Knowledge

For each question, select the best answer from the four alternatives.

1. Which statement is false, as suggested by the universal wave equation, $v = f\lambda$? (8.4) K/U
   (a) If the frequency is held constant, the speed increases as the wavelength increases.
   (b) Speed is the product of the frequency and the wavelength.
   (c) If the wavelength is held constant, the speed increases as the frequency decreases.
   (d) If the speed is held constant, wavelength increases as the frequency decreases.
2. Which best describes sound waves? (8.2) K/U
   (a) transfer of energy from one place to another
   (b) transfer of mass from one place to another
   (c) positive displacement of particles
   (d) movement in a direction perpendicular to the direction of the wave

Use Figure 1 to answer Questions 3 to 5.

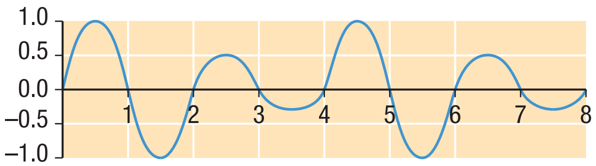

Figure 1

3. What is the amplitude of the wave? (8.3) K/U
   (a) 0.5 units
   (b) 0.75 units
   (c) 1 unit
   (d) 2 units
4. What is the wavelength of the wave? (8.3) K/U
   (a) 8 units
   (b) 4 units
   (c) 2 units
   (d) 1 unit
5. If the wave is moving 4 units to the right per second, what is its frequency? (8.4) K/U
   (a) 1 cycle per second
   (b) 1/2 cycle per second
   (c) 2 cycles per second
   (d) 8 cycles per second
6. If the frequency of a wave is 300 Hz and the wavelength is 1.5 m, what is the speed of the wave? (8.3, 8.4) K/U
   (a) 0.005 m/s
   (b) 200 m/s
   (c) 300 m/s
   (d) 450 m/s
7. If the frequency of a wave is 300 Hz and the wavelength is 1.5 m, how long does it take for a single wave to pass by? (8.4) K/U
   (a) 0.0033 s
   (b) 0.033 s
   (c) 200 s
   (d) 300 s
8. Balboa Park in San Diego, California, has an outdoor organ. When the air temperature increases, the fundamental frequency of one of the organ pipes
   (a) increases
   (b) decreases
   (c) stays the same
   (d) impossible to determine (8.4, 10.2) K/U
9. Which equation correctly states the relationship between the speed of a wave on a string and the linear density and tension of the string? (8.4) K/U
   (a) $v = \sqrt{\dfrac{F_T}{\mu}}$
   (b) $v = \sqrt{\dfrac{\mu}{F_T}}$
   (c) $v = \dfrac{\sqrt{F_T}}{\mu}$
   (d) $\mu = \dfrac{\sqrt{F_T}}{v}$
10. Which of the following actions will increase the speed of sound in air? (8.5) K/U
    (a) decreasing the air temperature
    (b) increasing the frequency of the sound
    (c) increasing the air temperature
    (d) increasing the amplitude of the sound wave

11. Which diagram in **Figure 2** shows a standing wave in a free-end system, such as in a brass instrument? (9.2) K/U

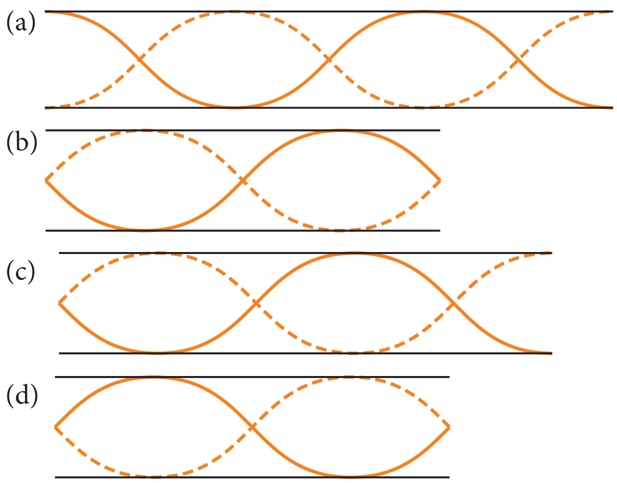

Figure 2

12. Which diagram in **Figure 3** shows the second harmonic for a violin string? (10.2) K/U

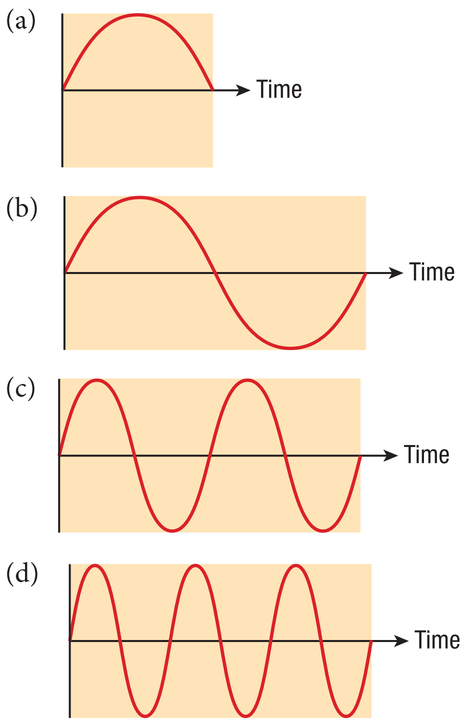

Figure 3

13. For the speed of sound to be 345 m/s, what must the air temperature be? (8.5) K/U
   (a) 8.1 °C
   (b) 18.1 °C
   (c) 19.3 °C
   (d) 22.4 °C

14. Which of the following definitions describes sound intensity? (8.5) K/U
   (a) loudness per metre
   (b) energy flowing through units of area
   (c) threshold of hearing between 1×10^{-12} W/m^2 and 1 W/m^2
   (d) decibels per cubic metre of volume

15. Of the following sounds, which is most likely to have an intensity level of 60 dB? (8.5) K/U
   (a) a rock concert
   (b) the turning of a page in this text
   (c) a cheering crowd at a football game
   (d) an alarm clock

16. Suppose you are on a hot-air balloon ride, carrying a buzzer that emits a sound of frequency f. If you accidentally drop the buzzer over the side while the balloon is rising at constant speed, what can you conclude about the sound you hear as the buzzer falls toward the ground? (8.5, 10.5) K/U
   (a) The frequency and intensity increase.
   (b) The frequency decreases and the intensity increases.
   (c) The frequency decreases and the intensity decreases.
   (d) The frequency remains the same, but the intensity decreases.

17. A pipe open at both ends resonates at a fundamental frequency, f_{open}. When one end is covered and the pipe is again made to resonate, the fundamental frequency is f_{closed}. Which of the following expressions describes how these two resonant frequencies compare? (9.2, 10.2) K/U
   (a) $f_{closed} = f_{open}$
   (b) $f_{closed} = \frac{3}{2} f_{open}$
   (c) $f_{closed} = 2f_{open}$
   (d) $f_{closed} = \frac{1}{2} f_{open}$

18. Which statement about the nodes of a standing wave on a string with two fixed ends is false? (9.2) K/U
   (a) The fixed ends are always nodes.
   (b) Adjacent nodes are separated by one wavelength.
   (c) Adjacent nodes are separated by a half wavelength.
   (d) The fundamental frequency occurs when the distance between adjacent nodes is from the standing wave pattern with the longest wavelength.

19. Which of the following frequencies is a higher harmonic of a string with a fundamental frequency of 150 Hz? (9.2) K/U
    (a) 200 Hz
    (b) 300 Hz
    (c) 400 Hz
    (d) 500 Hz
20. Which phrase best describes damping of a wave? (9.4) K/U
    (a) decreased velocity
    (b) constructive interference
    (c) decreased frequency
    (d) decreased amplitude
21. Which statement is appropriate for **Figure 4**? (9.5) K/U

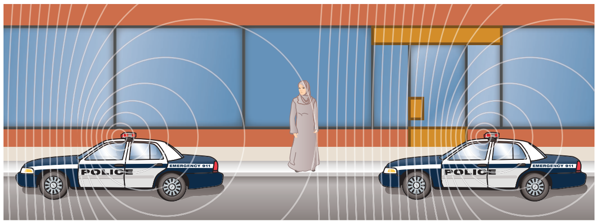

Figure 4

    (a) As the siren approaches the stationary observer, there are fewer sound waves per second, and the siren's frequency increases.
    (b) As the siren approaches the stationary observer, there are more sound waves per second, and the siren's frequency increases.
    (c) As the siren recedes from the stationary observer, there are more sound waves per second, and the siren's frequency decreases.
    (d) As the siren recedes from the stationary observer, there are fewer sound waves per second, and the siren's frequency increases.
22. Which statement describes a musical instrument with an air column that is open at both ends? (10.2) K/U
    (a) Antinodes are at both ends of the column.
    (b) The fundamental frequency occurs with the highest frequency and longest wavelength.
    (c) The fundamental frequency occurs when the length of the instrument equals the wavelength.
    (d) Nodes are at both ends of the column.
23. Which of the following is least likely to cause vibration in an aircraft? (10.6) K/U
    (a) engine operation
    (b) applying aerodynamic brakes
    (c) energy added to airflow around the wings is greater than energy lost
    (d) mass distribution

Indicate whether each statement is true or false. If you think the statement is false, rewrite it to make it true.

24. Sound travels fastest in a vacuum. (8.1) K/U
25. As an airplane flying with constant speed moves from a cold air mass into a warm air mass, the Mach number increases. (8.5, 8.6) K/U
26. Exposure to loud sounds, even for a short period of time, can cause hearing loss. (8.7) K/U
27. When two waves meet, the resultant wave's amplitude is the average of the two waves' amplitudes. (9.1) K/U
28. When a wave travels between two media and does not change its speed very much, more of the wave is transmitted than reflected. (9.2) K/U
29. The beat frequency is the difference between the frequencies of the waves interfering to produce a beat. (9.3) K/U
30. Standing waves are an example of resonance. (9.4) K/U
31. Rogue waves are caused by earthquakes. (9.6) K/U
32. The brain uses the number and location of hairs in the inner ear to determine the loudness and frequency of a sound. (10.1) K/U
33. Good concert hall acoustical design allows only direct sound to reach the audience. (10.3) K/U
34. Resonance caused the Tacoma Narrows Bridge to fall. (10.4) K/U
35. Body waves travel through Earth's atmosphere. (10.5) K/U
36. Dolphins can detect small objects over great distances using echolocation. (10.7) K/U

Match each term on the left with the most appropriate description on the right.

37.

(a) first harmonic	(i) λ
(b) second overtone	(ii) $\frac{3\lambda}{2}$
(c) second harmonic	(iii) $\frac{5\lambda}{2}$
(d) fourth harmonic	(iv) loop
(e) fourth overtone	(v) 2λ
(f) destructive interference	(vi) medical imaging
(g) seismic waves	(vii) bats' hunting
(h) acoustical beat	(viii) Earth exploration
(i) echolocation	(ix) piano tuning
(j) ultrasonic waves	(x) noise-cancelling earphones (8.5, 9.1, 9.2, 9.3, 10.5, 10.7) K/U

Write a short answer to each question.

38. A sound wave travels with a speed of 334 m/s through air with a frequency of 172 Hz. How far apart are the wave crests? (8.3) K/U
39. Humans hear sound with frequencies as low as 20 Hz. What is the wavelength of such a sound? (8.3) K/U
40. Explain or show the relationship between two waves with a phase shift of $\frac{1}{4}\lambda$. (8.3) K/U

Use Figure 5 to answer Questions 41 to 44.

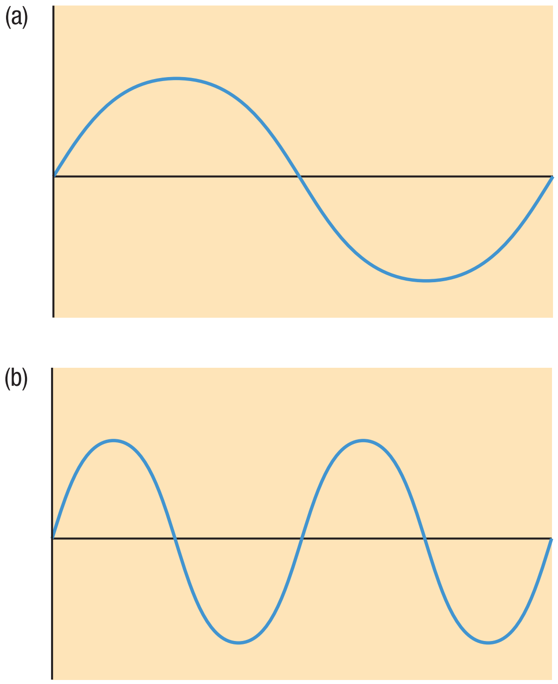

Figure 5

41. How do the frequencies of the two waves compare? (8.3) K/U
42. How do the wavelengths of the two waves compare? (8.3) K/U
43. How do the amplitudes of the two waves compare? (8.3) K/U
44. Identify where the two waves share a node. (9.2) K/U
45. What is the linear density of 6 m of rope with a mass of 330 g? (8.4) K/U
46. A man standing on a dock is watching the waves pass by the end of the dock. He times the passage of the waves as one crest every 2.5 s. He estimates the distance between two crests to be 2.0 m. How fast are the waves moving? (8.4) K/U
47. A tour guide shouts across a canyon. At a temperature of 20 °C, her echo is heard 2.00 s later. How wide is the canyon? (8.5) K/U T/I
48. What does it mean to say that a conversation in a room is at Mach 1? (8.5) K/U
49. Determine the fundamental frequency of a vibrating string if two successive harmonics of the string are 180 Hz and 270 Hz. (9.2) K/U
50. Explain what type of reflection is created by flicking a fishing rod. What is the orientation of the reflected wave? (9.2) K/U
51. The distance between successive antinodes in a standing wave pattern is equivalent to how many wavelengths? (9.2) K/U
52. A standing wave is produced in a rope by vibrating one end with a frequency of 75 Hz. The distance between the first and fourth nodes is 45 cm. How long is the wavelength? (9.2) K/U
53. Describe the Doppler effect when a moving ambulance with its siren on approaches an observer standing on a street corner. (9.5) K/U
54. Create a Venn diagram comparing rogue waves and tsunamis. (9.6, 10.5) K/U C
55. For each numbered step in **Figure 6**, write one sentence that explains the different stages of how we hear. (10.1) K/U C

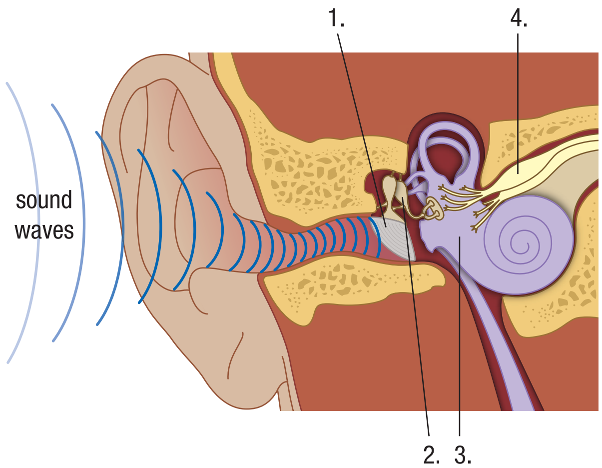

Figure 6

56. The auditory canal has a natural frequency of about 3500 Hz. If the speed of sound waves inside the canal is about 350 m/s, what is the length of the auditory canal? (10.1) K/U
57. Why does a vibrating guitar string sound louder when placed on the instrument than it would if allowed to vibrate in the air while off the instrument? (10.2) K/U
58. What happens to the pitch of a musical note if the frequency of the note is decreased? (10.2) K/U
59. How can the frequency produced by a kettledrum be changed? (10.2) K/U

60. At what frequencies do the higher harmonics of an open-air-column musical instrument occur? (10.2) K/U
61. A concert choir has a loudness of 73 dB. What will the sound level drop to after the reverberation time? (10.3) K/U
62. What can be done to shorten the reverberation time in a concert hall? (10.3) K/U
63. Explain how a mass damper improves a building's structural safety. (10.4) K/U
64. The length of a closed-end air column is how many wavelengths of the first harmonic? (10.2) K/U

Understanding

65. Explain why no work is done when a wave passes through a medium. (8.1) K/U
66. Explain why sound waves can be described as pressure waves. (8.2) K/U
67. In your own words, describe and distinguish between wave speed, wavelength, and wave frequency. (8.3) K/U
68. A violin string with a mass of 0.35 g is 33 cm long. The frequency of a wave supported by the string is 196 Hz. (8.4) T/I
    (a) What is the speed of the wave?
    (b) What is the linear density of the string?
    (c) What is the tension on the string?
69. Different factors determine the pitch created by a string fixed at each end. Copy **Table 1** into your notebook. For each factor listed, identify the effect that each factor will have on the pitch you would hear if the factor is increased or decreased. (8.4, 10.2) K/U

Table 1 Pitch Variation

Variable	Increased	Decreased
tension		
length		
diameter		
density		

70. Explain how constructive and destructive interference can be demonstrated when sending pulses from each end of a Slinky. (9.1) K/U
71. (a) How does a free-end reflection help explain the change in a wave's behaviour at a media boundary at which it slows down?
    (b) How does a fixed-end reflection help explain the change in a wave's behaviour at a media boundary at which it speeds up? (9.2) K/U
72. Explain how standing waves are examples of resonance. (9.4) K/U
73. Why does a cochlear implant work better than a hearing aid for a person with serious hearing loss? (10.1) K/U
74. Explain or demonstrate how noise and music are different. (10.2) K/U
75. Two different auditorium designs are shown in **Figure 7**. The arrows show sound coming from the stage and give a general idea of how the sound will reflect toward the audience. (10.3) K/U C
    (a) Which design has better acoustics? Explain your reasoning.
    (b) For the auditorium with inferior acoustics, describe the most obvious major design flaw.

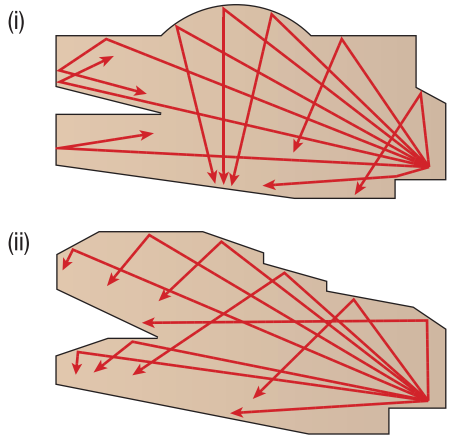

Figure 7

76. A parent pushes a child on a swing, and the swing develops large amplitudes.
    (a) Describe why this happens.
    (b) Will the swing develop large amplitudes no matter how much the parent pushes? (10.4) K/U
77. How are seismic waves used to gather information about Earth's interior? (10.5) K/U

Analysis and Application

78. A lightning flash dissipates an enormous amount of energy and is essentially instantaneous. How is the energy transformed into the sound waves of thunder? (8.1) T/I
79. To double the speed of a wave, by what factor would you change (a) the tension or (b) the linear density on a string? Explain your answer mathematically. (8.4) K/U
80. An autofocus camera used indoors sends out a pulse of sound and measures the time taken for the pulse to reach an object, reflect off it, and return to be detected to set the focus. If the camera is taken outdoors, where the temperature is cold, can the temperature affect the camera's focus? Explain your answer. (8.5) K/U T/I A

81. Intensity is said to be an objective measure of sound while loudness is said to be subjective. Explain why one term is objective and the other is subjective. (8.5) T/I

82. Use **Table 2** to answer the following questions. (8.5) T/I

Table 2 Typical Sound Levels

Type of sound	Sound level (dB)	Sound intensity (W/m²)
normal breathing	10	1×10^{-11}
whisper	20	1×10^{-11}
power saw	120	1
rain	130	10
military jet taking off	140	100

(a) Give an example of two sounds from the table, one that is twice as loud as the other.
(b) By what factor do the intensities of the two sounds from (a) compare?

83. Explain how the distance to a lightning bolt can be determined by counting the seconds between the flash and the sound of thunder. (8.5) K/U A

84. How might an acoustic shadow affect the interpretation of an ultrasound medical test? (8.5, 10.3) K/U

85. Are longitudinal waves in air always audible as sound, regardless of frequency or intensity? Explain your answer. (8.5, 10.1) T/I

86. Dolphins produce sounds ranging from 1.5 kHz to 11.0 kHz and can hear sounds up to 150 kHz. The high-frequency "clicks" of the bottle-nosed dolphin include sounds below 20 kHz and up to 120 kHz. How do these ranges compare to the range of human hearing? (8.5, 10.1, 10.7) T/I

87. The land vehicle Thrust SSC achieved a land speed of 1228 km/h in 1997 at an elevation of 1191 m. Determine if this car broke the sound barrier, and explain how the achievement would be different if the car were driven at sea level. (8.6) K/U T/I

88. Contrast the creation of the first harmonic frequencies for (a) a tube with open ends and (b) a tube with one open end and one closed end. (9.2) K/U

89. Based on what you have learned about open and closed air columns, explain the purpose of air holes on a clarinet. (9.2) K/U

90. A pipe resonates at successive frequencies of 540 Hz, 450 Hz, and 350 Hz. Is this an open or a closed pipe? (9.2) T/I

91. Explain why the bass notes of a car radio are heard by people on the street and not the high notes. (9.2) T/I

92. Beats can easily be heard on a guitar. When a finger is placed at the fifth fret of the second string, the note produced when the string is plucked should be identical to the note from the first string when it is plucked. When you pluck both strings together, and one of the strings is slightly out of tune, you will hear a very pronounced beat frequency. What happens to the beat frequency as the string tension is changed in small increments from too low for the intended tuning to too high? (9.3) T/I

93. Despite a reasonably steady hand, a person often spills his coffee when carrying it. Discuss resonance as a possible cause of this difficulty, and devise a means for solving the problem. (9.4) K/U

94. You see a video on the Internet of a crystal glass being shattered as an opera singer hits a certain note. Explain why this might occur. (9.4) T/I

95. Explain what happens to the detected frequency for a jet flying near the speed of sound as it passes a stationary observer below. (9.5, 9.6) K/U

96. Suppose you snip off the corners of one end of a paper straw so that the end tapers to a point, as shown in **Figure 8**. Then you flatten it, for example, by chewing on the tapered end. Suppose you put your lips around the tapered end of the straw, press them together slightly, and blow through the straw. You hear a steady tone, then you slowly snip off a piece of the straw at the other end. (10.2) T/I

(a) How does the frequency of the sound change as the straw becomes shorter?
(b) Why does this change occur?

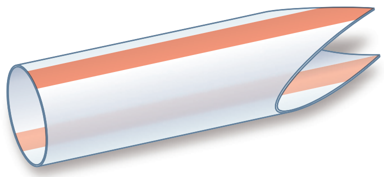

Figure 8

97. Explain the audible tone produced by drawing a wet finger around the rim of a crystal glass. (10.2) T/I

98. A musical octave is separated into 12 equal divisions called semi-tones, each differing from the next by a factor of $2^{n/12}$. **Table 3** shows the semi-tones and their frequencies beginning with A, which has a frequency of 440 Hz. Use Table 3 to answer the following questions. (10.2) T/I C

Table 3 Musical Frequencies

Note	*f* (Hz)	Note	*f* (Hz)	Note	*f* (Hz)	Note	*f* (Hz)
A	440	C	523	$D^{\#}$	622	$F^{\#}$	740
$A^{\#}$	466	$C^{\#}$	554	E	659	G	784
B	494	D	587	F	698	$G^{\#}$	831

(a) Explain or show why the frequency of a note 12 semi-tones above A is 880 Hz.
(b) What is the ratio of the frequency of E to that of A?
(c) If an open tube of length L has a fundamental frequency of 440 Hz, what length of tube would produce an E?

99. A piezoelectric material is a natural or manufactured substance that produces an electrical charge when subjected to a mechanical strain such as being hit or vibrated. If the material is subjected to an electrical current, it will bend or vibrate depending on the material and the nature of the current. How could the properties of piezoelectric materials be used to reduce vibrations and noise? (10.4, 10.6) T/I

100. A blowing whistle is attached to the roof of a car that moves around a circular race track. Assuming you are standing near the outside of the track, explain the nature of the sound you hear as the whistle comes by each time. (9.5) K/U C

Evaluation

101. Evaluate the following statement. Explain your reasoning. "The speed of sound is the same for all wavelengths." (8.4) T/I

102. **Figure 9** shows an object moving very quickly to the right. (8.6, 9.5) T/I
(a) Relate Figure 9 to the speed of sound and the sound barrier.
(b) Modify the diagram to show an object moving at a speed that is (i) less than the speed of sound and (ii) greater than the speed of sound. Support your reasoning for each diagram using the Doppler effect and/or the speed of sound in air.

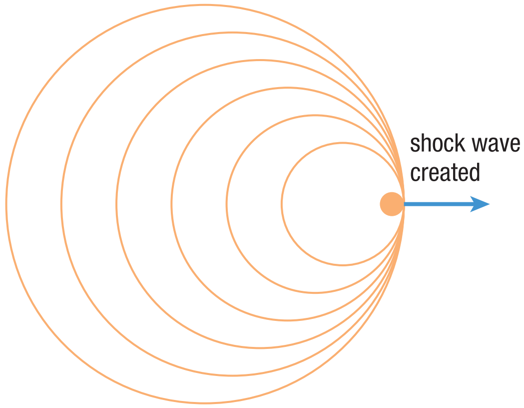

Figure 9

103. A friend suggests all people can reduce the effect of noise pollution at work by using earplugs all day. Evaluate the effectiveness of this solution. (8.7) T/I

104. When is resonance to be avoided, and when is it desirable? (9.4, 10.4) T/I

105. Decide if a dome-roofed stadium or a parabola-shaped shell would be suitable for a concert venue. (10.3) T/I

106. Compare and contrast mechanical resonance and aeroelastic flutter. (10.4) T/I

Reflect on Your Learning

107. How did your learning in this unit connect to your prior knowledge of waves? T/I

108. Explain an idea that you initially had difficulty with but gained an understanding of in this unit. T/I

109. What was the most surprising thing you learned in this unit? C

110. How did the information you learned in this unit affect your thinking about the dangers and benefits of vibrations and waves? T/I

111. What further aspects of waves and sound and their applications would you like to know more about? T/I

Research

GO TO NELSON SCIENCE

112. Research the 1929 Grand Banks earthquake and tsunami. Prepare a visual presentation. Provide observations of eyewitness or newspaper accounts contemporary with the actual events. Contrast these reports with more recent scientific explanations in terms of seismic wave activity and landslides. T/I C

113. Investigate the criteria for acceptable levels of noise at the federal and provincial levels. Consult information provided by the Canadian Centre of Occupational Health and Safety. Prepare a brief presentation explaining criteria levels and exchange rates. Include some sound samples. Discuss the implications of standards on particular types of occupational or recreational noise. T/I C

114. Investigate the mathematical relationship between sound intensity and loudness. Prepare a brief presentation explaining this relationship. Pose and solve some problems illustrating this relationship. T/I C

115. The Bay of Fundy is legendary for its high tides. Find out what tidal resonance means. Which body of water holds the world's record for the highest tides? Write a short report about your findings. T/I C

116. The Canadian composer R. Murray Schafer introduced the idea of sound ecology in his World Soundscape Project. Research his work on sounds in the environment and noise pollution. Listen to a recording of the Vancouver Soundscape. Prepare a brief podcast discussing the history of this project and the role it has played in promoting acoustic technology and sound legislation. T/I C

117. Ultrasound stethoscopes make use of the Doppler effect. As a result, these stethoscopes are more effective than traditional stethoscopes in noisy environments. Prepare a brief report on how ultrasound stethoscopes make use of the Doppler effect. T/I C

118. Sound therapy is said to have a healing effect on both the creator of the sound and the listener. Research sound therapy, and make a brief presentation on sound therapy with instruments such as the didgeridoo. Include audio clips if possible. T/I C

119. Find out and explain how research on bat echolocation has been applied to robotics. T/I C

120. Scales provide a palette of tones for melodies and harmonies to someone writing and playing music. The scales are based on relationships between the frequencies of successive tones. Prepare a brief presentation contrasting the frequencies and wavelengths of the notes in a musical major scale and its related minor scale. Compare and contrast the tones in these two scales. C

121. The production of human sounds depends on the regulation of airflow through the lungs, throat, nose, and mouth. This airflow is altered in various ways by systems involving the lungs, trachea, voice box, and oral and nasal cavities. Investigate the production and frequencies of men's and women's voices. Prepare a brief report on the physiology and physics of speech. T/I C

122. Investigate and prepare a brief report on the acoustical properties of a nearby auditorium or sports arena. Consider major elements of design as well as materials. You may wish to construct a scale model and explain how an acoustic model would differ from an architectural model. T/I C

123. Acoustical feedback occurs when sound coming out of a speaker travels back into the microphone and is re-amplified. Investigate a microphone and sound system or the microphone in a hearing aid for feedback. Prepare the text for a short email that you could send to a friend explaining how feedback can be suppressed. T/I C

124. You have been hired to design an open office that will minimize noise pollution for workers. The owners of the company do not want to insert walls in the space because they want to foster cooperation among the employees. However, they also want to minimize distractions due to noise from other workers. Research acoustics principles as applied to office design. In a simple diagram, design an office suited for eight employees. Include a half-page explanation describing how you have achieved your goals. Mention the different ways sound can reach the workers and how your design helps reduce the amount of sound. T/I C

125. Research how the Doppler effect has been applied to monitoring heart rates. Include in your research how this new method is an advantage over older methods. Describe any difficulties with using the Doppler effect to monitor heart rate, and explain how these difficulties have been overcome. T/I C

126. The blue whale (**Figure 10**) uses echolocation for reasons other than detecting prey. Research blue whales and echolocation. Prepare a blog or wiki page that explains two ways that blue whales use echolocation. Include an audio file of the blue whale's sound. K/U C A

Figure 10