2.1 Waves

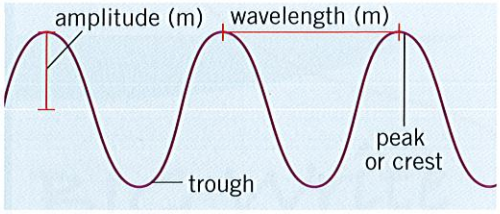
Learning objectives

After this topic you will be able to:

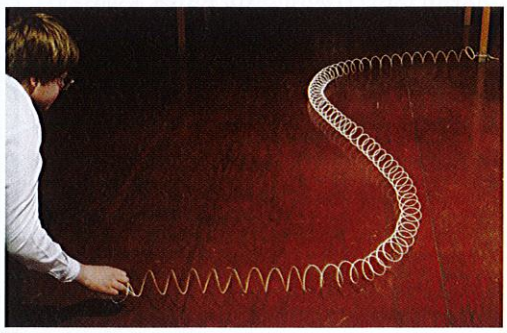
- describe the different types of wave and their features
- describe what happens when water waves hit a barrier
- describe what happens when waves superpose.

Key Words

oscillation, vibration, energy, undulation, sound, amplitude, frequency, wavelength, peak, crest, trough, transverse, longitudinal, compression, rarefaction, reflection, incident wave, reflected wave, superpose



▲ This diagram shows the amplitude and wavelength of a wave.



▲ You can make a transverse wave on a slinky.

Mexican waves are very popular at concerts and sporting events. But what is a wave?

What is a wave?

In science a wave is an **oscillation** or **vibration** that transfers **energy** or information. A wave can also be an **undulation** on the surface of water. Matter does not get transferred. Waves have many uses, for example, microwaves cook food, and **sound** waves help you communicate.

Features of a wave

All waves have three important features:

- an **amplitude**, which is the distance from the middle to the top or bottom of a wave
- a **frequency**, which is the number of waves that go past a particular point per second
- a **wavelength**, which is the distance from one point on a wave to the same point on the next wave.

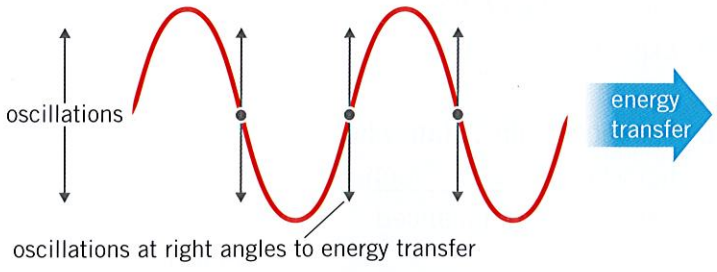
The top of a wave is called a **peak** or **crest**, and the bottom of a wave is called a **trough**.

A Name three properties of a wave.

Transverse or longitudinal?

You can send pulses down a slinky spring. You can make the pulses in two ways.

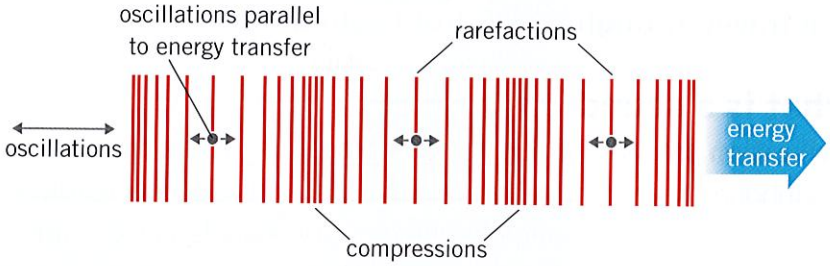
You can move your hand at right angles to the spring. This produces a **transverse** wave on the slinky. In a transverse wave the oscillation is at 90° to the direction of the wave.



▲ In a transverse wave the oscillation is at 90° to the direction of the wave.

You can also push and pull the spring. This produces a **longitudinal** wave on the slinky. The oscillation is parallel to the direction of the wave – it is in the same direction as the spring itself.

In a **compression** the coils of the spring are close together. In a **rarefaction** the coils are further apart. Sound is a longitudinal wave and light is a transverse wave.



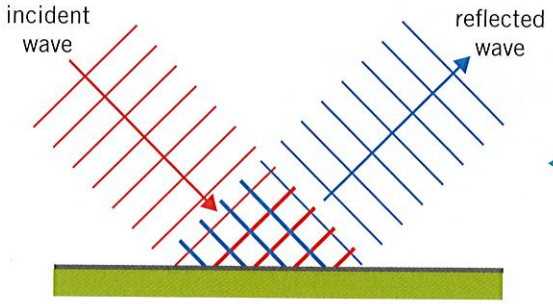
▲ In a longitudinal wave the oscillation is parallel to the direction of the wave.

B State the direction of the oscillation of a longitudinal wave.

Reflecting waves

Waves bounce off surfaces and barriers, just like a football bounces off a wall. This is called **reflection**.

The wave coming into the barrier is called the **incident wave**. The wave bouncing off is called the **reflected wave**.



◀ A wave reflects off a barrier.

C State the name of the wave that hits the barrier.

Adding waves

When waves are put together they **superpose**. This means that they add up or they cancel out.

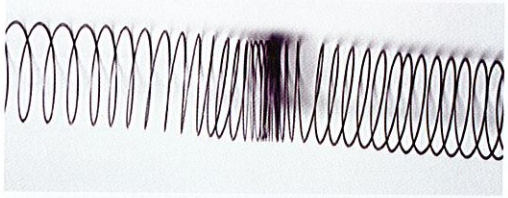
If the waves are in step they will add up. You get more than you had before. If they are not in step then they cancel out and you get less than you had before.

Spot the word

Write the word from each of these definitions:

a the distance from the top to the bottom of a wave

b where the links of a spring are squashed together



▲ You can make a longitudinal wave on a slinky.

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

A wave is an oscillation or vibration that transfers **energy/matter**. The distance from the centre to the top of the wave is the **amplitude/wavelength**. The distance from one crest to the next crest is the **amplitude/wavelength**. Waves can **reflect/superpose** when they hit a barrier, and cancel out or add up when they **reflect/superpose**.

(5 marks)

2 Describe the difference between a compression and a rarefaction in a longitudinal wave on a spring.

(2 marks)

3 Explain in detail the difference between longitudinal and transverse waves, giving examples of each.

(6 marks QWC)

2.2 Sound and energy transfer

Learning objectives

After this topic you will be able to:

- describe how sound is produced and travels
- explain why the speed of sound is different in different materials
- contrast the speed of sound and the speed of light.

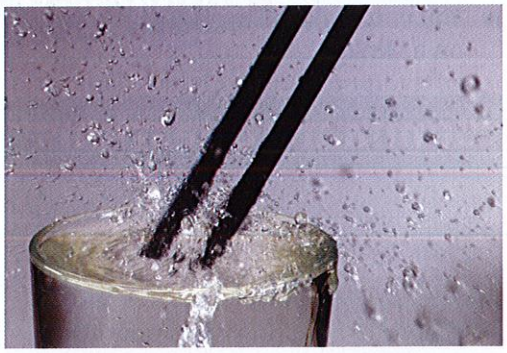
If you very gently press the front of your throat while you are talking you will feel a vibration. This is your vocal chords vibrating. The vibration produces the sound waves that travel through the air from your mouth.

What is a sound wave?

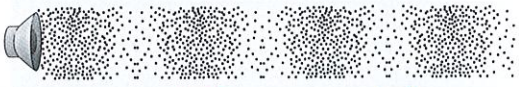
A **vibration** produces a sound wave. All speakers, like the ones in your headphones, have something that moves backwards and forwards, or vibrates. This makes the air molecules move backwards and forwards, which produces a sound wave.

Some people think that sound just 'dies away'. It doesn't. It spreads out as it moves away from the source.

A State what produces a sound wave.



▲ The ends of a tuning fork are vibrating.



▲ Air molecules move backwards and forwards.

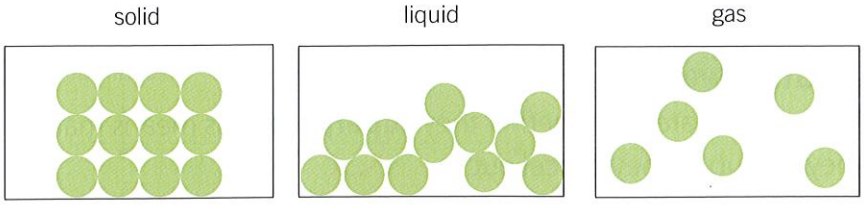
▲ Dolphins communicate underwater.

What does sound travel through?

Dolphins and whales use sound waves to communicate underwater. Elephants stamp their feet when a predator comes near – the warning travels through the ground to other elephants. Sound needs a **medium** like a solid, liquid, or gas to travel through. It cannot travel through empty space, a **vacuum**, because there are no air molecules to vibrate.

How fast does sound travel?

Sound travels at 340 m/s in air. Sound travels much faster in liquids, about 1500 m/s. Sound travels fastest in solids. In metals like steel it can travel at 5000 m/s. You can explain why a sound wave travels faster in a solid than in a gas if you think about particles. The particles in a solid are very close together, so the vibration is passed along more quickly than in a gas.



▲ The arrangement of particles explains the speed of sound in different materials.

Some people talk about the 'sound barrier'. There is no difference between travelling at or beyond the **speed of sound**.

Felix Baumgartner found this out when he became the first human to travel faster than the speed of sound when he jumped from a balloon 24 miles above the surface of the Earth.

◀ Felix Baumgartner travelled faster than sound.

B State the speed of sound.

How fast?

A student uses some secondary sources of information to make a list of the speed of sound in different materials.

a Draw a suitable table that she could use to record the data.

b State and explain which type of graph she could plot to show the data.

C Name the three types of medium that sound can travel through.

Which is faster: sound or light?

Light travels much faster than sound. The **speed of light** is 300 000 000 m/s, so it is almost a million times faster than sound. You notice this difference during a thunderstorm. The thunder and lightning are produced at the same time. You see the lightning immediately but it takes time for the sound of thunder to reach you.

Light can travel through a vacuum. It doesn't need a medium to travel through.

Key Words

vibration, medium, vacuum, speed of sound, speed of light

Stormy night

A girl sees a flash of lightning and then hears the thunder four seconds later.

a How far away is the storm? State your answer in kilometres.

b What would she notice about the thunder and lightning when the storm is directly overhead?

Summary Questions

1 Copy and complete the sentences below.

Sound is produced by objects that are _____. This makes the air molecules _____ and produces a sound wave. Sound travels fastest in _____ and slowest in _____, and it cannot travel through a _____.

(5 marks)

2 Explain why sound travels slower in a gas compared to a liquid.

(2 marks)

3 Compare the time it takes the light to travel from your teacher to your eye with the time it takes sound to travel the same distance.

(6 marks QWC)

2.3 Loudness and pitch

Learning objectives

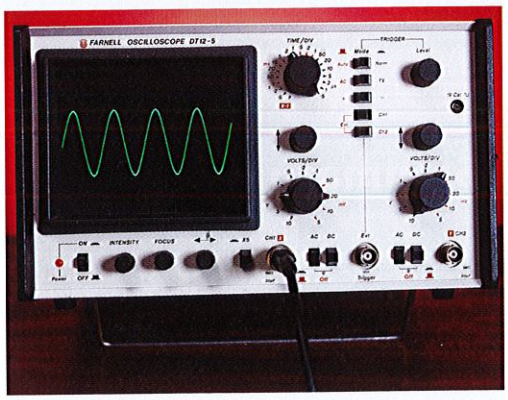
After this topic you will be able to:

- describe the link between loudness and amplitude
- describe the link between frequency and pitch
- state the range of human hearing and describe how it differs from the range of hearing in animals.

If you play a loud note of exactly the right pitch then you can shatter a glass. What's the difference between loudness and pitch?

Seeing sound

You can plug a **microphone** into an **oscilloscope** to see what the sound of your voice looks like. The wave on the screen is transverse but the wave that you are making when you talk is longitudinal. The microphone produces a signal that represents the sound wave.

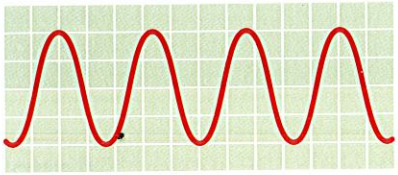


▲ An oscilloscope shows a representation of a sound wave made, for example, by a tuning fork.

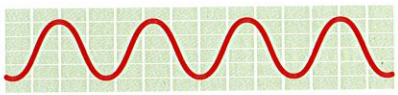
What affects the loudness of a sound?

If a drummer hits the drum harder the sound is louder.

▲ A drum produces a sound with a large amplitude.



loud



soft

▲ A loud sound has a bigger amplitude than a soft sound.

You bang a drum harder or pull a guitar string more to produce a louder sound. A loud sound has a bigger amplitude than a soft sound. It transfers more energy than a soft sound. To make a louder sound you need to make the vibration bigger.

A State the property of a sound wave that affects the loudness of the sound.

What affects the pitch of a sound?

Some singers can sing higher-pitched notes than others. The **pitch** of a note depends on the frequency. High-pitched sounds have a high frequency and low-pitched sounds have a low frequency. Frequency is measured in **hertz** (Hz) or **kilohertz** (kHz).

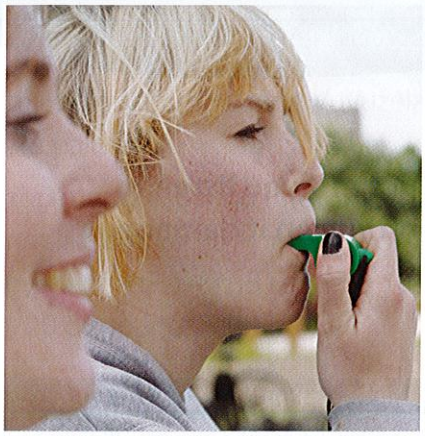
1 kHz = 1000 Hz. To make a higher-pitched sound you need to make something vibrate faster, so that there are more waves per second.

Key Words

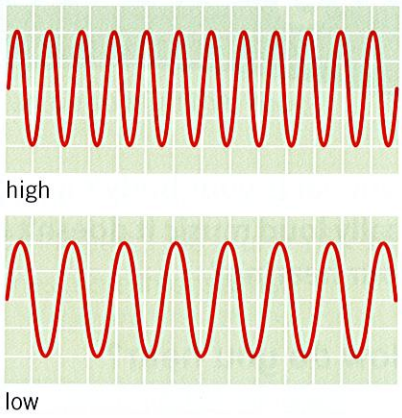
pitch, loudness, microphone, oscilloscope, hertz, kilohertz, audible range, infrasound, ultrasound

Fantastic Fact!

Grasshoppers make sounds that they cannot even hear.



▲ A whistle produces a sound with a high frequency.



▲ A high sound has a higher frequency than a low sound.

You can have a loud, high-pitched sound or a loud, low-pitched sound. Changing the frequency does not affect the amplitude.

B State the property of a sound wave that affects the pitch of the sound.

What frequencies can you hear?

You can only hear a particular range of frequencies, called the **audible range**. You have the biggest audible range when you are young: 20–20 000 Hz. Your audible range changes as you get older. You will find it more difficult to hear high-frequency sounds.

What frequencies can other animals hear?

Bats, dolphins, and grasshoppers have a completely different audible range to humans. Lots of animals can hear frequencies that are much higher than the frequencies we can hear. Frequencies below 20 Hz are called **infrasound**. Frequencies above 20 000 Hz are called **ultrasound**.

Species	Audible range (Hz)
bat	2000–110 000
cat	45–64 000
dog	67–45 000
dolphin	1000–100 000
goldfish	20–3000
hedgehog	250–45 000
whale	1000–123 000

Conversions

a Convert the audible range for humans into kilohertz.

b Convert the audible range of the whale into kilohertz.

Link

You can learn more about ultrasound in P1 2.5 Echoes and ultrasound

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

The loudness of a sound depends on the **amplitude/frequency** and the pitch of the sound depends on the **amplitude/frequency**. Frequency is measured in **hertz/metres**. The range of frequencies you can hear is called the **audible/visible** range.

(4 marks)

2 State the range of human hearing and compare it to the range of dolphin hearing.

(2 marks)

3 A singer produces sounds that vary in pitch and loudness. Use the ideas above to suggest and explain in detail what her vocal chords do to produce different types of sound wave.

(6 marks QWC)

2.4 Detecting sound

Learning objectives

After this topic you will be able to:

- describe how the ear works
- describe how your hearing can be damaged
- describe how a microphone detects sound.

Your ear is your body's microphone. If you listen to really loud music it doesn't hurt but can it damage your hearing?

How do you hear?

Your **ear** detects sound waves. The part of your ear that you can see, called the **pinna**, directs the sound wave into your auditory canal towards your ear drum. The pinna, **auditory canal**, and **eardrum** make up your **outer ear**.

Your eardrum vibrates and passes the vibration on to the **ossicles**. The ossicles make up your **middle ear**. They are tiny bones that **amplify** the sound. They make the **oval window** vibrate.

This passes the vibration on to liquid in the **cochlea**. This contains thousands of tiny hairs. As the liquid moves the hairs move. Specialised cells at the base of the hairs convert the movement to an electrical signal. The signal travels down the **auditory nerve** to your brain. You hear the music.

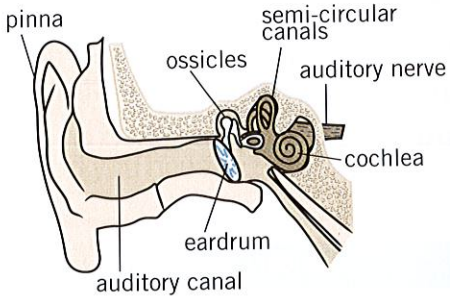
The cochlea and the semi-circular canals make up your **inner ear**. The semi-circular canals help you to balance.

Link

You can learn more about specialised cells B1 1.3 Specialised cells

Key Words

ear, pinna, auditory canal, eardrum, outer ear, ossicle, middle ear, amplify, oval window, cochlea, auditory nerve, inner ear, decibel, diaphragm, amplifier



▲ Structure of the ear.

▲ Without these tiny hairs inside your cochlea you would not be able to hear.

Foul Fact!

Your ossicles don't grow. They are the correct size when you are born. They are the smallest bones in your body.

A Name the first part of the ear that vibrates when a sound wave enters it.

How do you measure loudness?

In the 2010 World Cup in South Africa the crowd used vuvuzelas to make very loud sounds. Vuvuzelas can be so loud that they are painful.

You measure sound intensity in **decibels** (dB). The decibel scale is not like a ruler. Each increase of 10 dB increases the sound intensity by 10 times. A 40 dB sound is 100 times more intense than a 20 dB sound.

0 dB	20 dB	40 dB	60 dB	80 dB	100 dB	120 dB	140 dB
cannot be heard	leaves rustling	talking quietly	normal speech	heavy traffic	jet taking off	pain threshold	gun shot

What protection?
Two companies make ear defenders. Plan an experiment to find out which pair is best at reducing sound intensity.

How can you damage your hearing?

Your hearing can be damaged if a sharp object makes a hole in your eardrum but your eardrum will grow back. A build-up of ear wax can also be damaging. Very loud sounds or head injuries can permanently damage your hearing.

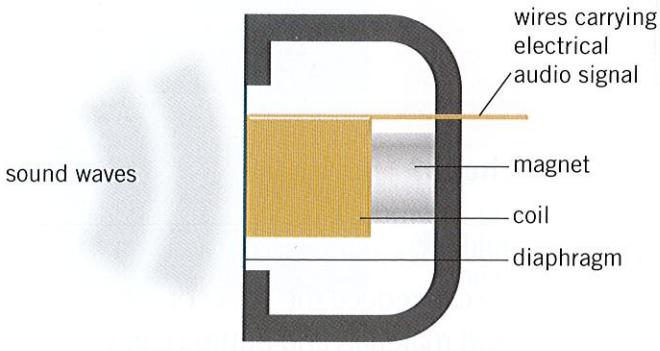
You can reduce the risk of damage by turning down the volume or using ear defenders.

B Describe one way that your hearing can be damaged.

How does a microphone work?

When a singer sings into a microphone the sound wave hits a flexible plate called a **diaphragm**. The diaphragm vibrates, like your eardrum. It produces an electrical signal, just like the cells in your cochlea. The signal carries the information that the sound wave carried.

You can use an **amplifier** to make the sound louder. Loudspeakers convert the electrical signal back into sound when they vibrate.



▲ A microphone detects sound in a similar way to your ear.

Summary Questions

1 Copy and complete the sentences below.

When a sound wave enters your ear it makes the _____ vibrate. This makes the _____ vibrate. The _____ vibrates and this makes the liquid inside your _____ vibrate. Cells at the base of _____ inside your _____ produce an electrical signal that travels up your _____ to your brain. Sound intensity is measured in _____. Your hearing can be _____ by loud sounds. In a microphone a _____ vibrates, which produces an electrical signal.

(10 marks)

2 Describe one way that your hearing can be damaged that is not permanent, and one way that it can be permanently damaged.

(2 marks)

3 Compare the ear and the microphone.

(6 marks QWC)

2.5 Echoes and ultrasound

Learning objectives

After this topic you will be able to:

- describe what ultrasound is
- describe some uses of ultrasound.

▲ This room is designed to produce no echoes.

Where is the quietest place in the world? Scientists have designed a room where it is so quiet you can hear your own heartbeat. The surfaces are designed to absorb sounds. There are no echoes.

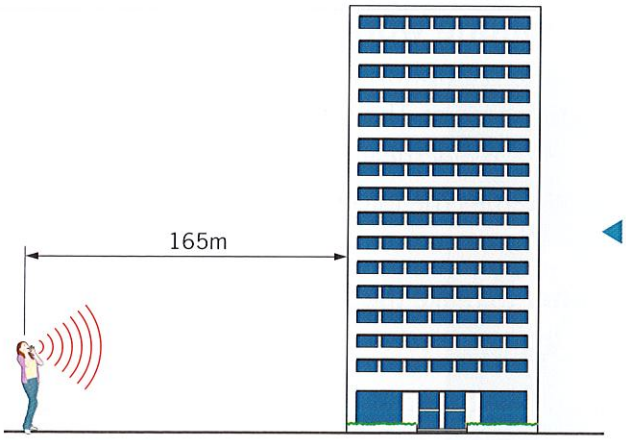
What is an echo?

When sound reflects off a surface it produces an **echo**. Sound takes time to travel. There is a time delay between making a sound and hearing an echo.

Measuring distances

Imagine that you are standing a long way from the school sports hall. You clap and you hear an echo one second later. How far away is the wall?

The speed of sound in air is 340 m/s. The sound travels a total distance of 340 m in one second. The distance to the wall is 165 m because the sound has travelled there and back. You can use the time taken to hear the echo to work out distance.



◀ You can work out how far away a wall is using echoes.

A State what an echo is.

How do you reduce echoes?

If lots of echoes join together to produce a longer sound this is called a **reverberation**. Reverberations can be a nuisance in concert halls or cinemas. You can reduce the effect of echoes by covering the walls with soft materials and putting carpet on the floor.

Key Words

echo, reverberation, transmitter, receiver

Fantastic Fact!

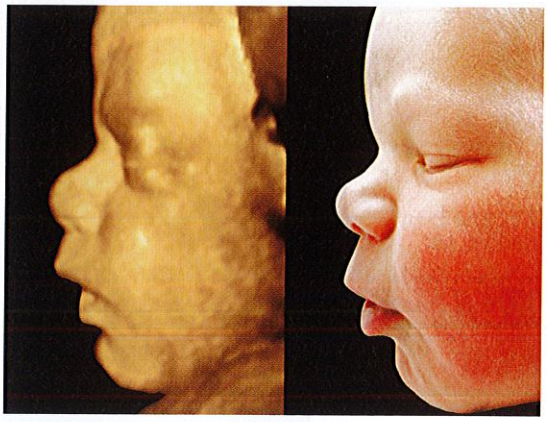
People used to think that a duck's quack and a wolf's howl don't echo. They do. Sometimes the echo gets mixed in with noise so you don't hear it.

What is ultrasound?

Bats use ultrasound to find their food. Doctors use ultrasound to make images of unborn babies. Ultrasound is sound with a frequency above 20 000 Hz.

B State the frequency of ultrasound.

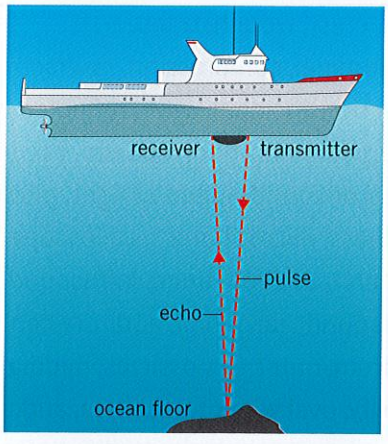
When doctors make images of unborn babies, the ultrasound wave travels through the woman and reflects off the fetus. The machine detects the echo. It uses the time taken for the echo to build up an image of the fetus.



This shows an ultrasound image of a baby and a photograph of the same baby after he was born.

Doctors also use ultrasound in physiotherapy. For example, ultrasound reduces the pain and swelling of a damaged tendon. They can also look for cancer..

Another use of ultrasound is sonar, used on ships. A **transmitter** under the ship sends out a beam of ultrasound. It travels through the water and reflects off the seabed. A **receiver** detects the reflection and uses the time taken to work out the depth of the water.



Ships use ultrasound to work out the depth of the ocean.

C State a use of ultrasound.

Literacy

The word "sonar" is an acronym. It comes from the term "Sound Navigation And Ranging'.

How deep?

A ship's sonar detects an echo 1.6 s after it sends the pulse. The speed of sound in water is 1500 m/s. Work out how deep the water is.

Summary Questions

1 Copy and complete the sentences below.

An echo is a _____ of sound. You can use the _____ between making a sound and hearing an echo from a surface to calculate the _____ to it. Soft materials _____ sound and reduce echoes. Animals use ultrasound to _____ and _____. Ultrasound is used to make an _____ of a fetus, or break down _____. Fishermen can use ultrasound to find the _____ of the ocean.

(9 marks)

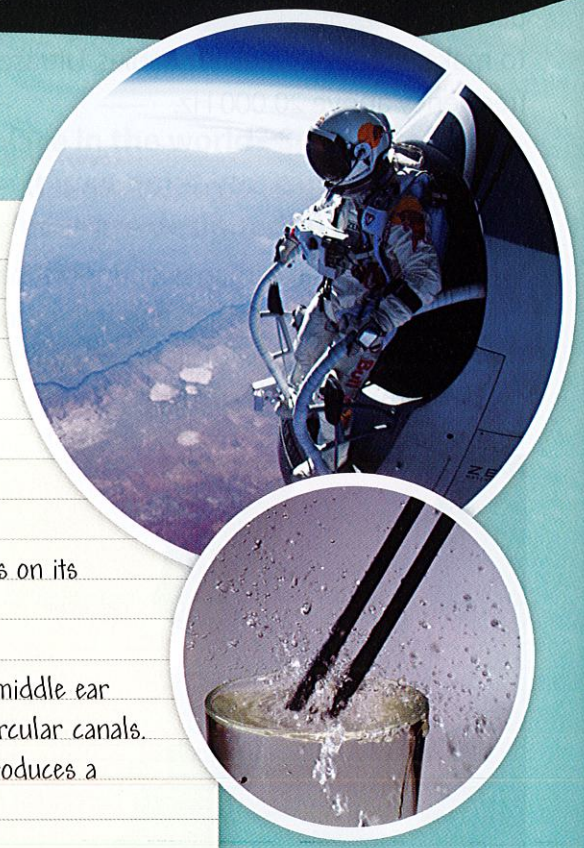
2 Describe one way that a doctor might use ultrasound.

(2 marks)

3 Imagine that you are the captain of a fishing boat. Write a detailed presentation that you will show to the fishermen, explaining how to use sonar to detect shoals of fish.

(6 marks)

P1 Chapter 2 Summary



Key Points

- Waves are oscillations or vibrations that have an amplitude, wavelength, and frequency. The top of a wave is a crest and the bottom is a trough.
- In a transverse wave the oscillation is at 90° to the wave direction, and in a longitudinal wave it is parallel to the wave direction.
- Waves can reflect from barriers and add up or cancel out.
- A sound wave is produced by vibrating objects and is longitudinal.
- Sound travels at 340 m/s. Sound travels fastest in solids and slowest in gases and cannot travel through a vacuum.
- The loudness of a sound depends on its amplitude, and the pitch depends on its frequency. Frequency is measured in hertz (Hz).
- A human's audible range is from 20–20 000 Hz.
- Your outer ear consists of the pinna, auditory canal, and eardrum. Your middle ear contains your ossicles. Your inner ear contains your cochlea and semi-circular canals.
- Vibrations travel from your eardrum to the hairs in your cochlea. This produces a signal that is sent to your brain.
- Loudness is measured in decibels (dB).
- An echo is a reflection of sound that you can use to work out distance. Soft materials absorb sound and don't produce echoes.
- Ultrasound is sound with a frequency of more than 20 000 Hz. Humans use ultrasound to produce images of inside the body, and to find the depths of water.

Big Write

Sound campaign

You are a scientific advisor to a council. There are several issues to do with sound in the area:

- Shopkeepers want to install high-frequency speakers to put off young people hanging around outside their shops.
- People who live near a busy road are concerned about the traffic noise.

Task

Produce an information pack that includes:

- what a sound wave is, its properties, and how it behaves
- how you hear, and how hearing can be damaged.

Key Words

oscillation, vibration, energy, undulation, sound, amplitude, frequency, wavelength, peak, crest, trough, transverse, longitudinal, compression, rarefaction, reflection, incident wave, reflected wave, superpose, vibration, medium, vacuum, speed of sound, speed of light, pitch, loudness, microphone, oscilloscope, hertz, kilohertz, audible range, infrasound, ultrasound, ear, pinna, auditory canal, eardrum, outer ear, ossicles, middle ear, amplify, oval window, cochlea, auditory nerve, inner ear, decibels, diaphragm, amplifier, echo, reverberation, transmitter, receiver