Chapter 15 continued

\[
(3.50 \text{ MHz}) \left( \frac{1482 \text{ m/s}}{1482 \text{ m/s} - 9.20 \text{ m/s}} \right) = 3.52 \text{ MHz}
\]

10. A sound source plays middle C (262 Hz). How fast would the source have to go to raise the pitch to C sharp (271 Hz)? Use 343 m/s as the speed of sound.

\( v = 343 \text{ m/s, } f_s = 262 \text{ Hz, } f_d = 271 \text{ Hz, } v_d = 0 \text{ m/s, } v_s \text{ is unknown} \)

\[ f_d = f_s \left( \frac{v - v_d}{v - v_s} \right) \]

Solve this equation for \( v_s \).

\[ v_s = v - f_s \left( \frac{v - v_d}{v - f_d} \right) \]

\[ = 343 \text{ m/s} - \left( \frac{262 \text{ Hz}}{271 \text{ Hz}} \right) (343 \text{ m/s} - 0 \text{ m/s}) \]

\[ = 11.4 \text{ m/s} \]

Section Review

15.1 Properties and Detection of Sound

pages 403–410

page 410

11. Graph The eardrum moves back and forth in response to the pressure variations of a sound wave. Sketch a graph of the displacement of the eardrum versus time for two cycles of a 1.0-kHz tone and for two cycles of a 2.0-kHz tone.

12. Effect of Medium List two sound characteristics that are affected by the medium through which the sound passes and two characteristics that are not affected.

affected: speed and wavelength; 
unaffected: period and frequency

13. Sound Properties What physical characteristic of a sound wave should be changed to change the pitch of the sound? To change the loudness?

frequency; amplitude

14. Decibel Scale How much greater is the sound pressure level of a typical rock band’s music (110 dB) than a normal conversation (50 dB)?

The sound pressure level increases by a factor of 10 for every 20-dB increase in sound level. Therefore, 60 dB corresponds to a 1000-fold increase in SPL.

15. Early Detection In the nineteenth century, people put their ears to a railroad track to get an early warning of an approaching train. Why did this work?

The velocity of sound is greater in solids than in gases. Therefore, sound travels faster in steel rails than in air, and the rails help focus the sound so it does not die out as quickly as in air.

16. Bats A bat emits short pulses of high-frequency sound and detects the echoes.

a. In what way would the echoes from large and small insects compare if they were the same distance from the bat?

They would differ in intensity. Larger insects would reflect more of the sound energy back to the bat.

b. In what way would the echo from an insect flying toward the bat differ from that of an insect flying away from the bat?

An insect flying toward the bat would return an echo of higher frequency (Doppler shift). An insect flying away from the bat would return an echo of lower frequency.

17. Critical Thinking Can a trooper using a radar detector at the side of the road determine the speed of a car at the instant the car passes the trooper? Explain.

No. The car must be approaching or
Chapter 15 continued

receding from the detector for the Doppler effect to be observed. Transverse motion produces no Doppler effect.

Practice Problems

15.2 The Physics of Music pages 411–419

18. A 440-Hz tuning fork is held above a closed pipe. Find the spacing between the resonances when the air temperature is 20°C.

Resonance spacing = \( \frac{\lambda}{2} \) so using \( \lambda = \frac{v}{f} \) the resonance spacing is

\[
\lambda = \frac{v}{2f} = \frac{343 \text{ m/s}}{(2)(440 \text{ Hz})} = 0.39 \text{ m}
\]

19. A 440-Hz tuning fork is used with a resonating column to determine the velocity of sound in helium gas. If the spacings between resonances are 110 cm, what is the velocity of sound in helium gas?

Resonance spacing = \( \frac{\lambda}{2} = 1.1 \text{ m} \) so \( \lambda = 2.2 \text{ m} \)

\[ v = \lambda f = (2.2 \text{ m})(440 \text{ Hz}) = 970 \text{ m/s} \]

20. The frequency of a tuning fork is unknown. A student uses an air column at 27°C and finds resonances spaced by 20.2 cm. What is the frequency of the tuning fork? Use the speed calculated in Example Problem 2 for the speed of sound in air at 27°C.

\[ v = 347 \text{ m/s at 27°C} \]

Resonance spacing gives \( \frac{\lambda}{2} = 0.202 \text{ m} \), or \( \lambda = 0.404 \text{ m} \)

\[ \frac{v}{\lambda} = \frac{347 \text{ m/s}}{0.404 \text{ m}} = 859 \text{ Hz} \]

21. A bugle can be thought of as an open pipe. If a bugle were straightened out, it would be 2.65-m long.

a. If the speed of sound is 343 m/s, find the lowest frequency that is resonant for a bugle (ignoring end corrections).

\[ \lambda_1 = 2L = (2)(2.65 \text{ m}) = 5.30 \text{ m} \]

The lowest frequency is

\[ f_1 = \frac{v}{\lambda_1} = \frac{343 \text{ m/s}}{5.30 \text{ m}} = 64.7 \text{ Hz} \]

b. Find the next two resonant frequencies for the bugle.

\[ f_2 = \frac{v}{\lambda_2} = \frac{343 \text{ m/s}}{2.65 \text{ m}} = 129 \text{ Hz} \]

\[ f_3 = \frac{v}{2L} = \frac{3v}{2(2.65 \text{ m})} = 194 \text{ Hz} \]

Section Review

15.2 The Physics of Music pages 411–419

22. Origins of Sound What is the vibrating object that produces sounds in each of the following?

a. a human voice

vocal cords

b. a clarinet

a reed

c. a tuba

the player’s lips

d. a violin

a string

23. Resonance in Air Columns Why is the tube from which a tuba is made much longer than that of a cornet?

The longer the tube, the lower the resonant frequency it will produce.

24. Resonance in Open Tubes How must the length of an open tube compare to the wavelength of the sound to produce the strongest resonance?

The length of the tube should be one-half the wavelength.

25. Resonance on Strings A violin sounds a note of F sharp, with a pitch of 370 Hz. What are the frequencies of the next three harmonics produced with this note?

A string’s harmonics are whole number multiples of the fundamental, so the frequencies are:

\[ f_1 = \frac{v}{\lambda_1} = \frac{343 \text{ m/s}}{5.30 \text{ m}} = 64.7 \text{ Hz} \]

\[ f_2 = \frac{v}{\lambda_2} = \frac{343 \text{ m/s}}{2.65 \text{ m}} = 129 \text{ Hz} \]

\[ f_3 = \frac{v}{2L} = \frac{3v}{2(2.65 \text{ m})} = 194 \text{ Hz} \]