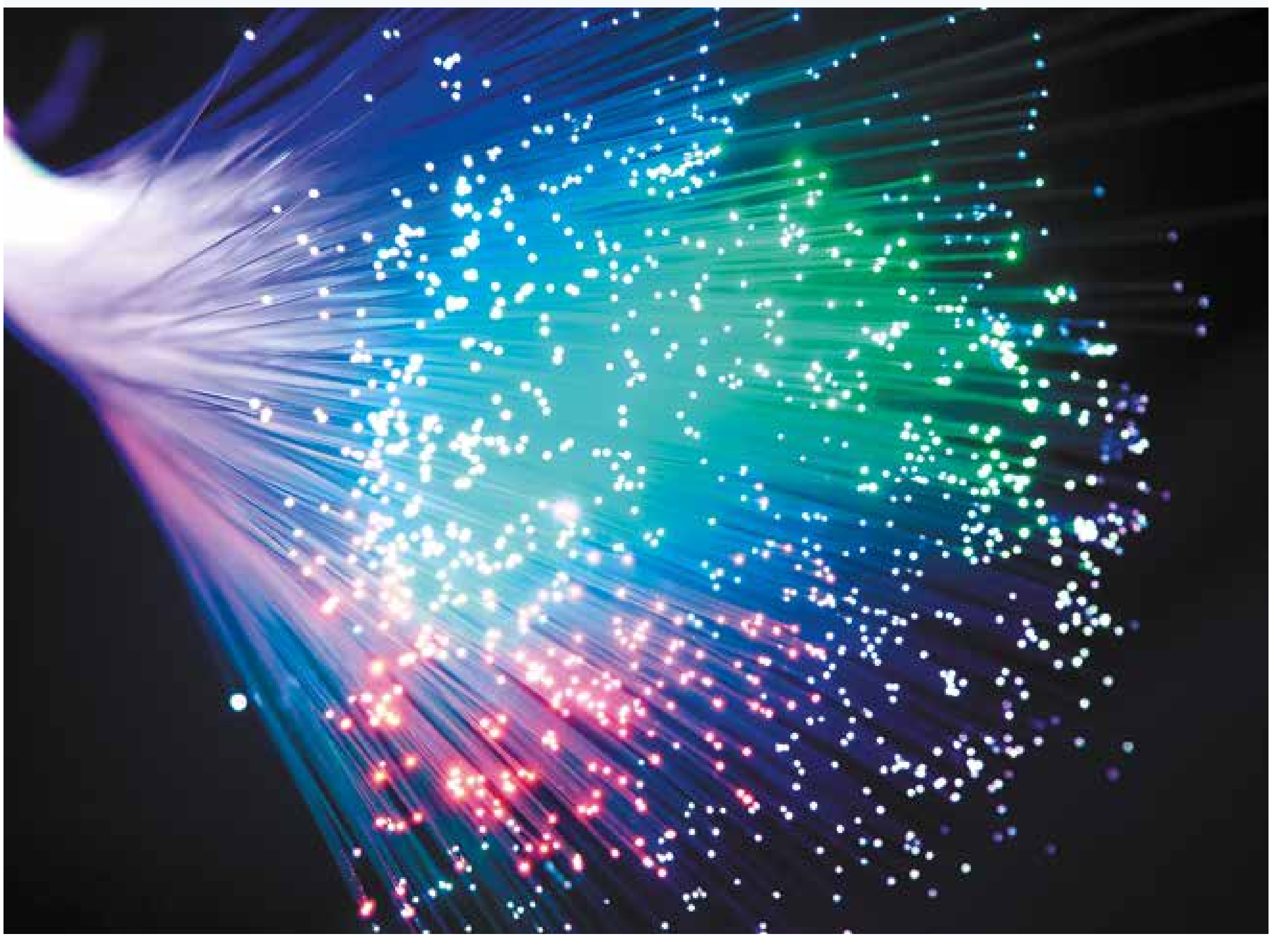
TOPIC 4
Invisible waves

4.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

LEARNING SEQUENCE

Optic fibre technology is set to revolutionise digital communication.



4.1.1 Why learn this?

Light and sound are forms of energy carried by invisible waves. Our senses are attuned to detecting them, and many household devices like musical instruments, mirrors and sunglasses utilise them.

Light is just one example of electromagnetic radiation which is becoming increasingly important in the development of technologies used for communication, such as mobile phones, and for entertainment like radios, televisions and A/V remote controls. In addition, electromagnetic waves in the form of X-rays and gamma rays assist in the diagnosis and treatment of injuries and diseases.

As optic fibre technology takes off in Australia, electromagnetic waves are set to revolutionise computer and phone use in the near future allowing even faster communication around the planet and almost unlimited possibilities in the use of digital media.

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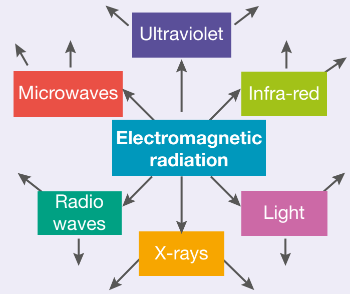
Thinking about communication

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Most of our communication today relies on electromagnetic radiation but this was not always the case. The table below contains some key steps in the history of communication. Draw a timeline to scale and label the key events from the table.

Time	Development
26 000 BC	Oldest known Indigenous Australian rock art in Northern Territory
c. 3000 BC	The Egyptians develop hieroglyphic writing.
776 BC	The first recorded use of homing pigeons, used to send messages to the Athenians, announcing the winner of the Olympic Games
c. 500 BC	Papyrus rolls made of dried reeds, the precursor to modern paper, are used.
37 BC	The first records indicating Roman Emperor, Tiberius used mirrors to send messages
105 BC	Paper as we know it is invented in China.
1041 AD	Movable type printing (made of clay) is invented in China.
1455 AD	Johannes Gutenberg invents a printing press with movable metal type.
1843	Samuel Morse invents the first long distance electric telegraph line utilising Morse code.
1876	Alexander Graham Bell patents the electric telephone.
1901	Guglielmo Marconi transmits radio signals from Cornwall to Newfoundland — the first radio signal across the Atlantic Ocean.
1916	The first radios with tuners become available allowing listeners to tune into different stations.
1927	Television broadcasting begins in England.
1951	Computers are first sold commercially.
1966	Xerox invents the Telecopier — the first successful fax machine.
1966	Launch of A Intelsat II, first satellite link between Australia and overseas
1979	The first mobile phone communication network starts in Japan.
1986	The first fibre-optic cable across the English Channel begins service.
1994	American government releases control of internet and WWW is born — making communication travel at light speed.
2009	Australia launches a program to install optic fibre nationwide.

2. In our homes and at work we use a range of technologies that utilise electromagnetic radiation. Use a mind map to brainstorm devices or applications that rely on the electromagnetic radiation identified at right.
3. Morse code is illustrated below.
   (a) Write a message to a student in your class using Morse code while they write one to you. Decipher each other's message.
   (b) Refer to the timeline in question 1 to identify the technology that replaced Morse code and explain the advantages that it has.



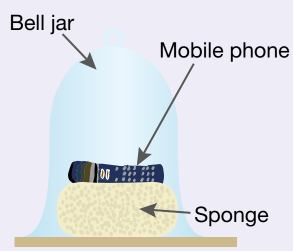
A • –	H • • • •	O – – –	V • • • –
B – • • •	I • •	P • – – •	W • – –
C – • – •	J • – – –	Q – – • –	X – • • –
D – • •	K • – •	R • – •	Y – • – –
E •	L • – • •	S • • •	Z – – • •
F • • – •	M – –	T –	
G – – •	N – •	U • • –	

1 • – – – –	7 – – • • •
2 • • – – –	8 – – – • •
3 • • • – –	9 – – – – •
4 • • • • –	0 – – – – –
5 • • • • •	. (Full stop) • • • • • •
6 – • • • •	, (Comma) • – • – • –

Rules

1. A dash lasts as long as three dots.
2. A space as long as one dot is left between each pulse.
3. A space as long as one dash is left between each letter of a word.
4. A space as long as five dots is left between each word of a sentence.

4. Compare the transmission of sound waves and radio waves to and from a mobile phone by conducting this simple experiment.
   - Place a mobile phone that has a loud ring tone in a bell jar supported by a sponge.
   - Try calling the mobile phone with the bell jar containing air and try again with the air removed by a vacuum pump.
     Does removing the air prevent the radio wave reaching the mobile phone in the bell jar or prevent the sound of the ring tone from reaching you outside the bell jar?



4.2 Waves — carriers of energy

4.2.1 The transformation and transfer of energy

Light and sound are forms of energy and, like other types of energy such as heat, electrical and chemical energy, they can be transformed or converted into other forms of energy. In photosynthesis for example, plants convert light into chemical energy in the form of sugar. Some homes have solar panels installed. The photovoltaic cells in these panels convert light to electrical energy. Even vision relies on special cells in the retina inside the eye, to transform light into small electrical impulses that are transmitted to the brain.

Sound energy is transformed into electrical energy by microphones. Amplifiers then channel this electrical signal to loudspeakers which convert the electrical energy back to sound again.

The transfer of energy does not involve conversion to another form; rather, energy remains in its original form but travels to a new medium or region. Light energy from the sun, for example, is transferred through space and the Earth's atmosphere and into the sea, allowing marine algae to photosynthesise in shallow water along the coastline.

Heat, or thermal energy is transferred spontaneously from a region of high temperature to a region of cold temperature through one or more of the following processes: conduction, convection and radiation. Heat transfer by conduction occurs mainly in solids, while convection occurs generally through liquids and gases. Radiation can occur through any space, even in a vacuum.

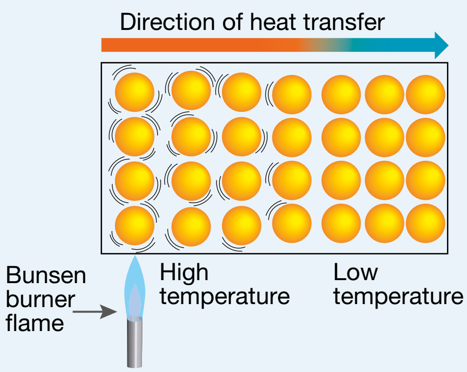
Heat transfer by conduction

Heat travels by conduction when fast-moving particles collide with other nearby particles, making them move faster. If you heat one end of a metal bar, the energy is transferred from the hot end to the cold end by atoms of that metal bumping into one another. Heat can travel by conduction through objects, or from one object to another, such as from a cooktop to a saucepan.

When particles are heated (for example, with a flame), they start to move more quickly.

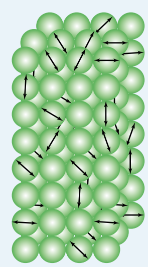
When the fast-moving particles collide with other particles, they cause nearby particles to start vibrating more quickly as well.

Eventually, as particles keep colliding with others, some of their energy is transferred along the object. This process is known as conduction.

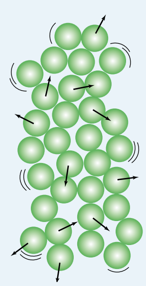


Conduction in solids, liquids and gases

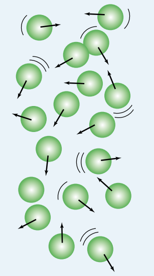
The particles in a solid are packed closely together. If some particles receive heat energy and begin to move faster, they collide easily with other particles nearby and pass the heat energy along.



The particles in liquids are further apart than the particles in solids. When some particles receive heat energy and start to move faster, they collide with other particles. But the distance between the particles means that there are fewer collisions. So, heat is transferred by conduction more slowly in a liquid than in a solid.



The particles in a gas are far apart. Heat does not travel easily by conduction through gases.



Heat travels by conduction at different speeds, depending on the type of material and its state of matter. Heat travels more quickly in solids than in liquids or gases because conduction occurs more quickly when the particles in an object are closer together. Gases are the poorest conductors because the particles in them are far apart. While solids are usually very good conductors of heat because the particles in them are packed closely together, not all solids conduct heat well. Metals are generally good conductors of heat and electricity, while non-metals like glass, plastic and wood do not conduct as well. The free, mobile electrons in metals that allow them to conduct electricity also assist in the transfer of heat energy through the metal. Materials that conduct heat and electricity poorly are called **insulators**.

INVESTIGATION 4.1

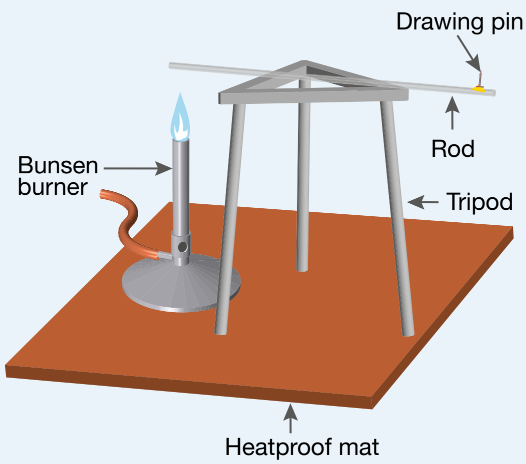
Investigating heat transfer by conduction

AIM: To investigate the rates of conduction in metals and non-metals

You will need:

heatproof mat, Bunsen burner and matches
glass rod
aluminium rod
Vaseline
drawing pin
stopwatch

- Place a rod of aluminium on top of a tripod so that it is stable.
- Place a lump of Vaseline 15 cm from one end of the rod and position a drawing pin on the Vaseline so that it is upright.
- Light the Bunsen burner.
- Heat the near end of the rod (away from Vaseline and drawing pin) with the blue flame of the Bunsen burner.
- Time how long it takes for the drawing pin to fall.
- Repeat the experiment with a glass rod and record your data in a table.

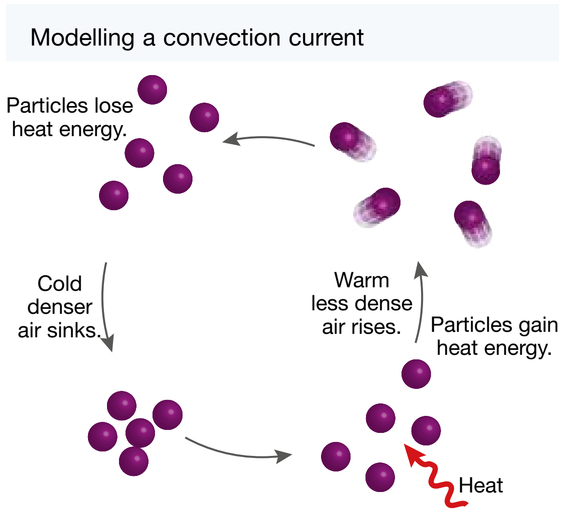


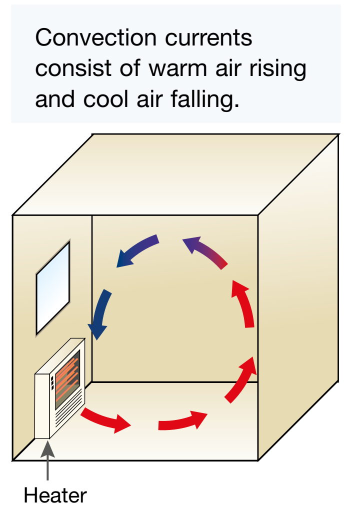
Discussion

1. Through which rod was heat conducted the fastest? Explain why in terms of the particles making up that material.
2. For this investigation identify the:
   (a) independent variable
   (b) dependent variable
   (c) variables that you managed to control.
3. Describe improvements that you would make to the design of the experiment, given a wider choice of equipment and why you would make those changes.

Heat transfer by convection

The transfer of heat by conduction in liquids and gases is not very efficient; instead, heat travels through these substances by **convection**. Convection can be best explained by examining how convection heaters work. These heaters blow out warm air which then rises. This is because the particles of warm air have greater kinetic energy and so the moving particles take up more space, making the warm air less dense than the cooler surrounding air. As the warm air rises, it transfers some of its energy to the surroundings causing the air to cool. As it cools the air loses kinetic energy, bringing the particles closer, resulting in the density of the air increasing and so it begins to fall. This flow of warm air up and cool air down creates a circular current called a convection current. The same pattern can be seen in liquids.





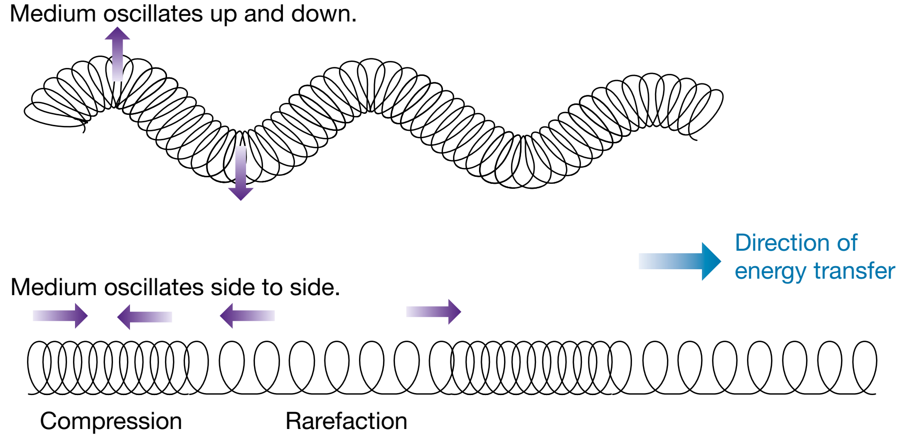
4.2.2 Waves — carriers of energy

Like heat, sound and light energy can be transferred from one place to another. However, sound and light travel as waves and it is these waves which transfer or propagate that energy. The circular ripples created when a stone is dropped in a still pool of water are an example of waves propagating energy. The stone falling through the water causes the water to bob up and down, creating waves. The energy of the oscillating water moves outwards from the centre of the disturbance, creating a circular pattern of waves.

Types of waves

Water waves created on the surface of a lake are examples of **transverse waves**. Transverse waves can be demonstrated in a slinky too. The medium or material carrying the transverse wave oscillates up and down, at right angles to the direction of energy transfer. In fact, the word ‘transverse’ means ‘across’. Transverse waves consist of a series of crests and troughs. In transverse waves, the wavelength is the distance between two adjacent crests, or two troughs, or the distance between any two corresponding points on neighbouring waves. The amplitude of a wave is the maximum distance that each particle moves away from its usual resting, or equilibrium, position.

Two types of energy transfer in a slinky: a transverse wave (top) and a compression wave (bottom)



INVESTIGATION 4.2

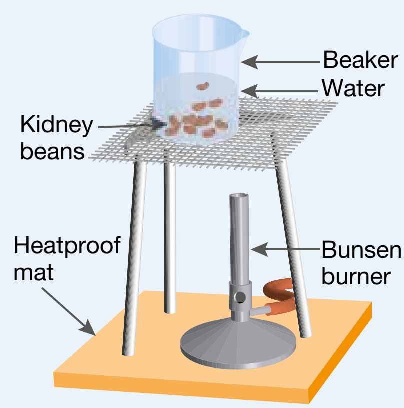
Investigating heat transfer by convection

AIM: To investigate convection currents

You will need:

600-mL beaker
6 red kidney beans
tripod
heatproof mat
gauze mat
Bunsen burner and matches

- Fill a 600-mL beaker with approximately 400 mL of water.
- Add approximately 6 red kidney beans to the water.
- Set up the equipment as illustrated at right.
- Light the Bunsen burner and position it to heat the edge of the beaker with a blue flame.
- Observe the motion of the kidney beans as the water heats and allow it to boil for a minute or two.
- Draw a diagram to illustrate the motion of the kidney beans.



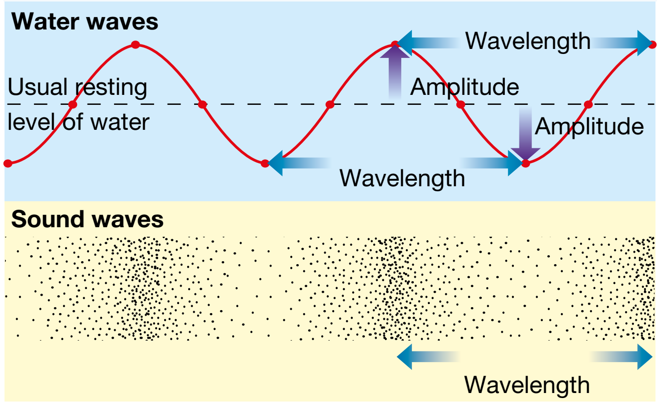
Discussion

1. Describe the pattern in the motion of the kidney beans.
2. Assuming that the kidney beans are carried by the currents of water moving in the beaker, explain why the currents travel in the pattern you observed by referring to the particles (molecules) of water.

4.2.3 Sound

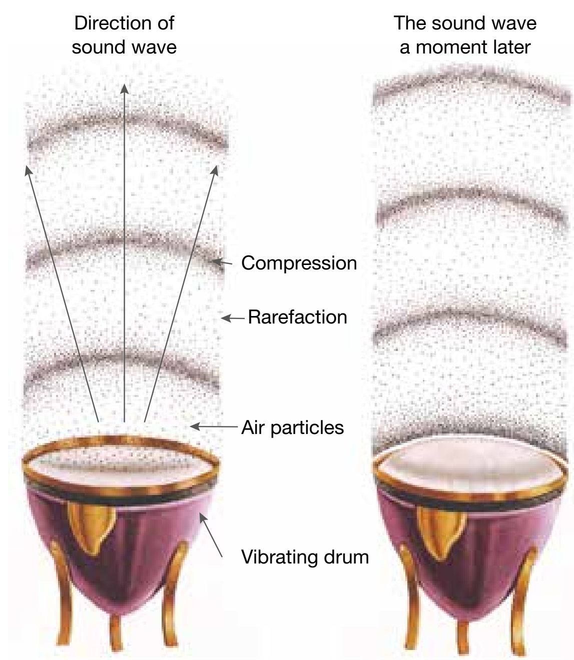
Sound energy is not carried as transverse waves but rather in the form of compression waves. Sound is created by fast back and forth movements called vibrations. When you create sound by striking a drum, the drum skin causes air particles around the drum to be pushed together, then a moment later spread apart. The energy of the vibrating drum skin is transferred to the nearby air particles, making them vibrate as quickly as the drum skin. The vibrating air particles bump into nearby air particles, making them vibrate as well. This creates a series of **compressions** (a region of air particles that are close together) and **rarefactions** (a region of air particles that are spread apart) that we call **sound waves**.

Wavelength and amplitude are useful in describing waves.



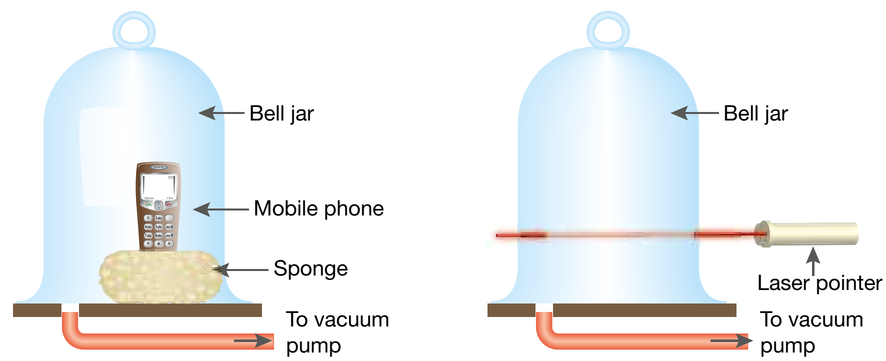
In compression waves, the medium oscillates backwards and forwards parallel to the direction in which the energy is transferred. Compression waves are also known as **longitudinal waves**. The wavelength of a compression wave is the distance between the centre of two adjacent compressions or two adjacent rarefactions.

Sound waves consist of a series of compressions and rarefactions.



When a mobile phone rings in a bell jar, the sound can be heard clearly. When the air in the bell jar is sucked out by a vacuum pump, the sound fades. If all of the air is removed, no sound can be heard at all. This is because sound cannot travel through empty space. Sound energy can only be transferred through a medium in which vibrating particles carry that energy. In empty space, there are no particles to vibrate. Light on the other hand does not require a medium to travel through. It can travel through a vacuum. So you can still see the mobile phone, even if you can't hear it.

Sound waves require a medium to travel through; light does not.



The frequency of a vibration or wave is the number of complete waves generated per second. Frequency is measured in hertz (Hz), a unit named after Heinrich Hertz, the German physicist who, in 1887, was the first to detect radio waves. One hertz is equal to one oscillation or wave per second, so a middle C note produced by a musical instrument creates sound waves corresponding to 256 vibrations per second or a frequency of 256 hertz. The frequency of a sound determines its pitch. High-frequency vibrations produce high pitch, and low-frequency vibrations produce low pitch.

As the frequency of a sound gets higher, that is, as more compressions are produced per second, the compressions become closer together. Thus, low-frequency sounds have long wavelengths and high-frequency sounds have short wavelengths.

While the frequency of a sound wave determines its pitch, the amplitude determines its loudness; higher amplitudes correspond with louder sounds.

INVESTIGATION 4.3

Frequency and wavelength

AIM: To investigate how frequency relates to wavelength

You will need:

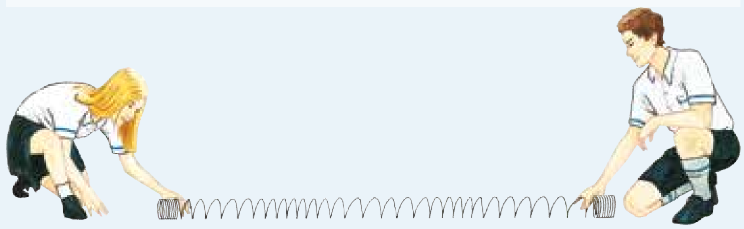
slinky
water soluble marker
stopwatch

- Work in groups of four and allocate roles based on the skills and interest of each student.
- Two members of the group hold the ends of a stretched slinky.

Part A: Compression waves

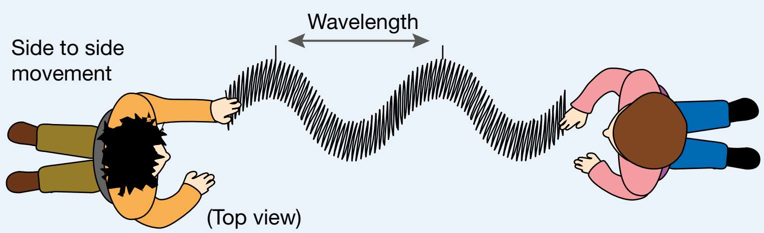
- Create pulses of compression waves by flicking an end of the slinky in and out.
- Observe the compressions and rarefactions as they move through the stretched slinky.

Modelling compression waves using a slinky spring



Part B: Transverse waves

- Create a transverse wave pulse by flicking an end of the slinky side to side once or twice along the ground.
- Observe the transverse pulse as it moves through the stretched slinky.
- Now create continuous transverse waves by flicking the slinky side to side along the ground at a constant rate.
- While the transverse waves are in motion:
  – another student records the time taken for five to-and-fro movements by the group member creating the waves
  – a fourth group member marks the position on the floor of two adjacent crests of the transverse wave.
- Repeat this experiment, but this time create transverse waves with a smaller wavelength by flicking the slinky side to side at a faster rate.



- Copy and complete the table below. The frequency for each experiment is calculated as follows:

$$\text{Frequancy (Hz)} = \frac{\text{5 waves}}{\text{time taken for 5 waves}}$$

Transverse wave motion	Wavelength(m)	Time taken for 5 waves (s)	Frequency (Hz)
Slow rate			
Fast rate			

Discussion

1. Copy and complete the table below to compare the compression and transverse waves in terms of the direction in which the medium (slinky coils) moves and the direction of the wave as pulses are created.

Type of wave	Direction of movement of medium	Direction of wave movement
Compression		
Transverse		

2. Identify which of the two transverse waves had the greatest frequency and outline how an increased frequency can be created.
3. The velocity of a wave can be calculated using the wave equation that follows:

$$\text{Velocity (m/s)} = \text{frequency (Hz)} \times \text{wavelength (m)}$$

   (a) Calculate the velocity of the two transverse waves.
   (b) Analyse whether there was a significant change to the velocity of the transverse waves in the slinky in each experiment. Suggest a reason for this.

INVESTIGATION 4.4

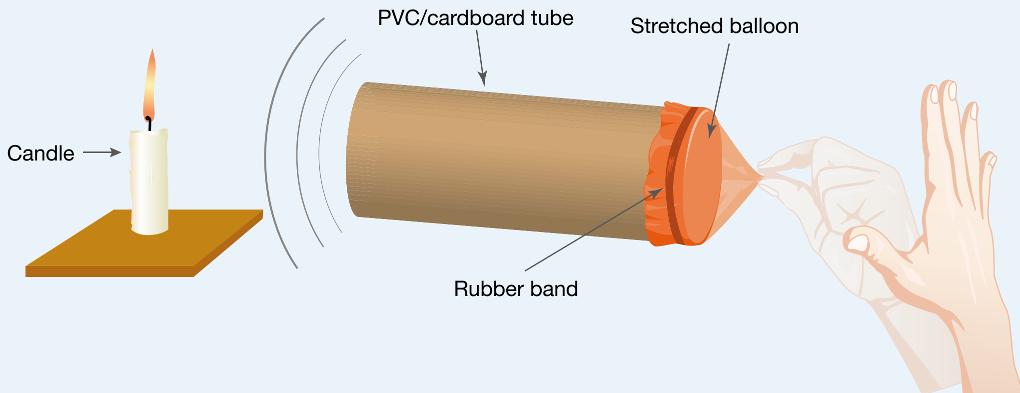
Target practice

AIM: To investigate the most effective design for an air cannon

You will need:

PVC or cardboard tubes of various lengths and diameters
balloon
scissors
rubber band
ruler
candle and holder
matches
metre ruler

- Select a tube. Measure and record its length and diameter.
- Build an air cannon by cutting the neck from the balloon. Open the balloon and stretch it over the end of the tube and secure it firmly to the tube using the rubber band.
- Light the candle and place it on a bench.
- Starting just in front of the candle, try to blow out the candle by pinching and then pulling and releasing the stretched rubber sheet at the end of the balloon. If you were successful move back away from the candle and try again. Record the maximum distance from which you can blow out the candle.
- Collate the class's results, including the lengths and diameters of the tubes.
- You could design a separate experiment to determine the tube diameter and length that are most effective at blowing out the candle.



Discussion

1. Explain why you were able to blow out the candle.
2. Identify an independent variable in this experiment.
3. Identify the dependent variable in this experiment.
4. Analyse the class's results to determine the most effective dimensions for your air cannon.

The speed of sound

Sound energy is carried by compression waves and so relies on the collision of neighbouring particles in a medium. In a medium in which the particles are more tightly packed and have less distance to travel to collide, such as in a liquid or a solid, sound waves travel faster. In air, sound travels at a speed of approximately 340 m/s, while in sea water sound waves travel at 1533 m/s — well over 4 times faster than in air. Several ocean-dwelling animals rely upon sound waves to communicate with other animals and to locate food. These animals make use of this method of communication effectively over long distances because sound travels so much faster in water. Dolphins for example use **echolocation** (reflected sound) to locate food and to communicate with each other while travelling in groups. They send out high frequency sound pulses, or ultrasound, that are reflected back when they strike a target. This echo helps the dolphin to identify the size, shape and direction that an object is moving.

The speed of sound in gases depends on temperature. Sound travels faster in warm air as the particles of mainly nitrogen and oxygen have more kinetic energy and so move more quickly.

The speed of sound through various materials is shown in the table at right.

A jet plane travelling faster than the speed of sound in air is said to be travelling at supersonic speeds. The speeds of supersonic objects are often expressed in terms of a Mach number — the ratio of the object's speed to the speed of sound in the surrounding air. Thus an object travelling at Mach 2 is travelling at twice the speed of sound. Supersonic aircraft produce a sonic boom as pressure waves produced at the nose and tail of the plane are forced together at these high speeds.

Dolphins travel in large groups, therefore sound is important for communication to maintain group structure.

	Material	Speed of sound (m/s)
Gases	Carbon dioxide (0 °C)	259
	Air (0 °C)	331
	Air (20 °C)	343
	Hydrogen (0 °C)	1 286
Liquids	Mercury	1 450
	Water	1 493
	Sea water	1 533
Solids	Rubber	1 600
	Copper	3 560
	Iron	5 130
	Pyrex glass	5 640
	Diamond	12 000

A Super Hornet jet travelling beyond the speed of sound generates a sonic boom. The pressure waves over the plane are visible as a cone-shaped cloud behind the plane. The origin of this cloud is still debated. It may be that a drop in air pressure around the plane occurs so moist air condenses there to form water droplets.

4.2.4 Ultrasound

While the human ear can detect sound frequencies between 20 and 20 000 Hz, frequencies well beyond the range of human hearing are used in a variety of useful technologies.

Sound with frequencies higher than those that humans can hear is called ultrasound. This image of an unborn baby is produced with ultrasound. To produce images like the one at right, ultrasound is sent through the mother's body.

Some of it is reflected from the surface of the baby. A computer is used to change the reflected ultrasound into an image. The images are used to check for problems during pregnancy.

Ultrasound is also used in industry to check for cracks in metal, drill holes in glass and steel.

Sonar

Ultrasound is used in *sonar* to produce images of underwater objects or the ocean floor.

1. Ultrasound is sent down into the water.
2. Objects under the water (and the ocean floor) reflect some of the ultrasound.
3. A receiver detects the reflected ultrasound.

Measuring sound

While we can hear sound waves, they are invisible. However, they can be studied by converting the sound energy into electrical energy using a device called a **cathode ray oscilloscope** (CRO). A microphone connected to the CRO measures the **air pressure** changes associated with the compressions and rarefactions of a sound wave and produces a graph on the CRO screen called a **waveform**. This allows us to record how quickly the sound wave makes the air vibrate and compare the energy levels of sound waves.

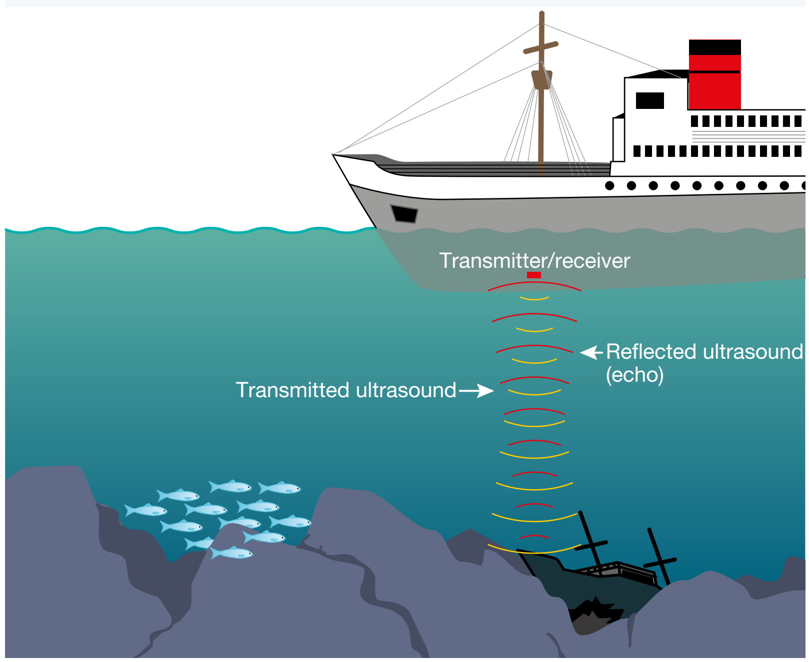
The **pitch** of a sound depends on how quickly it makes the air vibrate. High-pitched sounds have a high frequency and make the air vibrate quickly. As a result, they produce 'bunched-up' waveforms. Low-pitched sounds have a low frequency and make the air vibrate less quickly, so the waveforms are more spread out.

As in all waves, frequency is measured in Hz. High-frequency sounds are more high pitched than low-frequency sounds.

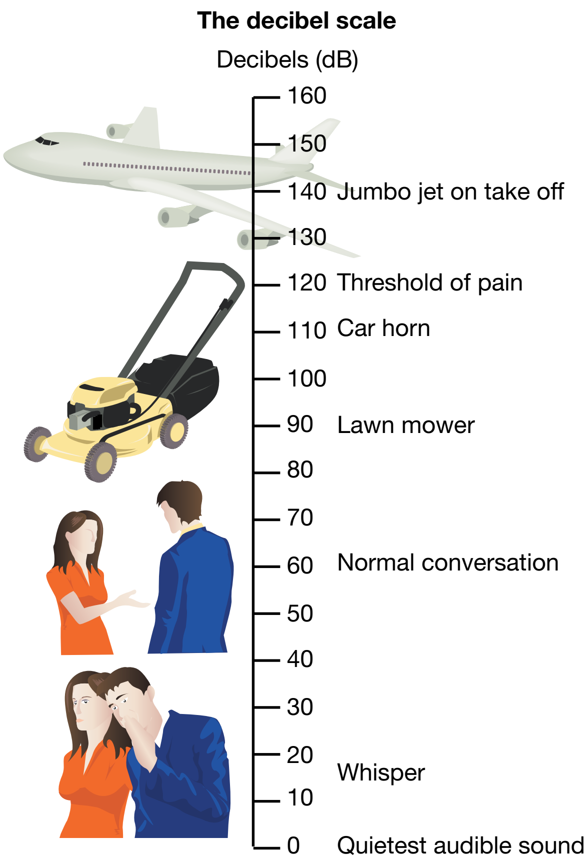
Loud sounds produce a tall waveform on a CRO display. This is because more sound energy produces a larger electrical signal. Soft sounds, on the other hand, produce a shorter waveform.

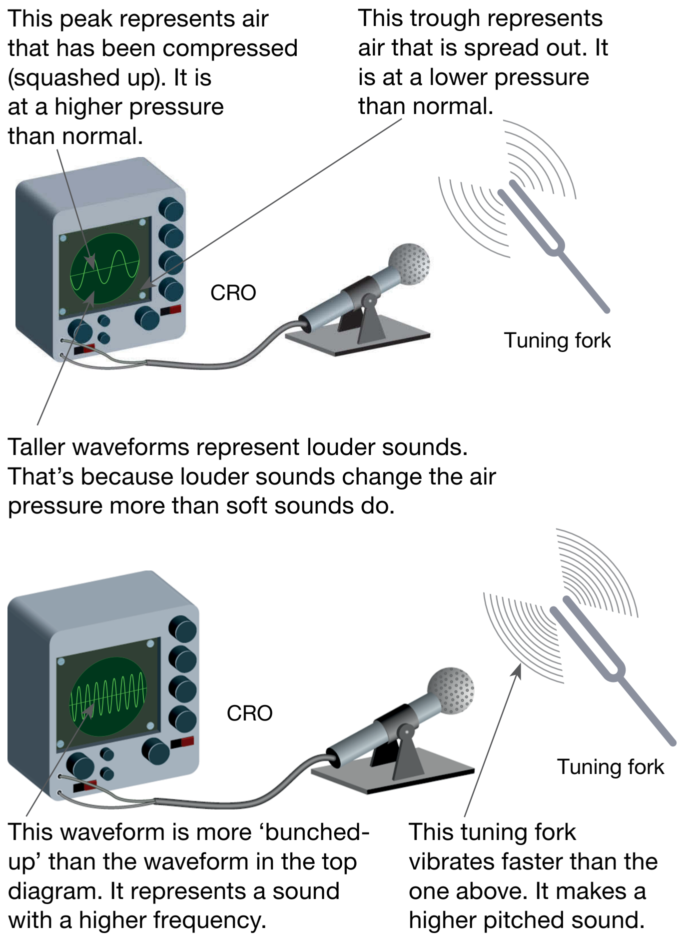
The decibel (dB) scale is commonly used to measure the sound level or loudness of sound. On the **decibel scale**, the quietest audible sound is 0 dB. Each tenfold increase in sound level is an extra 10 dB higher. So a sound 1000 times more powerful than the quietest audible sound is 30 dB. Some common sounds and their decibel ratings are shown on the following page.

A computer uses the time taken for the reflected ultrasound to return to the ship to calculate the depth of objects in the water. It can also map the ocean floor.



Any sound above 85 dB can cause **hearing loss**, and the loss is related both to the loudness of the sound as well as to the length of exposure. You know that a sound exceeds 85 dB if you have to raise your voice to be heard by somebody else.





HOW ABOUT THAT!

The calls of the blue whale, with sound levels of more than 180 dB, can be even louder than the launch of a rocket. Scientists working in the Southern Ocean recorded blue whale calls at this sound level and could, therefore, locate blue whales up to 200 km away.

INVESTIGATION 4.5

Sound proofing

AIM: To investigate the most effective material to insulate against noise

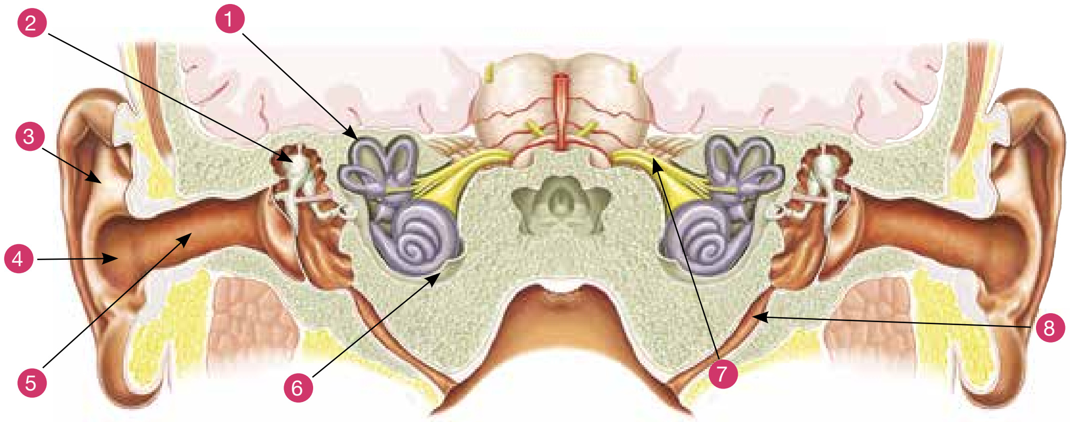
You will need:

variety of materials to test (such as wood, fabric, glass and cardboard)
source of sound (such as an MP3 player)
sound level meter or data logger and sound probe

- Design an experiment to investigate the most effective material to insulate against noise.
- Record your results in a suitable table and graph.
- Analyse your results to draw an appropriate conclusion.

4.2.5 The ear and hearing

The main function of the ear is to detect sound. It collects the energy of vibrating air and changes it into electrical signals, which are sent to the brain. Each ear has three main parts — the outer ear, the middle ear and the inner ear.



1 Semicircular canals

These three tubes have nothing to do with hearing. They control your sense of balance. When you move, fluid in the tubes flows past cells that sense the movement. These cells send signals to the brain. The signals tell you when you are moving and whether you are up, down or on your side. When you move around in circles quickly, the fluid moves quickly — even for a while after you stop. The messages from the cells in the **semicircular canals** tell your brain that you are still moving. However, the messages from your eyes tell the brain that you are not moving. These mixed messages to the brain make you feel dizzy.

2 Middle ear

The middle ear contains the three smallest bones in the body. Together, they are known as the ossicles. These tiny bones send vibrations from the **eardrum** to the inner ear. They also make the vibrations larger. One of the ossicles (the stirrup) presses against a thin layer of skin called the oval window at the entrance to the inner ear.

3 Auricle

The outside part of the ear contains a spongy type of tissue called cartilage.

4 Outer ear

The outer ear collects the energy of the vibrating air and funnels it along the **ear canal**. The air along the ear canal vibrates. That makes the eardrum vibrate. High-pitched sounds make the eardrum vibrate quickly. Low-pitched sounds make the eardrum vibrate slowly.

5 Ear canal

The ear canal contains wax and tiny hairs to trap dust so that it doesn't get to the eardrum. If the wax builds up enough to block your ear canal, a doctor can remove it.

6 Inner ear

The inner ear is filled with fluid. The vibrations are passed along the fluid into a snail-shaped tube called the cochlea. The inside of the cochlea is lined with millions of tiny hairs. Each hair is attached to a nerve receptor. When the fluid vibrates, the hairs move. The receptors change the energy of the moving hairs into electrical energy and send signals through the **auditory nerve** to the brain. You interpret those signals as sound.

7 Auditory nerve

Nerves from the receptors in the **cochlea** merge to form this large nerve that sends signals to the brain.

8 Eustachian tube

This tube joins the middle ear to the nose and throat. It is usually closed. When the air pressure on the eardrum is not the same on both sides, the tube opens. Air then moves either into or out of the middle ear until the pressure is balanced again.

When the air pressure on one side of the eardrum changes quickly, you can feel a 'pop' as the **Eustachian tube** opens and air rushes through it. This happens when you are in a plane that is climbing steeply. The air pressure in the plane becomes less than the air pressure in your middle ear. The Eustachian tube then opens and some air moves from the middle ear to the nose and throat so that the air pressure on your eardrum is balanced.

HOW ABOUT THAT!

The aye-aye is a rare animal that lives on the island of Madagascar. It feeds at night and has goggle eyes and huge ears. The aye-aye searches for food by tapping one of its stick-like fingers on tree trunks. It listens to the sound as vibrations go through the wood. The sound tells it where gaps, cracks and hollows are under the bark and where tasty grubs are hiding. Then it chews through the wood and hooks out the grub with its long middle finger.

4.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note*: Question numbers may vary slightly.

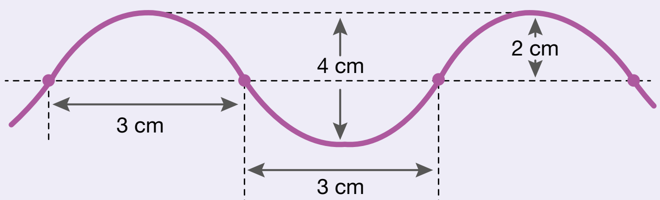
Remember

1. **Outline** how sound waves are created.
2. Draw and label a sound wave to demonstrate rarefactions and compressions.
3. Explain the difference between a compression and a rarefaction.
4. **Explain** why sound cannot travel through empty space.
5. **Describe** how the ear enables us to hear sounds.
6. **Define** the term ‘frequency’ and identify its unit of measurement.
7. **Identify** the feature of sound that frequency determines.

Think

8. **Explain** whether a Mexican wave, as seen among the crowds at some sporting events, is a transverse wave or a compression wave.
9. **Explain** why there are three semicircular canals in the ear rather than just one.
10. The speed of sound through various materials is listed at right.
    (a) **Identify** the trend in the data.
    (b) **Explain** why there is such a trend.
11. **Identify** the wavelength and amplitude of the transverse wave shown in the diagram at right.

Material	Speed of sound (m/s)
Brick	3650
Sea water	1531
Iron	5950
Air (at room temperature)	343
Glass	5100
Distilled water	1497



Investigate

12. You can feel your vocal cords vibrate if you place your hand gently over your throat while you talk. Say a long ‘hummmm’ in a deep voice and feel the vibrations. **Describe** how the vibrations change when you say ‘hummmm’ in:
    (a) a louder voice
    (b) a higher voice.
13. Is it true that older people find it more difficult to hear high-pitched sounds? Using secondary sources, **investigate** the normal frequency range of human hearing and whether that range depends on age.
14. The speed of sound through hydrogen gas is almost 1300 m/s, much greater than the speed through air and similar to the speed of sound through liquids. Use appropriate secondary sources to **explain** why.
15. Use the **Virtual oscilloscope** weblink in the Resources tab to simulate measuring sound energy.
16. Use the **My ear** weblink in the Resources tab to watch an animation of the effect of sound waves on cochlear structures.

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Explore more with this weblink: Virtual oscilloscope

Explore more with this weblink: My ear

4.3 Light

4.3.1 Light

The transverse waves created in a slinky or in water are easily seen because the medium through which the wave travels is visible. Light is an example of an **electromagnetic wave**. Like water waves, electromagnetic waves are also transverse but they are not quite so easily seen.

Like all waves, electromagnetic waves transfer energy from one place to another. All electromagnetic waves travel through air at 300 000 kilometres per second. Unlike sound waves and water waves, electromagnetic waves can travel through a vacuum.

What's the difference?

Some of the differences between sound waves and electromagnetic waves are summarised in the following table.

Sound and electromagnetic waves: some differences

Sound waves	Electromagnetic waves
Compression (longitudinal) waves	Transverse waves
Travel through all solids, liquids and gases, but are unable to travel through a vacuum	Able to travel through most substances including through a vacuum
Speed in air between about 330 m/s and 350 m/s, depending on temperature	Speed in air about 300 000 km/s

The reflection of light

Light travels in straight lines. In diagrams, the lines used to show the path that light takes are called **rays**. Our eyes receive countless light rays reflected from objects that we view and the brain constructs an image of these objects using impulses from the eyes.

Individual rays of light are not visible but streams of light rays or beams of light may be seen when the light is **scattered**, or reflected from particles through which it travels and then redirected to the eye. For instance, beams of light can often be seen from car headlights on a foggy night as light is scattered from water vapour in the air.

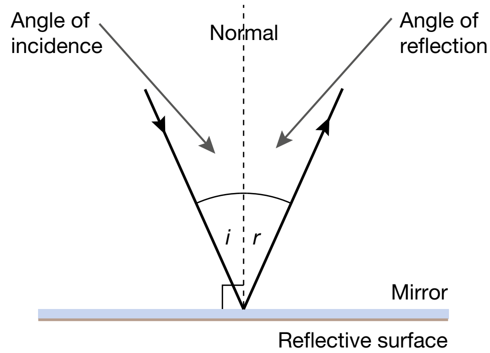
When light strikes a shiny surface like a mirror, light is reflected from that surface. Light reflected from a mirror follows the **law of reflection** which states:

The angle of incidence (i) = the angle of reflection (r)

These angles are measured from the **normal** (perpendicular) to the mirror surface.

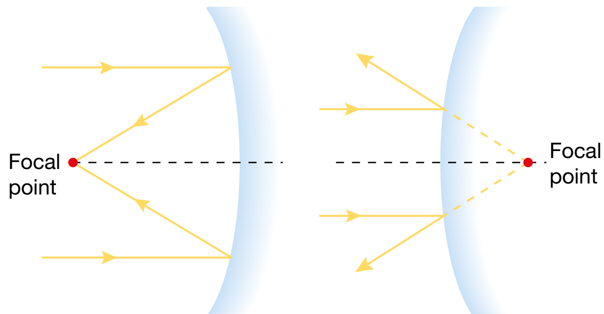
A beam of light may be visible if light is scattered by particles in the air, such as on a foggy night.

The reflective coating is commonly placed on the back surface of a flat or plane glass mirror to protect the coating from damage.



Reflection from curved mirrors

Flat mirrors, also called plane mirrors, are commonly found in the home. Curved mirrors have many applications too, including make-up mirrors, security mirrors in shops and safety mirrors at dangerous street intersections. Curved mirrors may be **concave** (curved inwards) or **convex** (curved outwards). Light reflecting from concave and convex mirrors also follows the law of reflection, such that the parallel rays of light are reflected to a **focal point** as shown at right.



Reflected light rays converge from a concave mirror.

Reflected light rays diverge from a convex mirror.

The reflected image of an object close to a concave mirror is enlarged, making concave mirrors useful for make-up mirrors.

Convex mirrors reflect light from a wide angle, creating an image reduced in size that captures much of the surrounds. These mirrors may serve as security mirrors in shops or to improve visibility at dangerous intersections.

INVESTIGATION 4.6

Reflection from plane and curved mirrors

AIM: To compare the light rays reflected from plane and curved mirrors

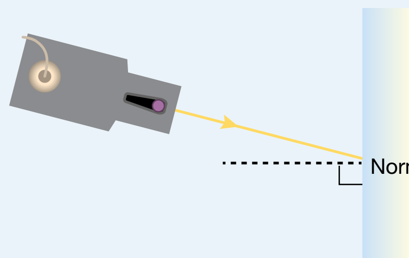
You will need:

ray box kit
DC power supply
protractor
ruler

The 'ray' box. It provides a way of tracing the path of light.

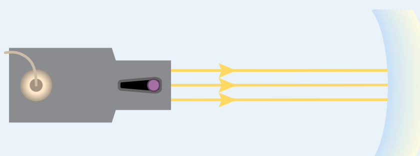
- A ray box contains a light source and a lens that can be moved to create rays of light that converge, travel straight or diverge. The light box can be placed on a sheet of paper making light rays reflected from the paper visible to the eye. Black plastic sliders can be placed in front of the light source to create a single ray of light or multiple parallel rays. The path of the rays can be traced on the paper by marking several small crosses along the path then drawing a line to represent the rays using a ruler.

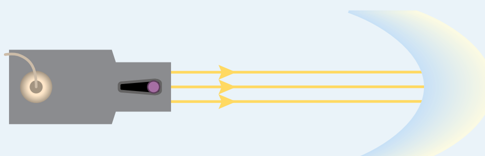
Part A: The plane mirror

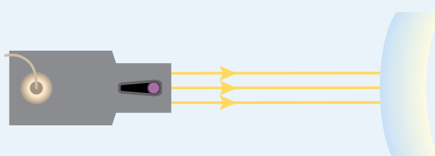


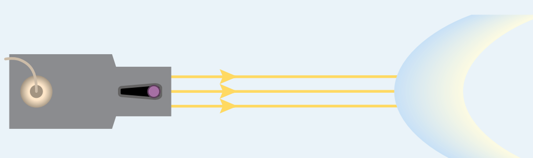
- Create a single narrow ray of light from the ray box by selecting the appropriate black plastic slide.
- Shine the ray onto a plane mirror tilted at an angle as shown at right.
- Draw a line along the plane mirror to mark its position then draw a series of small crosses to mark the position of the incident and reflected rays.
- Remove the mirror and draw lines to represent the incident and reflected rays. Use arrows to illustrate the direction of the light rays before and after striking the mirror.
- Using a protractor draw a dotted line 90° to the mirror to represent the normal as shown above right.
- Measure the incident angle and the reflected angle.

Part B: Curved mirrors









- Create multiple parallel rays of light from the ray box by selecting the appropriate black plastic slide.
- Shine the light rays onto spherical concave and parabolic concave mirrors as shown at right.
- Draw a line along the inner surface of each of the curved mirrors to mark their position then draw a series of small crosses to mark the position of the incident and reflected rays.
- Remove the mirror and draw lines to represent the incident and reflected rays. Use arrows to illustrate the direction of the light rays.
- Repeat this process for spherical and parabolic convex mirrors as shown at right.
- Create parallel rays of light from the ray box by selecting the appropriate black plastic slide.

Discussion

1. Compare the incident and reflected angles. Discuss whether your data follows the law of reflection.
2. Describe what happens to parallel rays of light striking concave mirrors.
3. Compare the reflected rays of light from the two concave mirrors.
4. Explain why parabolic reflectors serve as more efficient receivers for communication dishes.
5. Describe what happens to light striking convex mirrors.

Just passing through

Shiny surfaces reflect light but if a surface absorbs light it is said to be **opaque**. If most of the light travels through a material, the surface is called **transparent** because enough light passes through to enable objects on the other side to be clearly seen.

Some surfaces allow just enough light to travel through to allow objects to be detected on the other side, but they scatter so much light that the objects are not clearly visible. Frosted glass used in bathroom windows is an example of this. Such materials are said to be **translucent**.

Transparent

Translucent

Opaque materials

4.3.2 Refraction — bending light

Although it doesn't look like it, the stem of the flower at right is close to straight. Light from the part of the stem above the water travels in a straight line through the air to your eyes. Light reflected from the lower part of the stem travels firstly through water and then through the air. It bends when it emerges into the air.

Light normally travels in straight lines. However, under certain conditions, it is possible to change the direction of light. In the example on the next page, the light has been bent. Light can be made to bend by passing it through different transparent media. This bending of light through different media is called **refraction**.

As light travels from water to air, it changes direction.

Changing the speed of light

When light travels from one transparent medium to another, it speeds up or slows down. For example, when light travels from air to water it slows down. When it travels from water to air, it speeds up.

The bending of a light ray as it passes from one medium to another is caused by the light's change in speed. The speed of light through different media is given in the table below.

Medium	Speed of light (10^8 m/s)
Vacuum	3.00
Air	2.997
Water	2.25
Crown glass (used in lenses)	1.97
Perspex	2.05
Diamond	1.24

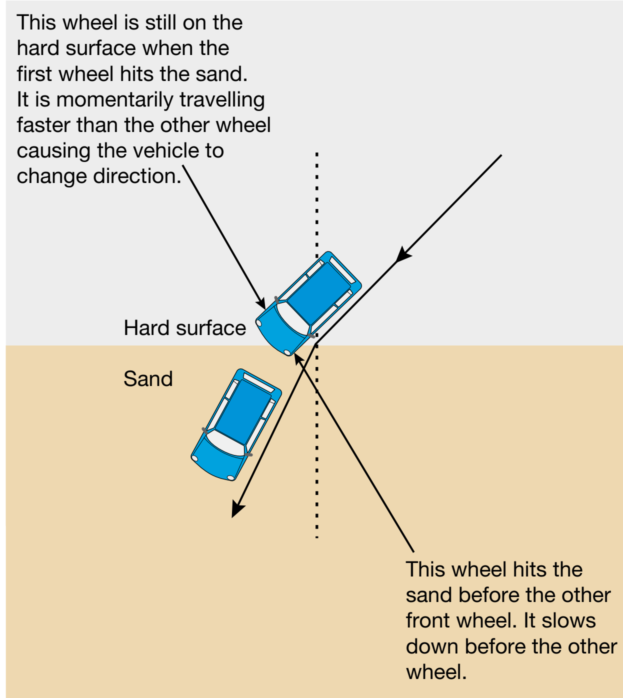
Imagine driving a vehicle from a hard surface onto soft sand. If both wheels strike the sand at the same time, they will slow down at the same time and the vehicle will remain straight. However, if one wheel hits the sand before the other, the wheels will momentarily be travelling at different speeds. The vehicle will change direction.

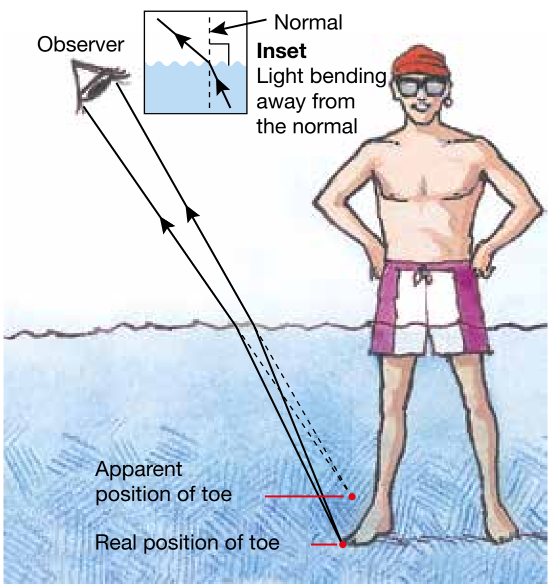
Likewise, when the vehicle drives off the sand onto a hard surface, it changes direction again.

Refraction diagrams

The best way to describe which way the light bends is to draw a line at right angles to the boundary. This line is called the normal. When light speeds up, as it does when it passes from water into air, it bends *away* from the normal. When light slows down, as it does when it passes from air into water, it bends *towards* the normal.

The light coming from the swimmer's legs in the photograph below bends away from the normal as it emerges from the water into the air. The light arrives at the eyes of an observer as if it were coming from a different direction. The diagram below shows what happens to two rays of light coming from one of the swimmer's toes. To the observer, the rays appear to be coming from a point higher than the real position of the toe. The amount of bending depends on the angle at which the light crosses the boundary.





Short legs? Not really.

HOW ABOUT THAT!

Why diamonds sparkle

A diamond can sparkle with coloured light, each of its surfaces producing a dazzling display. Diamond is the most optically dense, naturally occurring material on Earth. This means that light entering a diamond through each of its facets (or geometrically cut sides) is refracted by a huge angle, causing light inside the gemstone to bounce back and forth several times before it strikes a facet with an angle straight enough to escape. Because the light has travelled so far, the spectrum of colours that make up light have dispersed (or separated) so significantly that a stunning display of colours is produced.

INVESTIGATION 4.7

Floating coins

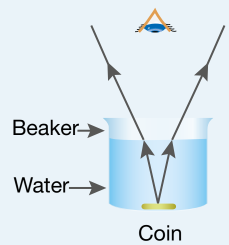
AIM: To investigate the effect of refraction on the image of a submerged object

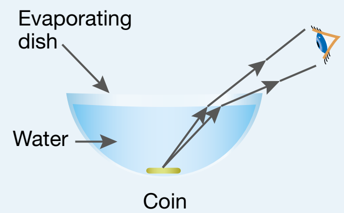
You will need:

2 beakers
evaporating dish
coin

- Place a coin at the bottom of an empty beaker and look at it from above while your partner slowly adds water from another beaker.
- Place the coin in the centre of an evaporating dish and move back just far enough so you can no longer see the coin. Remain in this position while your partner slowly adds water to the dish.
- Make a copy of the diagrams at right. Use dotted lines to extend back the rays shown entering the observer's eye to see where they seem to be coming from. This enables you to locate the centre of the image of the coin.

The image of the coin is not in the same place as the actual coin.





Discussion

1. How does the position of the coin appear to change while the water is being added?
2. Which other feature of the coin appears to change?
3. What appears to happen to the coin as water is added to the evaporating dish?
4. Is the image of the coin above or below the actual coin?

INVESTIGATION 4.8

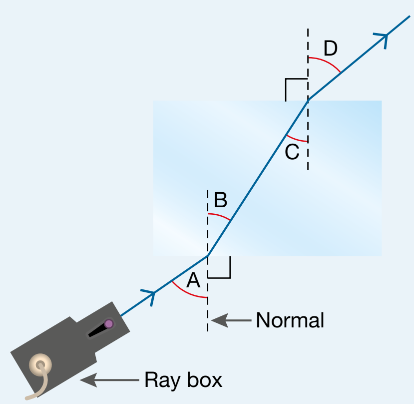
Predicting the way light bends

AIM: To investigate how light is refracted when it enters and leaves a material

You will need:

transparent rectangular prism
pencil
ray box
ruler
12 V DC power supply
protractor

- Place the ray box on the edge of your notebook page and connect it to the power supply.
- Position the ray box so that a single light ray strikes the edge of the rectangular prism as shown.
- Trace around the prism. Use arrows to mark the points where the ray enters and exits the block.
- Remove the prism and turn off the ray box.
- Use a ruler to draw the normal line as shown in the diagram.
- Using the ruler again, draw the ray as it enters the prism, passes through it and exits the other side.
- Measure angles A, B, C and D. Record the measurements in a table.
- Repeat the experiment three more times. Change angle A each time by positioning the ray box at a slightly different angle and record angles A–D.



Discussion

1. Two of the angles can be labelled 'angle of incidence' and two can be labelled 'angle of refraction'. Which of A, B, C and D are angles of refraction and which are angles of incidence?

2. Compare angle A with angle B. What do you notice about the size of A compared with B?
3. Compare angle C with angle D. What do you notice about the size of C compared with D?
   Light travels more slowly in the rectangular block than in air. In general, the more dense the transparent material, the slower light will travel through it.
4. Complete the following conclusion:
   (a) When light travels from one medium to another and slows down, the refracted angle is ____________________ than the incident angle.
   (b) When light travels from one medium to another and speeds up, the refracted angle is ____________________ than the incident angle.

INVESTIGATION 4.9

Focusing on light

AIM: To investigate how biconvex lenses refract rays of light

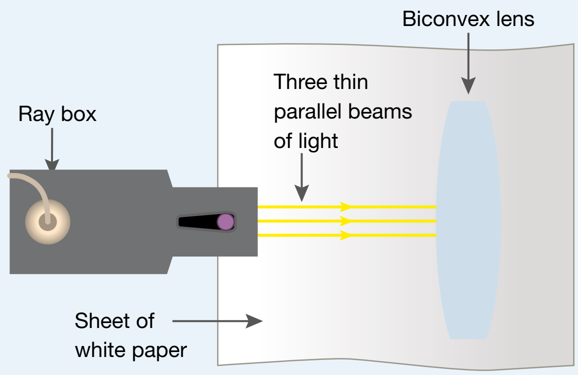
You will need:

ray box kit
12 V DC power supply
sheet of white paper
ruler and fine pencil

- Connect the ray box to the power supply and place it on a page of your notebook.

Part A: Biconvex lenses

- Place the thinner of the two biconvex lenses in the kit on the page and trace out its shape. Project three thin parallel beams of white light towards the lens.
- Trace the paths of the light rays as they enter and emerge from the lens. Remove the lens from the page so that you can draw the paths of the light rays through the lens.
- Replace the thin biconvex lens with a thicker one and repeat the previous steps.



Part B: Biconcave lenses

- Place the thinner of the two biconcave lenses on your notebook page and trace out its shape.
- Trace the path of each of the three thin light beams as they enter and emerge from the lens. Remove the lens from the page so that you can draw the paths of the light beams through the lens.

Discussion

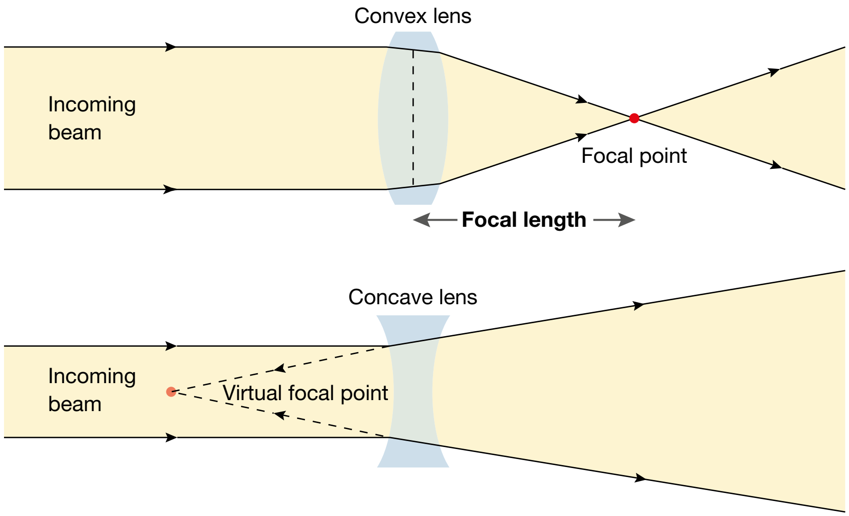
1. Determine the focal length (distance from the focal point to the centre of the lens) for each lens.
2. Identify which lens bends light more, the thin one or the thicker one.
3. Explain why the middle light ray does not bend.
4. Identify how many times each of the other rays bend before arriving at the focal point.
5. Do the diverging rays come to a focus?
6. Do the diverging rays appear to be coming from the same direction? Use dotted lines on your diagram to check.

4.3.3 Lenses at work

The bending of light through transparent materials can be used to produce some interesting and useful effects. Lenses are useful because they bend light in a predictable way and can change the way we see the world. The type of **image** produced by a lens depends on the shape of the lens.

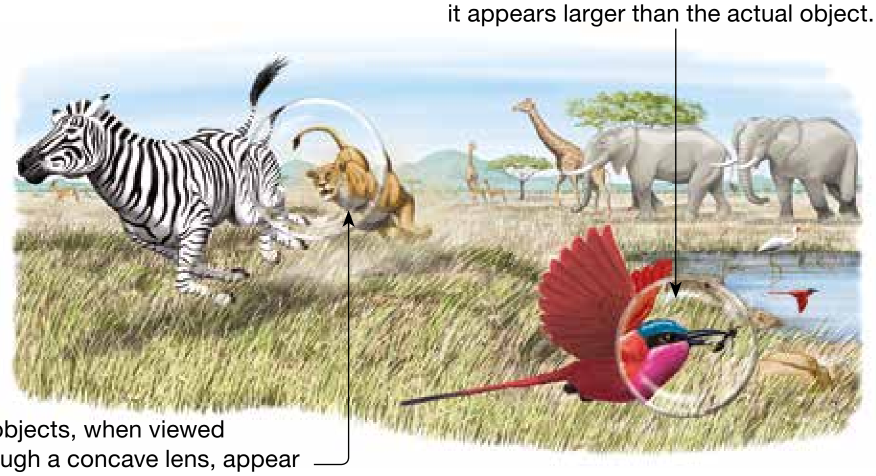
Two basic shapes

Lenses can be shaped in two basic ways; the ones that curve outwards are called convex lenses. Those that curve inwards are called concave lenses.



Convex lenses are sometimes called **converging lenses**. That's because light rays that pass through them are refracted towards each other so that they meet (converge) at a point. The point where the light rays meet is called the focal point of the lens.

Concave lenses are sometimes called **diverging lenses**. When rays of light pass through these lenses, they refract away (diverge) from each other. Concave lenses have no real focal point, because rays of light do not meet after passing through the lens. However, if you trace the rays back to where they appear to have come from, they do meet at a point, called a 'virtual' focal point.



INVESTIGATION 4.10

Searching for an image

AIM: To investigate the image formed by a biconvex lens

You will need:

candle
matches
jar lid to hold candle
biconvex lens
lens holder
A4 sheet of paper folded in half to act as a screen

- Place the biconvex lens in the lens holder, with the candle about one metre in front of it. Light the candle, and move the screen backwards and forwards on the other side of the lens until a clear image of the flame is visible on it.
- Move the candle towards the lens, stopping every 10 cm or so, while you try to locate the image on the screen. Do not move the candle closer than about 10 cm from the lens. Don't be concerned if you cannot get a clear image on the card when the candle is close to the lens.
- Place the candle 5 cm from the lens. Attempt to find an image on the screen. If you cannot, look through the lens towards the candle, observing the image in the lens.

Discussion

1. Is the image on the screen upright or inverted?
2. How does the image change as the candle is moved closer to the screen?
3. When the candle is close to the lens, can an image be found on the screen?
4. When you look through the lens at the candle, you see an image. Is it upright or inverted? Is it larger or smaller than the real candle?

4.3 Exercise: Remember and think

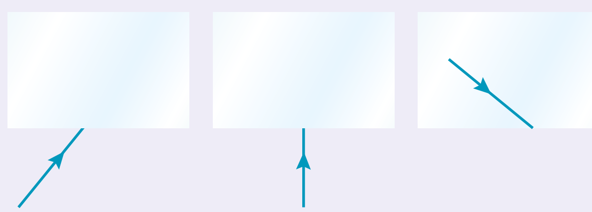
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify**:
   (a) a feature that sound waves and electromagnetic waves have in common.
   (b) a feature that differs between sound waves and electromagnetic waves.
2. **Define** the term 'refraction' and **explain** what causes it.
3. **Identify** the type of lens that causes light rays to:
   (a) diverge
   (b) converge.
4. You cannot usually see light as it travels through air. **Explain** what makes it possible to see beams of light.
5. **Outline** what happens to light when it travels through air and meets:
   (a) a transparent surface
   (b) a translucent surface
   (c) an opaque surface.

Think

6. Copy and complete the light rays in the diagram at right as they move from one medium to another. All the prisms are Perspex and are surrounded by air.



7. Light travels more slowly through diamond than any other transparent material. **Explain** how a jeweller could determine if a piece of diamond is real or fake.
8. **Explain**, with the aid of a diagram, why the image in a convex lens can be upside down.
9. The illustration at right shows a ray of light emerging from still water after it has been reflected from a fish. Should the spear be aimed in front of or behind the image of the fish? Use a diagram to **explain** why.

Calculate

10. The distance between the sun and the Earth is approximately 150 million kilometres. **Calculate** how long sunlight takes to reach Earth.

Investigate

11. Stand a brightly coloured pencil in a glass of water. Make an accurate drawing of how the water distorts the image of the pencil.
12. You can make a microscope by looking through two convex lenses that are placed one behind the other. Experiment with different distances between the two lenses to get the best possible magnification and report on your results.
13. Test your knowledge of the lenses used in common items by completing the **Time out 'Lenses'** interactivity in the Resources tab.
14. Use the **Bend it** interactivity in the Resources tab to test your knowledge of the refraction of light.

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- **Try out these interactivity:** Time out 'Lenses' (int-1017)
- **Try out these interactivity:** Bend it (int-0673)
- **Complete this digital doc:** Worksheet 4.1: Reflection and scattering of light (doc-12753)
- **Complete this digital doc:** Worksheet 4.2: Curved mirrors (doc-12754)
- **Complete this digital doc:** Worksheet 4.3: Refraction (doc-12755)

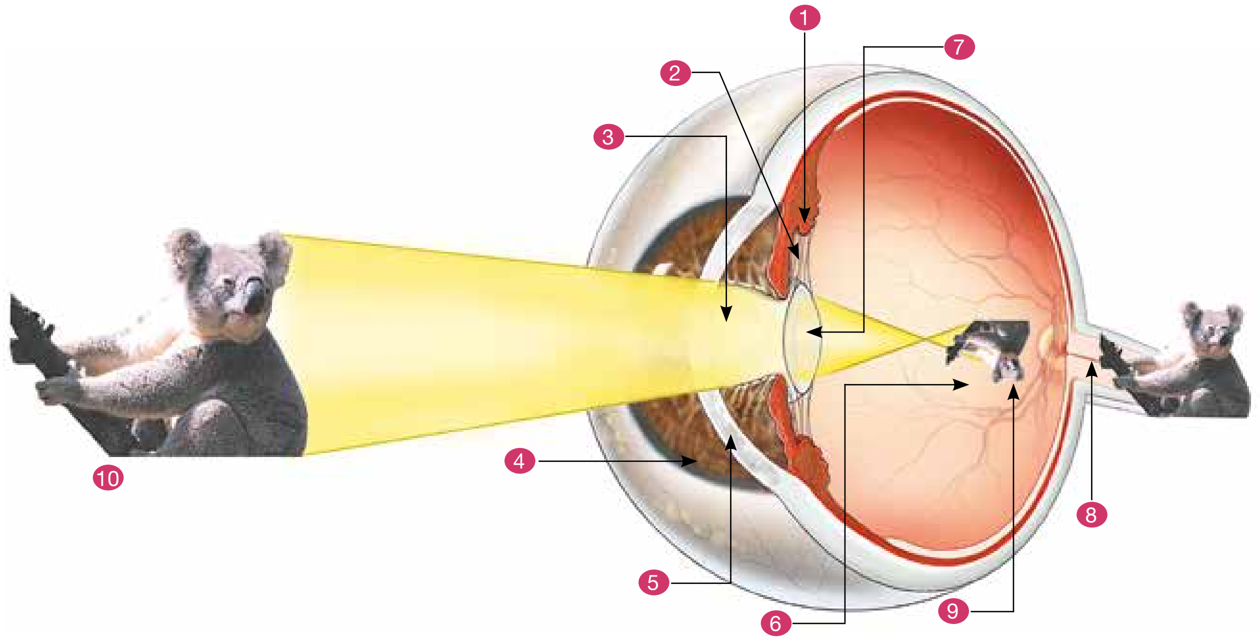
4.4 Colour vision

4.4.1 Vision

Everything that you see is an image! A sharp image of what you are looking at is formed on a 'screen' at the back of your eye. This screen, called the retina, is lined with millions of cells that are sensitive to light. These cells respond to light by sending signals to your brain through the optic nerve.

The light reflected from your surroundings enters your eye and is refracted as it passes through the outer surface of your eye. This transparent outer surface, called the cornea, is curved so that the light converges towards the lens. Much of the bending of light done by the eye occurs at the cornea.

On its way to the lens, the light travels through a hole in the coloured iris called the pupil. The iris is a ring of muscle that controls the amount of light entering the lens. In a dark room the iris contracts to allow as much of the available light as possible through the pupil. In bright sunlight the iris relaxes, making the pupil small to prevent too much light from entering. The clear, jelly-like lens bends the light further, ensuring that the image formed on the retina is sharp. This image is inverted; however, the brain processes the signals coming from the retina so that you see things the right way up.

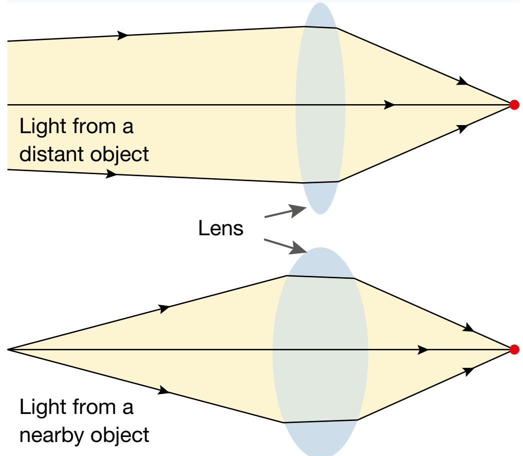


1. **Ciliary muscles**
Contract to thin the lens when viewing distant objects.
2. **Suspensory ligaments**
Attach the ciliary muscle to the lens.
3. **Pupil**
The opening through which light travels towards the lens. The iris opens and closes to control its size.
4. **Iris**
The coloured ring of muscle that opens and closes to control the amount of light entering the pupil.
5. **Cornea**
Refracts the incoming light, so that it passes through the pupil towards the lens.
6. **Retina**
The image forms here. The light-sensitive cells detect the brightness and colour of the different parts of the image. This information is sent to the brain through the optic nerve. The image is upside down on the retina. The brain constructs a final image that is the right way up.
7. **Lens**
Completes the refracting, so that the rays from each point are focused on the retina.
8. **Optic nerve**
Connects the retina to the brain.
9. **Image**
The image is upside down. If the cornea and lens have worked together to refract the incoming light by just the right amount, the image is clear and sharp.
10. **The object**
The object will not be seen unless it is either:
   - luminous: that is, emits light itself
   - illuminated by the sun or another light source. Light from these sources is reflected from the object.

4.4.2 Getting things in focus

Although most of the bending of light by the eye occurs at the cornea, it is the lens that ensures that the image you see is sharp. The shape of the lens is controlled by the **ciliary muscles**. When you look at distant objects, these muscles are relaxed and the lens is thin. When you look at nearby objects, the ciliary muscles contract. The **suspensory ligaments** become slack, causing the lens to bulge. This action of the lens in obtaining a sharp image on the retina is called **accommodation**.

The light coming from a nearby object needs to be bent more than the light coming from a distant object. The lens in your eye becomes thicker when focusing on nearby objects.



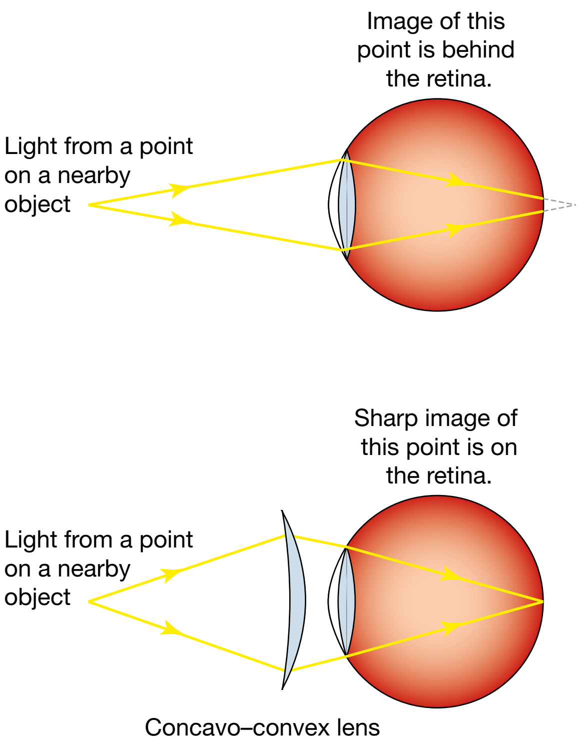
Correcting vision problems

For some people, the cornea and/or the lens of their eye is unable to **focus** a sharp image onto the retina. These people need to wear glasses or contact lenses to correct the problem.

If the cornea and lens bend the light too much, the light rays focus before the retina. People with this condition are short-sighted. They can usually see nearby objects clearly, but cannot focus on distant objects. The problem can be corrected by wearing convexo–concave glasses or contact lenses. The lenses in these glasses **diverge** the light rays a little before entering the eye.

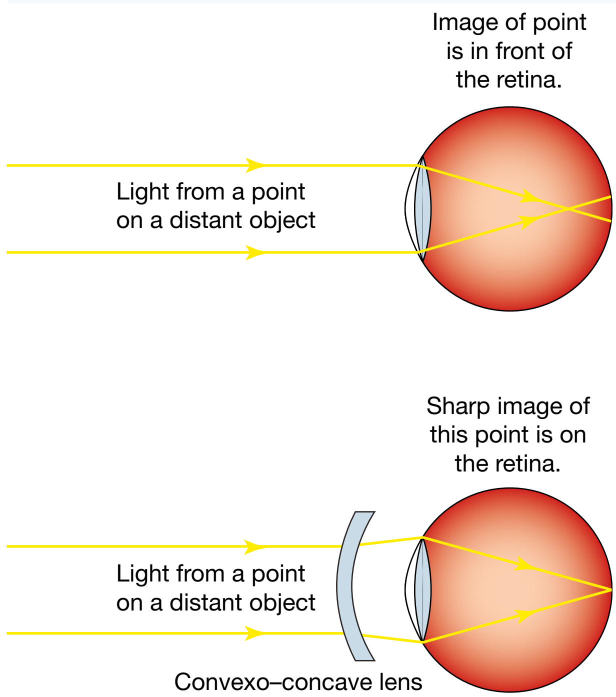
Correcting long-sightedness

A concavo–convex lens has one side slightly concave and the other slightly convex. The convex side is more curved than the concave side, so it acts like a convex (converging) lens.



Correcting short-sightedness

A convexo–concave lens has one side slightly convex and the other slightly concave. The concave side is more curved than the convex side, so it acts like a concave (diverging) lens.



If the cornea and lens do not bend the light enough, the light rays focus at a point past the retina. People with this condition are long-sighted. They can usually see far-away objects clearly, but cannot focus on nearby objects. The problem can be corrected by wearing concavo–convex glasses. The lenses in these glasses converge the light rays a little before entering the eye.

HOW ABOUT THAT!

Insect eyes

Each human eye contains just one biconvex lens. Insects have compound eyes. Each eye contains many lenses. Some types of dragonfly have more than 10 000 lenses in each eye. Each eye can focus light coming from only one direction.

HOW ABOUT THAT!

Cataracts

As the lens becomes less flexible with age, it can become less transparent. Small cloudy spots, called *cataracts*, can develop in parts of the lens. Sometimes, they spread through the whole lens causing blurred vision. In severe cases, cataracts cause blindness as the lens becomes completely opaque.

When cataracts are serious enough to blur vision, the affected lens is surgically removed. It is replaced with a plastic lens. Unlike the original lens, it has a fixed shape and cannot accommodate to focus on both distant and nearby objects. Therefore, people who have had cataracts removed need glasses or contact lenses to compensate for the lack of accommodation.

INVESTIGATION 4.11

Accommodation

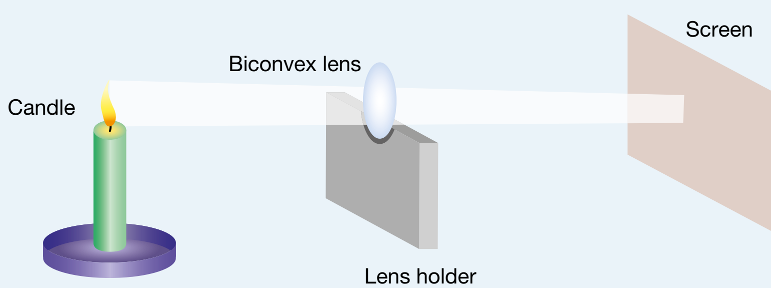
AIM: To model the process of accommodation of the eye

You will need:

candle matches
jar lid to hold candle
ray box kitw
biconvex lens
lens holder
12 V DC power supply
ziplock bag
A4 sheet of paper folded in half to act as a screen

Part A: A rigid lens

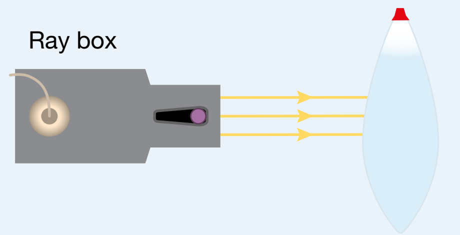
- Dim the room.
- Place the biconvex lens in the lens holder, and position the candle about one metre in front of it. Light the candle, and move the white card backwards and forwards on the other side of the lens until a clear image of the flame is visible on it.
- Move the candle towards the lens, stopping every 10 cm or so, while you try to locate the image on the screen. Do not move the candle closer than about 10 cm from the lens.
- How does the image change as the candle is moved closer to the screen?



Part B: Accommodating

- Fill the ziplock bag with water so that it is almost full and seal firmly.
- Set up a ray box to produce parallel rays of light.

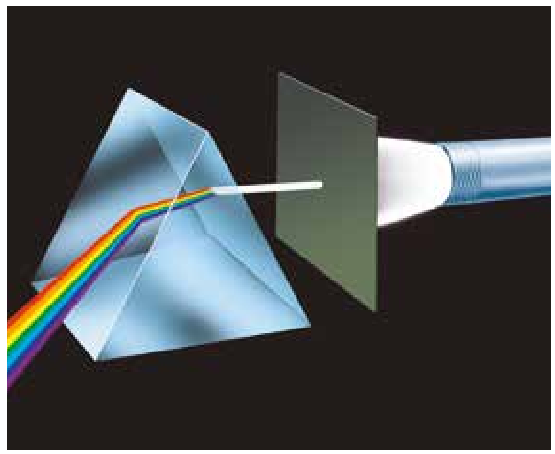
- Shine the light rays through the ziplock bag held vertically and sketch the path of the light rays as they travel from the ray box through the bag and onto the other side. The ray box may need to be elevated by placing it over a textbook so that the light rays pass through the centre of the bag.
- Now pull the ziplock bag tightly from either side and once again sketch the path of the light rays.



Discussion

1. Describe the problem with using a rigid lens to produce images of objects at differing distances.
2. Define the term 'accommodation'.
3. Refer to your results in part B of this experiment to explain how the eye can accommodate images of different distances.
4. Discuss the benefits and limitations of modelling accommodation by the eye through this activity.

4.4.3 The visible spectrum



In 1666, Sir Isaac Newton discovered that white light in fact consists of different colours. Today, this set of colours is called the **visible spectrum** of red, orange, yellow, green, blue, indigo and violet colours.

In his experiments, Newton used a glass triangular prism, similar to the one in the diagram at right. When white light enters a triangular prism at an angle, different colours emerge from the other side of the prism. The separation of white light into its component colours as a result of refraction is called **dispersion**. This occurs because each colour of light has a slightly different speed in glass and is, therefore, refracted at a slightly different angle. In a triangular prism, this difference is enhanced because the white light is refracted twice in the same direction. When white light enters the prism, the different colours are bent by slightly different amounts. When the light emerges back into the air, the different colours are bent by different amounts again.

INVESTIGATION 4.12

Eye dissection

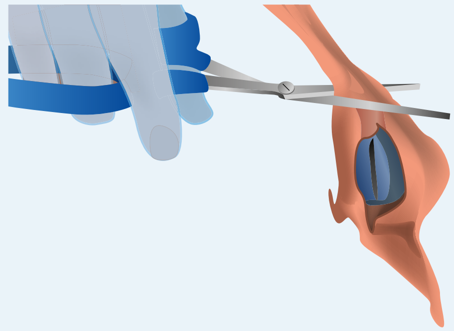
AIM: To examine the inner structure of the mammalian eye and to identify the components involved in vision

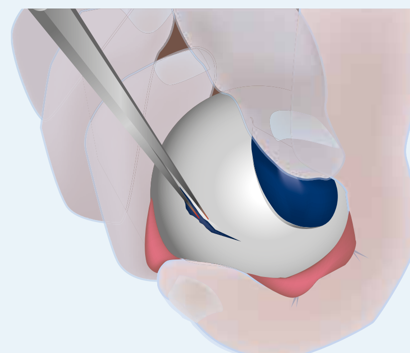
You will need:

sheep or cow's eye
scalpel
dissecting scissors
newspaper
surgical gloves
cutting board or other surface on which you can cut
soap and detergent for cleaning up

CAUTION: Take care when using dissecting instruments. Carry them carefully to and from your workbench and be careful not to make contact with sharp ends.

- Allocate roles to each member of your group based on their skills and interest. One or two students could carry out the dissection, while another student records observations, and draws and labels the specimen. Another student may have a managerial role, reading directions and providing advice.
- Examine the outside of the eye. Draw and label:
  - the sclera, the tough, outer covering of the eyeball
  - fat and muscle surrounding the eye
  - the cornea which was clear when the animal was alive but is now probably cloudy
  - the iris, or coloured part of the eye
  - the pupil, the dark oval in the middle of the iris.
- Cut away the fat and muscle.
- Use the sharp point of a pair of scissors to make an incision on the side of the eye through the thick *sclera*. Then cut around the middle of the eye, cutting the eye in half. You'll end up with two halves; the front half will contain the *cornea* and *lens*.
- Cut away the cornea and locate the *iris* between the cornea and the lens and extract it in one piece. The hole in the centre of the iris, called the *pupil*, should be visible.
- Locate and remove the lens. It should be a transparent, jelly-like lump about the size of a pea. Hold the lens up and look through it at a distant object. Describe what you see.
- Place the lens down on newspaper print and describe the appearance of the print.
- Locate the *retina*, the uppermost layer inside the back of the eye and describe its appearance.
- Locate the position in the retina where the optic nerve commences.
- Draw a labelled diagram of the interior parts of the eye.
- When complete, wrap all tissues and dissecting gloves in the newspaper for disposal.
- Place all dissecting instruments in a basin of detergent for washing.





Discussion

1. Identify the shape of the lens in the eye. Explain why the lens is this shape. You might like to include a diagram.
2. Between the cornea and lens is a transparent liquid called the aqueous humour, and between the lens and the back of the eye is a transparent jelly-like fluid called the vitreous humour. Suggest the function of these two substances.
3. The spot where the nerve cells from the retina are attached to the optic nerve at the back of the eye is called the blind spot. Can you suggest why?
4. The surface under the retina may appear shiny; suggest why. (*Hint:* Think of the appearance of the eyes of a cat when lights are flashed towards it at night.)

4.4.4 How do we see coloured objects?

It's not just a triangular prism that can split white light into separate colours. Coloured objects can separate white light by absorbing some colours and reflecting others.

The colour of an object depends on which parts of the spectrum are reflected towards your eyes.

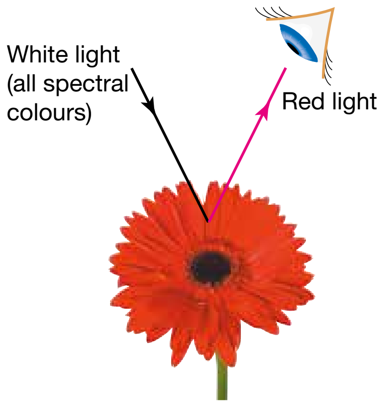
When white light falls on any opaque surface, some colours are reflected while others are absorbed. A red surface absorbs all of the colours of the spectrum except red. Only red light is reflected. A green substance absorbs all of the colours except green, and a blue substance absorbs all of the colours except blue.

Transparent objects, such as cellophane and coloured glass, split white light by absorbing some colours and allowing others to pass through.

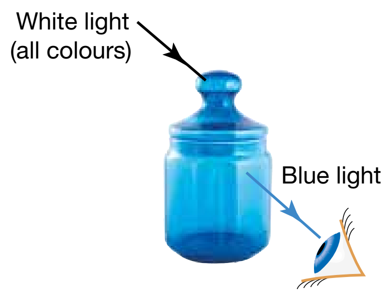
The way we see colours has more to do with our brain than our eye. The human eye has only three kinds of colour-sensitive cells — blue, green and red. The colour-sensitive cells, called **cones**, are found in the retina. The brain uses the information from the three types of cone to create a multi-coloured image of the world around us.

The three colours that our eye is sensitive to (blue, green and red) are called the **primary colours**. Our brain re-creates the rich colours of the world around us by interpreting the response from each of the three types of cone. For example, a red object causes only the red cones to 'fire'. So, we see red. A yellow object, however, causes both red and green cones to 'fire' in equal amounts. Our brain takes this mixture of red and green from the eye and we see it as yellow. In this way, it is possible to create a unique firing pattern for each possible colour.

When white light strikes this red flower, all of the colours in the white light, except red, are absorbed. Red light is reflected into our eye and we see a red flower.

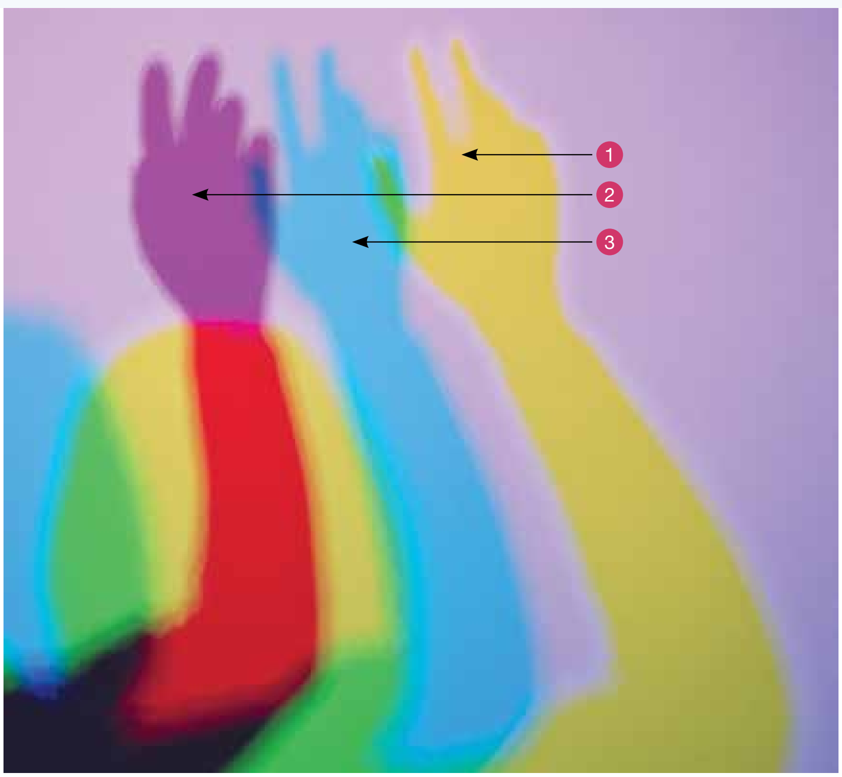


When white light shines onto blue glass, all colours, except blue light, are absorbed. Blue light passes through the glass. If you look through the glass, everything appears blue because only blue light passes through it to reach your eye.



Colours that are created by equal amounts of 'firing' from two different cones are called secondary colours. The **secondary colours** are yellow, magenta and cyan — all of which can be seen in the diagram below. If all three cones 'fire' equally, we see white light.

Blue, red and green light are used to illuminate the hands.

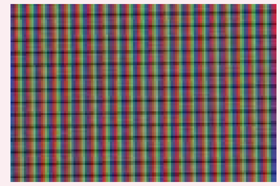


1 **Yellow** This part of the screen receives equal amounts of light from the red and green lamps, but no light from the blue lamp.
2 **Magenta** This part of the screen receives equal amounts of red and blue light, but no green light.
3 **Cyan** This part of the screen receives equal amounts of green and blue light, but no red light.
The three colours mixed together in equal amounts produce white light.

HOW ABOUT THAT!

Colour television

A TV screen can re-create all possible colours by using only the three primary colours. The image on a television screen is made up of thousands of dots of blue, green and red light. These dots are called pixels. By carefully adjusting the brightness of each colour pixel, any colour can be re-created. So, when we view an area of a TV screen where both the green and the red pixels are equally bright, we see yellow.



INVESTIGATION 4.13

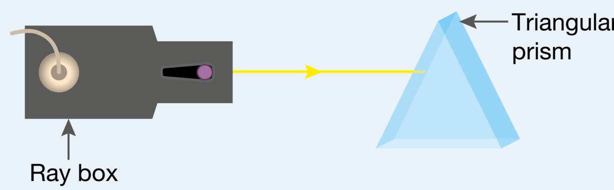
What's in white light?

AIM: To demonstrate that white light consists of a visible spectrum

You will need:

torch
triangular glass prisms
sheet of white A4 paper
ray box
12 V DC power supply

- Place the triangular glass prism about 10 cm in front of the beam of light from a torch.
- Use the sheet of white paper as a screen just behind the prism and move the prism around until you can see a band of different colours on the screen. Once you have found the band, move the screen away from the prism and try to project it onto a wall.
- Connect the ray box to the power supply. Place the sheet of white paper in front of the ray box. Project a single thin beam of light towards the triangular prism as shown in the drawing at right.
- Move the triangular prism as necessary until a band of colours is produced.
- Use a second prism to try to merge the colours into a beam of white light on the screen.



Discussion

1. What colours could you see when the white light was separated into different colours by the prism?
2. Which colour is bent the most by the prism? Which colour is bent the least?
3. Suggest how the glass in the prism managed to separate the colours.
4. Draw a diagram to show how a second prism can be used to merge the colours separated by the first prism.

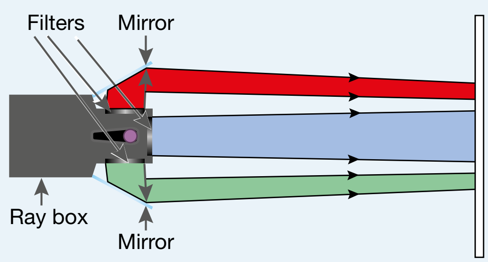
INVESTIGATION 4.14

Adding colours

AIM: To investigate the result of combining colours

You will need:

ray box kit, including coloured filters
12 V DC power supply
white surface to use as a screen



- Place the blue, green and red filters in the slide slots provided on the ray box. This investigation works best if you put the blue filter in the forward-facing slide slot.
- Use the ray box in a darkened room to produce separate red, green and blue patches on the screen.
- Move the mirrors of the ray box to create areas where the different primary colours overlap.
- Replace the blue, green and red filters with yellow, magenta and cyan filters and record your results to the table.

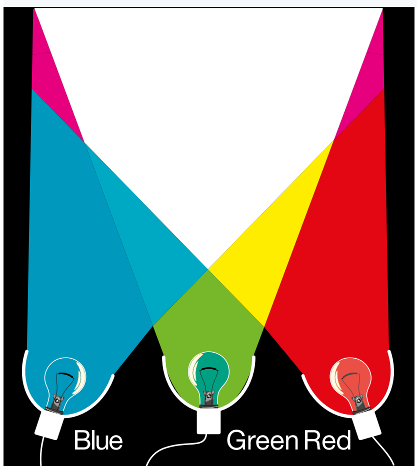
Discussion

1. Copy the table at right and record the possible combinations of primary colours and the resulting secondary colours observed on the screen.
2. Were the results obtained when each set of colours were combined expected? Explain why or why not.

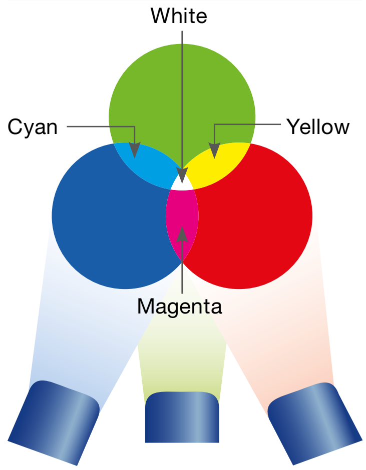
Adding colours

Colours combined	Colour observed on screen
Red + green + blue	
Red + green	
Red + blue	
Green + blue	
Yellow + magenta + cyan	

Blue, green and red light are combined here to produce white light. If someone were to stand in the way of the lights, they would be blocking blue light on one region of the wall, red on another and green on another. This creates yellow, magenta and cyan.



The primary and secondary colours



INVESTIGATION 4.15

Subtracting colours with filters

AIM: To investigate the result of colours being filtered out

You will need:

ray box
12 V DC power supply
red, green, blue, yellow, magenta and cyan filters
white surface to use as a screen

- Make a copy of the table on the next page in which you can record your predictions and observations.
- Connect the ray box to the power supply and darken the room.
- Project a beam towards the screen and place the magenta filter in the ray box. Predict the colour that you would expect to observe on the screen if you place a red filter in front of the magenta filter. Test your prediction and record the colour observed in the table.

- Replace the red filter with a green filter and again predict and observe the colour seen on the screen.
- Replace the green filter with a blue filter and yet again predict and observe the colour seen on the screen.
- Remove the blue filter and place both the cyan and yellow filters directly in front of the magenta filter. Make and record your prediction about what you will observe on the screen before you make your observation.
- Use the filters that you have available to complete the table. Add lines to the table if you would like to test other combinations.

Discussion

1. Which primary colours (red, green or blue) are *transmitted* by the:
   (a) magenta filter?
   (b) cyan filter?
   (c) yellow filter?
2. Which primary colour is *subtracted* by the:
   (a) magenta filter?
   (b) cyan filter?
   (c) yellow filter?
3. What colour was produced when the magenta, cyan and yellow filters were all placed in front of the white beam?

Subtracting colours with filters

Filter in ray box	Filter placed in front	Predicted colour on screen	Observed colour on screen
Magenta	Red		
	Green		
	Blue		
	Cyan and yellow		
Cyan	Red		
	Green		
	Blue		
Yellow	Red		
	Green		
	Blue		

HOW ABOUT THAT!

Animal vision

It is widely believed that dogs see their world strictly in black and white. Recent scientific research shows that this is not true. Dogs can see colours, but not as well as humans. They have fewer cones and appear to completely lack cones that detect red light. The result is that dogs see the world in shades of blue, yellow and grey.

Most birds and many insects have good colour vision as it plays an important role for them in finding food, protecting themselves from predators and finding mates so that they can reproduce. Some of them have more than three types of cone cell. Pigeons, for example, have six types of cone cell. Bees have three types of cone, one of which detects ultraviolet radiation, which humans are unable to detect.

It's not all black and white for dogs.

4.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** the two parts of the eye responsible for focusing light.
2. **Identify** whether a short-sighted person has trouble getting a sharp image of distant or near objects.
3. When the eye changes focus from a distant to a near object, **explain** whether the lens of the eye becomes thicker or thinner. Use a diagram to support your answer.
4. **Explain** how the lens changes shape to accommodate objects of different distances.
5. **Identify** the three primary colours detected by cells in the retina.
6. **Explain** how the eye regulates how much light enters it.
7. **Describe** how you can demonstrate that light is actually made up of a mixture of colours.

Think

8. **Explain** why an opaque object appears:
   (a) blue
   (b) white
   (c) black.
9. **Explain** why a section of a stained glass window appears red.
10. **Explain** why it is impossible for a person who has had cataract surgery to accommodate.

Create

11. **Create** a mnemonic, rhyme or song to help you remember the seven colours of the visible spectrum in the correct sequence.
12. **Create** a colour wheel with a disc of cardboard. Colour one third of the cardboard red, another third green and the final third blue. Make a hole in the centre of the cardboard disc so that a pencil can be inserted through it. The pencil needs to fit tightly enough so that the wheel spins when you spin the pencil. What colour do you see when the disc is spun quickly?

Analyse

13. The data in the table on the right shows how the smallest distance (on average) from written text that a clear image can be obtained varies with age.
    (a) Draw a line graph and a curve of best fit to show how the ability to focus changes with age.
    (b) Use your graph to **predict** the smallest distance at which a clear image can be obtained by a person of your age.
    (c) Use your graph to determine from what age the decrease in focusing ability appears to be most rapid.

Age (years)	Distance (cm)
10	7.5
20	9.0
30	12
40	18
50	50
60	125

Investigate

14. Research one of the following topics and produce a poster or ICT presentation to present your findings.
    - How a rainbow is formed and why it is curved
    - What colour blindness is and what causes it
    - Colour vision in animals
    - Why the sky appears blue

learnON RESOURCES — ONLINE ONLY

Explore more with this weblink: Eye dissection

Explore more with this weblink: Colour vision

Complete this digital doc: Worksheet 4.4: The eye (doc-12756)

Complete this digital doc: Worksheet 4.5: Spectrum (doc-12757)

4.5 The communication revolution

Science as a human endeavour

4.5.1 Electromagnetic waves

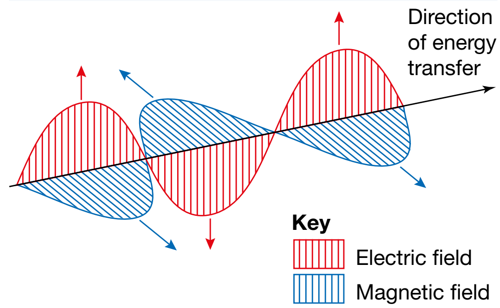
Light is just one example of electromagnetic waves.

All electromagnetic waves travel through air at 300 000 kilometres per second and can travel through a vacuum. The waves actually consist of pulsing electric and magnetic fields. These fields are generated by oscillating electric charges.

Luminous objects, be they human-made, such as compact fluorescent lights, or naturally occurring like stars, cause charged particles (mainly electrons) to be accelerated, generating the pulsing magnetic and electric fields which we call electromagnetic waves.

The frequency of electromagnetic waves is a measure of the number of pulses of electric and magnetic fields generated per second. The wavelength is the distance between adjacent crests or troughs in the electric or magnetic fields. The electric and magnetic fields pulse at right angles to the direction of motion of the wave.

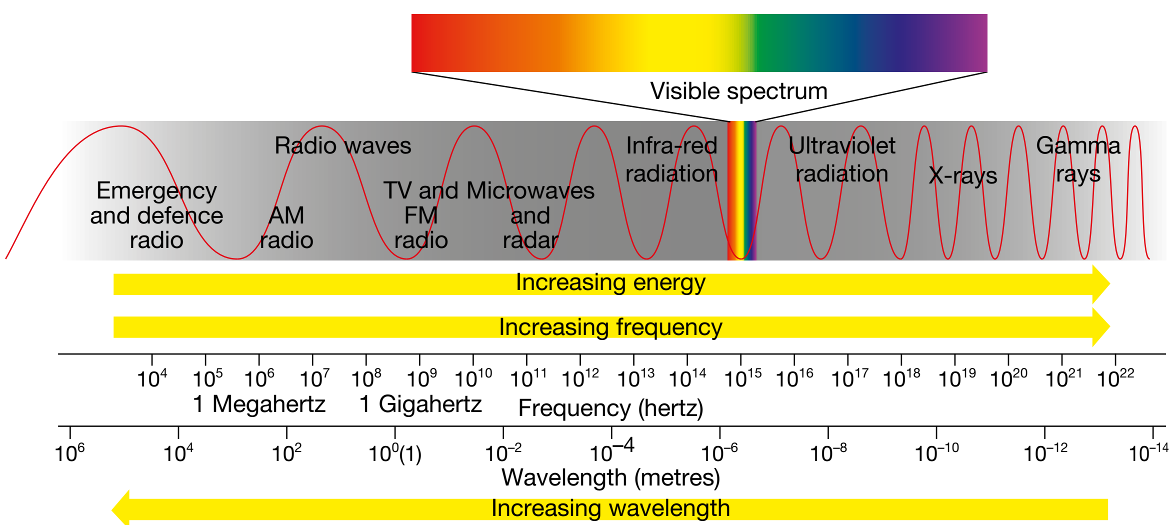
A representation of part of an electromagnetic wave



Light is not the only example of electromagnetic waves. Ultraviolet light, X-rays and radio waves are all examples of energy carried in the form of electromagnetic waves. Electromagnetic 'radiation' is the term often used to describe these energy forms because like heat energy, their energy can be transferred or radiated through vacant space, without the need for a medium.

4.5.2 The electromagnetic spectrum

Light, X-rays and radio waves are all examples of electromagnetic radiation but they are quite different. X-rays can penetrate the body to provide a bone scan and radio waves can carry communication from radio stations. Each type of electromagnetic radiation exists as an electromagnetic wave with a specific frequency range that matches the frequency of oscillating electric charges which produced them. The entire range of electromagnetic radiation is called the electromagnetic spectrum and is illustrated below. Higher frequency radiation in the electromagnetic spectrum, namely X-rays and gamma rays, carry higher energy intensity and hence can penetrate objects, including body tissues. Gamma rays are used in radiotherapy to attack cancerous cells in tumours.



Ultraviolet (UV) light is invisible to the eye. UV light has a higher frequency than visible light and so has a greater energy intensity that causes certain materials to glow or fluoresce. The energy of UV light excites the molecules in these materials to emit visible light. For example, ultraviolet beads change colour in the presence of UV light. They are normally opaque and colourless but change to bright colours upon exposure to UV light.

Ultraviolet radiation

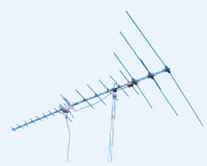
Like infra-red radiation, ultraviolet radiation is invisible to the human eye. It is more energetic than visible light and as a result can cause chemical changes in many substances, including human skin. Exposure to ultraviolet radiation in sunlight leads to tanning but prolonged exposure can cause sunburn. Some sunscreens contain chemicals that absorb the ultraviolet light before it can damage the surface of your skin. Others, like zinc oxide, block the ultraviolet light. Long-term exposure to the sun's ultraviolet radiation increases your chances of skin cancer. Unfortunately, Australia has one of the highest incidences of skin cancer.

Infra-red radiation

These electromagnetic waves are invisible to the human eye and are emitted by all objects, unless those objects are extremely cold. The amount of infra-red radiation emitted by an object increases as its temperature increases. Remote control devices send out infra-red beams which are detected by receivers with garage doors, TVs and DVD players. Infra-red cameras are used to detect heat.

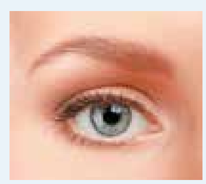
Radio waves

These are low in energy intensity and include the electromagnetic waves used in TV, AM and FM radio transmissions, microwave waves used in radar, wireless internet and mobile phone communication. The frequency of these waves causes electrons in the receiving antennas of these devices to vibrate at the same frequency, and results in sound and images being produced.



Visible light

This represents only a very small part of the electromagnetic spectrum and contains all the colours of the rainbow, ranging from red (the lowest frequency) to violet (the highest). Visible light is necessary for vision in humans and for the process of photosynthesis in green plants.



X-rays

These high-energy electromagnetic waves can pass through some opaque materials including body tissues, making them useful for diagnosing internal injuries such as bone fractures. X-rays can also be used to kill cancer cells and analyse the molecular structure of complex chemicals. X-rays are produced when fast-moving electrons give up their energy quickly. In X-ray machines, this happens when the electrons strike a metal target made of tungsten.

Gamma rays

These are the highest frequency and most energetic electromagnetic waves. Like X-rays, they are also very penetrating. Gamma rays can pass through many materials, including metals; hence they are sometimes used to find weaknesses in metals. In fact, a thick layer of lead is required to absorb these rays, preventing them from travelling further. Gamma rays can cause serious damage to living cells but they can also be used to kill cancer cells. Gamma rays are produced when energy is lost from the nucleus of an atom. This can occur during radioactive decay of nuclei or as a result of nuclear reactions. Some of the most distant and hottest stars in our universe give out enormous amounts of gamma radiation.

INVESTIGATION 4.16

UV protection

AIM: To investigate the effectiveness of sunscreen lotions

You will need:

UV colour beads
3 suntan lotions of low-range, mid-range and high-range sun protection factor (SPF)
4 small ziplock bags
4 petri dish containers

- Place a small handful of UV beads into each of the ziplock bags and seal them.
- Apply a low-range SPF lotion over the outside of a ziplock bag and label it with the SPF value.
- Repeat this step with the mid-range and high-range SPF lotions and leave the fourth bag as a control.
- Expose the bags to direct sunlight for 10 minutes.
- Tip the contents of each of the bags into separate petri dishes.
- Describe the colour intensity of each sample or take photographs of each as a record.

Discussion

1. What purpose did the control serve in this experiment?
2. Were the higher SPF lotions more effective in reducing exposure to UV light? Justify your response using your observations.
3. Investigate using secondary sources how sunscreen lotions work to reduce UV exposure.

INVESTIGATION 4.17

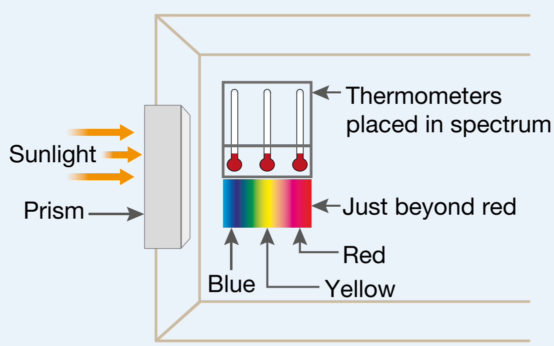
Infra-red radiation

AIM: To detect infra-red radiation

You will need:

glass prism (Note: plastic prisms do not work well for this experiment.)
4 thermometers or temperature probes and a data logger
black marker (water soluble)
scissors and sticky tape
cardboard box (e.g. photocopier paper box)
blank sheet of white paper

- Conduct this experiment on a sunny day.
- If using thermometers, blacken the bulbs of the thermometers to make them energy absorbers.
- Tape the white sheet of paper flat in the bottom of the cardboard box.
- Cut a notch into an edge of the box to mount the prism. The notch should hold the prism snugly, while permitting its rotation about the prism's long axis.



- Place the prism into the notch cut from the box and rotate the prism until the widest possible spectrum appears onto a shaded portion of the sheet of paper at the bottom of the box.
- The side of the box facing the sun may have to be tilted up to produce a sufficiently wide spectrum.
- After the prism is secured in the notch, place the thermometers in the shade and record the ambient air temperature.
- Tape the thermometers into position at the base of the box so that the bulb of a thermometer is placed within the following portions of the spectrum:
  - blue
  - yellow
  - just beyond red.

You may need to cut out a flap along the side of the box to allow the thermometers to sit flat at the base.

- After approximately 10 minutes, exposure to the sun, record the maximum temperature reached by each of the thermometers.
- Calculate the temperature rise at each position in the spectrum and record all your data in a suitable table. Compare your results with other groups.

Discussion

1. Was there a trend in the temperature readings? Was this trend consistent with the results obtained from other groups?
2. Account for your findings.
3. Evaluate the effectiveness of this procedure and your findings. Suggest any improvements that could be made.
4. Why was Herschel's experiment such an important one in our understanding of the electromagnetic spectrum?

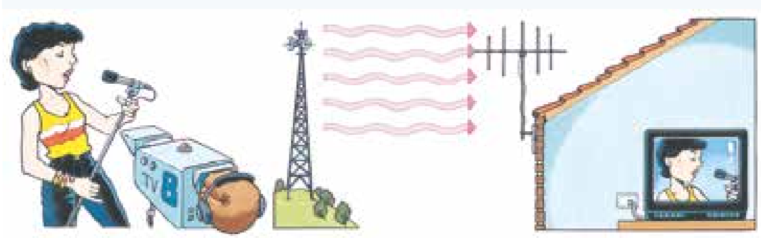
Sir Frederick William Herschel discovered the existence of infra-red light in 1800 by passing sunlight through a glass **prism**, causing it to be dispersed into a spectrum. Just beyond the red end of the spectrum he detected the greatest amount of heat of the visible colours that make up sunlight. Herschel was interested in measuring the amount of heat and realised that there must be another, invisible type of light beyond red in the spectrum.

4.5.3 We're on the air

Many of the devices we use today to communicate, including radios, TVs and mobile phones rely on radio waves. Radio waves were discovered by Heinrich Hertz in 1887 and were first used by Italian scientist Guglielmo Marconi to transmit a message across the Atlantic in 1901.

Radio waves are emitted naturally by stars. They can also be produced artificially when electrons in a metal rod are made to oscillate rapidly. This metal rod is called a **transmitting antenna** or transmitter. These vibrations cause radio waves to travel through the air at the typical speed for an electromagnetic wave; 300 000 kilometres per second. The radio waves can be detected by a receiving antenna, which is a metal rod just like the transmitter. The radio waves cause electrons in the receiving antenna to oscillate rapidly, producing an electrical signal in it. The process of using radio waves to transmit either sound or television pictures is illustrated at right.

Using radio waves to transmit sound and pictures



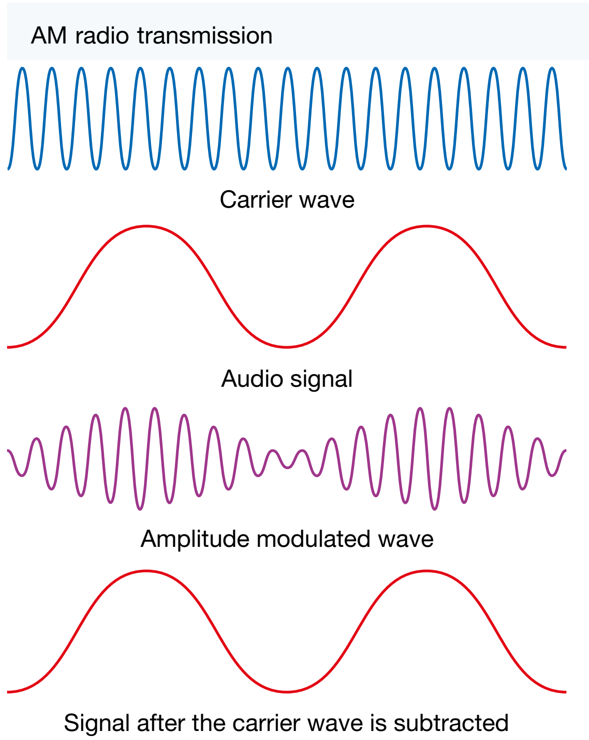
AM radio

Each AM radio station is allocated a particular frequency of radio wave through which it transmits sound signals. The sound signal must firstly be changed to an electrical signal. This electrical signal is called an **audio** signal.

The waves on which messages are sent are called **carrier waves**. The audio signal is added to the carrier wave, producing a modulated wave, as shown in the diagram at right. The receiving antenna of your radio detects the modulated wave. Your radio then 'subtracts' the carrier wave from the signal, leaving just the audio signal. The audio signal is amplified by an audio amplifier inside the radio and sent to speakers. In the speakers, the changing electric current is used to make the surrounding air vibrate to produce sound.

The carrier signals for AM radio stations have frequencies ranging from about 540 kilohertz up to about 1600 kilohertz. When you tune in your radio, you are selecting the frequency of the carrier wave that you wish to receive. For example, if you tune to ABC Local Radio Sydney, you are selecting the carrier wave with a frequency of 702 kilohertz.

AM stands for amplitude modulation, and the diagram at right shows why: the audio signal changes the **amplitude** of the carrier wave.

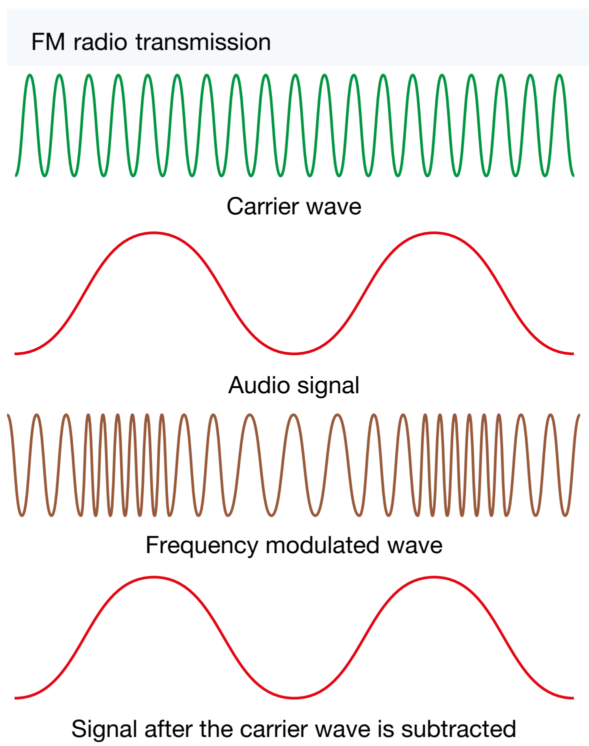


FM radio

Like AM radio stations, each FM radio station has its own carrier wave frequency. However, the carrier frequencies are much greater — between 88 megahertz and 108 megahertz (1 megahertz equals 1 million hertz). The other major difference between AM and FM radio is the way that the audio signal is carried on the carrier wave. Instead of adding the audio signal to the carrier wave and changing its amplitude, the audio signal changes the **frequency** of the carrier wave as shown in the diagram at right. FM stands for frequency modulation.

As with AM radio, when you tune in your radio to FM you are selecting the frequency of the carrier wave that you wish to receive. For example, if you tune to 2 Day FM in Sydney, you are selecting the carrier wave with a frequency of 104.1 megahertz.

FM radio waves are affected less by electrical interference than AM radio waves and therefore provide a higher quality transmission of sound. However, they have a shorter range than AM waves.



Television

Television signals are transmitted on two separate carrier waves. The visual signal is added onto one carrier wave using amplitude modulation. The audio signal is carried on a separate carrier wave using frequency modulation. When you tune your television set to a particular channel, you are selecting the visual and audio carrier waves that you wish to receive. Your television set then completes the task of removing the carrier waves and translating the signals sent into a picture and sound. This is quite a complex task, as you might imagine!

INVESTIGATION 4.18

AM and FM radio

AIM: To compare the reception of AM and FM radio under different conditions

You will need:

a portable radio

- Tune the radio to an AM station of your choice.
- Plan a path through the school that will take you through at least 5 different locations; e.g. classroom → corridor → undercover courtyard → playground → hall.
- At each different location, observe and record the quality of reception as good, medium or poor and record this information in a suitable table.
- Repeat these steps while listening to an FM station of your choice at the same volume level.

Discussion

1. For which station was the reception generally poorer, AM or FM? Were there any 'blackspots'?
2. Account for the locations in the school with the poorest reception in terms of the structures around you.
3. Investigate using secondary sources whether AM or FM radio reception is more likely to be affected by interference and why. Is this research consistent with your findings?

Digital communication

Australian television and radio recently moved from the broadcast of an analogue signal to a digital transmission. While digital transmission has allowed each TV station to broadcast a greater number of programs, what's the difference between digital and analogue transmission?

The radio waves carrying the audio transmission described earlier are examples of analogue signals. Analogue quantities vary continuously over time just as the amplitude and frequencies of AM and FM radio vary. Digital signals on the other hand are non-continuous. They consist of a series of 'on' and 'off' pulses, each representing a particular signal strength or value. The digital value at any particular time is generated using a binary code of 0s (representing off) and 1s (representing on) as shown in the table at right.

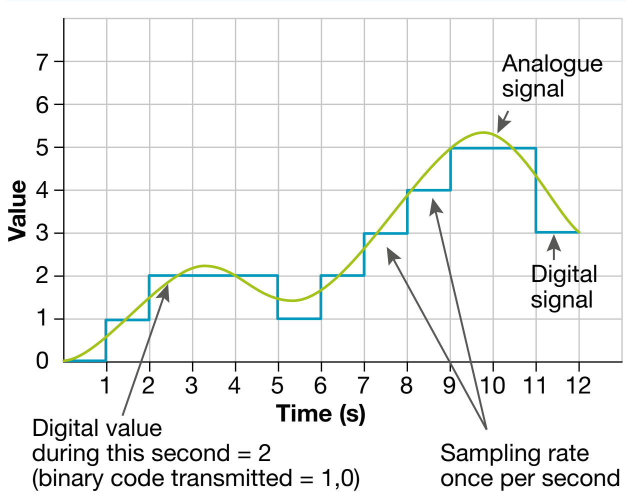
The binary code for the first 10 decimal values

Decimal value	Binary code
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010

The process of converting the original analogue signal into a series of digital values is called sampling. In 8-bit processing, the amplitude of an analogue wave at any given point in time is converted to a number value on a scale from 0 to 256 (or 2^8). The sampling rate of a signal, on the other hand, determines how frequently the amplitude of an analogue audio or video wave is recorded.

A digital signal is encoded from the original analogue wave and is then transmitted as a binary sequence representing each of the samples taken. A decoding device then reconstructs the amplitude of the analogue wave. You will notice in the diagram at right that the digitised signal has lost some of the sensitivity of the analogue wave. To increase the accuracy of a

An analogue vs a digital signal



digital signal, the sampling rate can be increased. Audio signals are generally sampled 40 000 times per second while video signals are sampled more than 13 million times per second.

Another strategy employed is to increase the sensitivity of the digital scale used. Digital technology commonly utilises 14-bit processing (providing a scale with 2^{14} or 16 384 levels), 32-bit (2^{32} levels) or even 64-bit (2^{64} levels) processing.

Analogue or digital — smooth or in bits

You can read the time from an analogue watch with hands that continuously rotate, or from a digital watch with LEDs (light-emitting diodes) or liquid crystals that simply turn off and on.

All physical quantities like time, speed, weight and pH can be represented in analogue or digital form. Likewise, invisible waves like sound and radio waves can be transmitted in analogue or digital form.

- Analogue forms change smoothly if the quantity being measured changes smoothly.
- Digital forms display or transmit quantities as a limited series of numbers or pulses. Digital devices are usually electronic. Their displays are made from devices that can only ever be 'on' or 'off'. For example, each number display of a digital measuring device is made up of seven LEDs/LCDs, each of which can be either 'on' or 'off'. The arrangement of the seven LEDs/LCDs allows all of the numbers from 0 to 9 to be displayed.

An analogue watch represents time as a quantity that changes smoothly.

A digital watch represents time as a quantity that changes in 'bits'.

Each number in this digital display is made up of seven LEDs, each of which can be either 'on' or 'off'.

4.5.4 What's the advantage?

Both analogue and digital television signals fade away as they travel through the air. Like all other waves, the energy they carry spreads out. So, as they travel over distance their intensity, or strength, decreases. As the continuous analogue signal becomes weaker, any background radiation and signals from other sources have a greater effect on the amplitude of the wave. It becomes distorted. The result is a fuzzy picture and poor quality sound. Because digital signals consist only of 'on' or 'off' pulses, background radiation and signals from other sources cannot interfere with them — even as they become weaker. The rapidly pulsating signals are still either 'on' or 'off' until the 'on' signals have faded away to nothing.

As a result, digital television has several advantages over analogue television. It provides:

- sharper images and 'ghost free' reception
- widescreen pictures
- better quality sound
- capability of 'surround' sound
- access to the internet and email
- capability of interactive television, allowing the viewer to see different camera views or even different programs on the same channel.

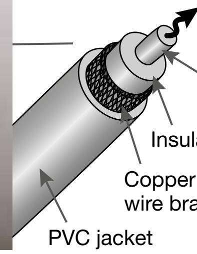
4.5.5 Communication highways

Digital communication has enhanced the quality and capacity of audio and video transmitted to consumers, but the communication revolution also involves developing new technologies to carry this digital signal.

The electrical way

The **coaxial cable** was designed during World War II to improve the speed of communications. The first major coaxial cable in Australia was laid between Sydney, Melbourne and Canberra in 1962. Coaxial cables can simultaneously transmit many more telephone calls and television signals than the copper cables which were previously used.

Many coaxial cables can be bundled together and buried underground or laid on the ocean floor. Coaxial cables can carry television signals as well as telephone calls and facsimile messages.



A coaxial cable consists of a conducting wire at the centre that can carry an analogue or a digital signal. This central wire is surrounded by an insulating material and an outer conductor, usually of a copper or aluminium braided cylinder, which acts as a shield to minimise electrical and radio frequency interference between adjacent cables. The cable is then encased in a protective PVC jacket. Most Australian coaxial cables contain four, six or twelve tubes and are buried under the ground or laid on the ocean floor.

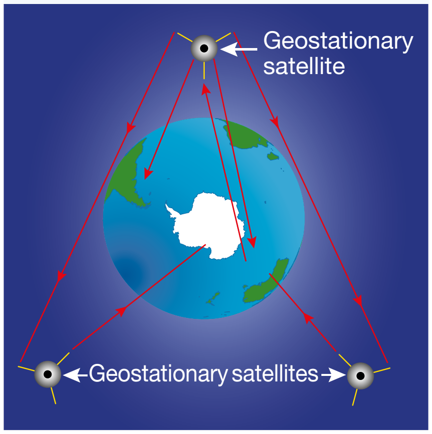
Wireless technology

Analogue and digital television, wireless broadband and mobile phone calls can all be transmitted over long distances using high frequency radio waves, also called **microwaves**. Microwaves range in frequency from about 0.3 GHz to 300 GHz and can carry many signals at the same time. However, repeater stations need to be used so that the signal does not fade away before it reaches its destination. Antennas on the repeater stations receive the microwave signals and send them on to the next station. Each repeater tower needs to be within sight of the next one because radio waves, like visible light, travel in straight lines. So, the repeater towers are built in elevated positions wherever possible.

Repeater stations are towers with dish-shaped antennas.

Communications **satellites** also allow high frequency radio waves to be transmitted at the speed of light from continent to continent. In Australia, satellites are used to transmit radio, television and telephone signals between cities and are a particularly important mode of communication for remote areas. Signals are transmitted to a satellite that is in a **geostationary** orbit, meaning that it orbits the Earth once every 24 hours, thus remaining over the same point on Earth at all times. In order for the satellite to orbit at that rate, it must be positioned at an altitude of about 36 000 kilometres above the equator. Dish antennas, such as the ones in the photograph on the following page, are aimed at particular satellites ready to receive signals. The shape of the dish allows for the collection of large amounts of electromagnetic energy, which is then focused towards the central antenna.

A geostationary satellite relays radio signals to other locations in Australia, or to other continents.



These antennas receive signals that have been re-transmitted by a geostationary satellite.

Optic fibres

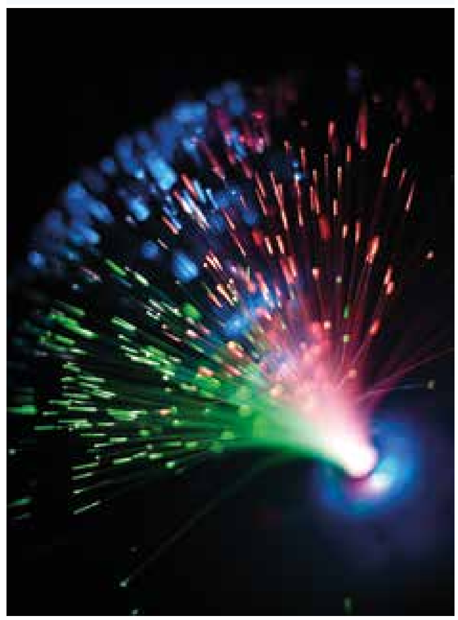
From 2010, the Australian government began rolling out a new super-fast National Broadband Network based on optic fibre technology. While optic fibres currently link major Australian cities and link Australia with other continents, this new network plans to run optic fibres to suburbs, providing broadband speeds that will be 100 times faster than those currently available via conventional wireless or coaxial cable. The table at right demonstrates that optic fibres can also transmit many more messages at one time than coaxial cable or microwaves.

Options for long-distance communication over land

Signal carrier	Number of two-way conversations at once
Copper cable	600
Coaxial cable	2 700
High frequency radio wave	2 000
Optic fibres	30 000

Optic fibres are long, thin, flexible strands of glass. Electrical signals from sources such as a microphone, television camera, computer or facsimile machine are converted into high frequency pulses of light, generally near the infra-red range, which carry a digital signal through the optic fibre. The light pulses received at the other end are converted back into electrical signals that can be fed into speakers, televisions, computers or fax machines. The messages can also be re-transmitted as microwaves if necessary.

Optic fibres use total internal reflection to transmit light pulses.



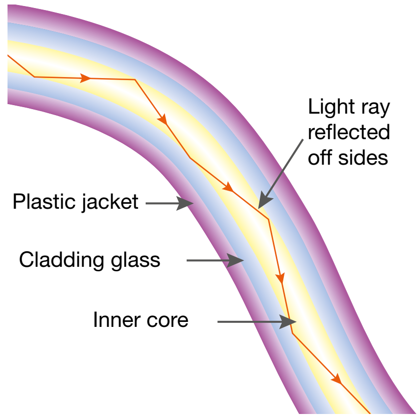
The idea of using visible light to transmit messages over long distances was not feasible until the invention of the laser in 1958. A laser produces an intense beam of light of one pure colour. As the beam travels through the optic fibre, the glass absorbs some of the light energy. Repeaters are needed every 35 to 55 kilometres along the optic fibre cables to amplify the signal. The laser light loses energy less quickly than normal light would, because a laser beam disperses very little.

Optic fibres can be laid under the ground or under water. They are smaller, lighter, more flexible and cheaper than coaxial cables previously used for long-distance telephone, radio and television communication, and the light pulses are not affected by interference from radio waves, so there is no 'static'.

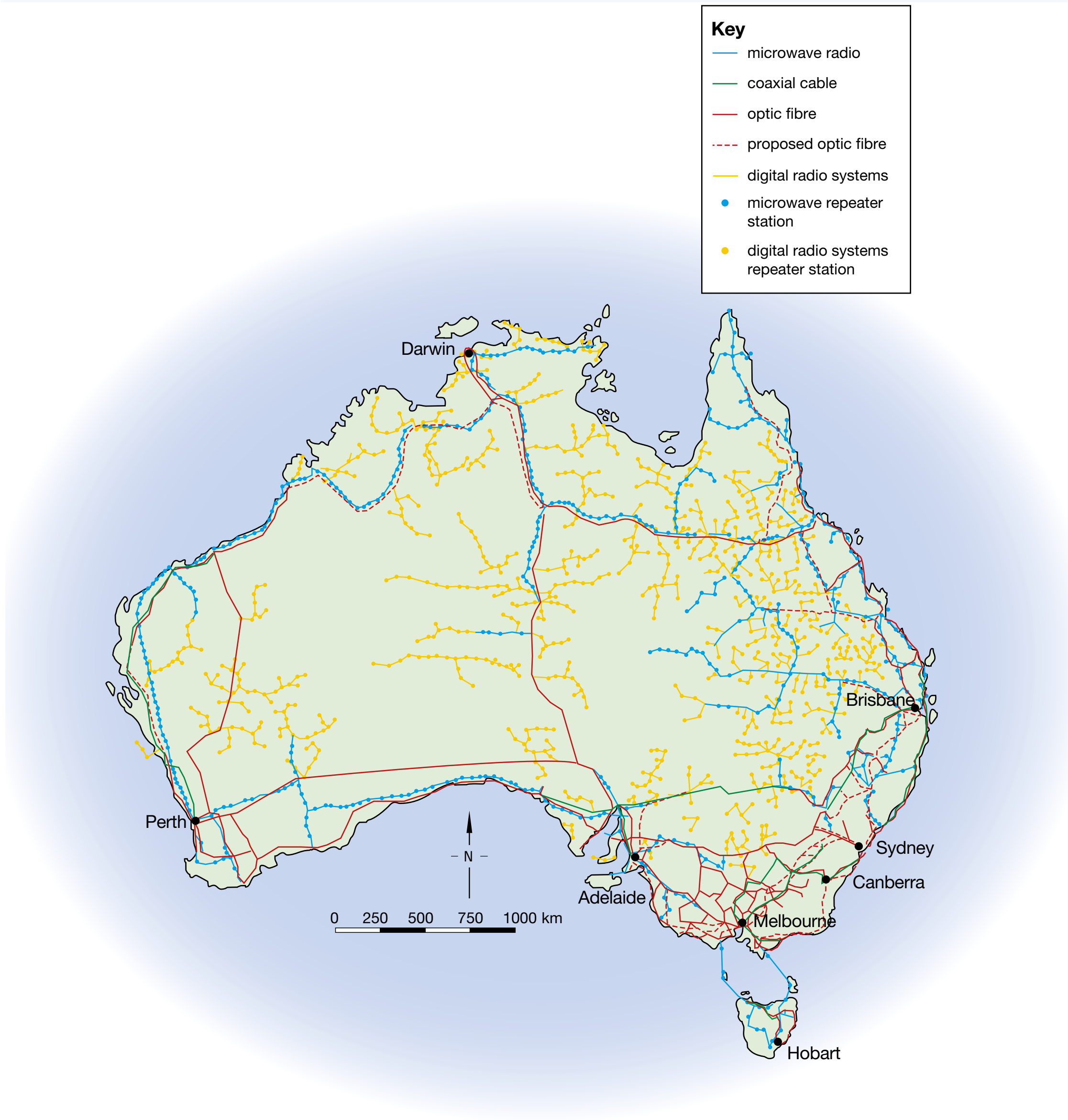
Optic fibres — how they work

The glass in optic fibres is made so that light is unable to escape from the glass. This is achieved by covering the glass with a cladding of denser glass or plastic. As light travels from the inner glass core to the denser cladding, it bends (refracts) so much that, instead of leaving the glass, it is reflected back into it. This process is called **total internal reflection**. The diagram shows how total internal reflection occurs in an optic fibre. Even if the fibre is bent a little, the light is 'trapped' inside by total internal reflection.

Total internal reflection in an optic fibre



Australia's existing long-distance communication network prior to the optic fibre broadband rollout



INVESTIGATION 4.19

Total internal reflection

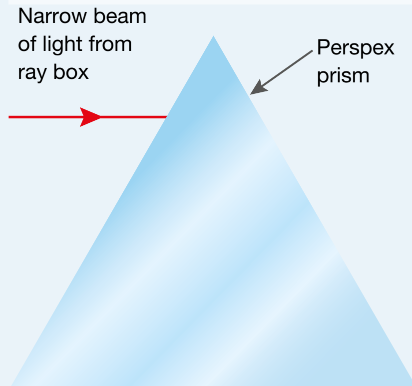
AIM: To observe total internal reflection of light in a Perspex prism

You will need:

ray box kit
12 V DC power supply
Perspex triangular prism

- Connect the ray box to the power supply. Place the ray box over a page of your notebook. Use one of the black plastic slides in the ray box kit to produce a single thin beam of light which is clearly visible on the white paper.
- Place a Perspex triangular prism on your notebook and direct the thin beam of light towards it as shown in the diagram at right. Observe the beam as it passes through the prism.
- Turn the prism slightly anticlockwise, closely observing the thin light beam as it travels from the Perspex prism back into the air. Continue to turn the prism until the beam no longer emerges from the prism.

Observe the beam of light as it passes through the prism.



Discussion

1. Describe what happens to the thin light beam as it passes from air into the Perspex prism and back into the air.
2. Outline what happens to the beam of light when it no longer emerges from the prism.
3. Draw a series of two or three diagrams showing how the path taken by the beam of light changed as you turned the prism.

INVESTIGATION 4.20

Optic fibres

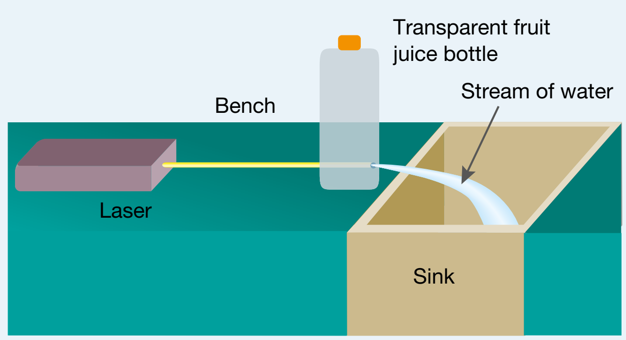
AIM: To investigate the principle utilised in optic fibres

This investigation is carried out as a teacher demonstration to minimise the risks associated with the use of lasers.

You will need:

transparent 2–3 L fruit juice bottle
large nail
laser (class 1)
demonstration optical fibre cable or light pipe

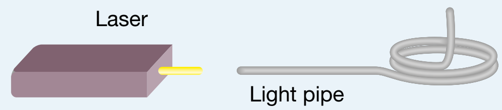
- Use the nail to poke a narrow 5 mm hole into the front of a fruit juice bottle approximately 5 cm from the bottom.
- Darken the room.
- Fill the container to the top with water and position it on the edge of a sink so that a thin stream of water flows from the container into the sink.



CAUTION: Class 1 and class 2 lasers have a relatively low power output and so are safe for classroom use under direct supervision of the teacher. Laser beams should not be pointed towards others in the room because of the sensitivity of the retina of the eye. Ensure that those viewing this demonstration are positioned on either side of the stream of water to eliminate the possibility of the laser beam being directed towards them.

- Direct a laser beam into the bottle and out through the centre of the stream of water.
- Describe the path of the laser beam.

- Shine a laser beam down a length of 'light pipe' or loop of optic fibre. Describe your observations.



Discussion

1. Explain why the laser beam took the path of light observed in these demonstrations.
2. Compare the speed of light in air to that in water or the material making up the optic fibre core. Explain how these demonstrations rely on the difference in the speed of light through these media.

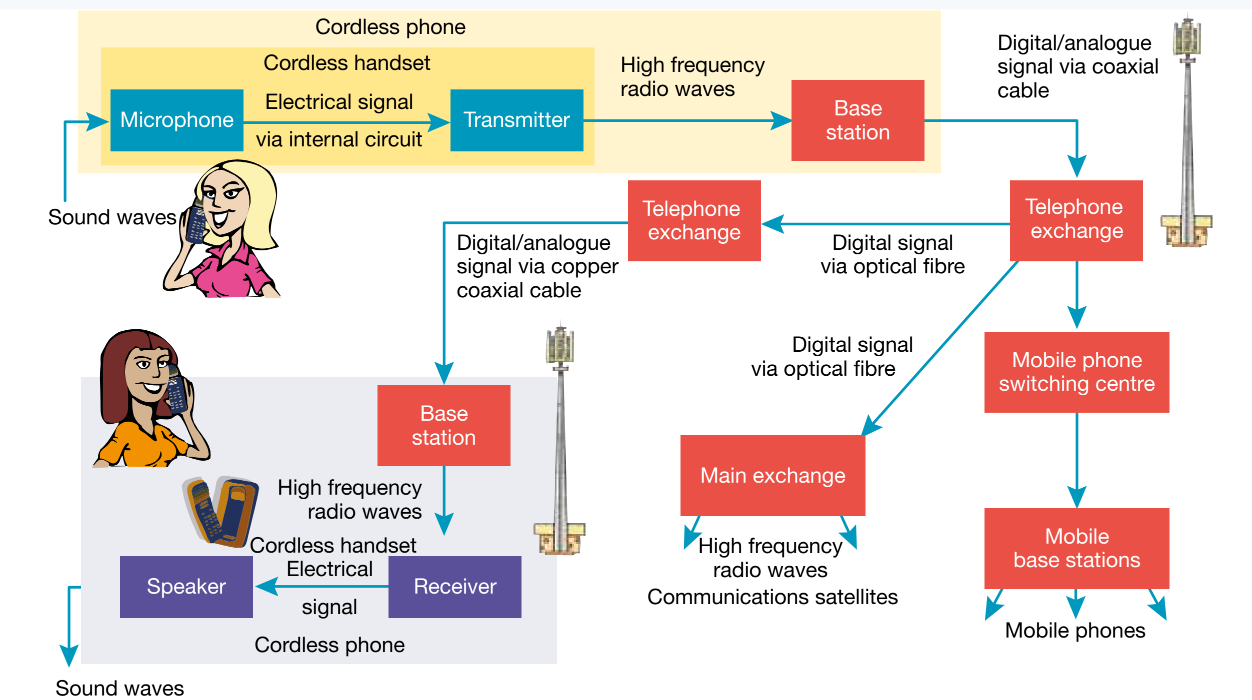
4.5.6 Phone a friend

The landline

Alexander Graham Bell is often credited with the invention of the telephone in 1876 although, like many areas of science, several of Bell's contemporaries, including Thomas Edison, contributed significantly to the early development of this technology. Australia's first telephone service, in Melbourne, was launched in 1879. Today, telephones send and receive electric signals over a complex network of coaxial cables that link urban and rural areas throughout Australia. More recently, optic fibres have been incorporated into the network, linking telephone exchanges.

Modern telephones are often cordless, with digital phones increasingly replacing earlier analogue technology. A simple phone call involves quite a bit of technology. To begin with, sound waves from the caller are first converted to an electrical signal by the microphone in the handset. The electrical signal is analogue or digital, depending on the type of telephone. A transmitter in the handset generates radio waves of a specific frequency (in the microwave range) which are detected by a receiver in the phone's base station. An electrical signal is transmitted from the base station of your phone via copper coaxial cables to the telephone exchange in the phone network. The various telephone exchanges are connected by optic fibre, so electrical signals are converted to digital pulses of light or to high frequency radio waves if the call is to be routed to the mobile phone or satellite network. From the telephone exchange the phone call is once again converted to an electrical signal, and travels to the base station of the receiver's phone. There it is transformed to a radio wave which is received by the handset and converted by a speaker to a sound wave again.

A landline is part of the communications network.



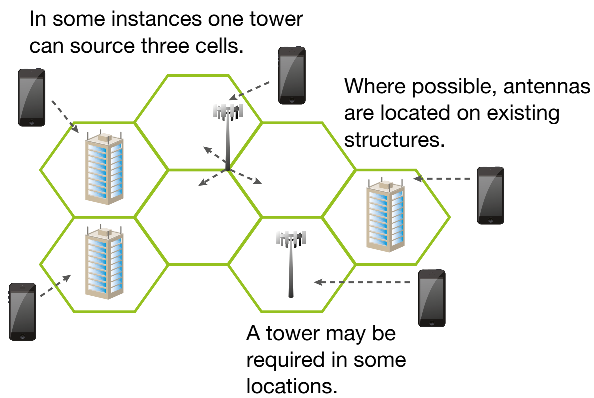
Going mobile

Since the first major mobile phone service was introduced in Australia in 1987, millions of Australians have purchased mobile phones.

How mobile phones work

Domestic and business telephones are connected by cable to the network of microwave and radio links, coaxial cables and optical fibres. Mobile phones transmit signals on radio waves to a **base station**, which consists of several antennas at the top of a large tower or on top of a tall building. The base station is connected to a **switching centre**. Each switching centre is, in turn, connected to many base stations. The switching centre switches the call to other mobile phones through the **cellular system** or the fixed telephone system.

The mobile phone network consists of a series of hexagonal cells that are serviced by base stations.



A network of cells

Mobile phones are also called **cell phones**. That is because the base stations are set up in a network of hexagonal cells.

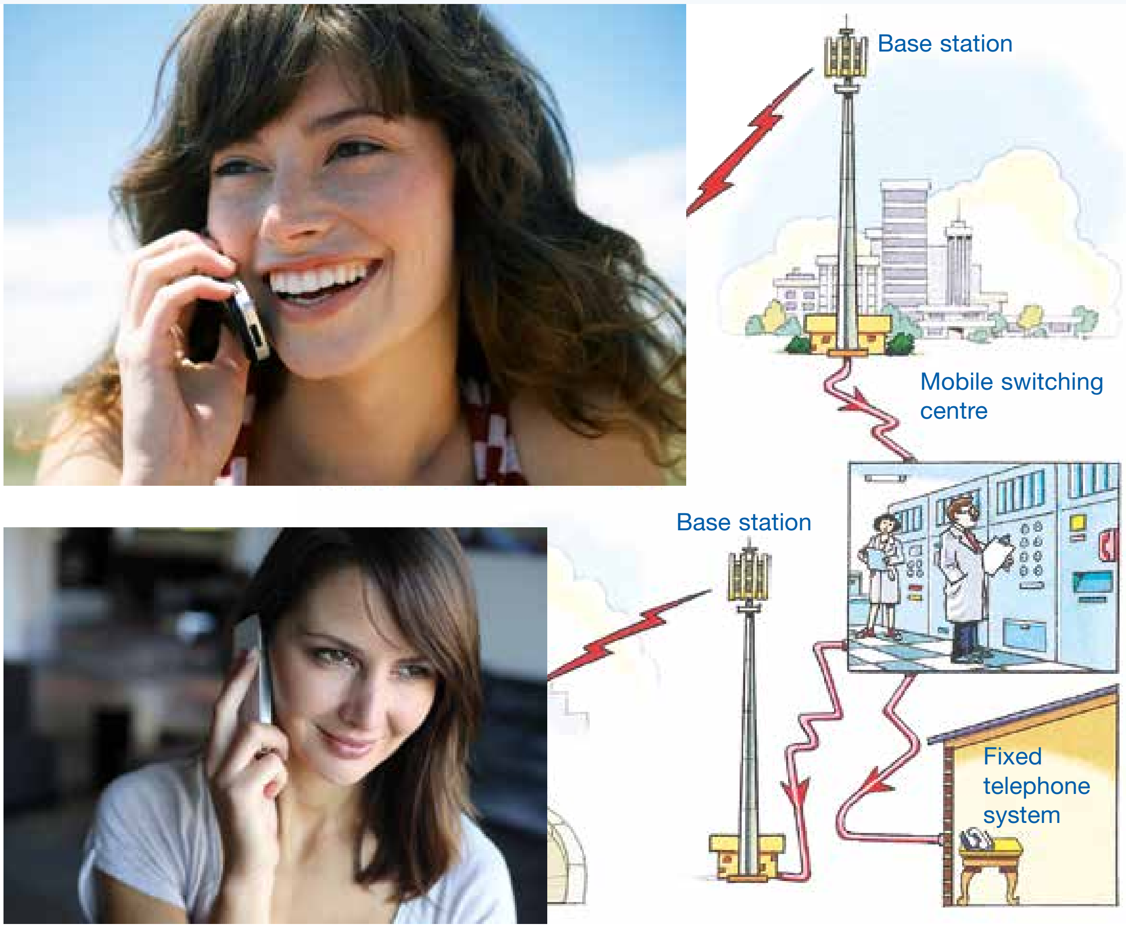
Base stations may consist of large free-standing towers or structures located on building rooftops, and are located either in the centre of each cell or on the corner of a group of cells.

The cells range in size from 100 metres across to over 30 kilometres across depending on the terrain and the concentration of mobile phone users. The base stations receive and transmit mobile phone signals from the cells that adjoin them. In addition, each base station is connected to the main telephone network either via a high frequency radio wave antenna, or via optical fibre cable.

When you make a call, your mobile phone will always 'talk' to the base station antennas nearest to you. As you move around, the phone will 'talk' to different base stations, which ever is the closest, or the least congested.

Typical mobile phone base stations

The pathway followed by a mobile phone call



INVESTIGATION 4.21

The impacts of digital technology

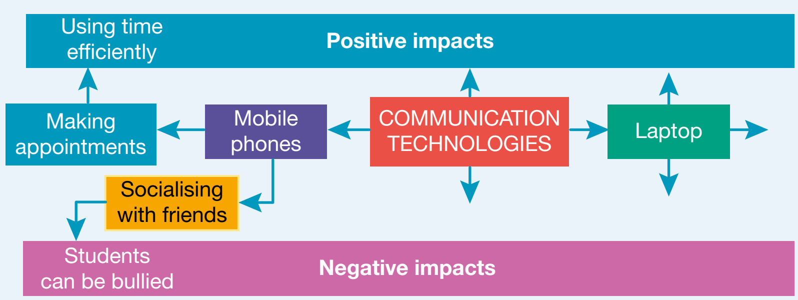
AIM: To evaluate the impact of new and emerging technologies on society and the environment

There is no doubt that fast and flexible digital technology is revolutionising the way we communicate at work and in recreation. In this investigation you will evaluate the impact of new and emerging digital technologies on society and the environment.

You will need:

butcher's paper

- Work in small groups and record the group's ideas in the form of a mind map.
- Identify digital technologies in common use. These may include a tablet, laptop, mobile phone, landline, MP3 player etc.
- For each technology, brainstorm the specific uses for that device in your work or recreation.
- For each use, brainstorm any positive or negative impacts on society (physical health, mental health, lifestyle, productivity, etc.) or the environment (pollution, waste etc.).



Discussion

1. Using information in your mind map, individually, discuss, using examples, the positive and negative impacts of digital communication technologies on society and the environment.
2. Give reasons why society should support scientific research in the development of better communication technologies.

4.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note*: Question numbers may vary slightly.

Remember

1. **Summarise** the differences between the digital and analogue signals that are added to carrier waves for television transmission.
2. Digital television has several advantages over analogue television.
   (a) List three of these advantages.
   (b) **Explain** why digital signals have these advantages.
3. **Identify** the components of a coaxial phone cable that:
   (a) carries the analogue or digital signal
   (b) reduces interference.
4. **Explain** why repeater stations are necessary for the transmission of microwaves and other radio waves.
5. Use a labelled diagram to **describe** total internal reflection.
6. **Explain** when total internal reflection can occur.
7. **Explain** how light can be used to transmit the signals from phones or computers.
8. **Describe** how mobile phones are different from landline telephones in the way that they transmit and receive voice messages.
9. **Explain** why mobile phones are also known as cell phones.

Think

10. **Explain** why repeater stations are necessary along coaxial cables.
11. **Explain** why microwaves and other radio waves are preferred for communication in the outback rather than optical fibres or coaxial cables.
12. **Explain** why communication satellites are placed in geostationary orbit.
13. **Identify** an analogue device (or technique) that measures:
    (a) time
    (b) speed
    (c) weight
    (d) pH.
14. **Construct** a table to list the advantages and disadvantages of mobile phones over landline phones.
15. Refraction is the bending of light as it passes from one medium to another. **Describe** the role of refraction in an optic fibre.

Investigate

16. Research using secondary sources the progress on the optic fibre roll out. When will your suburb be provided with optic fibre to the home?
17. Photonics is the study of optic fibres and their application. Research how scientists in Australia are developing a computer chip based on light pulses rather than electrical circuitry.
18. Some people are concerned that the electromagnetic radiation from mobile phones and base stations could affect people's health. Research this area and **assess** the arguments put forward.

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Complete this digital doc: Worksheet 4.6: Communications (doc-12758)

4.6 Project: Did you hear that?

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4.6.1 Did you hear that?

Scenario

Since the invention of the Walkman — a portable cassette tape player — in 1979, through to the modern iPod, we have loved to carry our favourite music around with us everywhere we go. Wherever you look, you'll see people walking the dog, riding the bus, going for a run, hitting the books or just sitting around hooked in to an audio device of some form. With more than 220 million iPods alone sold since their release in 2001 and the increasing affordability of personal music players in general, more and more people are spending time plugged in. But for every person who loves their MP3 player, there's another who'll be warning them that channelling all that sound directly into their ears will have long-term effects on their hearing.

Your fifty-year-old principal wonders whether there aren't short-term effects as well, because she finds it difficult to hear her mobile ringing for about ten minutes after she has stopped listening to music on her iPod. She comes to your science class (known for their cleverness) for some possible answers. One clever classmate suggests that maybe the type of music she was listening to had lots of high frequency sounds in it and that this had somehow affected her ear's ability to pick up the high frequencies of her mobile ring tone. Another clever classmate thinks that maybe she had the volume up too high on her iPod and that this might have caused some temporary deafness. A cheeky classmate suggests that maybe she can't hear it because she's old! Somewhat grumpy with that last comment, your principal decides that maybe she should just ban all personal music players in the school unless you can provide her with some thorough scientific evidence that something other than age can have short-term effects on hearing range after iPod use.

Your task

Using personal music players and online hearing tests, your group will perform a series of scientific investigations to explore the short-term effects of personal music players (such as iPods) on hearing range. You will then present your findings in the form of a scientific report suitable for sending to the principal.

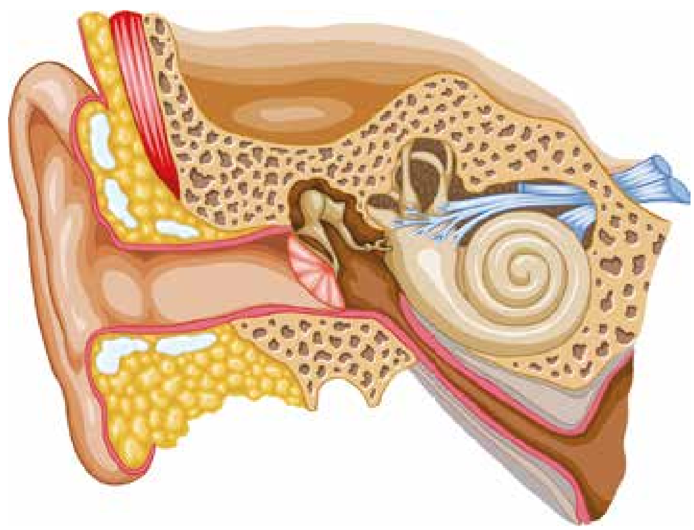
Suggested factors to consider include:

- volume used
- hearing range differences between males and females
- type of music (for example, classical, jazz, R&B or pop).

Note that you will need to minimise any risk of permanently causing damage to the hearing of your human subjects by ensuring that the volume does not exceed 90 dB and limiting trial durations to a few minutes.

Process

- You can complete this project individually or invite other members of your class to form a group.
- Start researching. Make notes of information that you gather that will provide background for your investigation and direct its design. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information about human hearing and the factors that might influence a person's hearing range.
- Design your investigation by determining what will be the dependent, independent and controlled variables, establishing the use of controls and repeated measurements, and deciding what factors you will test and how you will measure the hearing range of your subjects.
- Perform your investigation. Take photographs during your investigation for inclusion in your report.



4.7 Review

4.7.1 Waves — carriers of energy

- **explain**, using the particle model the processes underlying convection and conduction of heat energy **4.2**
- **identify**, with the use of examples the transfer of energy by waves **4.2**
- **compare** longitudinal (compression) waves and transverse waves **4.2**
- **describe**, using the wave model, the features of waves including frequency, wavelength and speed **4.2**
- **explain**, using the particle model, the transmission of sound in different media **4.2**
- **describe**, how the ear functions to provide hearing **4.2**

4.7.2 Light

- **identify** visible light as a form of electromagnetic radiation 4.3
- **identify** the properties of electromagnetic waves 4.3
- **describe** the reflection of light from plane and curved mirrors and identify some useful applications 4.3
- **describe** and **account for** the refraction of light and outline everyday instances in which refraction is evident 4.3
- **describe** the way in which lenses focus light and identify some useful applications of lenses 4.3

4.7.3 Colour vision

- **describe** how the eye functions to provide vision 4.4
- **account for** the colour of objects in terms of absorption, transmission and reflection of the colour spectrum 4.4
- **describe** some familiar examples of scattering and dispersion 4.4

4.7.4 The communication revolution (SHE)

- **identify** the features of different types of radiation in the electromagnetic spectrum and their uses 4.5
- **compare** AM and FM radio 4.5
- **compare** analogue and digital signals and **outline** the advantages of digital technology 4.5
- **describe** advances in technology involved in our communication network, in particular the coaxial cable, wireless and optic fibre technology 4.5
- **describe** the scientific principles involved in optic fibre communication 4.5
- **describe** the scientific principles and the technology involved in communication using landline phones and mobile phones 4.5

Individual pathways

ACTIVITY 4.1
Investigating invisible waves
doc-10643

ACTIVITY 4.2
Analysing invisible waves
doc-10644

ACTIVITY 4.3
Investigating invisible waves further
doc-10645

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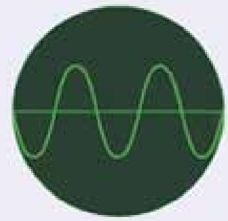
FOCUS ACTIVITY

Create a poster or multimedia presentation that explains clearly to your peers how we perceive different colours and how the eye works to provide vision in colour.
Access more details about focus activities for this topic in the Resources tab (doc-10642).

4.7 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

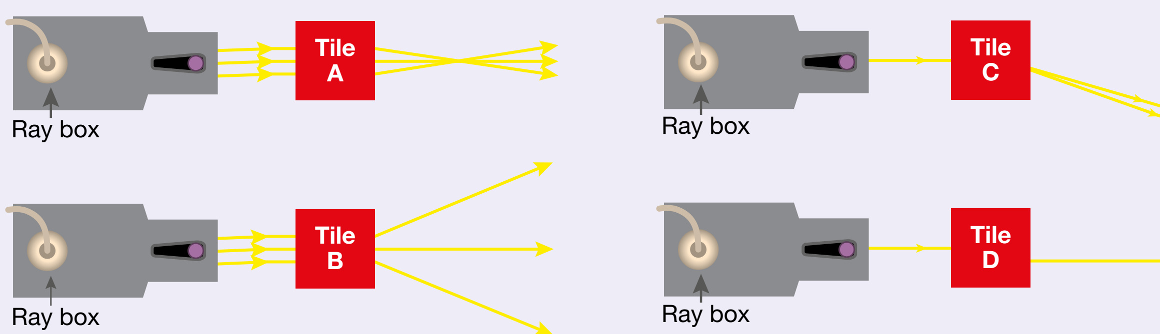
1. When heating water in a metal pot, **identify** how most of the heat is transferred through:
   (a) the metal base of the pot
   (b) the water in the pot.
2. The waveform at right was produced by plucking a string on an electric guitar. Copy the waveform. In another circle of the same size, draw a waveform that:
   (a) shows a louder sound
   (b) has a higher pitch.



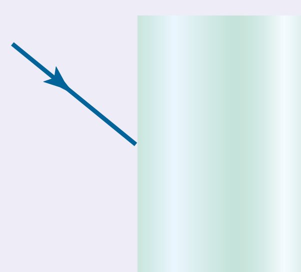
3. Copy and complete the table below, indicating with a tick which statements refer to light and which refer to sound. Some of the statements apply to both light and sound.

Statement	Light	Sound
Travels through empty space at 300 000 km/s		
Can be reflected		
Always caused by vibrating objects or substances		
Can travel through transparent substances		
Cannot travel through opaque objects		
Can be measured in decibels		
Can be produced from another form of energy		
Is detected by receptors in the human body		

4. (a) **Explain** why sound waves cannot travel through empty space.
   (b) **Explain** why light waves can travel through empty space.
5. Thin beams of light are projected from a ray box towards four objects. Each object is covered by a tile. The beams emerging from each of the objects are shown in the diagrams below.
   Identify the object under each tile.

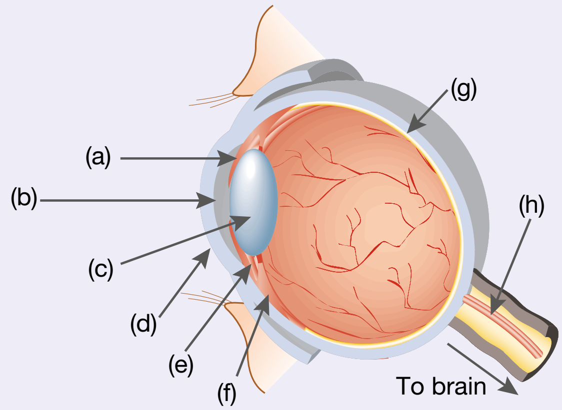


6. Copy and complete the diagram at right to show the path of the light ray as it passes through a glass rectangular prism and emerges into the air on the other side.

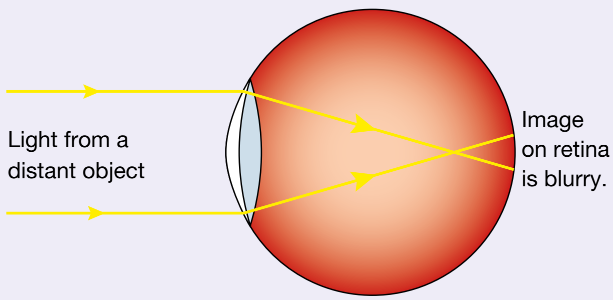


7. A light ray passes from air to glass and back into air again. **Identify** how its speed changes when it enters the glass. As a result, does the light ray refract towards or away from the normal?
8. Use a diagram to **explain** why your legs appear to be shorter when you stand in clear, shallow water.
9. **Identify** whether a convex lens has a greater focal length if it is thick or thin. Draw a diagram to illustrate your answer.

10. **Identify** the parts of the eye labelled (a)–(h) and **outline** the main function of each of the parts labelled. **Construct** a table to record this information.



11. The diagram below right shows how rays from a distant object arrive at the retina of a person with blurry distance vision.
    (a) **Identify** the condition illustrated below right.
    (b) **Outline** what the correcting lens needs to do to the incoming light to correct the problem.
    (c) Draw a diagram to show how an appropriate lens placed in front of the eye shown can correct this eye condition.



12. Imagine that you are riding on parallel beams of light as they enter a human eye. Write an account of your journey on the beam from the time that you reach the eye until you arrive at the receptor cells in the retina.
13. **Explain** how the eye can focus on both near and distant objects.
14. **Explain** how you are able to see so many different colours when receptor cells on the surface of your retina are able to detect only red, green and blue light.
15. **Describe** what happens to white light when it passes through a blue filter.
16. **Explain** why:
    (a) blue paint appears blue when it is illuminated by white light
    (b) a white shirt can look red when you are at a dance or concert
    (c) a green shirt can look black when you are at a dance or concert.
17. Make a copy of the table at right. However, rearrange the invisible waves in the first column so that they are listed in order of increasing frequency. Complete the table by filling in the other column.

Electromagnetic waves

Electromagnetic wave type	Uses
Infra-red radiation	
Gamma rays	
Ultraviolet radiation	
Light	
X-rays	
Radio	

18. **Identify** three differences between sound waves and the waves listed in the table at right.
19. **Identify** two properties that all of the waves listed in the table have in common.
20. **Identify** which type of electromagnetic waves listed in the table microwaves belong to.
21. **Identify** which of the electromagnetic waves listed in the table at right:
    (a) transmits the most energy
    (b) is used in remote control devices.
22. **Describe** how digital radio signals are different from analogue radio signals.
23. List some reasons why analogue television was phased out and replaced with digital television.

Test yourself

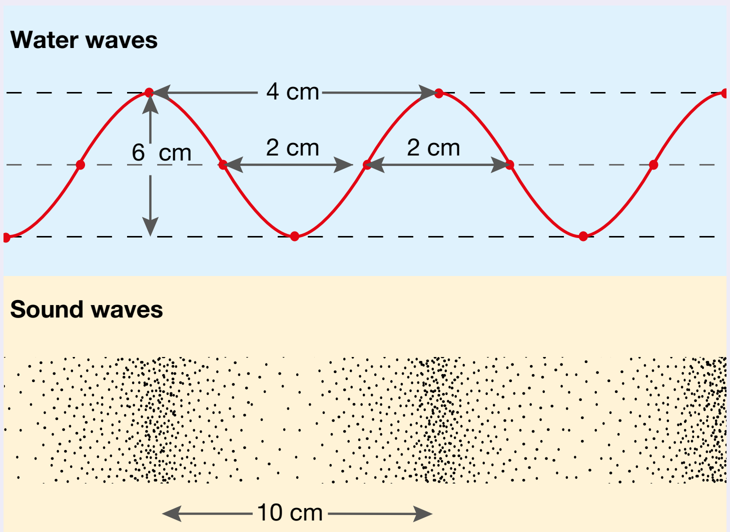
1. A feature of sound waves is that they
   (A) travel at about 340 m/s through air.
   (B) do not require a medium to travel through.
   (C) consist of troughs and crests.
   (D) travel faster through less dense objects like liquids than through solids. **(1 mark)**
2. **Identify** the structure(s) of the eye responsible for refracting light.
   (A) The lens
   (B) The pupil
   (C) The cornea and lens
   (D) The retina **(1 mark)**

3. A make-up mirror would consist of a
   (A) plane mirror.
   (B) convex mirror.
   (C) convex lens.
   (D) concave mirror. **(1 mark)**
4. Which of the following options correctly matches an electromagnetic wave with its common application?

	Electromagnetic wave	Application
A	Microwaves	Killing cancerous cells
B	Radio waves	Mobile phone communication
C	Infra-red radiation	Cooking
D	Gamma rays	Remote controls

(1 mark)

5. A blue light passes through a red filter. Light coming through the filter will be
   (A) blue.
   (B) red.
   (C) white.
   (D) black, there will be no light. **(1 mark)**
6. The questions below refer to the water wave and sound wave shown in the following figure. **(2 marks)**



   (a) **Identify** the amplitude and the wavelength of the water wave.
   (b) **Identify** the wavelength of the sound wave.
7. **Explain** how visible light is used to transmit phone calls along optical fibres. Use diagrams to illustrate your explanation. **(3 marks)**

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Complete this digital doc: Worksheet 4.7: Invisible waves puzzles (doc-12759)

Complete this digital doc: Worksheet 4.8: Invisible waves summary (doc-12760)