Chapter 10 Review, pages 480–485

Knowledge

1. (d)
2. (c)
3. (c)
4. (a)
5. (c)
6. (d)
7. (d)
8. (a)
9. (b)
10. False. Damage to the eardrum can be repaired with surgery, *but not* damage to hairs in the cochlea.
11. True
12. False. Vibrations caused by extension and retraction of landing gear and the deployment of aerodynamic brakes are *not* unusual *or* dangerous.
13. False. Animals that use echolocation use a variety of frequencies in the range *40 kHz to 130 kHz*.
14. (a) (ii)
(b) (iii)
(c) (i)
15. Frequencies from 1000 Hz to 5500 Hz are magnified in the auditory canal by a factor of about 10.
16. The eardrum separates the outer ear from the middle ear.
17. Music is sound that originates from a combination of musical notes originating from a source that vibrates in a uniform manner with one or more constant frequencies.
18. Musical loudness, pitch, and quality are subjective characteristics in that they depend both on the nature of the source and the perception of the listener.
19. The resonator improves the loudness and quality of the sound produced.
20. A piano can also be classified as a percussion instrument because you have to strike the keys to produce sound, like a percussion instrument.
21. Reverberation time is the time for the sound to drop by 60 dB from its maximum intensity or to drop to an inaudible level.
22. Yes, singing does sound better in the shower because sound is better managed acoustically and the echoes produced increase the loudness and quality of the sound. The shower functions like a resonant cavity.
23. Aeroelastic flutter is the response when the energy added to a structure vibrating in air exceeds the energy lost due to damping, causing large vibrations.
24. Concrete and steel pendulums are installed in skyscrapers to develop sympathetic vibrations, taking energy from a building and reducing the vibrations of the building.
25. Echolocation is the locating of objects through the analysis of echoes or reflected sound.
26. Aside from the ears, elephants have hearing receptors located in their trunks and feet.

Understanding

27. Answers may vary. Flow charts should include most of the following points:

- Sound waves enter the pinna.
- The pinna funnels the sound into the auditory canal.
- The sound waves reach the eardrum.
- The eardrum vibrates as a result of the compressions and rarefactions exerting pressure on it.
- The hammer, anvil, and stirrup bones transmit the vibrations to the inner ear while magnifying the pressure variations by a factor of 22.
- Sound waves reach the cochlea in the inner ear and cause the microscopic hair cells to vibrate.
- The mechanical energy of the hair is converted to electrical energy in the cells.
- The auditory nerve transmits the energy to the brain.
- The brain interprets the energy as sound.

28. Answers may vary. Sample answer:
Human ears best detect sounds between 20 Hz and 20 KHz. The highest attainable voice of 1000 Hz is only a small fraction of the upper value in that range.
29. During a sinus infection, the Eustachian tube gets blocked and pressure equalization will not occur resulting in improper connection between inner ear and middle ear.
30. (a) The bones that transmit sounds from the eardrum to the cochlea are the hammer, the anvil, and the stirrup.
(b) When sound is heard, the eardrum starts vibrating which then causes the hammer to vibrate. When the eardrum vibrates, the hammer transfers that vibration to the anvil. The anvil transmits vibrations to the stirrup, which is connected to the cochlea.
(c) These three bones are in the middle ear.

31. The brain interprets pitch by which hairs are vibrating because hairs are associated with individual pitch ranges. Volume is interpreted by how many of each of those frequency-specific hairs are vibrating.

32. Amplitude is objective in that it is a measurable characteristic of a wave. Subjective loudness is dependent on the amplitude of a sound wave and the listener's ability to translate that amplitude into a brain signal. If a sound occurs at a frequency that cannot be heard by a person, the amplitude of that sound could be quite high, while the loudness seems very low to that person. Loudness can enhance the listening capability of a person who cannot detect certain frequency ranges. On the other hand, the amplitude is independent.

33. The sound produced by a tuning fork is only the tuning fork's resonant frequency and does not have any other harmonics. It is not subjected to a resonator the way musical instruments are.

34. The three types of musical instruments are stringed instruments, which create sound through vibrating strings by plucking striking or bowing them; wind instruments, which use vibrating air molecules in columns to produce sounds; and percussion instruments, which produce sound by striking a surface.

35. The wavelength is twice the length of the string because it is fixed at both ends.

2(1.25 m) = 2.50 m

The wavelength of the vibration is 2.50 m.

36. (a) The length of the string is half the wavelength because the string is fixed at both ends.

$$\frac{0.656\text{ m}}{2} = 0.328\text{ m}$$

The length of the string is 0.328 m.

(b) Given: L_1 = 0.328 m; f_1 = 293 Hz; L_2 = 0.287

Required: f_2

Analysis: $f_1L_1 = f_2L_2$

$$f_2 = \frac{f_1L_1}{L_2}$$

Solution:
$$f_2 = \frac{f_1L_1}{L_2} = \frac{(293\text{ Hz})(0.328\ \cancel{\text{m}})}{(0.287\ \cancel{\text{m}})}$$

$$f_2 = 335\text{ Hz}$$

Statement: The new frequency is 335 Hz.

37. Given: L_1 = 0.875 m; f_1 = 3650 Hz; f_2 = 4260 Hz

Required: L_2

Analysis: $f_1L_1 = f_2L_2$

$$L_2 = \frac{f_1L_1}{f_2}$$

Solution:
$$L_2 = \frac{f_1L_1}{f_2} = \frac{(3650\ \cancel{\text{Hz}})(0.875\text{ m})}{(4260\ \cancel{\text{Hz}})}$$

$$L_2 = 0.750\text{ m}$$

Statement: The wire is 0.750 m or 75.0 cm long.

38. (a) Given: L = 64.8 cm = 0.648 m; v = 190.2 m/s

Required: f_0

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

$$f_0 = \frac{v}{2L}$$

Solution:
$$f_0 = \frac{v}{2L} = \frac{\left(190.2\ \frac{\cancel{\text{m}}}{\text{s}}\right)}{2(0.648\ \cancel{\text{m}})}$$

$$f_0 = 147\text{ Hz}$$

Statement: The fundamental frequency of the string is 147 Hz.

(b) The wavelength is twice the length of the string because it is fixed at both ends.

2(64.8 cm) = 130 cm

The wavelength of the vibration is 130 cm or 1.30 m.

(c) These higher strings might have a smaller diameter, a lower linear density, or higher tension than the string in part (a).

39. (a) When the trombone slide is extended, length of the air column increases. This decreases the pitch of the note.

(b) Retracting the trombone slide reduces the length of the air column. This increases the pitch of the note.

40. A flute's vibrations are caused by blowing across vibrating air over an opening. A clarinet's vibrations are caused by blowing across and vibrating a thin strip of material called a reed. A trumpet's vibrations are caused by blowing air and vibrating lips.

41. The nominal note heard by a wind instrument is determined by the frequency of the loudest frequency detected: the fundamental frequency. Harmonic frequencies are combined with the fundamental frequency to create a more complex sound, thereby increasing the sound quality.

42. Single indefinite pitch instruments create more than one frequency at a time and no one pitch can be heard over the other. These sounds are often used to keep the beat of the music.
Multiple indefinite pitch instruments produce different resonant frequencies. These sounds may be used in similar ways to other melodic instruments in music composition.
Variable pitch instruments produce sounds that can change in pitch. This can also be used within limited range to create melodies.

43. Answers may vary. Sample answer:
To reduce the reverberation time in the concert hall, install panels with a high absorption coefficient on the walls and ceiling.

44. (a) It is difficult to design a single room that acts as a venue for choral music and for speaking engagements because both uses require their spaces to have different reverberation times.
(b) A venue for choral music requires a longer reverberation time.

45. Concave shapes are difficult because sounds will be reflected in a way that concentrates sound on a single point, making the sound uncomfortably loud in some areas.
Reflections off convex shapes cause sound intensity to drop off so quickly that it can be difficult to hear clearly.

46. Answers may vary. Sample answer:
(a) A live room is one with a longer reverberation time. An intimate room is one where the first early reflection reaches the audience in less than 20 ms. A full room means the reflected sound intensity is very close to the direct sound intensity.
(b) Yes. A live room requires a long reverberation time, which automatically would mean that there are a lot of echoes, the first of which should reach the audience quickly.
(c) Yes. A full room requires having objects with very little absorption capability, which automatically equates to having a long reverberation time.
(d) No. An anechoic chamber is a room that does not produce echoes meaning there is zero reverberation time. It cannot be a full room.

47. Answers may vary. Sample answer:
Constructing the building using concrete or heavy metal pillars would absorb the vibrations and installing mass dampers would decrease the amplitude, both of which decrease the risk of aeroelastic flutter.

48. Both: seismic waves; can travel through solids.
P-waves: longitudinal waves; can travel through liquids; twice as fast as S-waves.
S-waves: transverse waves; twice as slow as P-waves.

49. Striking the ground produces sound waves that move through Earth in all directions from their source. As these waves hit different materials they reflect and refract in different ways depending on the material encountered. Geophones are used to detect the reflections of these waves and record data that can be translated into information about the location and characteristics of underground materials.

50. Figure 3 (a) illustrates a P-wave. Figure 3 (b) illustrates an S-wave.

51. Answers may vary. Sample answer:
(a) A pulse test is performed by a pilot in an aircraft. The pilot controls the plane in such a manner that the airflow around the wing is drastically disturbed. Engineers monitor the vibration induced in the wing. This test is used to determine an aircraft's flutter characteristics.
(b) In a sweep test, engineers mechanically produce large vibrations in the wing. A computer vibrates the wing across a wide range of frequencies one at a time. This test is also used to determine an aircraft's flutter characteristics.

52. Some precautions engineers take against the pogo effect in rockets are changing the length of the propellant pipes and adding dampers to the propellant pipes.

53. (a) Dolphins use nasal sacs to make high-frequency sounds. The sounds pass through the melon, which is an oval-shaped sac filled with special fats called acoustical lipids. From the melon, the sound is focused into a beam in front of the dolphin. When the sound waves reflect off an object in the water, such as a fish, the sound travels back to the dolphin's lower jaw, which passes the sound to the dolphin's ear, which detects the sound and translates it into a location of the object.
(b) A bat's echolocation sound is produced in its larynx and passes through the mouth. Sound that is reflected to the bat travels to its ears and is detected there and passed to the brain.

Analysis and Application

54. People who are sensitive to cabin pressure changes in aircraft should chew gum during takeoff and landing because chewing gum makes people salivate and swallow. Swallowing opens the Eustachian tube, equalizing the uncomfortable pressure that is often felt in an airplane during rapid elevation changes.

55. Given: v = 340 m/s; L = 2.8 cm = 0.028 m; open and closed ends

Required: f_0

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

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

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

$$= \frac{340\ \frac{\text{m}}{\text{s}}}{4(0.028\ \text{m})}$$

$$L = 3.0 \times 10^3\ \text{Hz}$$

Statement: The fundamental frequency around which we would expect hearing to be most sensitive is 3.0×10^3 Hz or 3.0 kHz.

56.

Note	Fret number	Frequency (Hz)	Length (m)
A	Open	111	0.642
B^b	**1**	**117**	0.609
B	2	123	**0.579**
C	**3**	131	**0.544**
$C^{\#}$	**4**	**139**	0.513
D	5	**147**	0.485

Row B^b: $f_1L_1 = f_0L_0$

$$f_1 = \frac{f_0L_0}{L_1}$$

$$= \frac{(111\ \text{Hz})(0.642\ \text{m})}{(0.609\ \text{m})}$$

$$f_1 = 117\ \text{Hz}$$

Row B: $f_2L_2 = f_0L_0$

$$L_2 = \frac{f_0L_0}{f_2}$$

$$= \frac{(111\ \text{Hz})(0.642\ \text{m})}{(123\ \text{Hz})}$$

$$L_2 = 0.579\ \text{m}$$

Row C: $f_3L_3 = f_0L_0$

$$L_3 = \frac{f_0L_0}{f_2}$$

$$= \frac{(111\ \text{Hz})(0.642\ \text{m})}{(131\ \text{Hz})}$$

$$L_3 = 0.544\ \text{m}$$

Row $C^{\#}$: $f_4L_4 = f_0L_0$

$$f_4 = \frac{f_0L_0}{L_1}$$

$$= \frac{(111\ \text{Hz})(0.642\ \text{m})}{(0.513\ \text{m})}$$

$$f_4 = 139\ \text{Hz}$$

Row D: $f_5L_5 = f_0L_0$

$$f_5 = \frac{f_0L_0}{L_5}$$

$$= \frac{(111\ \text{Hz})(0.642\ \text{m})}{(0.485\ \text{m})}$$

$$f_5 = 147\ \text{Hz}$$

57. (a) Given: L_1 = 59.1 cm = 0.591 m; f_1 = 172 Hz; L_2 = 59.1 cm – 13.2 cm = 45.9 cm = 0.459 m

Required: f_2

Analysis: $f_1L_1 = f_2L_2$

$$f_2 = \frac{f_1L_1}{L_2}$$

Solution: $f_2 = \frac{f_1L_1}{L_2}$

$$= \frac{(172\ \text{Hz})(0.591\ \text{m})}{(0.459\ \text{m})}$$

$$f_2 = 221\ \text{Hz}$$

Statement: The new frequency is 221 Hz.

(b) The frequency will be slightly higher than 221 Hz due to the change in the tension.

(c) Guitar manufacturers can compensate for this increased tension by making the placement of the notes along the fret board at slightly longer string lengths than would be required without this tension increase.

58. Answers may vary. Sample answer:
When wind instruments are tuned, the musicians' air increases the temperature of the instrument, or "warms up" the instrument. Sound travels faster in warmer air so the frequency increases. When string instruments are warmed up, the strings are loosened, causing a reduction in tension. The reduced tension causes the frequency to decrease.

59. (a)

$$v = f(2L)$$
$$v = \sqrt{\frac{F_T}{\mu}}$$
$$f(2L) = \sqrt{\frac{F_T}{\mu}}$$
$$f = \frac{\sqrt{\frac{F_T}{\mu}}}{2L}$$

(b) $f(2L) = \sqrt{\frac{F_T}{\mu}}$

$$4f^2L^2 = \frac{F_T}{\mu}$$
$$F_T = 4f^2L^2\mu$$
$$F_T = 4f^2L^2\left(\frac{m}{L}\right)$$
$$F_T = 4mf^2L$$

(c) Given: F_T = 340 N; μ = 0.0036 kg/m; f = 640 Hz
Required: L

Analysis: $f = \frac{\sqrt{\frac{F_T}{\mu}}}{2L}$

$$L = \frac{\sqrt{\frac{F_T}{\mu}}}{2f}$$

Solution: $L = \frac{\sqrt{\frac{F_T}{\mu}}}{2f}$

$$= \frac{\sqrt{\frac{340\text{ N}}{0.0036\text{ kg/m}}}}{2(640\text{ Hz})}$$
$$L = 0.24\text{ m}$$

Statement: The length of the string is 0.24 m.

(d) Given: F_T = 340 N; μ = 0.0036 kg/m; f = 830 Hz
Required: L

Analysis: $f = \frac{\sqrt{\frac{F_T}{\mu}}}{2L}$

$$L = \frac{\sqrt{\frac{F_T}{\mu}}}{2f}$$

Solution: $L = \frac{\sqrt{\frac{F_T}{\mu}}}{2f}$

$$= \frac{\sqrt{\frac{340\text{ N}}{0.0036\text{ kg/m}}}}{2(830\text{ Hz})}$$
$$L = 0.19\text{ m}$$

Statement: The string would need to be shortened to 0.19 m.

(e) Given: L = 0.33 m; f = 440 Hz; F_T = 220 N
Required: m

Analysis: $F_T = 4mf^2L$

$$m = \frac{F_T}{4f^2L}$$

Solution: $m = \frac{F_T}{4f^2L}$

$$= \frac{220\text{ N}}{4(440\text{ Hz})^2(0.33\text{ m})}$$
$$m = 8.6\times10^{-4}\text{ kg}$$
$$m = 0.86\text{ g}$$

Statement: The mass of the string is 0.86 g.

60. (a) Answers may vary. Many large empty rooms such as gymnasiums or large bathrooms have high reverberation times. Students should name the room and discuss if they know from experience that the room has a high reverberation time or if they conducted a small experiment (making a loud noise in the space and observing the results) to identify the space as having a high reverberation time.

(b) Answers may vary. Students should note the general geometry of the room and perhaps highlight the nature of the materials (most likely hard materials with low sound absorption characteristics).

61. Mechanical resonance is the transfer of energy from one object to another at the same natural/resonant frequency. Aerolastic flutter is when the energy added to vibrations is greater than that the energy lost to natural damping.
The worst-case scenario for flutter is an object with low damping to which energy is being applied at its natural frequency. This case becomes an example of flutter and resonance because the energy is being transferred at matching natural frequencies and at a higher rate than energy is being lost from the system.
62. Answers may vary. Sample answer:
The Tacoma Narrows Bridge collapse illustrates that even at low wind speeds flutter can be catastrophic to any structure. The overwhelming nature of the collapse shows that even a well-designed structure such as an aircraft can be destroyed by flutter.
63. (a) Human hearing is limited to the range of 20 Hz to 20 kHz while dolphins, sperm whales, and orca whales produce clicks between 40 kHz and 140 kHz, well outside the range detectable by human ears.
(b) Animals use higher frequencies for echolocation to detect smaller objects. Higher frequencies are also required for animals in water because sound travels much faster through water than through air.

Evaluation

64. Answers may vary. Sample answer:
Add curtains, seat cushions, rugs, and panels that absorb sound on the walls and ceiling.
65. Answers may vary. Sample answer:
(a) Since the audience will be seated, the engineer should make the empty seats as similar in acoustical properties as the occupied seats.
(b) Design choices to be avoided include convex or concave surfaces that would be exposed only when the space is empty, hard non-absorbing materials that would be otherwise blocked by people, and spaces with high reverberation times while empty.
66. Answers may vary. Sample answer:
(a) The following modifications will make the room better for speaking engagements:

- Make the wall behind the presentation area concave like a band shell.
- Make the wall behind the seating area straight.
- Carpet the entire room.
- Square the pillars and cover them with fabric.
- Cover the walls with a material that absorbs sound.

(b) Diagrams may vary. Design choices should reflect the modifications recommended in part (a).
67. The driver should change speeds so the wheel is not spinning at the natural frequency of the car. This will stop the resonance because the imbalance vibration will not transfer its energy to the car, because the car's natural frequency will no longer be matched by the rotating imbalance.
68. Answers may vary. Sample answer:
It is risky to build all three of these structures with the same natural frequency. When wind is funnelled between the two buildings, the aerodynamic forces transferred to the footbridge could be high. If the footbridge experienced aeroelastic flutter, the three structures' shared natural frequency would create a situation of very high sympathetic vibration, and catastrophic flutter could be passed from the footbridge to each building attached to it.
69. (a) Answers may vary. Sample answer:
The sweep test seems safer since it is a computer simulation. However, the computer simulation are sometimes limited and might give results that could put actual planes at risk.
(b) Answers may vary. Students could evaluate that a real-world scenario of the pulse test is better at predicting flutter or that the methodical approach presented through a sweep test would be better. Students must describe why the decision was made in order to fully answer the question.

Reflect on Your Learning

70. Answers may vary. Students should have a keener understanding of the dangers of hearing loss and reflect that in their answer. A conscientious student will answer that knowledge provided in the chapter illustrates reasons to protect one's hearing.
71. Answers may vary. Students should recognize that each room has one or more purposes, and this should be taken into consideration when selecting how to furnish it. Perhaps students will discuss the dangers of purchasing noisy appliances for a very live or full room.
72. Answers may vary. Students should discuss the magnitude of their understanding of how different animals use sound and relate it to their understanding of human use of sound (especially with respect to communication).

Research

73. Answers may vary. Students should discuss at least one technology prior to the modern hearing aid and/or the development process that created the modern hearing aid. A discussion of cochlear implants should be included as well as more advanced hearing devices, such as the Baha hearing aid or any other emerging technology.
74. Answers may vary. Students should focus on one type of geophysical exploration, whether listed in the question or selected by the student after research and answer the questions about materials, limitations, costs, and strengths. This should be supplemental to a comparison of how the technology works and how it compares to seismic geophysical exploration.
75. Answers may vary. Students should discuss noise music and will probably approach from a perspective of defining noise music as a genre and possibly laying out a history of the genre. In addition, students should present and defend an argument about whether this is indeed music or simply noise.
76. Answers may vary. Students' reports should show a firm understanding that the complexity and quality of a sound rely on the overlay of multiple harmonic frequencies atop the fundamental frequency. Attention should be paid to the fact that it is the differences in these complex arrangements that allow instruments to sound different from each other and different from the pure tones at a specific fundamental frequency that can be created with a synthesizer.
77. Answers may vary. Students should pick a specific earthquake or tsunami and supply enough information to relay a sufficient description of the relative impact of the seismic activity on either a human or monetary scale. Other details that should be included range from standard information such as geographical location and date of occurrence to items specifically discussed in the question such as the preventive measures taken to reduce damage.
78. Answers may vary. This chapter's discussion of the human ear is a good starting point to judge how students approach discussing the human vocal folds structure. While the human ear is an input device, the vocal folds work in the reverse order, starting with a signal from the brain and a reaction in the lungs to pass air across the vocal cords and signals defining how to control the vocal cords in a way to alter pitch and tone of sounds created. Students may also approach the question from a purely physical perspective and simply describe the physical characteristics and physiological function of the vocal folds.
79. Answers may vary. Students should report the history of the Richter scale, including the source of its name, identify various values on the Richter scale and describe the effects of seismic activity at that Richter level. While logarithms are not studied until grades 12, some students may also mention that the Richter scale is a logarithmic scale of base 10 so that each numerical value is 10 times greater than the previous value,
80. Answers may vary. Students should outline the construction of an earthquake shaking table and design an experiment that uses the table to determine the resonant frequency of a model building. The earthquake shaking table should have an adjustable frequency for the experiment to work properly.
81. Answers may vary. Students may discuss this subject from the appealing human-interest perspective it presents, but they should also be sure to compare the limitations of the learned echolocation techniques used by humans when compared to the very sophisticated echolocation of the animal kingdom. A discussion might also include the lower frequency range of human hearing with respect to other animals that use this skill more effectively.
82. Diagrams may vary. Students' presentations should show how lobsters use friction to create sound in a similar way to playing a violin with a bow.