects vibrating in resonance with each other is a vibration of larger amplitude.
4. Objects that share the same natural frequency will often set each other into vibrational motion when one is plucked, strummed, hit or otherwise disturbed. This phenomenon is known as a forced resonance vibration.
5. A vibrating tuning fork can set a second tuning fork into resonant motion.
6. The resonant frequencies of a musical instrument are related by whole number ratios.

7. Which of the following statements are **TRUE** of the harmonics and standing wave patterns in guitar strings? Identify all that apply.

1. The fundamental frequency of a guitar string is the highest frequency at which the string vibrates.
2. The fundamental frequency of a guitar string corresponds to the standing wave pattern in which there is a complete wavelength within the length of the string.
3. The wavelength for the fundamental frequency of a guitar string is 2.0 m.
4. The wavelength for the second harmonic played by a guitar string is two times the wavelength of the first harmonic.
5. The standing wave pattern for the fundamental played by a guitar string is characterized by the pattern with the longest possible wavelength.
6. If the fundamental frequency of a guitar string is 200 Hz, then the frequency of the second harmonic is 400 Hz.
7. If the frequency of the fifth harmonic of a guitar string is 1200 Hz, then the fundamental frequency of the same string is 6000 Hz.
8. As the frequency of a standing wave pattern is tripled, its wavelength is tripled.
9. If the speed of sound in a guitar string is 300 m/s and the length of the string is 0.60 m, then the fundamental frequency will be 180 Hz.
10. As the tension of a guitar string is increased, the fundamental frequency produced by that string is decreased.
11. As the tension of a guitar string is increased by a factor of 2, the fundamental frequency produced by that string is decreased by a factor of 2.
12. As the linear density of a guitar string is increased, the fundamental frequency produced by the string is decreased.
13. As the linear density of a guitar string is increased by a factor 4, the fundamental frequency produced by the string is decreased by a factor of 2.

8. Which of the following statements are **TRUE** of the harmonics and standing wave patterns in air columns? Identify all that apply.

1. The speed of the waves for the various harmonics of open-end air columns are whole number multiples of the speed of the wave for the fundamental frequency.
2. Longer air columns will produce lower frequencies.
3. The pitch of a sound can be increased by shortening the length of the air resonating inside of an air column.
4. An open end of an air column allows air to vibrate a maximum amount whereas a closed end forces air particles to behave as nodes.
5. Open-end air columns have antinodes positioned at each end while closed-end air columns have nodes positioned at each end.
6. Closed-end air columns can only produce odd-numbered harmonics.
7. Open-end air columns can only produce even-numbered harmonics.
8. A closed-end air column that can play a fundamental frequency of 250 Hz cannot play 500 Hz.
9. An open-end air column that can play a fundamental frequency of 250 Hz cannot play 750 Hz.
10. A closed-end air column has a length of 20 cm. The wavelength of the first harmonic is 5 cm.
11. An open-end air column has a length of 20 cm. The wavelength of the first harmonic is 10 cm.
12. Air column A is a closed-end air column. Air column B is an open-end air column. Air column A would be capable of playing lower pitches than air column B.
13. The speed of sound in air is 340 m/s. An open-end air column has a length of 40 cm. The fundamental frequency of this air column is approximately 213 Hz.
14. The speed of sound in air is 340 m/s. A closed-end air column has a length of 40 cm. The fundamental frequency of this air column is approximately 213 Hz.
15. If an open-end air column has a fundamental frequency of 250 Hz, then the frequency of the fourth harmonic is 1000 Hz.
16. If a closed-end air column has a fundamental frequency of 200 Hz, then the frequency of the fourth harmonic is 800 Hz.

9. Which of the following statements are **TRUE** of sound interference and beats? Identify all that apply.

1. Beats result when two sounds of slightly different frequencies interfere.
2. Beats are characterized by a sound whose frequency is rapidly fluctuating between a high and a low pitch.
3. Two sounds with a frequency ratio of 2:1 would produce beats with a beat frequency of 2 Hz.
4. Two tuning forks are sounding out at slightly different frequencies - 252 Hz and 257 Hz. A beat frequency of 5 Hz will be heard.
5. A piano tuner is using a 262 Hz tuning fork in an effort to tune a piano string. She plucks the string and the tuning fork and observes a beat frequency of 2 Hz. Therefore, she must lower the frequency of the piano string by 2 Hz.

**Part B: Multiple Choice**

10. What type of wave is produced when the particles of the medium are vibrating to and fro in the same direction of wave propagation?

a. longitudinal wave. b. sound wave.

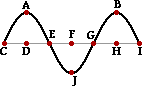
c. standing wave. d. transverse wave.

11. As a wave passes through a medium, the particles of that medium are vibrating in a direction that is perpendicular to the direction that energy is transported. Such a wave is categorized as a \_\_\_\_\_ wave.

a. sound b. standing

c. transverse d. longitudinal

12. The diagram below shows a *snapshot in time* of a transverse wave moving through a medium. The particles of the medium are vibrating \_\_\_\_\_.



a. parallel to the line that joins points A and D

b. along the line that joins points C and I

c. perpendicular to the line that joins points A and D

d. at various angles to the line that joins points C and I

e. along the curve CAEJGBI

13. A longitudinal wave travels through a medium that stretches from north to south. The particles of the medium \_\_\_\_\_.

a. move from north to south

b. move from east to west

c. vibrate northward and southward about a fixed position

d. vibrate eastward and westward about a fixed position

14. The main factor that affects the speed of a sound wave is the \_\_\_\_.

a. amplitude of the sound wave b. intensity of the sound wave

c. loudness of the sound wave d. properties of the medium

e. pitch of the sound wave

15. A wave traveling through medium 1 crosses the boundary and enters into medium 2. As it does, its speed increases. This causes the wavelength to \_\_\_\_\_.

a. decrease b. increase c. remain the same

d. … nonsense! Wave speed could never increase at the boundary between two media.

16. As a wave passes across a boundary into a new medium, which characteristic of the wave would NOT change?

a. speed b. frequency c. wavelength

17. The \_\_\_\_ is defined as the number of cycles of a periodic wave occurring per unit time.

a. wavelength b. period c. amplitude d. frequency

18. Many wave properties are dependent upon other wave properties. Yet, one wave property is independent of all other wave properties. Which one of the following wave properties is independent of the other listed properties?

a. wavelength b. frequency c. period d. velocity

19. Consider the motion of waves in a wire. Waves will travel fastest in a \_\_\_\_ wire.

a. tight and heavy b. tight and light

c. loose and heavy d. loose and light

20. **TRUE or FALSE:**

The standard unit for frequency is hertz.

a. True b. False

21. **TRUE or FALSE:**

Doubling the frequency of a sound source doubles the speed of the sound waves that it produces.

a. True b. False

22. A certain sound with a uniform pitch has a 4.0-meter wavelength. A compression and an adjacent rarefaction would be separated by a distance of \_\_\_\_\_ meter.

a. 1.0 b. 2.0 c. 4.0 d. 8.0

23. Which one of the following characteristics of a sound wave determines the pitch that observers hear?

a. The speed of the sound wave

b. The frequency of the sound wave

c. The amplitude of the sound wave

d. The distance of the sound wave from the source

24. A person can produce a note by blowing air into a long pipe. The manner in which the person blows on the pipe will affect the characteristics of the sound that is produced. If the person blows *more forcefully*, then one would observe an increase in \_\_\_\_.

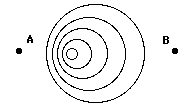
a. amplitude b. frequency c. pitch d. speed

e. wavelength

25. An object vibrates with a frequency of 220 Hz to produce sound waves that travel through air with a speed of 340 m/s. Adjacent compressions in the sound wave are a distance of \_\_\_\_\_\_ meters apart.

a. 0.773 b. 1.55 c. 3.09 d. 6.18

26. Consider the diagram below of several circular waves created at various times and locations. The diagram illustrates \_\_\_\_.



a. refraction

b. interference

c. a sonic boom

d. the Doppler effect

27. In the diagram above, a person positioned at point A would perceive \_\_\_\_\_\_\_\_\_\_ frequency as the person positioned at point B.

a. a higher b. a lower c. the same

28. An emergency vehicle has its siren on and is moving east along Lake Avenue at a constant speed. Geraldine is riding her bicycle west along Lake Avenue at a constant speed. Compared to the frequency of sound waves produced by the siren, the frequency that Geraldine hears is \_\_\_\_\_.

a. lower b. higher c. the same

29. An earth-based receiver is detecting electromagnetic waves from a source in outer space. If the frequency of the waves are observed to be increasing, then the distance between the source and the earth is probably \_\_\_\_.

a. decreasing. b. increasing. c. remaining the same.

30. As two or more waves pass simultaneously through the same region, \_\_\_\_ can occur.

a. refraction b. diffraction c. interference d. reflection

31. **TRUE or FALSE:**

If two crests meet while passing through the same medium, then constructive interference occurs.

a. True b. False

32. A node is a point along a medium where there is always \_\_\_\_.

a. a crest meeting a crest b. a trough meeting a trough

c. constructive interference d. destructive interference

e. a double rarefaction.

33. **TRUE or FALSE:**

It is possible that one vibrating object can set another object into vibration if the natural frequencies of the two objects are the same.

a. True b. False

34. An object is vibrating at its natural frequency. Repeated and periodic vibrations of the same natural frequency impinge upon the vibrating object and the amplitude of its vibrations is observed to increase. This phenomenon is known as \_\_\_\_.

a. beats b. resonance c. interference

d. amplification e. the Doppler shift

35. A standing wave experiment is performed to determine the speed of waves in a rope. The standing wave pattern shown below is established in the rope. The rope makes 90.0 complete vibration cycles in exactly one minute. The speed of the waves is \_\_\_\_ m/s.

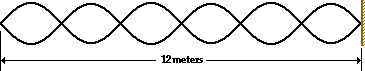


a. 3.0 b. 6.0 c. 180 d. 360 e. 540

36. Standing waves are produced in a wire by vibrating one end at a frequency of 100. Hz. The distance between the 2nd and the 5th nodes is 60.0 cm. The wavelength of the original traveling wave is \_\_\_\_ cm.

a. 50.0 b. 40.0 c. 30.0 d. 20.0 e. 15.0

37. Consider the standing wave pattern shown below.



A wave generated at the left end of the medium undergoes reflection at the fixed end on the right side of the medium. The number of antinodes in the diagram is

a. 3.0 b. 5.0 c. 6.0 d. 7.0 e. 12

38. The standing wave pattern in the diagram above is representative of the \_\_\_\_ harmonic.

a. third b. fifth c. sixth d. seventh e. twelfth

39. Any two adjacent nodes in a standing wave pattern are separated by a distance that is equal to \_\_\_\_\_ wavelengths.

a. ¼ b. ½ c. ¾ d. 1 e. 2.

40. A vibrating tuning fork is held above a closed-end air column, forcing the air into resonance. If the sound waves created by the tuning fork have a wavelength of **W**, then the length of the air column could NOT be \_\_\_\_.

a. 1/4 W b. 2/4 W c. 3/4 W d. 5/4 W e. 7/4 W

41. **TRUE or FALSE:**

A vibrating tuning fork is held above an air column, forcing the air into resonance. The length of the air column is adjusted to obtain various resonances. The sound waves created by the tuning fork have a wavelength of **W**.  The difference between the successive lengths of the air column at which resonance occurs is 1/2 W.

a. True b. False

42. **TRUE or FALSE:**

An organ pipe that is closed at one end will resonate if its length is equal to one-half of the wavelength of the sound in the pipe.

a. True b. False

43. A 20-cm long pipe is covered at one end in order to create a closed-end air column. A vibrating tuning fork is held near its open end, forcing the air to vibrate in its first harmonic. The wavelength of the standing wave pattern is \_\_\_\_.

a. 5 cm b. 10 cm c. 20 cm d. 40 cm e. 80 cm

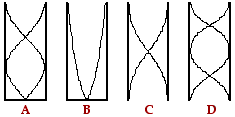
44. A stretched string vibrates with a fundamental frequency of 100. Hz. The frequency of the second harmonic is \_\_\_\_.

a. 25.0 Hz b. 50.0 Hz c. 100. Hz d. 200. Hz e. 400. Hz

45. A 40.0-cm long plastic tube is open at both ends and resonating in its first harmonic. The wavelength of the sound that will produce this resonance is \_\_\_\_.

a. 10.0 cm b. 20.0 cm c. 40.0 cm d. 80.0 cm e. 160. cm

46. The diagrams below represent four different standing wave patterns in equal-length air columns. Identify any column that is vibrating at its fundamental frequency? Include all that apply.



47. The diagrams above (Question 46) represent four standing wave patterns in equal-length air columns having the same air temperature. Which pattern is characteristic of the note that has the highest pitch?

a. A b. B c. C d. D

e. All patterns correspond to notes of the same pitch

48. A 30.5-cm long cylindrical pipe is filled with argon gas and closed off at one end. A 262-Hz tuning fork causes it to resonate in its first harmonic. The speed of sound waves through argon gas is \_\_\_\_\_.

a. 79.9 m/s b. 160. m/s c. 320. m/s

d. 523 m/s e. 1050 m/s

49. **TRUE or FALSE:**

A violinist plucks a string whose fundamental frequency is 220 Hz. The same string could also vibrate at 660 Hz.

a. True b. False

50. A person will hear *beats* when listening to the sounds from two sources as long as those two sources produce sound waves that \_\_\_\_\_.

a. have the same amplitude

b. travel at the same speed

c. have identical frequencies

d. have similar but slightly different frequencies

e. have frequencies that are simple whole number ratios of each other

51. **TRUE or FALSE:**

Two tuning forks with frequencies of 256 Hz and 258 Hz are sounded at the same time. Beats are observed; 2 beats will be heard in 2 s.

a. True b. False

52. A 440-Hz tuning fork and a vibrating guitar string are observed to produce exactly 20 beats in 10.0 seconds. The guitar string must be vibrating with a frequency of either \_\_\_\_ Hz.

a. 420 or 460 b. 430 or 450 c. 436 or 444 d. 438 or 442

**Part C: Problem-Solving and Computational Problems**

53. Determine the decibel rating of the following intensities of sound.

1. I = 1.0 x 10-5 W/m2
2. I = 1.0 x 10-2 W/m2
3. I = 6.1 x 10-6 W/m2
4. I = 2.2 x 10-4 W/m2
5. A sound that is 4 times more intense than the sound in part d.
6. A sound that is 7 times more intense than the sound in part d.
7. A sound that is 10 times more intense than the sound in part d
8. A sound that is 100 times more intense than the sound in part d.
9. The sound of an orchestra playing a movement pianissimo at 7.5 x 10-6 W/m2 (very softly)
10. The sound of an orchestra playing a movement fortissimo at 2.5 x 10-4 W/m2 (very loudly)

54. A machine produces a sound with an intensity of 2.9 x 10-3 W/m2. What would be the decibel rating if four of these machines occupy the same room?

55. The sound in the United Center during a Chicago Bulls basketball game in 1998 was seven times as intense as it is today. If the decibel rating today is 89 dB, then what was the intensity rating in 1998?

56. A sound has an intensity of 8.0 x10-3 W/m2 at a distance of 2.0 m from its source. What is the intensity at a distance of ...

1. ... 4.0 m from the source?
2. ... 6.0 m from the source?
3. ... 8.0 m from the source?
4. ... 24.0 m from the source?
5. ... 46.1 m from the source?

57. Ben Stupid is sitting 2.0 m in front of the speakers on the stage at the Twisted Brother concert. The decibel rating of the sound heard there is 110 dB. What would be the decibel rating at a location of ...

1. ... 4.0 m from the speaker?
2. ... 6.0 m from the speaker?
3. ... 20.0 m from the speaker?

58. Use the Doppler equation for a moving source to calculate the observed frequency for a 250.-Hz source of sound if it is moving with a speed of \_\_\_\_ . (Assume that the speed of sound in air is 340. m/s.)

1. 30. m/s towards the observer.
2. 30. m/s away from the observer.
3. 300. m/s towards the observer.
4. 300. m/s away from the observer.
5. 320. m/s towards the observer.
6. 335 m/s towards the observer.

59. Nostalgia Question: Shirley Yackin is holding the phone cord in her hand. It is stretched to a length of 2.4 m and has a mass of 1.8 kg. If the tension in the phone cord is 2.5 N, then determine the speed of vibrations within the cord.

60. (Referring to Question 59.) With what frequency must Shirley vibrate the cord up and down in order to produce the second harmonic within the cord?

61. (Referring to Question 60.) If Shirley maintains this same frequency and wishes to produce the fourth harmonic, then she will have to alter the speed of the wave by changing the tension. Assuming the same mass density as in Question 59, and the same frequency as in Question 60, to what tension must the cord be pulled to produce the fourth harmonic?

62. A guitar string has a mass of 32.4 g and a length of 1.12 m. The string is pulled to a tension of 621 N. Determine the speed at which vibrations move within the string.

63. (Referring to Question 62.) Stan Dingwaives is playing this guitar. If Stan leaves the string "open" and uses its full length to produce the first harmonic, then what frequency will Stan be playing?

64. (Referring to Question 62 and Question 63.) If Stan wishes to increase the frequency by a factor of 1.2599, then how far (in cm) from the end of the string must he "close" the string (i.e., where must he press his finger down to change the length and produce the desired frequency)? Use the same mass density and speed as in problem #62.

65. A guitar string has a fundamental frequency of 262 Hz. Determine the frequency of the ...

1. ... second harmonic.
2. ... third harmonic.
3. ... fifth harmonic.
4. ... eighth harmonic.

66. Determine the speed of sound through air if the temperature is ...

1. ... 0 degrees Celsius.
2. ... 12 degrees Celsius.
3. ... 25 degrees Celsius.
4. ... 40 degrees Celsius.

67. A wind chime behaves like an open-end air column. Determine the fundamental frequencies of a 62.5-cm chime when the temperature is ... .

1. ... 12 degrees on a cold autumn evening.
2. ... 25 degrees on a summer evening.
3. ... 40 degrees during a hot summer day.

68. An organ pipe has a length of 2.45 m and is open at both ends. Determine the fundamental frequency of the pipe if the temperature in the room is 25 degrees Celsius.

69. (Referring to **Question 68**.) Determine the fundamental frequency of the pipe if it is closed at one end.

70. The auditory canal of the outer ear acts as a closed end resonator that has a natural frequency of around 3500 Hz. This canal serves to amplify sounds with frequencies around this value, thus making us more sensitive to such frequencies. If the speed of waves inside the canal is 350 m/s, then what is the estimated length of the canal?

71. Determine the frequency of the lowest three harmonics at which a closed-end air column would sound out at 25 degrees Celsius if its length is 135 cm.

72. Suppose that a sound is produced in a helium-filled air column rather than an air-filled air column. By what factor will this change in medium alter the frequency of the sound. (GIVEN: vair = 331 m/s; vHe = 970 m/s)

73. An organ pipe is used to produce the lowest note audible to the human ear - 20.-Hz. If the temperature is 25 °C, then how long is the organ pipe? (First decide whether it will produce this low note as a closed- or as an open-end air column.)

74. Determine the length of an open-end air column that would produce a 262 Hz frequency on a balmy day when the temperature is 12 degrees.

75. A 440.-Hz tuning fork is held above the open end of a water-filled plastic tube and resonance is heard. The length of the tube (bottom to top) is 28.2 cm. If the speed of sound is 345 m/s, then to what height is the tube filled with water?