10.1 Review

SUMMARY

- Vibrating objects transfer energy through waves travelling outwards from the source. Waves on water, on a string and sound waves in air are examples of mechanical waves.
- A wave may be a single pulse or it may be continuous or periodic (successive crests and troughs or compressions and rarefactions).
- A wave only transfers energy from one point to another. There is no net transfer of matter or material.
- The particles within the medium undergo small vibrations or oscillations about a mean position.
- Mechanical waves can be either transverse or longitudinal.
- In a transverse wave, the oscillations occur about a mean position and are perpendicular to the direction in which the wave energy is travelling. A wave in a string is an example of a transverse wave.
- In a longitudinal wave the particles or medium oscillate back and forth about a mean position. The oscillations are parallel to (along) the direction the wave energy is travelling. Sound is an example of a longitudinal wave.
- When longitudinal sound waves are converted to electrical signals by a microphone and displayed on an oscilloscope, the signal takes the shape of a transverse wave, where the compressions are represented as a crest and the rarefactions as a trough.

KEY QUESTIONS

1 Describe the motion of particles within a medium as a mechanical wave passes through the medium.

2 State whether the following statements are true or false. For the false statements, rewrite them so they become true.

- **a** Longitudinal waves occur when particles of the medium vibrate in the opposite direction to the direction of the wave.
- **b** Transverse waves are created when the direction of vibration of the particles is at right angles to the direction of the wave.
- **c** A longitudinal wave is able to travel through air.
- **d** The vibrating string of a guitar is an example of a transverse wave.

3 The diagram below represents a slinky spring held at point A by a student.

Draw an image of the pulse a short time after that shown in the diagram and determine the motion of point B. Will point B move upwards or downwards, or is it stationary?

4 Which of the following are examples of mechanical waves?
light, sound, ripples on a pond, vibrations in a rope

5 Describe how the energy from the tuning fork in the diagram is transferred to point X. Justify your answer.

6 The diagram below shows dots representing the average displacement of air particles at one moment in time as a sound wave travels to the right.

Describe how particles A and B have moved from their equally-spaced undisturbed positions to form the compression.

7 A mechanical wave may be described as transverse or longitudinal. In a *transverse* wave, how does the motion of the particles compare with the direction of travel of the wave?

8 Classify the waves described below as either longitudinal or transverse:

- **a** sound waves
- **b** a vibrating guitar string
- **c** slinky moved with an upward pulse
- **d** slinky pushed forwards and backwards.

10.2 Review

SUMMARY

- Waves can be represented by displacement–distance graphs and displacement–time graphs.
- From a displacement–distance graph, you can directly determine the amplitude and wavelength of the wave.
- From a displacement–time graph, you can directly determine the amplitude and period of the wave.
- The period of a wave has an inverse relationship to its frequency, according to the relationship:

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

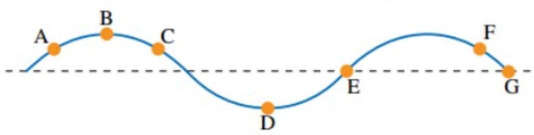
- The speed of a wave can be calculated using the wave equation:

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

- The Doppler effect is a phenomenon that is observed whenever there is relative movement between the source of waves and an observer. It causes an apparent *increase* in frequency when the relative movement is *towards* the observer and an apparent *decrease* in frequency when the relative movement is *away* from the observer.
- For a mechanical wave, the total Doppler effect may result from the motion of the source, the motion of the observer, or the motion of the medium.

KEY QUESTIONS

1 Using the displacement–distance graph below, give the correct word or letters for the following:



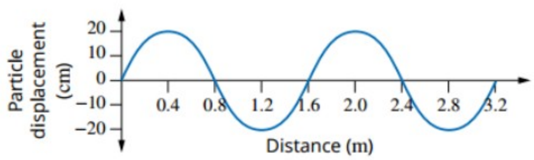
a two points on the wave that are in phase

b the name for the distance between these two points

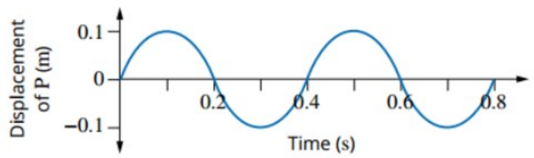
c the two particles with maximum displacement from their rest position

d the term for this maximum displacement.

2 Use the graph below to determine the wavelength and the amplitude of this wave.



3 This is the displacement–time graph for a particle P.



What is the:

a period of the wave?

b frequency of the wave?

4 Five wavelengths of a wave pass a point each second. The amplitude is 0.3 m and the distance between successive crests of the waves is 1.3 m. What is the speed of the wave?

5 Which of the following is true and which is false? For the false statements, rewrite them to make them true.

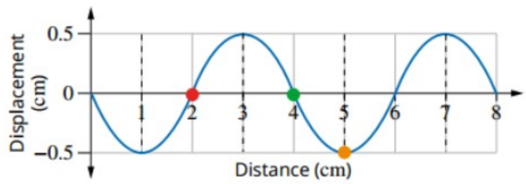
a The frequency of a wave is inversely proportional to its wavelength.

b The period of a wave is inversely proportional to its wavelength.

c The amplitude of a wave is not related to its speed.

d Only the wavelength of a wave determines its speed.

6 Consider the displacement–distance graph below.



a State the wavelength and amplitude of the wave.

b If the wave moves through one wavelength in 2 s, what is the speed of the wave?

c If the wave is moving to the right, which of the coloured particles is moving down?

7 Calculate the period of a wave with frequency 2×10^5 Hz.

8 A police car, travelling at $100\,km\,h^{-1}$ along a straight road, has its siren sounding. The police car is pursuing another car travelling in the same direction, also at $100\,km\,h^{-1}$. There is no wind at the time. Would an observer in the car being pursued hear the siren from the police car at a higher, lower or the same frequency as it emits? Explain your answer.

9 An ambulance sounding its siren in still air moves towards you, then passes you and continues to move away in a straight path. How would the siren sound to you?

10.3 Review

SUMMARY

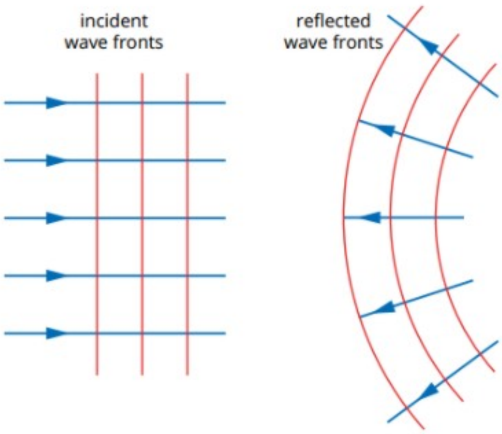
- A wave reaching the boundary between two materials in which it can travel will always be partly reflected, partly transmitted and partly absorbed.
- A wave has been reflected if it bounces back after reaching a boundary or surface.
- Waves reflect with a 180°, or $\frac{\lambda}{2}$, phase change from fixed boundaries. That is, crests reflect as troughs and troughs reflect as crests.
- Waves reflect with no phase change from free boundaries. That is, crests reflect as crests and troughs as troughs.
- When a wave is reflected from a surface, the angle of reflection will equal the angle of incidence.
- Refraction occurs when a wave changes speed as it passes from one medium to another.
- The refraction of the wave is measured by comparing the angle of incidence, i, to the angle of refraction, r.
- When a wave front speeds up at the boundary between two media, the wavelength increases and the wave front will bend away from the normal.
- When a wave front slows down at the boundary between two media, the wavelength decreases and the wave front will bend towards the normal.
- The frequency of the wave is unaffected by refraction.
- Total internal reflection occurs when the reflected angle is 90° to the normal.
- The incident angle at which total internal reflection occurs is called the critical angle.
- Diffraction, or spreading out of waves, around an obstacle or through an aperture occurs when λ is similar to or greater than the width of the aperture.
- Diffraction allows sound to be heard around corners and is more prominent at low frequency.

KEY QUESTIONS

1 A wave travels along a rope and reaches the fixed end of the rope. What occurs next?

2 Which of the following properties of a wave can change when the wave is reflected: frequency, amplitude, wavelength or speed?

3 The following diagram shows a wave before and after being reflected from an object.

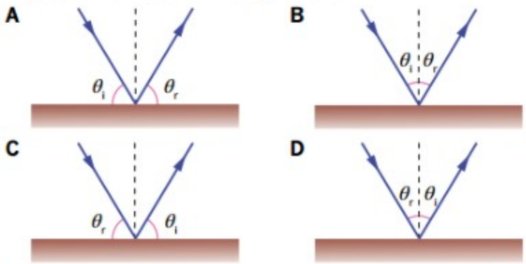


What is the shape of the object?

A flat **B** concave

C convex **D** parabolic

4 In which diagram are the angles of incidence and angles of reflection correctly labelled?



5 A geophysicist studying seismic waves determines that part of the interior of the Earth is molten. Explain why this statement can be made.

6 When water waves travelling through deep water reach a region of shallow water they can be refracted. Which of the properties of water waves given below always changes when the waves reach shallower water? (More than one correct answer is possible.)

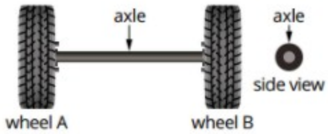
A frequency

B wavelength

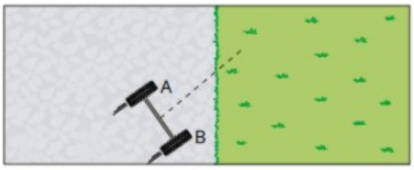
C direction

D speed

7 A popular analogy used to model refraction involves two wheels (A and B) attached to either end of an axle as shown in the figure below.



Rolling these wheels from a surface where they move faster (like on concrete) to where they move slower (like on grass) models the process of refraction (shown in the figure below).



Choose the correct words from those in brackets to complete the description of how this model works.

As wheel B rolls onto the grass it [speeds up/ slows down]. Since wheel A is now moving [faster/ slower] than wheel B, the wheels change [direction/ speed]. When wheel A rolls onto the grass the wheels' direction [continues/stops] changing.

8 The velocity of sound increases by about 0.60 m s^{-1} for each degree increase in temperature. The speed of sound in air at 0.0°C is 331 m s^{-1}. A flute plays a note of 880 Hz at 20°C. A short distance above the ground there is a sudden increase in temperature to 30°C.

- **a** Calculate the speed of sound in air at 20°C.
- **b** Calculate the speed of sound in air at 30°C.
- **c** If the sound travels through cold air and is incident on the warm air at an angle of 50°, what will happen to the refracted angle?
- **d** Calculate the refracted angle.
- **e** At what angles must the sound be incident on the warm air layer for the sound to be reflected rather than refracted?

9 A flute and a tuba are being played at the same time. The flute is producing a note with a frequency of 2000 Hz and the tuba is producing a note with a frequency of 125 Hz at the same volume. A listener to the side of the auditorium complains that the tuba is drowning out the flute. How can this be so?

10.4 Review

SUMMARY

- The principle of superposition states that when two or more waves interact, the resultant displacement or pressure at each point along the wave will be the vector sum of the displacements or pressures of the component waves.
- The process of superposition is also known as interference.
- Constructive interference occurs when the superposition of waves gives an increase in amplitude in the positive and/or negative direction.
- Complete constructive interference occurs when two waves of the same amplitude that are in phase combine to give a wave of double the amplitude.
- Destructive interference occurs when the superposition of two waves gives a reduction in amplitude.
- Complete destructive interference occurs when two waves of equal amplitude, exactly 180° or $\frac{\lambda}{2}$ out of phase, combine to give a wave with zero displacement.
- Resonance occurs when the frequency of a forcing vibration equals the natural or resonant frequency of an object.
- Two special effects occur with resonance:
  - the amplitude of vibration increases
  - the maximum possible energy from the source is transferred to the resonating object.

KEY QUESTIONS

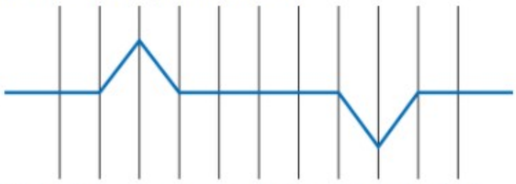
1 Which of the following about wave pulses are true and which are false? For the false statements, rewrite them so they are true.

a The displacement of the resultant pulse is equal to the sum of the displacements of the individual pulses.

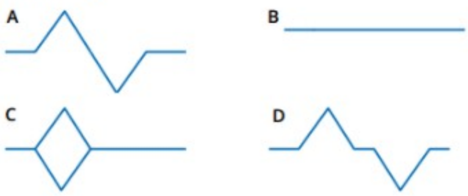
b As the pulses pass through each other, the interaction permanently alters the characteristics of each pulse.

c After the pulses have passed through each other, they will have the same characteristics as before the interaction.

2 Two triangular wave pulses head towards each other at $1\,m\,s^{-1}$. Each pulse is 2 m wide.



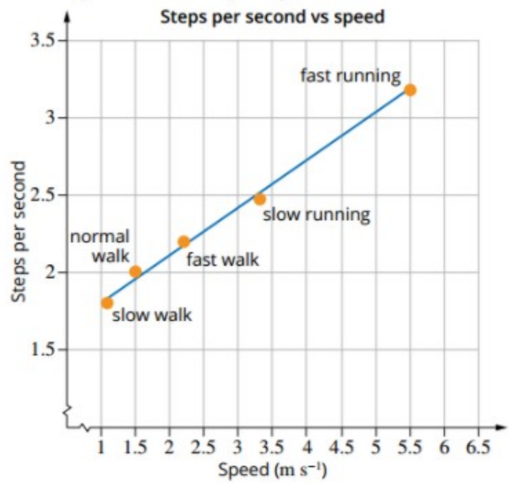
What will the superposition of these two pulses look like in 3 s?



3 Explain why resonance can result in damage to built structures.

4 A light ray strikes a flat surface at an angle of 38° measured from the surface. What is the angle of reflection of the ray?

5 A footbridge over a river has a natural frequency of oscillation from side to side of approximately 1 Hz. When pedestrians walk at a pace that will produce an oscillation in the bridge close to the natural frequency of the footbridge, resonance will occur. The graph below displays relevant data about pedestrians walking or running. A pedestrian completes 1 cycle of their motion every 2 steps. Which activity of the pedestrians is most likely to cause damage to the footbridge over time? Explain your answer.



10.5 Review

SUMMARY

- Standing or stationary waves occur as a result of resonance at the natural frequency of vibration.
- Standing waves are produced by the superposition of waves of equal amplitude and frequency/wavelength travelling in the opposite direction.
- Points on a standing wave that remain still are called nodes.
- Points of maximum vibration (in a string) or pressure variation (in a tube) on a standing wave are called antinodes.
- The standing wave frequencies are referred to as harmonics. The simplest mode is referred to as the fundamental frequency.
- The harmonics above the fundamental frequency are also the called the first overtone, second overtone, third overtone and so on.
- Within a string fixed at both ends, the wavelength of the standing waves corresponding to the various harmonics is:

  $$\lambda = \frac{2\ell}{n}$$

  and the frequency is:

  $$f = \frac{nv}{2\ell}$$

  All harmonics may be present.
- Longitudinal standing waves can also form in air columns.
- At the open end a phase change occurs and a pressure variation node forms.
- If a pipe is closed at one end, there is no phase change and a pressure variation antinode is formed at the closed end.
- An antinode in the standing wave (maximum pressure variation) corresponds to a minimum in particle displacement
- A node in the standing wave (minimum pressure variation) corresponds to a maximum in particle displacement.
- For a pipe open at both ends, the pressure variation is similar to that of a string fixed at both ends, therefore:

  $$\lambda_n = \frac{2\ell}{n}$$

  and the frequency is:

  $$f_n = \frac{nv}{2\ell}$$
- For a pipe with one end closed, an antinode forms at the closed end and a node forms at the open end:

  $$\lambda_n = \frac{4\ell}{n}$$

  and the frequency is:

  $$f_n = \frac{nv}{4\ell}$$
- Expressed this way, only the odd numbered harmonics, $n = 1, 3, 5...$, can be formed.

KEY QUESTIONS

1 A transverse standing wave is produced using a rope. Is the standing wave actually standing still? Explain your answer.

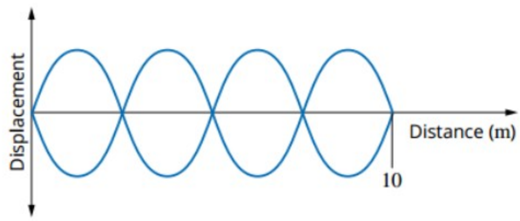
2 Describe how superposition and interference are related to the formation of standing waves in a stretched slinky spring.

3 What is the wavelength of the fundamental mode of a standing wave on a string 0.4 m long and fixed at both ends?

4 Calculate the length of a string fixed at both ends when the wavelength of the fourth harmonic is 0.75 m.

5 A standing wave is produced in a rope fixed at both ends by vibrating the rope with four times the frequency that produces the fundamental or first harmonic. How much larger or smaller is the wavelength of this standing wave compared to that of the fundamental or first harmonic?

6 A standing wave pattern in a string is shown over a distance of 10 m.



What is the length of the rope that would generate the first harmonic if a standing wave of the same wavelength shown in the diagram above was produced?

7 The fundamental frequency of a violin string is 350 Hz and the velocity of the waves along it is 387 m s^{-1}. What is the wavelength of the new fundamental when a finger is pressed to shorten the string to $\frac{2}{3}$ its original length?

8 A metal string (at constant tension) of length 50 cm is plucked, creating a wave pulse. The speed of the transverse wave created is 300 m s^{-1}. Both ends of the string are fixed.

a Calculate the fundamental frequency.

b Calculate the frequency of the second harmonic.

c Calculate the frequency of the third harmonic.

9 A flute can be considered an open-ended air column. For a flute of effective length 45.0 cm:

a What is the wavelength of the fundamental frequency?

b What is the wavelength of the second harmonic?

c Calculate the frequency of the third harmonic, assuming the speed of sound in the flute is 330.0 m s^{-1}.

10 An organ pipe is an air column closed at one end with an effective length of 75.0 cm. The speed of sound inside the pipe is 330 m s^{-1}.

a Calculate the frequency of the fundamental note produced by the pipe.

b Calculate the frequency of the third harmonic.

c Calculate the frequencies of the next two harmonics, after the third, that the pipe can produce.

11 **a** A pipe produces a fundamental frequency of 450 Hz and subsequent resonant frequencies of 900 Hz, 1350 Hz and 1800 Hz. Is this an open ended or closed pipe? Explain why.

b A pipe produces a fundamental wavelength of 3.0 m and subsequent resonances at 1.0 m and 0.6 m. Is this an open-ended or closed pipe? Explain why.

10.6 Review

SUMMARY

- The wave intensity will decrease with the square of the distance from the source according to the relationship $I \propto \frac{1}{r^2}$.
- Ultrasound frequencies are above 20000 Hz.
- Ultrasound can be used for medical imaging.
- High-intensity ultrasound can be used for heat treatment and for removing unwanted cells such as cancers and kidney stones.
- Acoustic engineering such as in theatres uses the properties of waves to optimise listening experiences.
- Noise pollution can be reduced by utilising the properties of reflection and understanding sound propagation.

KEY QUESTIONS

1 Earthquake waves are detected 250 km from the source with a strength of $2.5 \times 10^4\ \mathrm{W\,m^{-2}}$. What will the intensity of these waves be when they reach a major city at a distance of 1000 km from the source? Assume there is no loss from absorption between the source and where the waves are detected.

2 An ambulance started its siren 20 m after leaving the scene of an accident. After a short time, the intensity of the sound was measured as being $\frac{1}{8}$ of the original. Assuming the volume of the siren hadn't changed, how far away was the ambulance when the intensity was measured at the second position?

3 'High-intensity' sound waves are used in treating sports injuries. What does this mean?

4 An office has a lot of reverberation and echoes. How could this be reduced?

5 How does a diffuser reduce echoes and standing waves in a room without losing energy?

6 List two ways to reduce sound pollution from a busy road, and explain the physics of them.

Chapter review

10

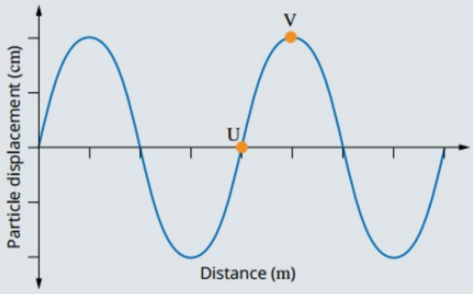
KEY TERMS

absorb
air pressure
amplitude
angle of incidence
angle of reflection
angle of refraction
antinode
compression
constructive interference
crest
critical angle
destructive interference
diffraction
diffuse
Doppler effect
echo
energy
first harmonic
forcing frequency
frequency
fundamental
harmonic
intensity
inverse square law
longitudinal
mechanical wave
medium
natural frequency
node
normal
oscillate
overtone
particle displacement
period
phase
plane wave
pulse
rarefaction
ray
reflect
refraction
resonance
resonant frequency
reverberation
seismic wave
sinusoidal
standing wave
superposition
total internal reflection
transmit
transverse
travelling wave
trough
vibration
wave front
wavelength

1 Imagine that you watch from above as a stone is dropped into water. Describe the movement of the particles on the surface of the water.

2 Describe the similarities and differences between transverse and longitudinal waves.

3 At the moment in time shown on the graph, in what directions are the particles U and V moving?



4 The source of waves in a ripple tank vibrates at a frequency of 10.0 Hz. If the wave crests formed are 30.0 mm apart, what is the speed of the waves (in $m s^{-1}$) in the tank?

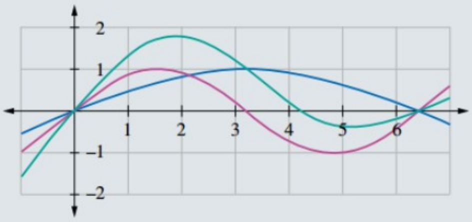
5 A submarine's sonar sends out a signal with a frequency of 32 kHz. If the wave travels at $1400 m s^{-1}$ in seawater, calculate the wavelength of the signal.

6 A motor bike is able to produce a long, steady sound. You are unable to see the motor bike, but can hear the sound from it rise in frequency and then fall. Which one or more of the following options best explains the motion of the motor bike relative to you?

A The bike travelled towards you.
B The bike travelled away from you.
C The bike travelled past you.
D The bike travelled towards you, then away from you.

7 If you decreased the wavelength of the sound made by a loudspeaker, what effect would this have on the frequency and the velocity of the sound waves?

8 The following graph shows three wave forms. Two of the wave forms superimpose to form the third wave form:



Which wave is the result of the superposition of the other two?

9 Using ideas about the movement of particles in air, explain how you know sound waves only carry energy and not matter from one place to another.

10 A sound wave is emitted from a speaker and heard by Lee who is 50 m from the speaker. He made several statements once he heard the sound. Which one or more of the following statements made by Lee would be correct? Explain your answers.

A Hearing a sound wave tells me that air particles have travelled from the speaker to me.

B Air particles carried energy with them as they travelled from the speaker to me.

C Energy has been transferred from the speaker to me.

D Energy has been transferred from the speaker to me by the oscillation of air particles.

11 Describe the concept of resonance and why it would need to be considered when designing structures like buildings or bridges.

The following information relates to questions 12–13.

A signal generator is attached to a device that produces vibrations down a string fixed at one end and free to move at the other. The string is kept at constant tension. The effective length of the string is 85 cm. The speed of the vibrations along the string is 340 m s^{-1}.

12 What is the lowest frequency of vibration that will produce a standing wave in the string?

13 What is the frequency of vibration of the third harmonic?

14 An earthquake causes a footbridge to oscillate up and down with a fundamental frequency once every 4.0 s. The motion of the footbridge can be considered to be like that of a string fixed at both ends. What is the frequency of the second harmonic for this footbridge?

15 The velocity of waves in a particular string at constant tension is 78 m s^{-1}. The string is fixed at both ends. If a particular frequency of a standing wave formed in the string is 428 Hz, how far apart would two adjacent antinodes be?

16 Reflection is possible from which of the following shaped surfaces if each surface is reflective? (More than one answer may be correct.)

A flat surface

B concave (curved in) surface

C uneven surface

D convex (curved out) surface

17 Resonance occurs when the frequency of a forcing vibration exactly equals the natural frequency of vibration of an object. Two special effects occur. Which one of the following responses relating to the effects of resonance is true? Explain your answer.

A The amplitude of vibration will decrease.

B The amplitude of vibration will increase.

C The frequency of vibration will increase.

D The frequency of vibration will decrease.

18 The third harmonic of an open pipe produces a frequency of 400 Hz. Assuming the speed of sound is 330 m s^{-1}, calculate the length of the pipe.

19 A signal generator connected to a speaker produces sound waves that are directed into a tube closed at one end. The effective length of the tube is 85 cm and the speed of sound is 340 m s^{-1}.

a What is the lowest frequency of sound that will produce resonance in the tube?

b What frequency of sound will cause the tube to resonate at its third harmonic?

20 If a sound wave travels through water into air at an angle, what would you expect to happen to the angle of refraction relative to the angle of incidence? Explain your answer.

21 Under what conditions does total internal reflection occur?

22 The intensity of a light measured at some distance is x W m^{-2}. If the distance to the light is doubled, what is the relative intensity of the light at this new distance?

A $2x$

B $4x$

C $\frac{x}{2}$

D $\frac{x}{4}$

23 Electromagnetic radiation also obeys the inverse square law. A radio transmitter produces a signal with an intensity of 1 W m^{-2} when measured at 1000 m. This signal was measured using a dish of 1 m^2. What diameter would a circular radio dish need to be to collect 1 W of signal at a distance of 4000 m? Give your answer to the nearest millimetre.

Chapter 10 The nature of waves

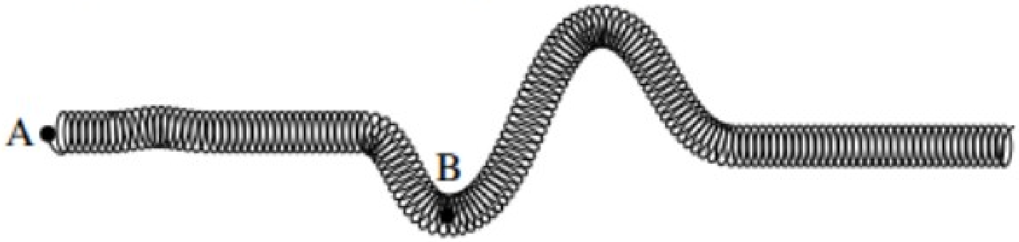
10.1 Longitudinal and transverse waves

10.1 Review

1 The particles oscillate back and forth or up and down around a central or average position and pass on the energy carried by the wave. They do not move along with the wave.

2 **a** False: Longitudinal waves occur when particles vibrate backwards and forwards about a mean position, parallel to the direction of the wave.
b True. **c** True. **d** True.

3 The pulse will move to the right and point B will move downwards.



4 sound, ripples on a pond, vibrations in a rope

5 The tuning fork vibrates back and forth, creating a series of compressions and rarefactions in the air as the energy is transferred.

6 The forward motion of the source (for example, the speaker or tuning fork) pushes particles together so particle A goes to the right, the backward motion of the source creates a low-pressure area (the rarefaction) as particle B is moved to the left.

7 In a transverse wave the motion of the particles is at right angles (perpendicular) to the direction of travel of the wave itself.

8 Longitudinal: a and d
Transverse: b and c

10.2 Review

1 **a** C and F **b** wavelength **c** B and D **d** amplitude

2 wavelength, $\lambda = 1.6\,\text{m}$, amplitude = 20 cm

3 **a** 0.4 s **b** 2.5 Hz **4** $6.5\,\text{m}\,\text{s}^{-1}$

5 **a** True.

b False: The period of a wave is *proportional* to its wavelength.

c True.

d False: The wavelength *and frequency* of a wave determine its speed.

6 **a** wavelength = 4 cm; amplitude = 0.5 cm

b $2\,\text{cm}\,\text{s}^{-1}$ or $0.02\,\text{m}\,\text{s}^{-1}$ **c** red

7 $5 \times 10^{-6}\,\text{s}$

8 As the speed of each vehicle is the same and there is no relative motion of the medium, the frequency observed would be the same as that at the source.

9 It would sound lower.

10.3 Review

1 The wave is reflected and there is a 180° change in phase.

2 amplitude **3** C **4** B

5 After an earthquake, P waves (longitudinal) can be detected after travelling through the region and can be refracted, but S waves (transverse) are not detected. P waves can travel through a fluid but S waves cannot. P waves are also refracted as they travel through the liquid interior and when they cross a boundary between different layers.

6 B, C and D

7 slows down, faster, direction, stops

8 **a** $343\,\text{m}\,\text{s}^{-1}$ **b** $349\,\text{m}\,\text{s}^{-1}$ **c** It will increase. **d** $r = 51.2$°C

e greater than 79°

9 The higher frequency sound of the flute corresponds to a shorter wavelength so it will be diffracted less and will be more directional. Therefore, it will not be heard as well at the sides of the auditorium. The tuba undergoes a lot more diffraction and so will be louder at the sides.

10.4 Review

1 **a** True.

b False: As the pulses pass through each other, the interaction *does not* permanently alter the characteristics of each pulse.

c True.

2 B

3 An object subjected to forces with a forcing frequency matching its natural oscillating frequency will oscillate with increasing amplitude as there is a maximum transfer of energy. This could continue until the structure can no longer withstand the internal forces and fails.

4 52°

5 Normal walking results in a frequency of 1 Hz or 1 cycle per second i.e. two steps per second. This frequency may result in an increase in the amplitude of oscillation of the bridge over time, which could damage the structure.

10.5 Review

1 It is only the pattern made by the amplitude along the rope that stays still at the nodes. The rope is still moving, especially at the antinodes.

2 A transverse wave moving along a slinky spring is reflected at a fixed end with a phase change. The interference that occurs during the superposition of this reflected wave and the original wave creates a standing wave. This standing wave consists of locations called nodes, where the movement of the spring is cancelled out, and antinodes where maximum movement of the spring occurs. Nodes always occur at the ends.

3 0.8 m **4** 1.5 m

5 It will have a wavelength $\frac{1}{4}$ of the fundamental wavelength.

6 2.5 m **7** 0.74 m

8 **a** 300 Hz **b** 600 Hz **c** 900 Hz

9 **a** 0.900 m **b** 0.450 m **c** 1100 Hz

10 **a** 110 Hz **b** 330 Hz **c** 770 Hz

11 **a** Each of the subsequent frequencies is double the previous, therefore all harmonics are formed and the pipe is open ended.

b The next resonance wavelength is $\frac{1}{3}$ that of the fundamental and the following is $\frac{1}{5}$ of the fundamental. This means the frequencies would be 3 times the fundamental and 5 times the fundamental, therefore the pipe is closed at one end.

10.6 Review

1 1560 W m^{-2} **2** 57 m

3 At high-intensity the vibration of the tisues as the ultrasound is propagated produces heat, which can promote faster healing.

4 Use an absorber like foam on the ceiling and carpets on the floor.

5 A diffuser is a corrugated surface that allows reflections to occur in multiple directions, thus reducing echoes. Standing waves also cannot form.

6 A high, solid barrier can be used to reflect the sound; vegetation can be used to absorb the sound.

Chapter 10 Review

1 The particles on the surface of the water move up and down as the waves radiate outwards, carrying energy away from the point on the surface of the water where the stone entered the water.

2 Similarities: both are waves, both carry energy away from the source, both are caused by vibrations.
Differences: transverse waves involve particle displacement at right angles to the direction of travel of the wave; longitudinal waves involve particle displacement parallel to the direction of travel of the wave.

3 U is moving down and V is momentarily stationary (and will then move downwards).

4 $0.300\,\text{m s}^{-1}$ **5** 0.044 m **6** C and D

7 The frequency would increase. **8** The green wave.

9 Sound waves are longitudinal mechanical waves where the particles only move back and forth around an equilibrium position, parallel to the direction of travel of the wave. When these particles move in the direction of the wave, they collide with adjacent particles and transfer energy to the particles in front of them. This means that kinetic energy is transferred between particles in the direction of the wave through collisions. Therefore, the particles cannot move along with the wave from the source as they lose their kinetic energy to the particles in front of them during the collisions.

10 C and D

11 All objects/materials have a resonant frequency. If the object is made to vibrate at this frequency, the amplitude of the object's vibrations will increase with time. If a building or bridge was subjected to wind that made it vibrate at its natural frequency, this vibration may increase in amplitude so much that the structure is damaged or collapses.

12 100 Hz **13** 300 Hz **14** 0.50 Hz

15 0.091 m or 9.1 cm **16** All of the options are correct.

17 B **18** 1.24 m

19 **a** 100 Hz **b** 300 Hz

20 The angle of refraction from the normal to the refracted ray would decrease relative to the angle of incidence.

21 When the wave goes from a slow-speed medium to a higher-speed medium.

22 D **23** 4.514 m