Chapter 8: Vibrations and Waves

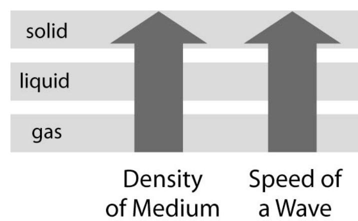
Mini Investigation: Observing Wave Motion, page 377

A. During the first type of movement, the Slinky moved back and forth across the line it originally made on the table. During the second type of motion, the Slinky stayed on the line, but the coils of the Slinky got closer together then farther apart.
B. When the far end was free, the Slinky moved from side to side during the first movement and in and out during the second movement.
C. When the far end was fixed, the Slinky did not move and it reflected the waves back to the start of the Slinky.

Section 8.1: What Is a Vibration?

Section 8.1 Questions, page 380

1. Answers may vary. Sample answer:
A vibration is the cyclical motion of an object about an equilibrium point. A wave is the transfer of energy through a material due to vibration. Vibration is the cause and the wave is the effect.
2. Answers may vary. Sample answers:
Five everyday vibrating objects are a swinging pendulum, a stretched elastic band, a skipping rope in motion, a plucked guitar string, and the motion of a tuning fork.
(a) The pendulum swings back and forth across an equilibrium point. Therefore, it is a vibration.
The elastic band vibrates back and forth across an equilibrium point when plucked. Therefore, it is a vibration.
The skipping rope swings around an equilibrium position. Therefore, it is a vibration.
A plucked guitar string vibrates back and forth about its equilibrium position. Therefore, it is a vibration.
The tuning fork vibrates about its equilibrium position. Therefore, it is a vibration.
(b) Since the particles in the elastic band, the guitar string, and the tuning fork are disturbed, those three vibrations transmit a mechanical wave.
(c) The elastic band transmits mechanical waves through itself. The guitar string transmits mechanical waves through itself. The tuning fork transmits mechanical waves through itself.
3. Answers may vary. Sample answer:
The density of the medium allows a wave to pass through most effectively. For example, a tuning fork is a solid with high density, so it sustains vibrations for longer time as waves pass through it more effectively.
4. Answers may vary. Sample answer:
Sonar and radar use waves to detect objects and navigate ships. Mobile phones use waves to send and receive signals. Musical instruments such as guitars and pianos use vibrations to make sounds.
5. Answers may vary. Sample answer:
Earthquakes can be highly destructive mechanical waves. Tidal waves (or tsunamis) can be harmful to boats and people living near the coast.
6. Answers may vary. Sample answer:



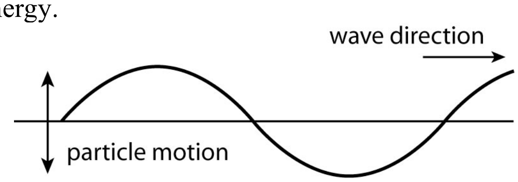
Section 8.2: Types of Mechanical Waves

Mini Investigation: Simulating Transverse and Longitudinal Wave Motion, page 383

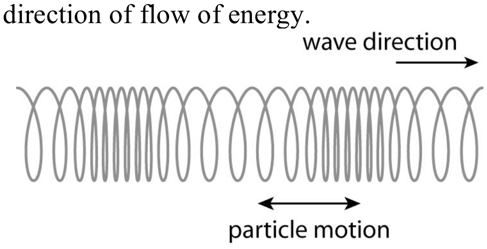
A. In the transverse wave demonstration, when we pass each other, we are still 1 m apart. If that is the *x*-axis, then in the *y*-axis I am always one step behind the person in front of me and one step ahead of the person behind me.
B. The farthest you could move was three steps. In a true medium, this aspect of the wave's motion would be controlled by the density of the medium and the size of the vibration.
C. In the longitudinal wave demonstration, it was difficult to maintain the motion because if we didn't all move at the same time, the people in front and behind me would get in my way.
D. Answers may vary. Sample answer:
The simulations were not fair because the particles did not all return to their equilibrium. Only the first person, fourth person, and so on, returned to their starting points.

Section 8.2 Questions, page 384

1. Answers may vary. Sample answer:
In transverse waves, particles of the medium move perpendicular to the direction of the flow of energy.



In longitudinal waves, particles move parallel to the direction of flow of energy.

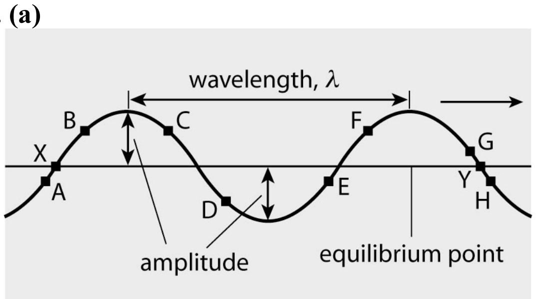


2. Answers may vary. Sample answer:
A vibrating string and a boat in a sea. The string vibrates perpendicular to the direction of energy flow. Similarly, the boat moves up and down, whereas the water waves move perpendicularly to the boat.
3. Answers may vary. Sample answer:
Sound waves and shock waves are examples of longitudinal waves. In these waves, the disturbance travels along the same axis as the motion of the wave.
4. The "wave" is not a true mechanical wave because there is no equilibrium point in the motion. People raise their hands in only one direction. Also, there is no flow of energy, just a simulation to give the appearance of it.
5. Answers may vary. Sample answer:
Longitudinal waves that have properties making them detectable to the human ear are referred to as sound. The energy transferred through successive compressions and rarefactions of a sound wave causes vibrations in our ears that our brain interprets as sound. Sound is transmitted effectively in solids due to their tight molecular arrangement.
6. Yes. Sound is a mechanical wave because it is caused by vibrations of materials.
7. Answers may vary. Sample answer:
Advantages of being able to detect sound include medical uses such as stethoscopes, aesthetic pleasure through musical instruments, and animals detecting food or predators.
8. Answers may vary. Sample answer:
Two examples of complex wave motion are ocean waves and the waves that result when you strike a solid object. The water particles move up and down at the same time as they move back and forth. These are characteristics of longitudinal and transverse waves. When a solid object is struck, the impact creates transverses waves along the surface and longitudinal waves below the surface. In sound waves, the disturbance travels along the same axis as the motion of the wave.
9. Answers may vary. Sample answers:
(a) Sound reduces as the air is removed from the jar and increases as the air is pumped back into the jar.
(b) Sound waves require a medium to move through. As the air is removed from the jar, the density of the medium decreases so the sound decreases.

Section 8.3: Wave Characteristics

Section 8.3 Questions, page 387

1. (a)

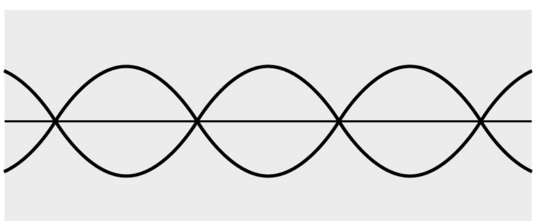


(b) The pairs of points that are in phase are A and E (one wavelength apart), and B and F (one wavelength apart).

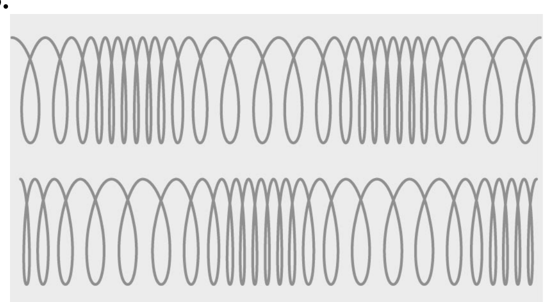
2. In transverse waves, wavelength is the distance between two similar points in successive identical cycles in a wave. In transverse waves, amplitude is the maximum displacement of a vibrating particle in a wave. In longitudinal waves, amplitude is the maximum pressure created and the same definition of wavelength applies.

3. Frequency is the number of times the wave repeats itself in a given time frame, whereas the wave speed is the measure of how far the wave travels per second.

4.



5.



6. Yes, those motions were examples of simple harmonic motion because they were continuous motions with constant amplitude, period, and frequency.

Section 8.4: Determining Wave Speed

Tutorial 1 Practice, page 389

1. Given: f = 230 Hz; λ = 2.3 m

Required: v

Analysis: $v = f\lambda$

Solution: $v = f\lambda$

$$= (230\text{ Hz})(2.3\text{ m})$$
$$v = 530\text{ m/s}$$

Statement: The speed of the wave is 530 m/s.

2. Given: v = 1500 m/s; f = 11 Hz

Required: λ

Analysis: $v = f\lambda$

$$\lambda = \frac{v}{f}$$

Solution: $\lambda = \frac{v}{f}$

$$= \frac{1500\text{ m/s}}{11\text{ Hz}}$$
$$\lambda = 140\text{ m}$$

Statement: The wavelength is 140 m.

3. Given: v = 405 m/s; λ = 2.0 m

Required: f

Analysis: $v = f\lambda$

$$f = \frac{v}{\lambda}$$

Solution: $f = \frac{v}{\lambda}$

$$= \frac{405\ \frac{\cancel{\text{m}}}{\text{s}}}{2.0\ \cancel{\text{m}}}$$
$$f = 2.0\times 10^2\text{ Hz}$$

Statement: The frequency of the wave is 2.0×10^2 Hz, or 200 Hz.

Tutorial 2 Practice, page 391

1. Given: L = 2.5 m; F_T = 240 N; v = 300 m/s

Required: m

Analysis: $v = \sqrt{\frac{F_\text{T}}{\mu}}$

$$v^2 = \frac{F_\text{T}}{\mu}$$
$$\mu = \frac{F_\text{T}}{v^2}$$
$$\mu = \frac{m}{L}$$
$$m = \mu L$$
$$m = \frac{F_\text{T}}{v^2}L$$

Solution: $m = \frac{F_\text{T}}{v^2}L$

$$= \frac{240\text{ N}}{(300\text{ m/s})^2}(2.5\text{ m})$$
$$= \frac{240\ \frac{\text{kg}\bullet\cancel{\text{m}}}{\cancel{\text{s}^2}}}{90\ 000\ \frac{\cancel{\text{m}^2}}{\cancel{\text{s}^2}}}(2.5\ \cancel{\text{m}})$$
$$m = 6.7\times 10^{-3}\text{ kg}$$

Statement: The mass of the string is 6.7×10^{-3} kg, or 6.7 g.

2. Given: μ = 0.2 kg/m; v = 200 m/s

Required: F_T

Analysis: $v = \sqrt{\frac{F_\text{T}}{\mu}}$

$$v^2 = \frac{F_\text{T}}{\mu}$$
$$F_\text{T} = \mu v^2$$

Solution: $F_\text{T} = \mu v^2$

$$= (0.2\text{ kg/m})(200\text{ m/s})^2$$
$$= \left(0.2\ \frac{\text{kg}}{\cancel{\text{m}}}\right)\left(40\ 000\ \frac{\text{m}^{\cancel{2}}}{\text{s}^2}\right)$$
$$= 8\times 10^3\ \frac{\text{kg}\bullet\text{m}}{\text{s}^2}$$
$$F_\text{T} = 8\times 10^3\text{ N}$$

Statement: The tension required is 8×10^3 N, or 8000 N.

3. Given: μ = 0.011 kg/m; F_T = 250 N

Required: v

Analysis: $v = \sqrt{\frac{F_\text{T}}{\mu}}$

Solution: $v = \sqrt{\frac{F_\text{T}}{\mu}}$

$$= \sqrt{\frac{250\text{ N}}{0.011\text{ kg/m}}}$$
$$= \sqrt{\frac{250\ \frac{\cancel{\text{kg}}\bullet\text{m}}{\text{s}^2}}{0.011\ \frac{\cancel{\text{kg}}}{\text{m}}}}$$
$$v = 1.5\times 10^2\text{ m/s}$$

Statement: The wave speed is 1.5×10^2 m/s, or 150 m/s.

Section 8.4 Questions, page 391

1. Given: v = 123 m/s; f = 230 Hz

Required: λ

Analysis: $v = f\lambda$

$$\lambda = \frac{v}{f}$$

Solution: $\lambda = \frac{v}{f}$

$$= \frac{123 \text{ m/s}}{230 \text{ Hz}}$$

$$\lambda = 0.53 \text{ m}$$

Statement: The wavelength is 0.53 m.

2. Given: F_T = 37 N; μ = 0.03 g/m = 3×10^{-5} kg/m

Required: v

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

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

$$= \sqrt{\frac{37 \text{ N}}{3\times10^{-5} \text{ kg/m}}}$$

$$= \sqrt{\frac{37 \frac{\cancel{\text{kg}}\cdot\text{m}}{s^2}}{3\times10^{-5} \frac{\cancel{\text{kg}}}{\text{m}}}}$$

$$= 1.11\times10^3 \text{ m/s}$$

$$v = 1000 \text{ m/s}$$

Statement: The speed of sound along this string is 1000 m/s.

3. Given: $T = 1.20 \times 10^{-3}$ s; $v = 3.40 \times 10^2$ m/s

Required: λ

Analysis: $v = f\lambda$

$$\lambda = \frac{v}{f}$$

$$\lambda = vT$$

Solution: $\lambda = vT$

$$= \left(3.40\times10^2 \frac{\text{m}}{\cancel{\text{s}}}\right)\left(1.20\times10^{-3} \cancel{\text{s}}\right)$$

$$\lambda = 0.408 \text{ m}$$

Statement: The wavelength is 0.408 m.

4. (a) P-waves:

Given: v = 8.0 km/s; $\Delta d = 2.4 \times 10^3$ km

Required: Δt

Analysis: $v = \frac{\Delta d}{\Delta t}$

$$\Delta t = v\Delta d$$

Solution: $\Delta t = \frac{\Delta d}{v}$

$$= \frac{2.4\times10^3 \ \cancel{\text{km}}}{8.0 \ \frac{\cancel{\text{km}}}{\text{s}}}$$

$$= (300 \ \cancel{\text{s}})\left(\frac{1 \text{ min}}{60 \ \cancel{\text{s}}}\right)$$

$$\Delta t = 5 \text{ min}$$

Statement: The P-wave should arrive in 5 min.

S-waves:

Given: v = 4.5 km/s; $\Delta d = 2.4 \times 10^3$ km

Required: Δt

Analysis: $v = \frac{\Delta d}{\Delta t}$

$$\Delta t = v\Delta d$$

Solution: $\Delta t = \frac{\Delta d}{v}$

$$= \frac{2.4\times10^3 \ \cancel{\text{km}}}{4.5 \ \frac{\cancel{\text{km}}}{\text{s}}}$$

$$= (533.3 \ \cancel{\text{s}})\left(\frac{1 \text{ min}}{60 \ \cancel{\text{s}}}\right)$$

$$\Delta t = 8.9 \text{ min}$$

Statement: The S-wave should arrive in 8.9 min.

(b) Transverse waves are called secondary waves because they arrive after the longitudinal wave.

(c) Answers may vary. Sample answer: Observing these waves helps geophysicists analyze the structure of the Earth's interior. By collecting data from around the world, they can determine the location of a liquid core and the composition of the layers of Earth. The information is based on which waves arrive at various stations and how long it takes for them to get there.

5. The wavelength is halved. The speed stays the same because the tension and linear density remain the same. That means that when the value of f doubles in the equation $v = f\lambda$, the value of λ must be divided by two.

6. The speed is doubled. Given the equation $v = f\lambda$, when frequency is doubled, for the left side of the equation to equal the right side, the velocity should also be doubled.

7. You would have to multiply the tension by a factor of 4 to double the speed. Double the speed and see how it changes the tension (linear density remains constant):

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

So, when velocity is doubled, the tension should be multiplied by so that the left side of the equation equals the right side.

8. Start with the equation for force: $F_T = ma$. Substitute for $a = \frac{v}{\Delta t}$: $F_T = m\frac{v}{\Delta t}$. Substitute for Δt knowing that the velocity is the length of the divided by the time:

$$F_T = m\frac{v}{\left(\frac{L}{v}\right)}$$
$$F_T = \frac{mv^2}{L}$$

Substitute in $\mu = \frac{m}{L}$, then rearrange to get the equation for wave speed on a string:

$$F_T = m\frac{v}{\left(\frac{L}{v}\right)}$$
$$F_T = v^2\mu$$
$$v^2 = \frac{F_T}{\mu}$$
$$v = \sqrt{\frac{F_T}{\mu}}$$

Section 8.5: Properties of Sound Waves

Research This: Using Ultrasound Technology in Medicine, page 392

A. This technology uses waves to break apart cancerous masses. The technology surgically removes previously inoperable tumours, such as brain tumours.

B. The ultrasound waves are at a specific frequency (about 23 kHz) that breaks up tumours without harming surrounding body tissue. The broken pieces are then easily removed through a hollow probe.

C. This technology is preferred over traditional surgery because it reduces blood loss. In addition, the tumour can be removed without causing serious damage to healthy surrounding tissue.

Tutorial 1 Practice, page 393

1. Given: T = 32 °C

Required: v

Analysis: $v = 331.4\text{ m/s} + (0.606\text{ m/s/°C})T$

Solution:

$$\begin{aligned} v &= 331.4\text{ m/s} + (0.606\text{ m/s/°C})T \\ &= 331.4\text{ m/s} + \left(0.606\ \frac{\text{m/s}}{\cancel{°\text{C}}}\right)(32\ \cancel{°\text{C}}) \\ &= 331.4\text{ m/s} + 19.4\text{ m/s} \\ v &= 351\text{ m/s} \end{aligned}$$

Statement: The speed of sound in 32 °C air is 351 m/s.

2. Given: v = 333 m/s

Required: T

Analysis: $v = 331.4\text{ m/s} + (0.606\text{ m/s/°C})T$

$$T = \frac{v - 331.4\text{ m/s}}{0.606\text{ m/s/°C}}$$

Solution:

$$\begin{aligned} T &= \frac{v - 331.4\text{ m/s}}{0.606\text{ m/s/°C}} \\ &= \frac{333\text{ m/s} - 331.4\text{ m/s}}{0.606\text{ m/s/°C}} \\ &= \frac{1.6\ \cancel{\text{m/s}}}{0.606\ \frac{\cancel{\text{m/s}}}{°\text{C}}} \\ T &= 2.64\ °\text{C} \end{aligned}$$

Statement: The ambient temperature is 2.64 °C.

3. Given: v = 350 m/s

Required: T

Analysis: $v = 331.4\text{ m/s} + (0.606\text{ m/s/°C})T$

$$T = \frac{v - 331.4\text{ m/s}}{0.606\text{ m/s/°C}}$$

Solution:

$$\begin{aligned} T &= \frac{v - 331.4\text{ m/s}}{0.606\text{ m/s/°C}} \\ &= \frac{350\text{ m/s} - 331.4\text{ m/s}}{0.606\text{ m/s/°C}} \\ &= \frac{18.6\ \cancel{\text{m/s}}}{0.606\ \frac{\cancel{\text{m/s}}}{°\text{C}}} \\ T &= 31\ °\text{C} \end{aligned}$$

Statement: The ambient temperature is 31 °C.

Tutorial 2 Practice, page 394

1. Given: v_{sound} = 344 m/s; v_{aircraft} = 910 km/h

Required: M

Analysis: $M = \frac{v_{\text{aircraft}}}{v_{\text{sound}}}$

Solution:

$$\begin{aligned} M &= \frac{v_{\text{aircraft}}}{v_{\text{sound}}} \\ &= \frac{910\text{ km/h}}{344\text{ m/s}} \\ &= \frac{910\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}}}{344\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}}\left(\frac{1000\ \cancel{\text{m}}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{h}}}{3600\ \cancel{\text{s}}}\right) \\ M &= 0.73 \end{aligned}$$

Statement: The Mach number is 0.73.

2. Given: v_{sound} = 320 m/s; M = 0.93

Required: v_{airplane}

Analysis:

$$M = \frac{v_{\text{airplane}}}{v_{\text{sound}}}$$

$$v_{\text{airplane}} = Mv_{\text{sound}}$$

Solution:

$$\begin{aligned} v_{\text{airplane}} &= Mv_{\text{sound}} \\ &= (0.93)(320\text{ m/s}) \\ &= 297.6\text{ m/s} \\ &= \left(297.6\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)\left(\frac{1\ \cancel{\text{km}}}{1000\ \cancel{\text{m}}}\right)\left(\frac{3600\ \cancel{\text{s}}}{1\ \cancel{\text{h}}}\right) \\ v_{\text{airplane}} &= 1100\text{ km/h} \end{aligned}$$

Statement: The speed of the airplane is 1100 km/h.

3. Given: $v_{airplane} = 850$ km/h; $M = 0.81$
Required: v_{sound}

Analysis: $M = \frac{v_{airplane}}{v_{sound}}$

$$v_{sound} = \frac{v_{airplane}}{M}$$

Solution:
$$\begin{aligned} v_{sound} &= \frac{v_{airplane}}{M} \\ &= \frac{850 \text{ km/h}}{0.81} \\ &= 1049 \text{ km/h} \\ v_{sound} &= 1.0 \times 10^3 \text{ km/h} \end{aligned}$$

Statement: The local speed of sound is 1.0×10^3 km/h, or 1000 km/h.

Mini Investigation: Testing Loudness, page 396

A. Answers may vary. Students' reports should include results of their measurements of the car stereo and include a warning about the hazards of listening to loud sounds for too long.

Section 8.5 Questions, page 397

1. (a) Cyanobacteria are also known as blue-green algae. It is important to control cyanobacteria because they are harmful if eaten.
(b) Cyanobacteria are traditionally controlled by chemicals such as copper sulphate. But using copper sulphate also kills any plants and animals in the water.
(c) The treatment proposes using low frequencies because such frequencies will immobilize the cyanobacteria. This is preferable to using high frequencies because high frequencies will break down the cell walls and spill the toxins into the water supply.
2. An aircraft flying at Mach 2 means that it is travelling at a speed equal to double the speed of the sound at that temperature.
3. Given: $M = 0.83$; $T = 10$ °C
Required: $v_{airplane}$
Analysis: $v_{sound} = 331.4 \text{ m/s} + (0.606 \text{ m/s/°C})T$;

$$M = \frac{v_{airplane}}{v_{sound}}$$

$$v_{airplane} = Mv_{sound}$$

Solution: Determine the local speed of sound:

$$\begin{aligned} v_{sound} &= 331.4 \text{ m/s} + (0.606 \text{ m/s/°C})T \\ &= 331.4 \text{ m/s} + \left(0.606 \frac{\text{m/s}}{\cancel{°C}}\right)(10 \cancel{°C}) \\ &= 331.4 \text{ m/s} + 6.06 \text{ m/s} \\ &= 337.46 \text{ m/s} \\ v_{sound} &= 337.5 \text{ m/s (two extra digits carried)} \end{aligned}$$

Determine the speed of the aircraft:

$$\begin{aligned} v_{airplane} &= Mv_{sound} \\ &= (0.83)(337.46 \text{ m/s}) \\ &= 280.09 \text{ m/s} \\ &= \left(280.09 \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)\left(\frac{1 \text{ km}}{1000 \cancel{\text{m}}}\right)\left(\frac{3600 \cancel{\text{s}}}{1 \text{ h}}\right) \\ &= 1008 \text{ km/h} \\ v_{airplane} &= 1000 \text{ km/h} \end{aligned}$$

Statement: The speed of the airplane is 1000 km/h.
4. The speed of sound varies by temperature and density of the medium, both of which depend on the molecular structure of various particles.
5. (a) Sound intensity is a measure of energy per unit area due to a sound wave.
(b) Loudness is a measure of the sound intensity. It can also be defined as a human perception of sound energy.
(c) The decibel is the unit of measurement of sound level used to describe sound intensity.
6. Loudness is expressed in a logarithmic scale using decibels (dB). Decibels are a more convenient measurement unit than watts per square metre (W/m^2). The watt per square metre values for loudness can vary from 1.0×10^{-12} (the threshold of human hearing) to 1.0×10^{13} (an atomic bomb).
7. Sound intensity is a measure of energy flowing through the unit area due to a sound wave.
8. (a) Yes, the greater the loudness, the less time it is safe to listen.
(b) Answers may vary. Sample answer:
One website suggested listening to no more than 2 h of 100 dB sound a day. This corresponds to a volume of 8 on the scale given.

9. The power saw operates at 120 dB, which is $1.0\ \text{W/m}^2$. The sound level of the city street is 90 dB, which is $1.0 \times 10^{-3}\ \text{W/m}^2$.

$$\frac{1.0\ \text{W/m}^2}{1.0 \times 10^{-3}\ \text{W/m}^2} = \frac{1000}{1}$$

The ratio of the sound intensity the power saw compared to the city street is 1000:1.

10. Yes, the burglar's cough is louder than $1.0 \times 10^{-7}\ \text{W/m}^2$, or 50 dB, so it will be detected because it is more than 30 dB greater than the detection threshold of $1.0 \times 10^{-10}\ \text{W/m}^2$, or 20 dB.

11. (a) Barriers can be made of several materials. Barriers have been made of earth, wood, metal, concrete, and other materials.

(b) Sound barriers provide a physical barrier between highways and residential areas. The barriers absorb some of the sound waves, reflect some, and limit the sound waves that get by it to those that pass over the barrier.

(c) The barriers can be very effective at reducing residential noise. One website suggests that they can reduce traffic noise levels by 5 to 10 dB, cutting the loudness of the noise by as much as 50 %.

Section 8.6: Physics Journal

Section 8.6 Questions, page 399

1. The race to break the sound barrier was a result of the Cold War and the need for the United States and the Soviet Union to have faster airplanes and weapons.

2. It is dangerous to go faster than the speed of sound because the sound waves emitted by an airplane will build up as multiple shock waves in front of the plane as it approaches the speed of sound. The shock waves can destroy an airplane or make it uncontrollable.

3. When an object breaks the sound barrier, an extremely loud noise called a "sonic boom" occurs. As a result of this loud noise, restrictions have been placed on aircraft accelerating passed the sound barrier over land. For example, the supersonic Concorde was required to fly at less than Mach 1 while over land. As it crossed the Atlantic, Concorde travelled at speeds around Mach 2.

4. The first woman to break the sound barrier was Jackie Cochran. The celebrated aviator, who was already well known for her participation in races and her wartime record, was offered a rare opportunity in the spring of 1953. With her friend Chuck Yeager as co-pilot, she flew a borrowed Canadian jet faster than the speed of sound. Later, she would add to her records as she became the first woman to fly faster than Mach 2.

5. The cloud-like phenomenon seen when an aircraft approaches the speed of sound is known by several names. These include vapour cone, shock collar, and the Prandtl-Glauert singularity. As an object approaches the speed of sound, if the atmospheric conditions are just right, then the drop in air pressure caused by the object will cause water condensation, which is visible as a cone of cloud.

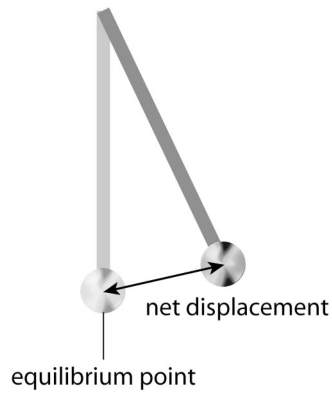
Chapter 8 Review, pages 408–413

Knowledge

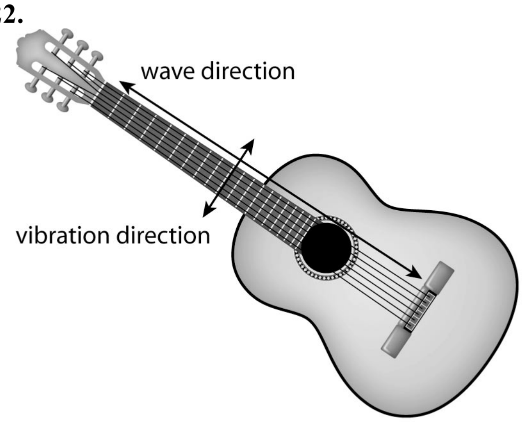
1. (b)
2. (c)
3. (d)
4. (a)
5. (c)
6. (b)
7. (c)
8. (a)
9. (b)
10. (d)
11. (d)
12. (c)
13. (a)
14. (a) (iv)
(b) (ii)
(c) (v)
(d) (iii)
(e) (i)
15. Answers may vary. Sample answer:
Three examples of waves that occur naturally are seismic waves, sound waves, and water waves.
16. As tension in the spring increases, the speed of the wave also increases.
17. The increase in pressure is caused by the collection of sound waves emitted by the aircraft that get closer and closer together as the aircraft approaches the speed of sound.
18. Answers may vary. Sample answer:
Noise pollution is the increase in loudness due to the sounds emitted by the surroundings. an example of noise pollution is the constant noise from cars on a nearby highway. This noise pollution can be reduced through construction of sound barriers along the highway or improvements to car engines.

Understanding

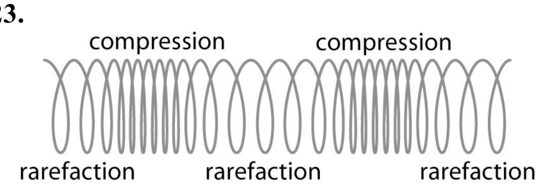
19.



20. Gases rely on translational molecular motion to transfer vibrations because gases have much lower density than liquids and solids and their gas molecules are much farther apart.
21. Vibrations are the cyclical motion of an object about an equilibrium point. Mechanical waves are the transfer of energy through a medium due to vibrations. Vibrations are the cause and waves are the effect.
22.



23.



24. Given: $T = 0.280$ s
Required: f

Analysis: $f = \frac{1}{T}$

Solution: $f = \frac{1}{T}$

$$= \frac{1}{0.280\text{ s}}$$

$$f = 3.57\text{ Hz}$$

Statement: The frequency of the pendulum is 3.57 Hz.

25. Given: $f = 82$ Hz
Required: T

Analysis: $f = \frac{1}{T}$

$$T = \frac{1}{f}$$

Solution: $T = \frac{1}{f}$

$$= \frac{1}{82\text{ Hz}}$$

$$f = 0.012\text{ s}$$

Statement: The period of the wave is 0.012 s.

26. Given: $\lambda = 0.620$ m; $T = 0.300$ s
Required: v

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

Solution: $v = \frac{\lambda}{T}$

$$= \frac{0.620\text{ m}}{0.300\text{ s}}$$

$$v = 2.07\text{ m/s}$$

Statement: The speed of the wave is 2.07 m/s.

27. The amplitude of a longitudinal wave is defined as the maximum pressure it creates compared to the pressure of the non-disturbed medium.

28. (a) The wavelength is 5.4 cm and wave B is shifted 13.5 cm to the right of wave A.

$$\frac{13.5\ \cancel{\text{mm}}}{54\ \cancel{\text{mm}}} = 0.25$$

The phase shift is 0.25.

(b) The wavelength is 5.4 cm and wave B is shifted 13.5 cm to the left of wave A.

$$\frac{-13.5\ \cancel{\text{mm}}}{54\ \cancel{\text{mm}}} = -0.25$$

The phase shift is –0.25.

(c) The phase shift of B is half a wavelength. The phase shift is 0.5.

(d) The waves are in phase. The phase shift is 0.

29. Given: $f = 0.40$ Hz; $\lambda = 7.0$ m
Required: v
Analysis: $v = f\lambda$
Solution: $v = f\lambda$

$$= (0.40\text{ Hz})(7.0\text{ m})$$

$$v = 2.8\text{ m/s}$$

Statement: The wave speed is 2.8 m/s.

30. Given: $v = 343.2$ m/s; $T = 0.00226$ s
Required: λ
Analysis: $v = f\lambda$

$$= \frac{\lambda}{T}$$

$$\lambda = vT$$

Solution: $\lambda = vT$

$$= \left(343.2\ \frac{\text{m}}{\cancel{\text{s}}}\right)(0.00226\ \cancel{\text{s}})$$

$$= 0.776\text{ m}$$

$$\lambda = 77.6\text{ cm}$$

Statement: The wavelength is 77.6 cm.

31. Given: $m = 0.180$ kg; $L = 1.60$ m
Required: μ

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

Solution: $\mu = \frac{m}{L}$

$$= \frac{0.180\text{ kg}}{1.60\text{ m}}$$

$$\mu = 0.112\text{ kg/m}$$

Statement: The linear density of the string is 0.112 kg/m.

32. Given: $\mu = 0.083$ kg/m; $L = 3.2$ m
Required: m

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

$$m = \mu L$$

Solution: $m = \mu L$

$$= \left(0.083\ \frac{\text{kg}}{\cancel{\text{m}}}\right)(3.2\ \cancel{\text{m}})$$

$$m = 0.27\text{ kg}$$

Statement: The mass of the string is 0.27 kg.

33. Given: $\mu = 0.19$ kg/m; $F_T = 184$ N
Required: v

Analysis: $v = \sqrt{\dfrac{F_T}{\mu}}$

Solution:
$$\begin{aligned} v &= \sqrt{\frac{F_T}{\mu}} \\ &= \sqrt{\frac{184 \text{ N}}{0.19 \text{ kg/m}}} \\ &= \sqrt{\frac{184 \dfrac{\cancel{\text{kg}} \bullet \text{m}}{s^2}}{0.19 \dfrac{\cancel{\text{kg}}}{\text{m}}}} \\ v &= 31 \text{ m/s} \end{aligned}$$

Statement: The speed of a wave along the string is 31 m/s.

34. Given: $F_T = 100.0$ N; $v = 40.0$ m/s
Required: μ

Analysis:
$$\begin{aligned} v &= \sqrt{\frac{F_T}{\mu}} \\ v^2 &= \frac{F_T}{\mu} \\ \mu &= \frac{F_T}{v^2} \end{aligned}$$

Solution:
$$\begin{aligned} \mu &= \frac{F_T}{v^2} \\ &= \frac{100.0 \text{ N}}{(40.0 \text{ m/s})^2} \\ &= \frac{100.0 \dfrac{\text{kg}\bullet\cancel{\text{m}}}{\cancel{s^2}}}{1600 \dfrac{\text{m}^{\cancel{2}}}{\cancel{s^2}}} \\ \mu &= 6.25 \times 10^{-2} \text{ kg/m} \end{aligned}$$

Statement: The linear density of the string is 6.25×10^{-2} kg/m, or 0.0625 kg/m.

35. Tightening the machine head increases the tension on the spring. As the tension increases, the wave speed increases. Likewise, loosening the machine head reduces the tension, which reduces the wave speed.

36. Waves generally travel faster in rigid media because the rigid intermolecular forces allow for a faster transfer of energy.

37. Given: $T = 18$ °C
Required: v

Analysis: $v = 331.4 \text{ m/s} + (0.606 \text{ m/s/°C})T$

Solution:
$$\begin{aligned} v &= 331.4 \text{ m/s} + (0.606 \text{ m/s/°C})T \\ &= 331.4 \text{ m/s} + \left(0.606 \frac{\text{m/s}}{\cancel{°\text{C}}}\right)(18 \cancel{°\text{C}}) \\ &= 331.4 \text{ m/s} + 10.9 \text{ m/s} \\ &= 342.3 \text{ m/s} \\ v &= 340 \text{ m/s} \end{aligned}$$

Statement: The speed of sound in 18 °C air is 340 m/s.

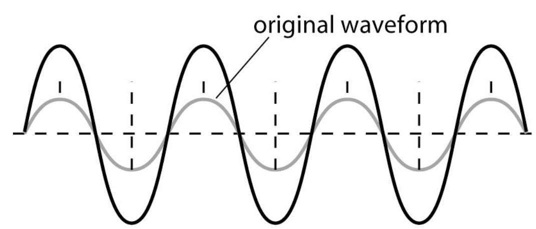
38. Given: $v = 349$ m/s
Required: T

Analysis:
$$\begin{aligned} v &= 331.4 \text{ m/s} + (0.606 \text{ m/s/°C})T \\ T &= \frac{v - 331.4 \text{ m/s}}{0.606 \text{ m/s/°C}} \end{aligned}$$

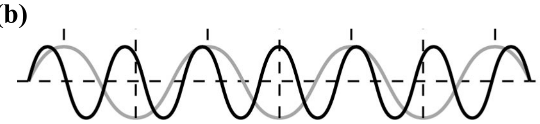
Solution:
$$\begin{aligned} T &= \frac{v - 331.4 \text{ m/s}}{0.606 \text{ m/s/°C}} \\ &= \frac{349 \text{ m/s} - 331.4 \text{ m/s}}{0.606 \text{ m/s/°C}} \\ &= \frac{17.6 \cancel{\text{m/s}}}{0.606 \dfrac{\cancel{\text{m/s}}}{°\text{C}}} \\ T &= 29.0 \text{ °C} \end{aligned}$$

Statement: The ambient temperature is 29.0 °C.

39. (a)



(b)



40. Given: $v_{sound} = 313$ m/s; $v_{aircraft} = 907$ km/h
Required: M

Analysis: $M = \dfrac{v_{aircraft}}{v_{sound}}$

Solution:
$$\begin{aligned} M &= \frac{v_{aircraft}}{v_{sound}} \\ &= \frac{907 \text{ km/h}}{313 \text{ m/s}} \\ &= \frac{907 \dfrac{\cancel{\text{km}}}{\cancel{\text{h}}}}{313 \dfrac{\cancel{\text{m}}}{\cancel{s}}}\left(\frac{1000 \cancel{\text{m}}}{1 \cancel{\text{km}}}\right)\left(\frac{1 \cancel{\text{h}}}{3600 \cancel{s}}\right) \\ M &= 0.805 \end{aligned}$$

Statement: The Mach number is 0.805.

41. Given: $v_{\text{sound}} = 300.0$ m/s; $M = 0.481$

Required: v_{airplane}

Analysis: $M = \dfrac{v_{\text{airplane}}}{v_{\text{sound}}}$

$$v_{\text{airplane}} = Mv_{\text{sound}}$$

Solution:

$$\begin{aligned} v_{\text{airplane}} &= Mv_{\text{sound}} \\ &= (0.481)(300.0 \text{ m/s}) \\ &= 144.3 \text{ m/s} \\ &= \left(144.3 \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)\left(\frac{1 \text{ km}}{1000 \cancel{\text{m}}}\right)\left(\frac{3600 \cancel{\text{s}}}{1 \text{ h}}\right) \\ v_{\text{airplane}} &= 519 \text{ km/h} \end{aligned}$$

Statement: The speed of the airplane is 519 km/h.

42. Loudness is expressed in a logarithmic scale using decibels (dB). Decibels are a more convenient measurement unit than watts per square metre (W/m^2). The watt per square metre values for loudness can vary from 1.0×10^{-12} (the threshold of human hearing) to 1.0×10^{13} (an atomic bomb).

43. Answers may vary. Sample answer:
Aircraft were used to break the sound barrier. There are no forces of friction to slow down an aircraft unlike a car (which is dependent on wheels rolling on the ground).

Analysis and Application

44. Answers may vary. Sample answer:
I do not think you would hear any sound because there is no air in space for sound waves to travel through.

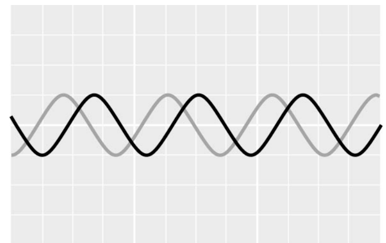
45. (a) Students should indicate the top of the wave on the right.

(b) Students should indicate the distance between the middle dotted line and either a crest or a trough.

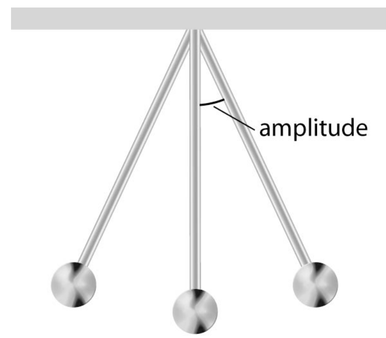
(c) Students should indicate the distance between a consecutive pair of waves.

(d) Students should indicate the bottom of the curve below the equilibrium, at the centre, as the trough.

46. Since each square represents 0.25 m, the new wave is shifted one square to the right:



47.



48. Given: $\lambda = 82$ cm $= 0.82$ m; $v = 540$ m/s

Required: f

Analysis: $v = f\lambda$

$$f = \frac{v}{\lambda}$$

Solution:

$$\begin{aligned} f &= \frac{v}{\lambda} \\ &= \frac{540 \frac{\cancel{\text{m}}}{\text{s}}}{0.82 \cancel{\text{m}}} \\ f &= 6.6 \times 10^2 \text{ Hz} \end{aligned}$$

Statement: The frequency of the wave is 6.6×10^2 Hz, or 660 Hz.

49. Given: $v = 62$ m/s; $L = 0.60$ m; $F_T = 200$ N

Required: m

Analysis: $v = \sqrt{\dfrac{F_T}{\mu}}$

$$\begin{aligned} v^2 &= \frac{F_T}{\mu} \\ \mu &= \frac{F_T}{v^2} \\ \mu &= \frac{m}{L} \\ m &= \mu L \\ m &= \frac{F_T}{v^2} L \end{aligned}$$

Solution:

$$m = \frac{F_T}{v^2}L$$

$$= \frac{200\ \text{N}}{(62\ \text{m/s})^2}(0.60\ \text{m})$$

$$= \frac{200\ \frac{\text{kg}\bullet\cancel{\text{m}}}{\cancel{\text{s}^2}}}{3844\ \frac{\cancel{\text{m}^2}}{\cancel{\text{s}^2}}}(0.60\ \cancel{\text{m}})$$

$$m = 3.1\times10^{-2}\ \text{kg}$$

Statement: The mass of the string is 3.1×10^{-2} kg or 31 g.

50. Given: $m = 0.220$ kg; $L = 4.30$ m; $v = 18.0$ m/s

Required: F_T

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

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

$$F_T = \mu v^2$$

$$F_T = \left(\frac{m}{L}\right)v^2$$

Solution: $F_T = \left(\frac{m}{L}\right)v^2$

$$= \frac{0.220\ \text{kg}}{4.30\ \text{m}}(18.0\ \text{m/s})^2$$

$$= \frac{0.220\ \text{kg}}{4.30\ \cancel{\text{m}}}\left(324.00\ \frac{\text{m}^{\cancel{2}}}{\text{s}^2}\right)$$

$$F_T = 16.6\ \text{N}$$

Statement: The tension in the string is 16.6 N.

51. Given: $f_E = 329.6$ Hz; $\lambda = 1.032$ m; $m = 180.0$ g $= 0.1800$ kg; $L = 32.0$ cm $= 0.320$ m; $f = 328.1$ Hz

Required: ΔF_T

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

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

$$F_T = \mu v^2$$

$$= \left(\frac{m}{L}\right)(f\lambda)^2$$

$$F_T = \frac{mf^2\lambda^2}{L}$$

Solution: Determine the current tension:

$$F_T = \frac{mf^2\lambda^2}{L}$$

$$= \frac{(0.1800\ \text{kg})(328.1\ \text{Hz})^2(1.032\ \text{m})^2}{0.320\ \text{m}}$$

$$F_T = 64\ 490\ \text{N}$$

Determine the tension required for an E:

$$F_{TE} = \frac{mf_E^{\,2}\lambda^2}{L}$$

$$= \frac{(0.1800\ \text{kg})(329.6\ \text{Hz})^2(1.032\ \text{m})^2}{0.320\ \text{m}}$$

$$F_{TE} = 65\ 081\ \text{N}$$

Determine the difference in tension:

$$\Delta F_T = F_{TE} - F_T$$

$$= 65\ 081\ \text{N} - 64\ 490\ \text{N}$$

$$\Delta F_T = 591\ \text{N}$$

Statement: You need to increase the tension by 591 N.

52. Given: $v = 1496$ m/s

Required: T

Analysis: $v = 331.4\ \text{m/s} + (0.606\ \text{m/s/°C})T$

$$T = \frac{v - 331.4\ \text{m/s}}{0.606\ \text{m/s/°C}}$$

Solution: $T = \frac{v - 331.4\ \text{m/s}}{0.606\ \text{m/s/°C}}$

$$= \frac{1496\ \text{m/s} - 331.4\ \text{m/s}}{0.606\ \text{m/s/°C}}$$

$$= \frac{1164.6\ \cancel{\text{m/s}}}{0.606\ \frac{\cancel{\text{m/s}}}{\text{°C}}}$$

$$T = 1922\ \text{°C}$$

Statement: The air temperature would need to be 1922 °C.

53. Given: $v_{aircraft} = 48.3$ km/h; $M = 0.040$

Required: T

Analysis: $v_{sound} = 331.4\ \text{m/s} + (0.606\ \text{m/s/°C})T$ **;**

$$M = \frac{v_{airplane}}{v_{sound}}$$

$$v_{sound} = \frac{v_{airplane}}{M}$$

Solution: Determine the speed of the sound:

$$v_{\text{sound}} = \frac{v_{\text{airplane}}}{M}$$

$$= \frac{48.3\ \frac{\text{km}}{\text{h}}}{0.040}\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)$$

$$= 335.4\ \text{m/s}\ \ \text{(one extra digit carried)}$$

$$v_{\text{sound}} = 335\ \text{m/s}$$

Determine the temperature:

$$v_{\text{sound}} = 331.4\ \text{m/s} + (0.606\ \text{m/s/°C})T$$

$$T = \frac{v_{\text{sound}} - 331.4\ \text{m/s}}{0.606\ \text{m/s/°C}}$$

$$T = \frac{335.4\ \text{m/s} - 331.4\ \text{m/s}}{0.606\ \frac{\text{m/s}}{\text{°C}}}$$

$$T = 6.6\ \text{°C}$$

Statement: The air temperature is 6.6 °C.

54. Given: $T = -56.0$ °C; $M = 3.00$

Required: v_{airplane}

Analysis: $M = \frac{v_{\text{airplane}}}{v_{\text{sound}}}$

$$v_{\text{airplane}} = Mv_{\text{sound}}$$

Solution: Determine the local speed of sound:

$$v_{\text{sound}} = 331.4\ \text{m/s} + (0.606\ \text{m/s/°C})T$$

$$= 331.4\ \text{m/s} + \left(0.606\ \frac{\text{m/s}}{\text{°C}}\right)(-56.0\ \text{°C})$$

$$= 331.4\ \text{m/s} - 33.936\ \text{m/s}$$

$$= 297.46\ \text{m/s}$$

$$v_{\text{sound}} = 297\ \text{m/s}$$

Determine the speed of the aircraft:

$$v_{\text{airplane}} = Mv_{\text{sound}}$$

$$= (3.00)(297.46\ \text{m/s})$$

$$= 892.38\ \text{m/s}$$

$$= \left(892.38\ \frac{\text{m}}{\text{s}}\right)\left(\frac{1\ \text{km}}{1000\ \text{m}}\right)\left(\frac{3600\ \text{s}}{1\ \text{h}}\right)$$

$$= 3213.6\ \text{km/h}$$

$$v_{\text{airplane}} = 3210\ \text{km/h}$$

Statement: The speed of the airplane is 3210 km/h.

55. Answers may vary. Sample answer: Without a medium, visual communication would be very useful. Some methods include writing, semaphore, and blinking lights in Morse code. Radio waves are a non-visual method of communication that work without a medium.

56. Answers may vary. Sample answer: As propeller planes approach the speed of sound, the propellers lose effectiveness due to increased drag on the propeller blades. This requires that the propeller blades be travelling at a speed much greater than the speed of sound. The blades may also have difficulty with the change in pressure near the speed of sound.

57. Answers may vary. Sample answer: Quartz clocks are still subject to temperature, but are more accurate than a mechanical watch.

58. Answers may vary. Students should have a journal of the sounds they hear during a day. Decibel levels will have to be estimated (unless sound meters are available) and may not be accurate, but the student should get an idea of the amount of sound they interact with on a daily basis.

59. Answers may vary. Sample answer: When a musical instrument like a guitar or a piano is not tuned properly, the sound it makes will not be quite right. The tension of the strings needs to be adjusted to get the right sound.

Evaluation

60. (a) Given: $T_1 = 5.40$ °C; $T_2 = 26.4$ °C; $\Delta t = 0.5(0.250\ \text{s}) = 0.125$ s

Required: Δd

Analysis: $\Delta d = d_2 - d_1$

Solution: Determine the speed of sound at T_1:

$$v_{\text{sound1}} = 331.4\ \text{m/s} + (0.606\ \text{m/s/°C})T_1$$

$$= 331.4\ \text{m/s} + \left(0.606\ \frac{\text{m/s}}{\text{°C}}\right)(5.40\ \text{°C})$$

$$= 331.4\ \text{m/s} + 3.2724\ \text{m/s}$$

$$= 334.67\ \text{m/s}$$

$$v_{\text{sound1}} = 335\ \text{m/s}$$

Determine the speed of sound at T_2:

$$v_{\text{sound2}} = 331.4\ \text{m/s} + (0.606\ \text{m/s/°C})T_2$$

$$= 331.4\ \text{m/s} + \left(0.606\ \frac{\text{m/s}}{\text{°C}}\right)(26.4\ \text{°C})$$

$$= 331.4\ \text{m/s} + 15.998\ \text{m/s}$$

$$= 347.40\ \text{m/s}$$

$$v_{\text{sound2}} = 347\ \text{m/s}$$

Determine the distance at v_{sound1}:

$$d_1 = v_{sound1}\Delta t$$
$$= (334.67 \text{ m/s})(0.125 \text{ s})$$
$$d_1 = 41.8 \text{ m}$$

Determine the distance at v_{sound2}:

$$d_2 = v_{sound1}\Delta t$$
$$= (347.40 \text{ m/s})(0.125 \text{ s})$$
$$d_2 = 43.4 \text{ m}$$

Statement: The range of distances from camera to subject is 41.8 m to 43.4 m.

(b) Answers may vary. Sample answer:
This difference in distance seems reasonable for a camera since the camera won't focus too differently for 40 m versus 50 m distances.

(c) Answers may vary. Sample answer:
No, I would want a much smaller range of error if measuring smaller distances.

Reflect on Your Learning

61. Answers may vary. Sample answer:
Sound is energy. I hadn't thought of sound in that way before.

62. Answers may vary. Sample answer:
I have a basic understanding now. I did not know that sound travels at different speeds in different media, and that there are different frequencies of sound.

63. Answers may vary. Sample answer:
I do not know if loud sound is really an issue. My hearing seems fine to me. OR I do not want to lose my hearing, so I think I will adjust my volume level when listening to my iPod.

Research

64. Answers may vary. Students' answers should indicate that sonograms allow doctors to examine soft tissue without having to operate on a patient. Sonograms are used to make images of muscles, tendons, breasts, liver, kidneys, brains, hearts, and other soft tissue in the body.

65. Answers may vary. Students' answers could include two of the following advantages of wave power: free, inexpensive, and renewable. Two disadvantages of wave power are the need for a consistent site and the variability of weather.

66. Answers may vary. Students' answers should indicated that ultrasound waves are used to determine the location of the stones. Then, high-energy sound waves are directed at the stones to break them into smaller, less invasive pieces that the body can flush out. Detailed descriptions of the physics behind this technology could be provided.

67. Answers may vary. Students' answers might include possible unaccredited flights that broke the sound barrier before Chuck Yeager; answers could include Thrust SSC setting the land speed record by breaking the sound barrier in 1997.

68. Answers may vary.

(a) Sample answer: Some animals that use infrasonic waves are whales, elephants, and giraffes.

(b) Students' answers should indicate that infrasonic waves allow animals to communicate over long distances especially when transmitted through a solid or liquid medium. For example, whales use infrasonic waves to communicate through hundreds of kilometres of ocean, and elephants can detect the waves transmitted through the ground. The early response by animals to natural disasters such as earthquakes and tsunamis may be because they can detect infrasonic waves that humans cannot detect.

69. Answers may vary. Students may include tornado detection, oil or gas leak detection, or arms testing detection.

70. Answers may vary. Historical string instruments include the harp, lute, lyre, rebab, sitar, erhu, and koto. The graphic organizer could be a table, t-chart, tree branch diagram, or other organizer.

71. (a) Descriptions should be similar to the following: Ultrasonic welding uses high-frequency vibrations to cause a tiny amount of melting at the joint of two materials.

(b) Answers may vary. Student answers should be similar to the following: Ultrasonic welding is used to manufacture a variety of medical and computer components, as well as plastic car parts and ordinary plastic containers that need to be airtight.

72. Answers may vary. Students' answers should include the following information:
The Wright brothers and others flew gliders before the first credited flight in 1903. One of the big hurdles to powered, manned flight was three axial control. The reports should compare the Wright Flyer I to other airplanes of this period. A comparison of the mechanical advantages and disadvantages between the Flyer I and other airplanes could be presented in a graphic organizer.