Unit 4 Review, pages 490–497

Knowledge

1. (c)
2. (a)
3. (c)
4. (b)
5. (a)
6. (d)
7. (a)
8. (a)
9. (a)
10. (c)
11. (a)
12. (b)
13. (d)
14. (b)
15. (d)
16. (c)
17. (c)
18. (b)
19. (b)
20. (d)
21. (b)
22. (a)
23. (c)
24. False. Sound *does not travel* in a vacuum.
25. True
26. True
27. False. When two waves meet, the resultant wave's amplitude is the *sum* of the two waves' amplitudes.
28. True
29. True
30. True
31. False. *Tsunamis* are caused by earthquakes.
32. True
33. False. Good concert hall design allows *both* direct sound *and some early reflections* to reach the audience.
34. False. *Some engineers believe that aeroelastic flutter* caused the Tacoma Narrows Bridge to fall.
35. False. Body waves travel through *Earth's interior*.
36. True
37. (a) (iv)
(b) (ii)
(c) (i)
(d) (v)
(e) (iii)
(f) (x)
(g) (viii)
(h) (ix)
(i) (vii)
(j) (vi)
38. The distance between wave crests equals the wavelength. The wavelength equals the speed divided by the frequency:

$$\lambda = \frac{v}{f}$$
$$= \frac{334\text{ m/s}}{172\text{ Hz}}$$
$$\lambda = 1.94\text{ m}$$

The wave crests are 1.94 m apart.
39. The wavelength equals the speed divided by the frequency. Use 345 m/s for the speed of sound:

$$\lambda = \frac{v}{f}$$
$$= \frac{345\text{ m/s}}{20\text{ Hz}}$$
$$\lambda = 17\text{ m}$$

The wavelength of such a sound is 17 m.
40. Since the phase shift is one quarter of the wavelength of the waves, the waves will look identical but one will be one quarter of the wavelength to the right of the other. This wave will start as the other has reached its crest, reach its crest as the other has returned to the equilibrium, and so on.
41. The frequency of (b) is double the frequency of (a) because two waves of (b) go by for every wave of (a).
42. The wavelength of (a) is double the wavelength of (b) because two waves of (b) take up the same length as a single wave of (a).
43. The two waves have the same amplitude.
44. The two waves share a node at the start, middle, and end of the graphs because these are the locations along the equilibrium where they intersect.
45. The linear density equals the mass in kilograms divided by the length in metres:

$$\mu = \frac{m}{L}$$
$$= \frac{330\ \cancel{\text{g}}}{6\text{ m}}\left(\frac{1\text{ kg}}{1000\ \cancel{\text{g}}}\right)$$
$$\mu = 0.06\text{ kg/m}$$

The linear density of the rope is 0.06 kg/m.
46. The speed of the waves equals the wavelength divided by the period:

$$v = \frac{\lambda}{T}$$
$$= \frac{2.0\text{ m}}{2.5\text{ s}}$$
$$v = 0.80\text{ m/s}$$

The speed of the waves is 0.80 m/s.

47. The width of the canyon is half the distance the sound waves travelled, or the distance sound can travel in half the time (1.0 s). First determine the speed of sound at 20 °C:

$$v = 331.4 \text{ m/s} + (0.606 \text{ m/s/°C})T$$
$$= 331.4 \text{ m/s} + \left(0.606 \frac{\text{m/s}}{\cancel{°\text{C}}}\right)(20 \cancel{°\text{C}})$$
$$v = 343.5 \text{ m/s (two extra digits carried)}$$

Then determine the width of the canyon:

$$\Delta d = v\Delta t$$
$$= \left(343.5 \frac{\text{m}}{\cancel{\text{s}}}\right)(1.0 \cancel{\text{s}})$$
$$\Delta d = 340 \text{ m}$$

The canyon is 340 m wide.

48. Mach 1 is another way of saying the speed of sound at a certain temperature. Saying the speed of conversation is at Mach 1 is a joke because it makes the conversation sound really fast, but it is also true because that is the speed of sound waves.

49. The difference between successive harmonics equals the fundamental frequency:

270 Hz – 180 Hz = 90 Hz

The fundamental frequency of the string is 90 Hz.

50. Flicking a fishing road creates free-end reflection. The orientation of the reflected wave is the same as the orientation of the original.

51. Successive antinodes are half a wavelength apart.

52. Successive nodes are half a wavelength apart. The first and fourth nodes are 1.5 wavelengths apart.

$$1.5\lambda = 45 \text{ cm}$$
$$= \frac{45 \text{ cm}}{1.5}$$
$$\lambda = 30 \text{ cm}$$

The wavelength is 30 cm.

53. As the ambulance approaches the observer, the frequency of the sound waves is observed as higher than what is actually emitted.

54. Both: large waves; can cause massive destruction.

Tsunamis: caused by earthquakes.

Rogue waves: caused by constructive interference by several waves.

55. 1. The sound waves vibrate the eardrum.

2. The eardrum causes the three small bones to vibrate.

3. The bones transmit the sound waves to the cochlea, where the hair cells vibrate.

4. The auditory nerve transmits the message to the brain, which interprets the sound.

56. Given: f_0 = 3500 Hz; v = 350 m/s; open and closed ends

Required: L

Analysis: $f_0 = \frac{v}{\lambda}$

$$= \frac{v}{4L}$$
$$L = \frac{v}{4f_0}$$

Solution: $L = \frac{v}{4f_0}$

$$= \frac{350 \frac{\text{m}}{\text{s}}}{4(3500 \text{ Hz})}$$
$$L = 0.025 \text{ m}$$

Statement: The length of the auditory canal is 0.025 m or 2.5 cm.

57. The guitar string sounds louder on the instrument than in the air because the instrument is a resonator. It increases the sound level and quality.

58. When the frequency of a note decreases, the pitch decreases.

59. The frequency can be adjusted by pressing on the pedal. When the pedal is pressed, it changes the tension in the head, which then changes the resonant frequencies of the head

60. Higher harmonics occur at whole-number multiples of the fundamental frequency in open-air column musical instruments.

61. The sound drops by 60 dB after the reverberation time.

73 dB – 60 dB = 13 dB

The sound level will drop to 13 dB.

62. Answers may vary. Sample answer:

To shorten the reverberation time in a concert hall, change the texture of the materials in the walls, ceiling, floor coverings, and furniture.

63. A mass damper decreases the amplitude due to resonance or aeroelastic flutter. The damper creates sympathetic vibrations, which absorb some of the energy from the building when the building is vibrating

64. A closed-end air column is one quarter of a wavelength of the first harmonic. A closed-end air column has a node at one end and an antinode at the other end. This occurs at the ends of a quarter of a cycle.

Understanding

65. No work is done because the particles of the medium have no net movement as a result of the wave's passage.

66. Sound waves are a series of alternating levels of pressure, caused by compressions and rarefactions in air particles.

67. A wave's speed is how fast the wave travels in units of distance per units of time. A wave's length is the distance between two identical adjacent points, such as two crests or two troughs. A wave's frequency is the number of times the wave repeats in a given amount of time.

68. (a) Given: L = 33 cm = 0.33 m; f = 196 Hz; two fixed ends

Required: v

Analysis:
$$v = f\lambda$$
$$= f(2L)$$
$$v = 2fL$$

Solution:
$$v = 2fL$$
$$= 2(196\text{ Hz})(0.33\text{ m})$$
$$v = 130\text{ m/s}$$

Statement: The wave speed is 130 m/s.

(b) Given: m = 0.35 g = 0.000 35 kg; L = 0.33 m

Required: μ

Analysis: $\mu = \dfrac{m}{L}$

Solution:
$$\mu = \frac{m}{L}$$
$$= \frac{0.000\ 35\text{ kg}}{0.33\text{ m}}$$
$$\mu = 0.0011\text{ kg/m}$$

Statement: The linear density of the string is 0.0011 kg/m.

(c) Given: m = 0.000 35 kg; L = 0.33 m; v = 130 m/s

Required: F_{T}

Analysis:
$$v = \sqrt{\frac{F_{\text{T}}}{\mu}}$$
$$v^2 = \frac{F_{\text{T}}}{\mu}$$
$$F_{\text{T}} = \mu v^2$$
$$F_{\text{T}} = \left(\frac{m}{L}\right)v^2$$

Solution:
$$F_{\text{T}} = \left(\frac{m}{L}\right)v^2$$
$$= \frac{0.000\ 35\text{ kg}}{0.33\text{ m}}(130\text{ m/s})^2$$
$$= \frac{0.000\ 35\text{ kg}}{0.33\ \cancel{\text{m}}}\left(16\ 900\ \frac{\text{m}^{\cancel{2}}}{\text{s}^2}\right)$$
$$F_{\text{T}} = 18\text{ N}$$

Statement: The tension on the string is 18 N.

69. Table 1

Variable	Increased	Decreased
tension	**higher pitch**	**lower pitch**
length	**lower pitch**	**higher pitch**
diameter	**lower pitch**	**higher pitch**
density	**lower pitch**	**higher pitch**

70. Send simultaneous pulses with the same orientation and same amplitude from each end of the Slinky to demonstrate constructive interference. The amplitude of the combined wave will be the sum of the two amplitudes. Send simultaneous pulses of the same amplitude but opposite orientation from each end to demonstrate destructive interference. The resultant will have no amplitudes.

71. (a) If a wave's speed is slower in the new medium, the wave encounters less restriction. As in the free-end case, the reflected wave has the same orientation as the original.

(b) If a wave's speed is faster in the new medium, the wave encounters more restriction. As in the fixed-end case, the reflected wave is inverted.

72. Standing waves occur when the wavelength is a multiple of the fundamental frequency, which is a resonant frequency.

73. Cochlear implants work better than hearing aids for people with serious hearing loss because the implant bypasses the damaged parts of the ear. The implant converts sound into electrical signals and then sends the electrical signals directly to the auditory nerve.

74. The sound waves of music are regular, repeating waves. The sound waves of noise are more chaotic patterns.

75. (a) Auditorium (ii) has better acoustics because everyone in the audience will experience the sound in about the same way.

(b) Auditorium (i) should not have a concave surface because it focuses sound waves in one location and does not reflect sound waves to other locations.

76. (a) The parent is adding energy at the resonant frequency of the swing, which increases the amplitude.
(b) No. Energy is lost to air resistance and gravity, so the amplitude would go to zero without the parent pushing.
77. Seismic waves pass through different materials in Earth's interior and partially reflect and partially refract whenever they pass into a new medium. Differences in the waves can be recorded at regular intervals and traced at the surface to determine locations of changes in the media. The data can be used to identify the different media, based on known properties.

Analysis and Application

78. When lightning strikes, huge amounts of electricity shoot through the air. This causes two things to happen. First, the electricity hits the air and starts the air vibrating, causing a sound. Second, the lightning is also very hot and it heats up the air around it. Hot air expands very quickly and pushes against the air particles, starting another vibration. These vibrations are what you are hearing when you hear thunder. The rumbling of thunder is caused by the vibration or sound bouncing off the ground and the clouds.
79. (a) To double the speed of a wave, multiply the tension by four:

$$v = \sqrt{\frac{F_T}{\mu}}$$

$$2v = 2\sqrt{\frac{F_T}{\mu}}$$

$$2v = \sqrt{\frac{4F_T}{\mu}}$$

(b) To double the speed of a wave, multiply the linear tension by $\frac{1}{4}$:

$$v = \sqrt{\frac{F_T}{\mu}}$$

$$2v = 2\sqrt{\frac{F_T}{\mu}}$$

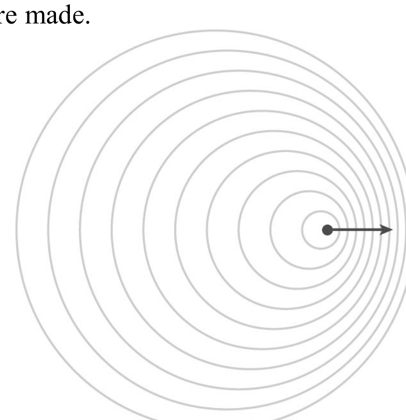
$$2v = \sqrt{\frac{F_T}{\frac{1}{4}\mu}}$$

80. Yes, the temperature can affect the camera's focus. The speed of sound is dependent on the temperature. So, the speed of sound can change by more than 12 m/s if there is a 20 °C difference in the temperature.
81. Units of intensity are watts per square metre, which are measurable with instruments and are objective. Loudness depends on human perception, which is subjective.
82. (a) The sound level of a whisper is double the sound level of normal breathing.
(b) A whisper has ten times the sound intensity as normal breathing.
83. The distance to a lightning bolt can be determined by counting the seconds between the flash and the thunder because the sound waves begin at the flash, so you can calculate the distance by multiplying the speed of sound by the time.
84. An acoustic shadow might prevent the detection of a tumour present in the shadow.
85. No they are not. Human ears can detect a range of frequencies from 20 Hz to 20 kHz. Frequencies outside this range are not audible to humans, even though the longitudinal waves exist. Intensity also makes a difference because the lower the frequency of the sound wave, the higher (generally) the intensity that is required to hear the sound.
86. Humans hear between 20 Hz to 20 kHz. Dolphins hear sounds at frequencies more than seven times as high as humans can hear. Humans may hear dolphin communication and some of the clicks below 20 kHz produced by dolphins.
87. At sea level, the speed of sound is 1225 km/h. At an elevation of 1191 m, the speed of sound would be less due to the change in temperature (closer to 1200 km/h) so the Thrust SSC did break the sound barrier.
88. In an open-ended tube, there are antinodes at both ends. In a closed-end tube, there is an antinode at one and a node at the other end. In an open-ended tube, the first harmonic has a wavelength equal to twice the length of the tube. In a closed-air tube, the first harmonic has a wavelength equal to four times the length of the tube.
89. The clarinet is a closed-air column. By pressing the holes on the side of the clarinet, the air column length is changed, thus changing the resonant wavelengths and frequencies. The holes are positioned to produce the tones of a scale.

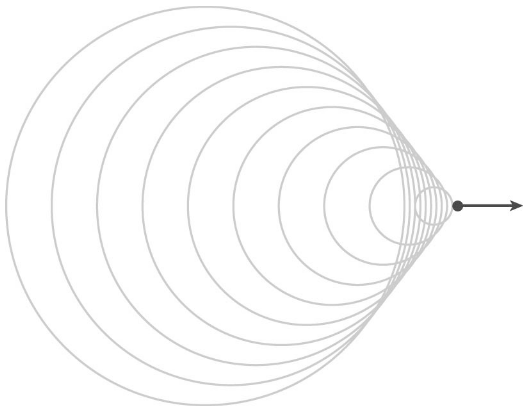
90. Determine the difference between successive harmonics, which equals the fundamental frequency.
540 Hz – 450 Hz = 90 Hz
450 Hz – 360 Hz = 90 Hz
Since the frequencies are odd- and even-number multiples of the fundamental frequency, this is an open pipe.
91. Low notes have longer wavelengths than high notes. Their wavelengths are wider than the car frame and windows and are transmitted through them rather than reflected.
92. The beat frequency decreases as the frequency of the string gets closer to the intended frequency. When the strings have the same frequency, there is no beat at all. As the tension gets too high, the beat frequency returns and increases.
93. Answers may vary. Sample answer:
A person walking with a mug of coffee could be stepping at the same frequency as the coffee sloshing in the mug, which increases the amplitude of the sloshing and spills the coffee. To avoid this resonance, the person should walk slower so the frequency of the steps and the coffee do not match.
94. If a note is sung at the resonant frequency of the glass, the glass may vibrate until it shatters.
95. As the speed of the jet gets closer to the speed of sound, the detected frequency gets higher and closer to the sonic boom.
96. (a) The frequency increases as the length decreases.
(b) The speed of sound is constant, so as the wavelength shortens, the frequency increases.
97. If you run a wet finger lightly along the rim of a crystal glass, the glass should begin vibrating. This involves a resonant transfer of energy in which your finger rhythmically pushes on the glass to make it vibrate more and more strongly. Your finger must stick and slip alternately, just as a bow does while sliding across a violin string.
98. (a) If $n = 12$, then the difference between A and the new frequency is a factor of two.
2(440 Hz) = 880 Hz
The frequency of a note 12 semi-tones above A is 880 Hz.
(b) E is seven semi-tones above A, so the ratio of the frequencies is $2^{\frac{7}{12}}$ or 1.50.
(c) The ratio of the frequencies is 1.50. The ratio of the lengths is the reciprocal of the ratio of the frequencies. So, L is 1.50 times the length of a tube that produces an E. The length is $\frac{2}{3}L$.
99. Answers may vary. Sample answer:
Piezoelectric materials can be used to absorb vibrations and convert them into electricity. Piezoelectric materials could also be used to send out sound waves that create destructive interference and cancel out noise.
100. As the whistle approaches you, the Doppler effect causes the sound to shift to a frequency higher than the natural frequency of the whistle. You will momentarily hear the natural frequency just as the whistle comes parallel with you and is in the act of passing. As soon as the whistle is past, you will hear sound that is shifted to a frequency lower than the natural frequency of the whistle. As the frequency of the sound changes, the intensity of the sound varies continuously. The loudness increases smoothly to a maximum and then decreases.

Evaluation

101. For any given medium, the speed of sound in that medium is the same for all wavelengths. As the wavelength of a sound wave changes, the frequency of the sound wave changes inversely. The result is the product $v = f\lambda$ stays the same.
102. (a) The object in Figure 9 is travelling at the speed of sound. It has reached the sound barrier which is a shock wave created by all the accumulating sound waves all at the same point.
(b) (i) At less than the speed of sound, observers detect the sound waves at a higher frequency than they are made.



(ii) At greater than the speed of sound, observers detect the more recent sound waves first.



103. Although wearing earplugs can reduce the damage caused by noise pollution, it will not decrease the actual noise, just the noise detected by your ears.
104. Resonance should be avoided in structures such as buildings and bridges and vehicles such as aircraft because the wide oscillations can cause damage. Resonance is desirable in musical instruments, which produce pleasing sounds when they resonate.
105. A parabola-shaped shell is suitable for a concert venue because it focuses sound waves out into the audience. A dome-roofed stadium focuses sound waves to specific points and deflects sound waves away from others, so it is less suitable for a concert venue.
106. Mechanical resonance and aeroelastic flutter both involve energy being added to an object from an outside source. In mechanical resonance, the outside source is another object with the same resonant frequency. In aeroelastic flutter, the energy comes from wind exerting a force on a structure due to the aerodynamics of the structure.

Reflect on Your Learning

107. Answers may vary. Students might reflect on their understanding of the Doppler effect.
108. Answers may vary. Students might reflect on an important idea such as resonance, which became clearer when observing and explaining some real-life examples, such as a swing, a rope, and a guitar string.
109. Answers may vary. Sample answer:
I was surprised to learn about acoustic beats. I had heard them before but never understood what was going on with the sound waves.
110. Answers may vary. Sample answer:
Now I know about the dangerous aspects of waves that need to be considered when building a skyscraper. I also know how to apply sympathetic vibrations to damp vibrations in a skyscraper.
111. Answers may vary. Students may be interested in how the larynx creates speech or applications of sound and waves in environmentalism.

Research

112. Answers may vary. Students should present their findings on the 1929 earthquake off the coast of Newfoundland and the damage caused by the ensuing tsunami. They should apply their knowledge of tsunamis from this unit to their presentations.
113. Answers may vary. Laws about noise levels do very slightly across Canada, and different provinces and municipalities have different specific laws. Students should prepare a presentation on about acceptable noise levels and include specific examples.
114. Answers may vary. Sound intensity is a linear scale while loudness is expressed using a logarithmic scale. Students should prepare a brief presentation expressing these scales and how they relate. Presentations should include examples and pose problems to solve.
115. Answers may vary. Sample answer:
The Bay of Fundy holds the world's record for the highest tides. The high tides result from tidal resonance. The Bay of Fundy's own tides are in sync with the incoming ocean tides, so the two tides combine to create higher high tides and lower low tides.
116. Answers may vary. Students' podcasts should discuss the origin of the World Soundscape Project (WSP) and the importance of this bank of environmental sounds. Student should also discuss the impact the WSP has had on noise pollution laws and the advancement of acoustic technology.
117. Answers may vary. Sample answer:
Ultrasound stethoscopes work like speed radar. The stationary stethoscope sends out waves that detect motion in the body, such as a heart beat, by watching for a Doppler effect in the waves that return to the stethoscope. The minor changes due to the Doppler effect are interpreted as heart beats or breathing by the stethoscope.

118. Answers may vary. Students should explain the benefits of listening to sound as well as the regular vibrations they cause. The benefits to those performing the music, such as the healthy rhythmic breathing for a woodwind instrument, should be included.

119. Answers may vary. Sample answer:
Bats can detect objects smaller than 1 cm across by using their natural echolocation. A few different teams of engineers have extended that ability using mechanically created waves. They have given robots echolocation skills so precise that they can tell whether a coin has landed heads or tails.

120. Answers may vary. Students should explain the differences between a major scale in music and its related minor scale.

121. Answers may vary. Students should present how all the various parts of the body come together to produce speech.

122. Answers may vary. Students should apply their knowledge of acoustics to the location they select. Analysis should include appropriate uses (such as concerts or speeches) and the effects of various architectural features.

123. Answers may vary. Sample answer:
There are many possible causes of feedback, from the placement or fit of the hearing aid to actual damage to the device. The sound of feedback can be terrible, but modern devices are able to prevent feedback. The devices can detect the early, quietest stage of feedback, and immediately adjusts to shut out the feedback. Yes, they cost more, but if you can afford the upgrade, it is worth it to not have to deal with feedback.

124. Answers may vary. Most students will try to increase distance between workers as much as possible to reduce noise through attenuation. In addition, they may surround individuals' desks with cubicles that can be used to absorb some direct and reflected sound. They can also use sound-absorbing materials in the walls, ceiling, floor, etc., to try to reduce the amount of reflected sound.

125. Answers may vary. Sample answer:
Radar works by measuring the tiniest movements in the chest due to breathing and even the beating of the heart. It has the advantage of avoiding the use of painful ECG leads. Random noise normally found in a hospital caused initial problems with this method, but it has been overcome by using multiple transmitters and receivers that can remove random noises.

126. Answers may vary. Sample answer:
Blue whales use echolocation to help them avoid objects in their path. Blue whales typically have a mass of 10^5 kg and travel at a relatively fast speed of 32 km/h, so it takes a long time for them to stop or change direction. Given their large mass, they could hurt themselves badly in a collision. Blue whales also use echolocation to navigate when they are migrating. The sounds can travel long distances and can reflect off land masses.