Section 15.1  Properties and Detection of Sound

In your textbook, read about properties and detection of sound on pages 403–410. Write the term that correctly completes the statement. You will not use every term.

334 m/s  longitudes  solid  velocities
343 m/s  frequency  oscillation  temperature  volume
amplify  pressure  distance  transverse  wavelength
interfere  slower  vacuum

Sound waves move in the same direction as the particles of the medium and are therefore
1. _______________ waves. The waves are caused by variations in
2. _______________ relating to the different _______________ of the atoms or molecules. Therefore, sound cannot travel through a(n) _______________.

The _______________ of a sound wave is the number of pressure oscillations per second. The _______________ is the distance between successive regions of high or low pressure. At 20°C, the sound moves through air at sea level at a speed of
3. _______________. In general, the speed of sound is _______________.

in liquids and solids than in gases. Reflected sound waves are _______________. The reflection of sound waves can be used to find the _______________ between a source and a reflecting surface.

Answer the following questions. Show your calculations.

11. If a sound wave produced by a speaker is at room temperature and has a wavelength of 1.85 m, what is the frequency of the sound that is generated?

12. How long is a wave that has a frequency of $2.70 \times 10^2$ Hz and is moving through copper at 3.56 m/s?

Section 15.2  The Physics of Music

In your textbook, read about the physics of music on pages 411–419. Circle the letter of the choice that best completes the statement or answers the question.

1. Sound is produced when there are
   a. increases in pressure
   b. oscillations in pressure
   c. increases in temperature
   d. electromagnetic waves

2. The frequencies of vibrating air set into resonance are determined by the _______________ of the air column.
   a. radius
   b. mass
   c. length
   d. width

3. Resonance occurs when
   a. any constructive interference occurs
   b. any destructive interference occurs
   c. a standing wave is created
   d. no nodes are formed

4. The pressure of a reflected wave is inverted _______________ resonators.
   a. only in closed-pipe
   b. only in open-pipe
   c. in both open- and closed-pipe
   d. in neither open- nor closed-pipe
5. In a standing sound wave in a pipe, nodes are regions of _______.
   a. maximum or minimum pressure and low displacement
   b. maximum or minimum pressure and high displacement
   c. mean atmospheric pressure and low displacement
   d. mean atmospheric pressure and high displacement

6. In a standing sound wave in a pipe, two antinodes are separated by _______.
   a. one-quarter wavelength
   b. one wavelength
   c. one-half wavelength
   d. two wavelengths

For each statement below, write true or rewrite the italicized part to make the statement true.

7. An open pipe can only have resonance if it has antinodes at both ends.

8. In a closed pipe, a column of length \( \lambda / 4 \) is in resonance with a tuning fork.

9. An open pipe can only have resonance if it has nodes at both ends.

10. In an open pipe, a column of length \( 3\lambda / 4 \) is in resonance with a tuning fork.

11. For both open and closed pipes, resonance lengths are spaced at half-wavelength intervals.

12. A string resonates only when there are nodes at both ends of the string.

13. The resonant frequencies of a string are whole-number multiples of the second harmonic.

14. The standing waves in a string occur when the string length is a whole-number multiple of quarter wavelengths.

Refer to the accompanying figures to answer questions 15–17.

15. In the three open tubes below, draw standing waves that show the fundamental, second harmonic \( (f_2 = 2f_1) \), and third harmonic \( (f_3 = 3f_1) \). Under each tube, indicate the wavelength of the standing wave in terms of \( L \).

16. In the three closed tubes below, draw standing waves that show the fundamental, third harmonic \( (f_3 = 3f_1) \), and fifth harmonic \( (f_5 = 5f_1) \). Under each tube, indicate the wavelength of the standing wave in terms of \( L \).

17. In the pressure and displacement graphs below, fill in the types of nodes and antinodes in the spaces provided.

   **Closed Pipe**

   ![Closed Pipe Diagram]

   a. 
   b. 
   c. 
   d. 
   e. 
   f. 

   **Open Pipe**

   ![Open Pipe Diagram]

   g. 
   h. 
   i. 
   j.
18. A particular note played on a cello has a frequency of 240 Hz. What is the frequency of the third harmonic of that pitch?

19. While tuning her guitar, a guitarist compares the pitch one string produces to the pitch produced by a string on another guitar. If the second guitar plays a note with a frequency of 330.0 Hz and the first guitar plays a note with a frequency of 335.0 Hz, what is the beat frequency produced?

20. The two guitars in Question 19 are playing so that the beat frequency between them is 3 Hz. If one of them is playing a frequency of 348 Hz, what are the possible frequencies the other instrument is playing?

21. A musical instrument produces a beat frequency of 3 beats per second with another sound source that produces a frequency of $8.80 \times 10^3$ Hz. What are the possible wavelengths if the sounds are generated at 20°C?

22. When a tuning fork with a frequency of 440 Hz is used with a resonator, the loudest sound produced occurs when the length of the closed-pipe tube is 20.5 cm and 58.5 cm.
   a. Resonance occurs at intervals of one-half wavelength. What is the value of the wavelength?
   b. What is the speed of sound in this case?
   c. What is the approximate temperature, assuming the measurements are made at sea level?
Section 15-2 Quiz

1. Define dissonance.

2. Give an example of a closed-pipe resonator.

3. Does a closed-pipe resonator have resonant frequencies that are odd-number or whole-number multiples of the fundamental?

4. While trying to tune a guitar string to a frequency of 400.0 Hz, a guitar player compares the note from the guitar string to a note from the piano. If the piano generates a frequency of 400 Hz, and the guitar string generates a frequency of 404.0 Hz, what is the beat frequency the guitar player hears?

5. Where are the pressure nodes in a 1.4-m open pipe that has a resonant frequency that is twice the fundamental?

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Chapter 15

Mini Lab

Expected Results
Bugles, saxophones, flutes, and oboes act as open-pipe resonators; clarinets act as closed-pipe resonators.

Analyze and Conclude
4. Using the frequency and speed of sound, students can determine the wavelength of the fundamental and then compare it to the length of the instrument. For example, if they discover that \( \lambda = 4L \), then the instrument acts as a closed-pipe resonator.
5. Students should determine the appropriate ratio of frequencies, such as 1:2 for an octave and 2:3 for a perfect fifth.

Physics Lab

Sample Data

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Total</th>
<th>Temperature (°C)</th>
<th>Accepted speed of sound (m/s)</th>
<th>Experimental speed of sound (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>345</td>
<td>320</td>
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</tr>
<tr>
<td>3</td>
<td>24</td>
<td>345</td>
<td>320</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Total</th>
<th>Tuning fork frequency (Hz)</th>
<th>Diameter (cm)</th>
<th>Length of tube above water (cm)</th>
<th>Calculated wavelength (m)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.197</td>
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<td>2</td>
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<td>0.094</td>
<td>0.195</td>
<td>0.064</td>
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<tr>
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<td>0.255</td>
<td>1.072</td>
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Answer Key

<table>
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<th>Table 3</th>
<th>Total</th>
<th>Tuning fork frequency (Hz)</th>
<th>Accepted speed of sound (m/s)</th>
<th>Corrected calculated wavelength (m)</th>
<th>Corrected experimental speed of sound (m/s)</th>
</tr>
</thead>
<tbody>
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<td>1.074</td>
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</tr>
</tbody>
</table>

Analyze
1. See Table 1 and 3.
2. See Table 2.
3. See Table 1.
4. Errors of 10–20% are not unusual.
5. See Table 3.
6. Errors should be 5% or less.

Conclusion and Apply
1. Lengths: \( \frac{3A}{4} \) or \( \frac{3A}{4} \)
2. Yes, provided the length of the pipe is at least \( \frac{3A}{4} \), the next resonant point should be obtainable.

Going Further
The analysis technique using corrected values for wavelength should be better.

Real-World Physics
The resonant frequency decreases with pipe length.

Chapter 15 Study Guide

Vocabulary Review
1. fundamental
2. sound wave
3. sound level
4. decibel
5. pitch
6. Doppler effect
7. beat
Section 15.2 Quiz

1. Dissonance is a set of pitches that combine in a manner that is unpleasant to the listener.
2. Possible answers include a seashell, a clarinet, and the pipes suspended under a xylophone.
3. odd number multiples
4. \( f_{\text{sum}} = f_A - f_D = 404.0 \text{ Hz} - 400.0 \text{ Hz} \)
   \[ = 4.0 \text{ Hz} \]
5. 0 m, 0.7 m, and 1.4 m

Reinforcement

Making a Guitar

1. The frequency increases. (The pitch is higher.)
2. The frequency increases.
3. standing wave
4. Answers will vary, but when the rubber bands have equal lengths, those with a smaller diameter tend to produce higher frequencies. Also, a rubber band with more tension produces a higher frequency.
5. Answers will vary, but hollow objects tend to amplify the sound more than solid objects.

Enrichment

1. There are always one fewer antinode than nodes.
2. The frequency in Figure C is 3 times the frequency in Figure A.
3. A 0.5, B 1, C 1.5, D 2, E 2.5, F 3
4. There are twice as many antinodes as wavelengths.
5. The number of nodes equals twice the number of wavelengths plus one.
6. \( (4)(220 \text{ Hz}) = 880 \text{ Hz} \)
7. \( \left( \frac{3}{2} \right)(344 \text{ Hz}) = 517 \text{ Hz} \)
8. \( v = \lambda f \)
   \[ = (4.25 \text{ m})(228 \text{ Hz}) \]
   \[ = 969 \text{ m/s} \]