2 Light and sound

In this chapter you will ...

Science Understanding

- investigate the reflection of light from mirrors and its refraction through various media, for example air, water and glass
- describe briefly how the human eye receives light
- compare and contrast the way in which energy is transferred as light waves and sound waves

Science as a Human Endeavour

- consider how technologies have been developed using optical fibres and polarising filters
- use the invention of the microscope to illustrate how advances in scientific understanding often rely on developments in technology

Science Inquiry Skills

- use a knowledge of the properties of light to explain why the sky is blue and how rainbows form

Based on Australian Curriculum, Assessment and Reporting Authority (ACARA) materials

Getting started

Work in a small group to discuss each of the following. Keep your answers for later on in this chapter.

- You are playing pool and you have to pocket the yellow ball by hitting it with the white ball. How does a knowledge of reflection help you pocket the yellow ball? Which pocket will you aim for? Why?
- When the sun shines onto a large crystal hanging in your bedroom window, you sometimes get a rainbow image on your wall. How is the rainbow of colours formed?
- How would you write the word SELF on paper so that when you hold it in front of a mirror you can see the reflection of the word written correctly?
- Two actors stand on a stage. One of them wears a white costume. When a spotlight with a coloured filter is turned on, one actor's costume looks red and the other's looks black. What colour is the filter and what colour is the other costume?

Activity

This is a revision activity. Form a small group and discuss each of the following questions. Be prepared to discuss your answers with the class.

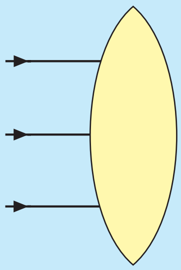
1 Light and sound are forms of energy. All forms of energy have a starting point or source. Name two sources of light and two sources of sound.

2 Which of the following shapes can be seen as the letter K in a mirror?

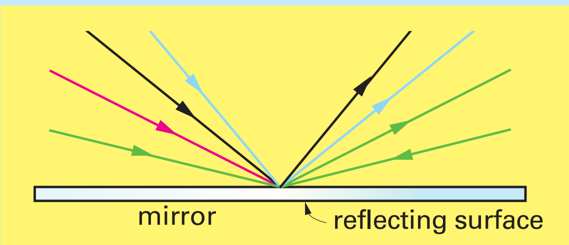
What does this tell you about the images formed in a mirror?

3 When you hit a metal cymbal with a drumstick, it rings. If you put your hand on the cymbal and hit it again, it does not ring. Explain why this happens.

4 Three rays of light shine onto a glass lens as in the diagram at right. What will happen to the light rays when they pass through the lens?



5 The diagram below shows four light rays reflecting from a plane mirror. Each light ray is coloured. There are five errors in the diagram. Can you find them?



2.1 Properties of light and sound

In the first Getting started problem in which you had to pocket the yellow ball, you used the fact that the angle at which the ball strikes the cushion is equal to the angle at which it leaves the cushion. This is the same principle as the reflection of light. Reflection is one of the *properties* of light and sound.

Both light and sound are forms of energy and both can be transformed into other sorts of energy. For example, light can be transformed into chemical energy in a leaf during photosynthesis, or into electrical energy in a solar cell. Sound can be transformed into kinetic energy in a radio speaker. The transformation of energy is another property of light and sound.

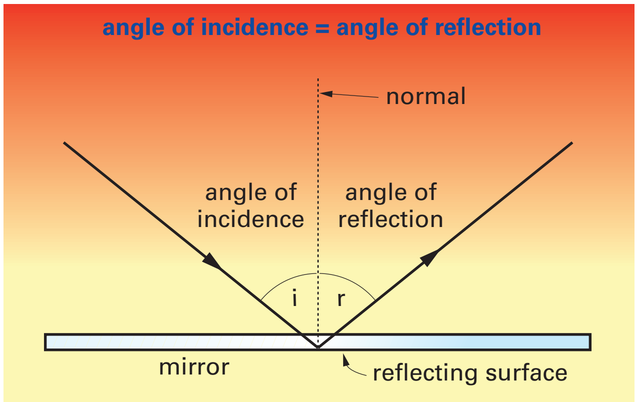
Another property of light is that it can travel in straight lines. Surveyors rely on this property when they use their instruments to find boundary lines or take measurements for new roads.

Fig 1 Surveyors use the property that light travels in straight lines to find the depth of the trench on the other side of the road.

The law of reflection

When light strikes a mirror, the reflected light ray bounces off the mirror at the same angle as it strikes the mirror. This is the **law of reflection**.

When doing experiments on the law of reflection, scientists measure the angle between the light ray and an imaginary line, called the *normal*. This line is at right angles to the surface. The light ray coming towards the surface is called the *incident ray*, and the outgoing one is called the *reflected ray*. The angles formed between the rays and the normal are called the *angle of incidence* and the *angle of reflection*. These two angles are always equal no matter how the light rays strike the surface. This is the law of reflection.



Reflection from curved mirrors

The law of reflection applies to curved mirrors as well as plane (flat) mirrors. In the diagram below, two parallel light rays hit a concave mirror (concave means curved inwards like a cave). These rays reflect off the mirror and meet at a point called the **focus**. The focal length of the mirror is the distance of the focus from the mirror's reflecting surface.

Notice that the light rays reflect off the curved mirror surface and obey the law of reflection—the angle of incidence (i) is equal to the angle of reflection (r).

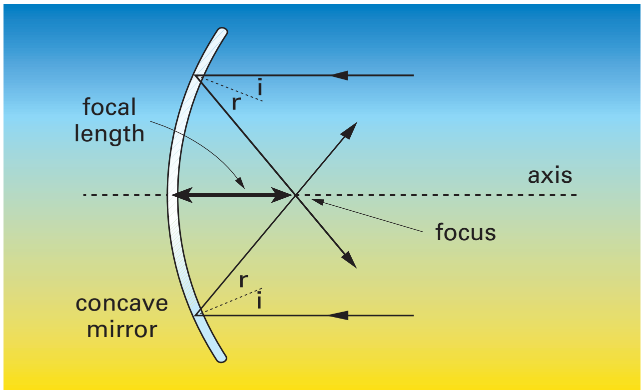


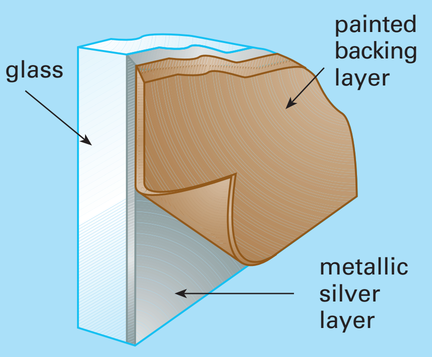
Fig 2 Parallel light rays reflect from a curved mirror and meet at a point called the focus.

The history of mirrors

Around 600 BCE, the early Etruscans and Greeks used polished discs of thin bronze as mirrors. During Roman Christian times, small metallic mirrors made of highly polished silver or steel were worn by fashion-conscious men and women.

Mirrors made of glass with a very thin layer of metal were first used in the 1300s. However, it wasn't until 1564 when the mirror-makers of Venice formed a corporation, that glass mirrors gained popularity. These mirrors were made from highly polished glass with a very thin metal backing, usually made from an alloy of tin and mercury. In very expensive mirrors, silver metal was used as the reflective backing.

Today, mirrors have a silver or aluminium layer that is sealed by a painted or plastic outer layer to protect the metal.



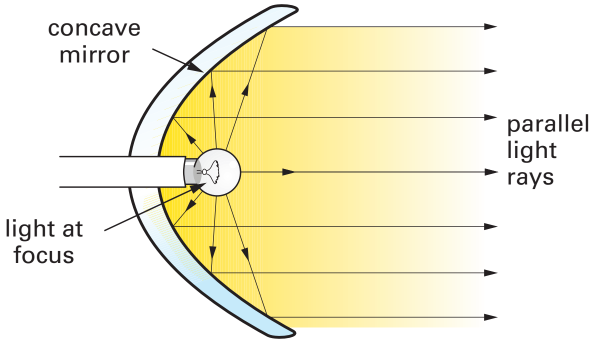


Fig 3 When a light source is placed at the focus of a concave mirror, a beam of parallel light rays is produced. This is why concave mirrors are used as reflectors in torches, car headlights and floodlights.

Fig 4 Convex mirrors are used on dangerous road intersections. Light rays from wide angles strike the mirror, giving a wider-angle image than would be seen using a plane mirror.

Investigation 4 Reflection

Aim

To investigate the reflection of light.

Materials

- ray box kit and power pack
- pencil, ruler and protractor

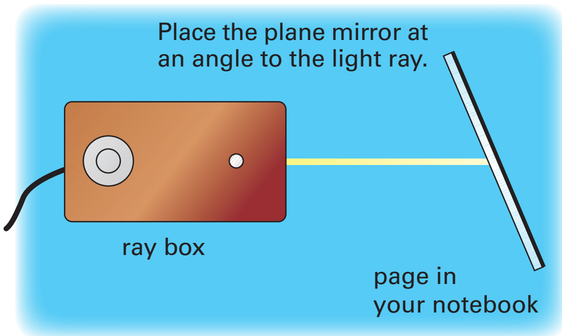
Planning and Safety Check

- Your teacher will tell you how to set up the power pack and ray box kit correctly.
- Make sure you ask your teacher to check your set-up before you turn on the power.

Method

1 Use the diagram on the right as a guide to set up the ray box and plane mirror on a clean page of your notebook. Draw a pencil line along the back of the mirror. Then draw pencil lines along the incident light ray and the reflected ray.
Use a protractor to draw the normal, then measure the angle of incidence and angle of reflection. How do they compare?

2 Change the angle of the mirror and repeat Step 1. Measure at least three different angles.



3 Replace the plane mirror with a concave mirror and shine parallel rays of light directly at it.
Describe what happens. Draw a diagram of the set-up and mark on it the axis and focus (see Fig 2 on the previous page).

4 Use a ruler to find the focal length of the mirror.
Record your results.

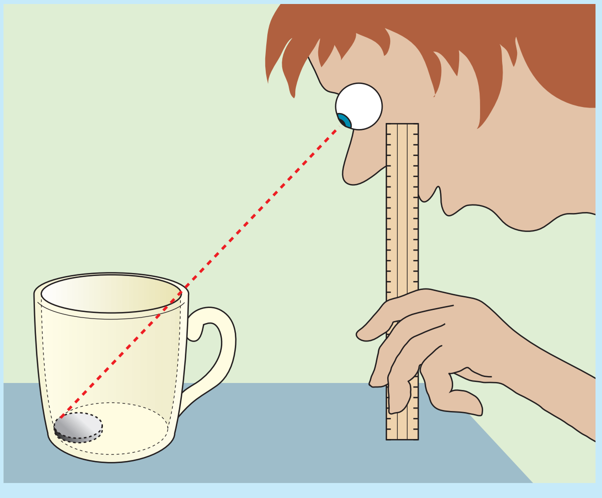
5 Try using a convex mirror.
Draw a diagram of what happens when parallel light rays strike the mirror. Does this mirror have a focus?

Refraction of light

Air and water are *transparent* substances. This means that light passes through them. Substances such as paper, wood and brick do not allow light to pass through them and are called *opaque*. However, when light passes from one transparent substance to another, for example from air to water, strange things happen.

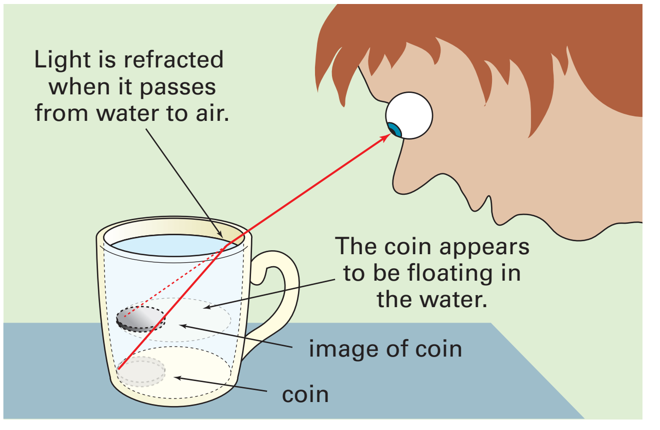
Activity

1. Put a coin in a coffee mug (or a beaker) and place it on a bench.
2. Hold a ruler vertically on the bench. Place your eye level with the zero mark on the ruler and have your partner position the mug until you can see only the far edge of the coin.



3. Have your partner slowly pour water into the mug until it is full.
   What happens to the coin as the water is added?
4. Move your eye down the ruler until you see the edge of the coin again.
   How far down the ruler did you move your eye?
   This effect shows another property of light—refraction.

The activity showed that when you put a coin in a mug and add some water, the coin seems to change position. This is caused by light bending when it passes through different transparent substances at an angle. This bending of light is called **refraction**. Refraction is another property of light.



You can see how light refracts as it passes through the glass block in the photo below. Notice that the angle of refraction is less than the angle of incidence. This is because the refracted light ray bends towards the normal.

In general, when light passes from air to another transparent substance such as water, glass, plastic, diamond or alcohol, it bends towards the normal—the angle of refraction is always less than the angle of incidence.

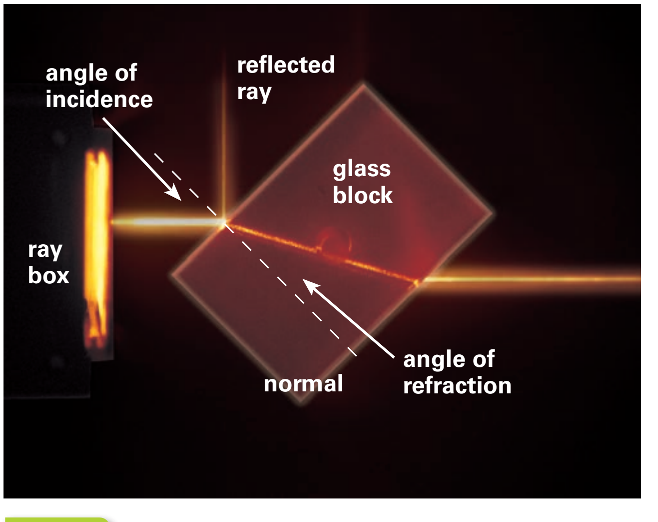
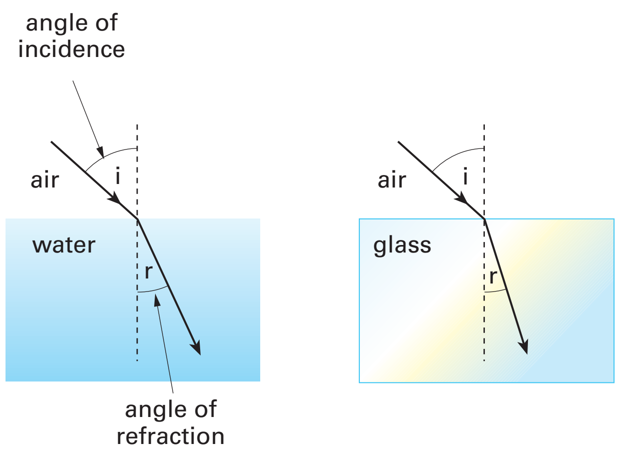
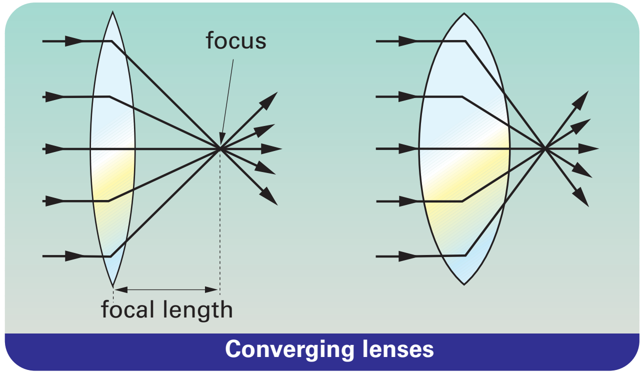
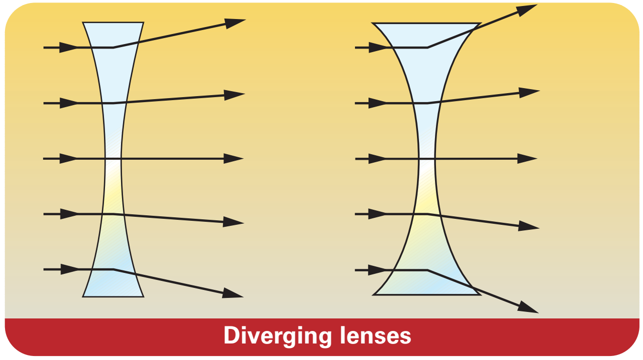


Fig 5 Light is refracted as it passes through a glass block. Notice that some light is also reflected by the block.

The amount of refraction of a light ray depends on the type of substance. For example, light bends more when it passes from air to glass than it does when it passes from air to water.







Lenses are pieces of glass or plastic curved on one or both surfaces. They refract light in certain patterns; for example, lenses that refract light inwards are called *converging lenses*. *Diverging lenses* refract light outwards.

Note: The light rays are usually drawn bending in the middle of the lens, even though they actually bend at both surfaces of the lens.

Investigation 5 Lenses and light

Aim

To observe how lenses refract light and form images on a screen.

PART A Ray box lenses

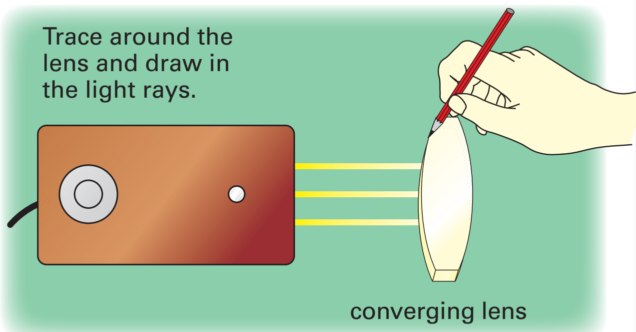
Materials

- ray box kit and power pack

Method

1 Set up the ray box and a converging lens as shown in the diagram on the right.

2 Find the focal length of the lens.



3 Replace the lens with a different converging lens and find its focal length.

What happens when you use a diverging lens instead of a converging lens? Can you find the focal length of a diverging lens? Try it.

Discussion

1 Does a fatter converging lens refract light more or less than a thinner one? Suggest a reason for your answer.

2 Do diverging lenses have a focus? Explain your answer.

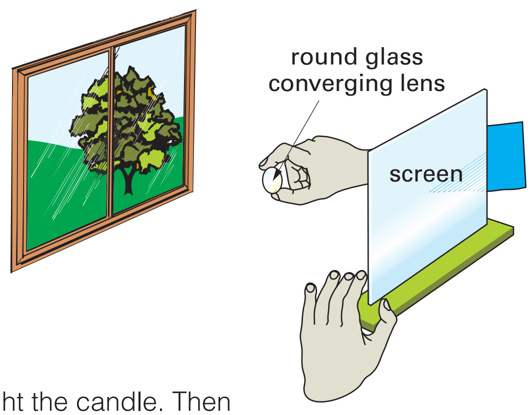
PART B Images with lenses

Materials

- metre ruler
- candle
- round glass converging lens and lens holder or plasticine
- screen (white hardboard or cardboard)

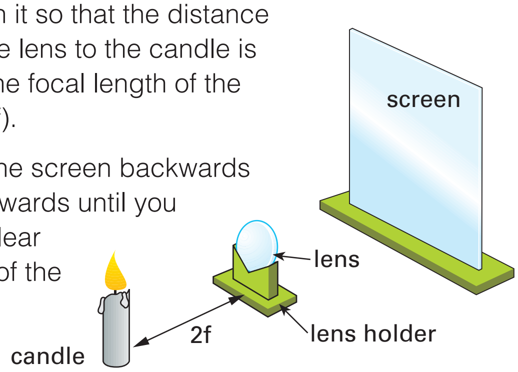
Method

1 Hold the converging lens near a window and focus the image of a distant object on the screen. Measure the distance between the lens and the screen. This is the *focal length*.
Record the focal length.



2 Light the candle. Then place the lens in a holder (or plasticine) and position it so that the distance from the lens to the candle is twice the focal length of the lens (2f).

3 Move the screen backwards and forwards until you get a clear image of the candle.



Is the image bigger, smaller or about the same size as the candle flame? Is it right side up or upside down?

4 Move the lens further away from the candle and describe what happens to the image. Do this for two or three distances.
Record your observations.

5 Now move the lens closer to the candle but not up to the focus.
What happens to the image?

6 Move the lens inside the focus. Remove the screen and look through the lens at the candle flame.
Describe the image.

Conclusion

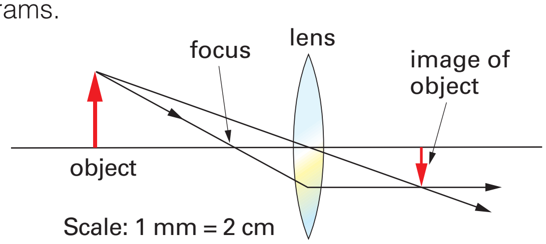
Summarise your results in a table. Put the distance between the lens and the candle in one column and the image description in another. The distances are:

- at twice the focal length (2f)
- further than 2f
- between 2f and f
- closer than f.

PART C Predicting images

Ray diagrams are scale models used to predict the position and size of the image. The ray diagram below uses a lens of focal length 20 cm. To find the image, draw one light ray straight through the centre of the lens, and another through the focus to the lens and then parallel to the axis. The image is where these two lines meet.

Take some measurements using your set-up from Part B, and then check the image distances with those predicted using ray diagrams.

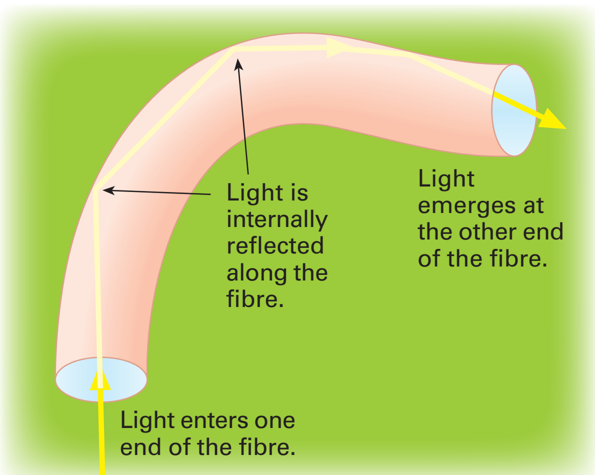


Optical fibres

The photo below shows a surgeon using an *endoscope* to examine a patient's stomach. The endoscope has a long flexible tube containing **optical fibres** that is inserted through the patient's mouth and oesophagus.

The endoscope contains bundles of optical fibres, each one about 10 micrometres in diameter. The optical fibres act like a flexible torch. Light shines through one end of the optical fibres in the endoscope and it comes out the other end, no matter how much the tube is twisted or bent.

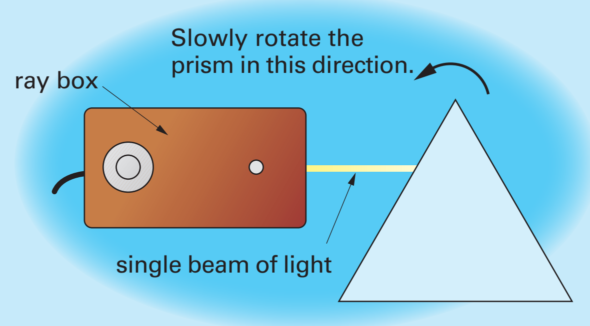
An optical fibre uses the principle of **total internal reflection** to transmit the light. The diagram bottom left shows how the light ray comes in from one end, hits the side of the fibre and is reflected back into it. None of the light escapes from the fibre. This is why it is called total internal reflection.



Activity

You will need a ray box kit and power pack for this activity.

1 Use the diagram below as a guide to set up the ray box and a triangular prism.
2 Shine one beam of light onto the side of the prism, and slowly rotate the prism until the light beam is totally internally reflected.



Endoscopes have two bundles of optical fibres inside the flexible tube, and each bundle consists of thousands of fibres. One bundle transmits the light from the surgeon's end to the patient so that the surgeon can see. The other bundle carries the image back to the surgeon via a microscope, video screen or computer.

Optical fibre communications

Optical fibres have replaced most metal cables used in communications. Electrical signals from computers, telephones, televisions and fax machines are converted to pulses of light using a laser. These light pulses are then sent along optical fibres that can transmit the signal over large distances.

Optical fibres are much lighter, and the same thickness of fibres can transmit thousands more messages than copper wire cables can.

How the eye focuses light

Light enters the eye through the transparent cornea that covers the front of the eye. The coloured part in the front of the eye is called the iris. This is a ring of muscle that changes in size and thus controls the amount of light that enters the eye. The light passes through the pupil, the lens and the jelly-like substance inside the eye and finally hits the retina. The retina contains structures called *vision receptors*, which detect light.

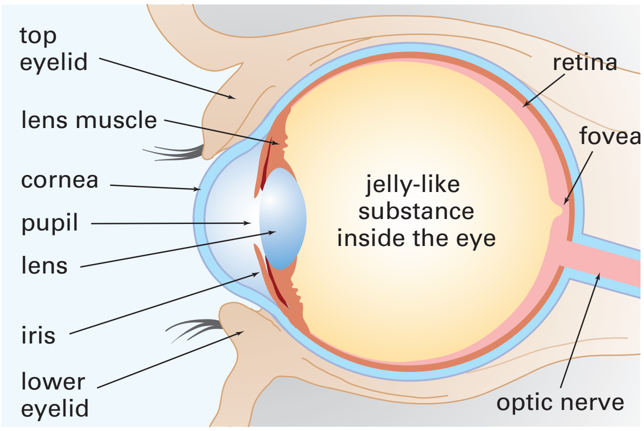
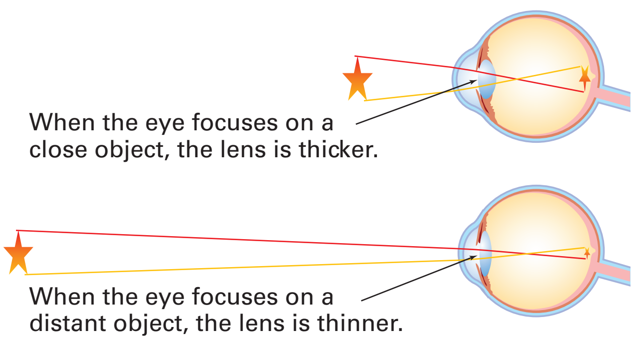


Fig 6 A cross-section of the human eye

Both the cornea and the lens refract the light and focus it onto the retina. The lens is much better than a glass lens because it can change shape to focus near objects and distant objects. To focus on close objects, tiny muscles around the lens make it thicker and more sharply curved. When you focus on distant objects, the lens becomes thinner and flatter.

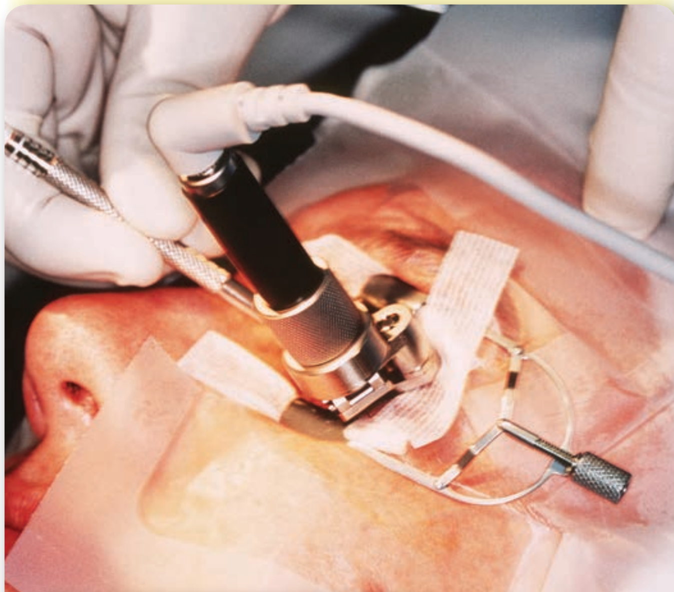


Corneal transplants

When a person's cornea becomes cloudy as a result of disease, injury or infection, their vision is reduced, often making them blind. In a surgical operation called a *corneal transplant*, a damaged cornea can be replaced by a donated healthy one.

In a corneal transplant, an eye surgeon, called an ophthalmologist (OFF-thal-MOL-o-gist), cuts a circular section of the damaged cornea using a tool that works in the same way as a round pastry cutter (see photo). The damaged section of cornea is removed and replaced with the same-sized section of a healthy cornea. The new cornea is held in place by hair-like stitches.

Corneal transplants are the most succesful of the organ donation transplants. Over 90% of all patients have restored vision after the operation. The greatest risk with corneal transplants is tissue rejection. This is where the body of the patient rejects the donor's eye tissue. The eye swells and the two types of tissues never bind together.



WEBwatch

Use the internet to find out more information on corneal transplants and organ donation of eyes. Try entering the following words in the search engine: *corneal transplant* and *eye organ donor*.

Check

1 Match these words with their descriptions:

image	reflection	incident ray
converging	plane mirror	refraction
focus	convex mirror	diverging

- a A mirror that is flat and not curved
- b When sound or light strikes a surface and bounces off
- c The ingoing ray of light
- d The point at which light rays meet after passing through a converging lens
- e A picture of an object formed after light rays have been reflected or refracted
- f Light rays that come together

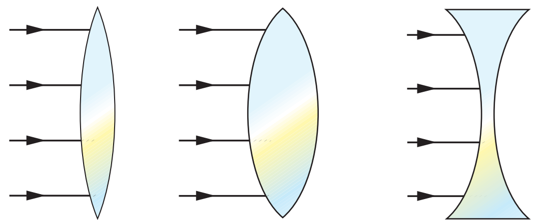
2 a How could you demonstrate to someone that light and sound are forms of energy?
b Apart from the things mentioned on page 29, name some other things that convert light or sound into other forms of energy.

3 Why is the sign on this van written like this?

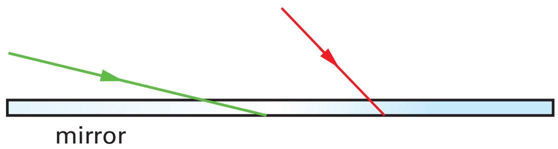
4 Explain the difference between the words *reflection* and *refraction*.

5 Some substances are transparent and some are opaque. Describe the differences between the two terms, giving two examples of each.

6 Copy the drawings below and show what happens to the light rays when they pass through the lenses. In each case label the focus.



7 Two light beams strike a plane mirror as shown in the diagram below. Copy the diagram and show the normal and the reflected rays.



8 Two plane mirrors are placed at right angles to each other. A light ray is shone onto mirror 1 at 30° to the mirror.
a At what angle will the beam strike mirror 2?
b Will the reflected ray from mirror 2 be parallel to the original incident ray? Explain.

9 Reflection is a property of light. Briefly describe how you would demonstrate two other properties of light.

10 Describe what happens to light rays from when they enter the eye until they hit the retina.

11 When you read these words, the lens in each eye automatically adjusts to focus on the words. Now look out of a window. Immediately you focus on distant objects. Describe what happens to the lens in your eye when you do this.

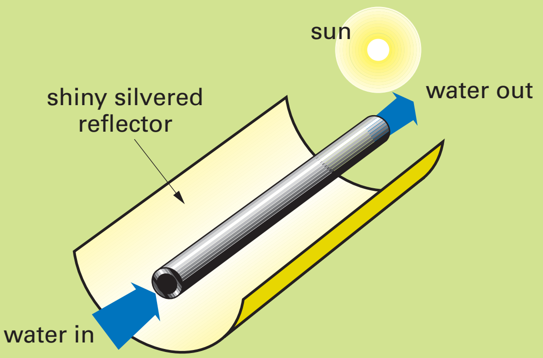
12 Some substances are transparent, some are opaque, while others are translucent. Use a dictionary to find out what the word *translucent* means.

Challenge

1 The diagram below shows a solar hot water heater using a semi-circular shiny, silvered reflector.

a Explain how you think the heater works.

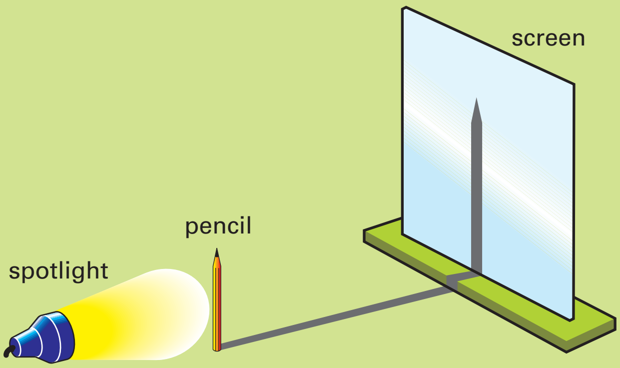
b Where would you place the water tube to get the maximum heating efficiency?



2 A pencil 15 cm long stands vertically on a bench 30 cm from a small spotlight. A screen is placed 1 m away from the spotlight and a shadow of the pencil forms on it.

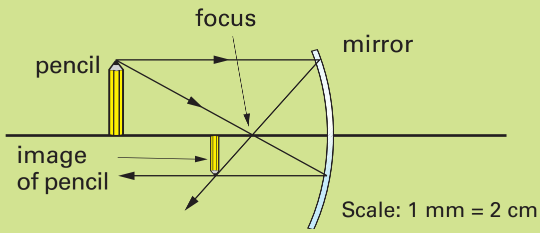
a Which property of light is being shown here?

b How tall will the shadow be?



3 What type of mirror (plane, concave or convex) would be best to use as a rear-vision mirror with a wide field of view. Your teacher will give you the mirrors to help you with your decision.

4 A pencil 20 cm high was placed 60 cm in front of a concave mirror of focal length 20 cm. The ray diagram (top right) shows that the image of the pencil is upside down and smaller than the object.



Do a similar drawing to find out what happens to the image if the pencil is placed 100 cm in front of the mirror.

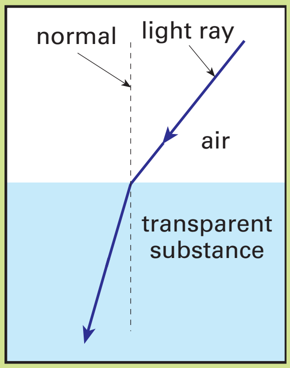
5 A converging lens has a focal length of 20 cm. If an object 15 cm high is placed 40 cm from the lens, use a ray diagram to describe what the image will be like.

6 Design the following items using mirrors.

a Make a periscope that can be used to see things around corners.

b Use a concave mirror to make a solar cooker.

7 This diagram shows a light ray hitting the surface of a transparent substance. The light ray refracts at the surface and bends towards the normal.



How much the refracted ray bends depends on the type of substance. The table below shows different substances and their refractive index. The higher the refractive index, the greater the refracted ray is bent.

Substance	Refractive index
air	1.00
water (at 25°C)	1.33
ethanol	1.36
glass	1.52
diamond	2.40

a Does light bend more when it goes from air to water, or when it goes from air to glass? Justify your answer.

b Glycerine has a refractive index of 1.47. Does glycerine bend light more or less than glass does?

c Predict what happens when a light ray passes from air to glass to water and out to air again. Draw a diagram of your prediction.

2.2 Light and colour

Rainbows make a ribbon of colours in the sky after rain. They form when sunlight passes through the raindrops. The drops split the white light from the sun into a **spectrum** of colours.

The colours that make up the spectrum are continuous and blend into each other, but for convenience we say there are seven colours—red, orange, yellow, green, blue, indigo and violet. The splitting up of white light into this spectrum of colours is called **dispersion**. This occurs because each colour is refracted slightly differently when it passes through a raindrop.

White light is also dispersed into separate colours when it passes through a glass prism.

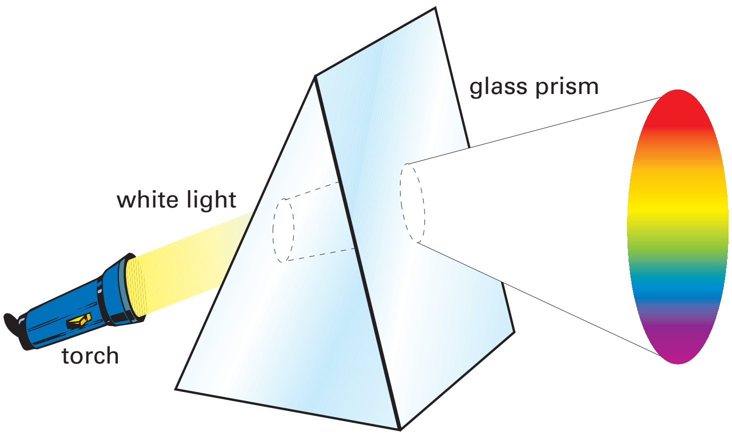


Fig 7 A glass prism disperses white light into colours because each colour is refracted slightly differently. Violet light is refracted more than red light and so appears at the bottom of the spectrum.

Why are things coloured?

Why is a leaf green, milk white and a tomato red?

When white light hits a leaf, most of the colours in the white light are absorbed. Only the green light is reflected, and it is this colour that reaches your eye. So you see the leaf as a green colour.

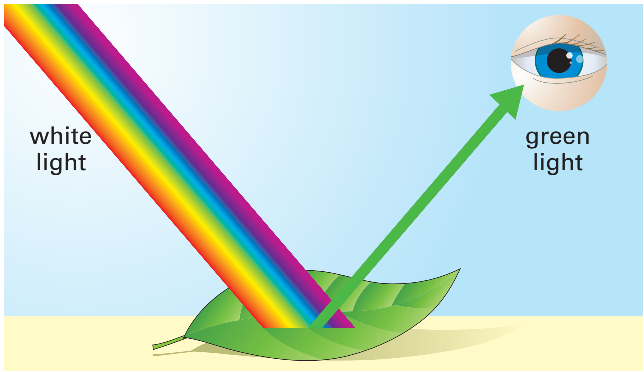


Fig 8 A leaf reflects the green colour in white light and absorbs the others, so it appears green.

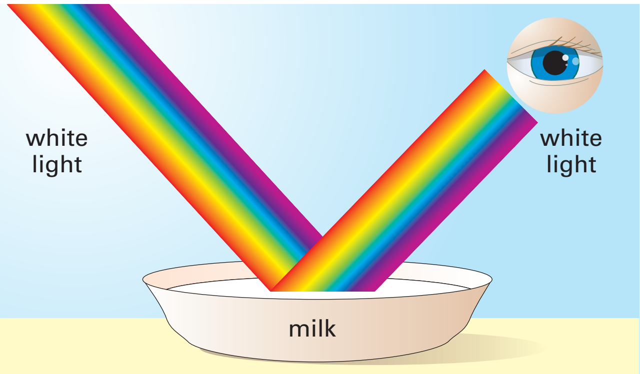


Fig 9 Milk reflects all the colours, so it appears white.

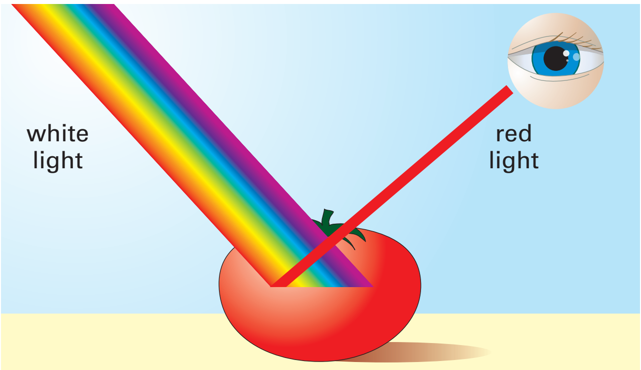


Fig 10 A red tomato reflects only red light and absorbs the others.

Filters made of coloured glass or plastic can also change the colour of light. When white light hits a red glass filter, the glass allows the red light to pass through and absorbs all the other colours. The colour of the filter tells you what colours it transmits (allows to pass through).

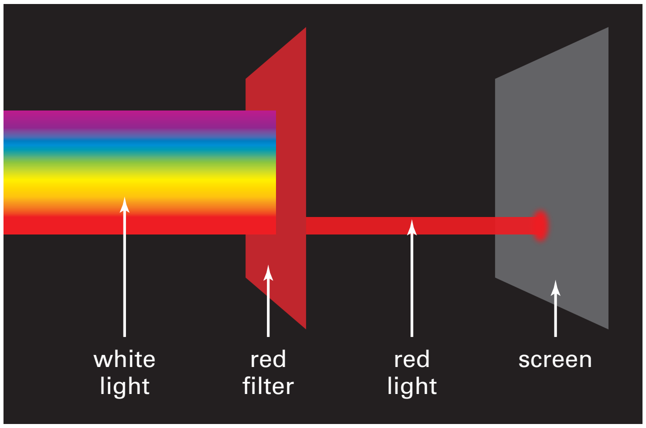


Fig 11 Coloured filters transmit their own colour and absorb the other colours.

What happens when you view a red tomato in green light? Since the tomato reflects only red light and absorbs all the others, green light is absorbed by the tomato. This means no light reaches your eyes, and the tomato therefore looks black.

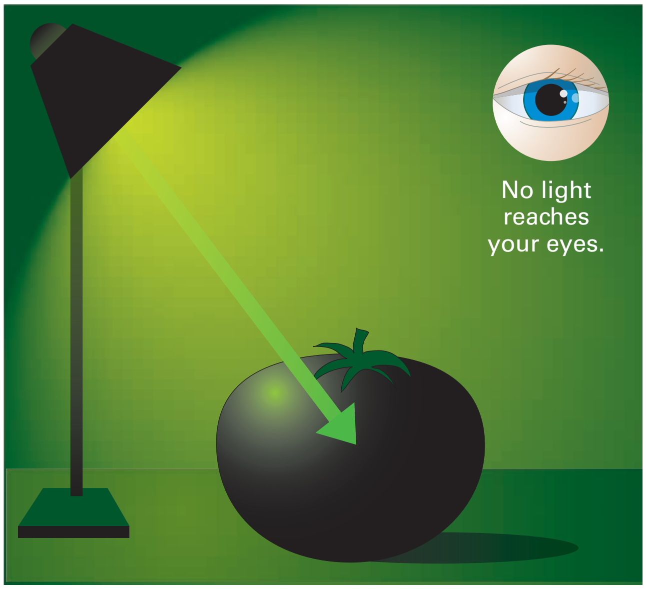


Fig 12 A red tomato will look black in green light because it absorbs all colours except red.

Investigation 6 Colours

Aim

To observe the effects of filters and coloured cards on white light.

Materials

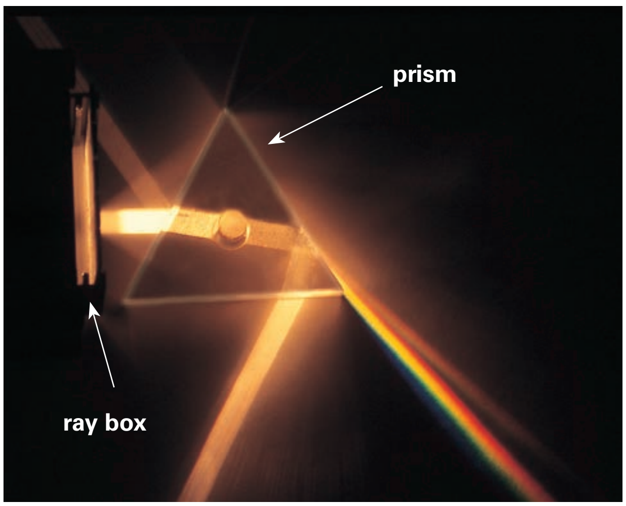
- ray box kit and power pack, with colour filters
- piece of white paper
- pieces of coloured card (red, green, yellow, blue)

Planning and Safety Check

This investigation is best done in a darkened room.
Make sure you ask your teacher to check your set-up before you turn on the power.

PART A Coloured filters

1 Place the ray box on a sheet of white paper. Shine a full beam of light onto a triangular prism and turn the prism until the spectrum of colours is formed.



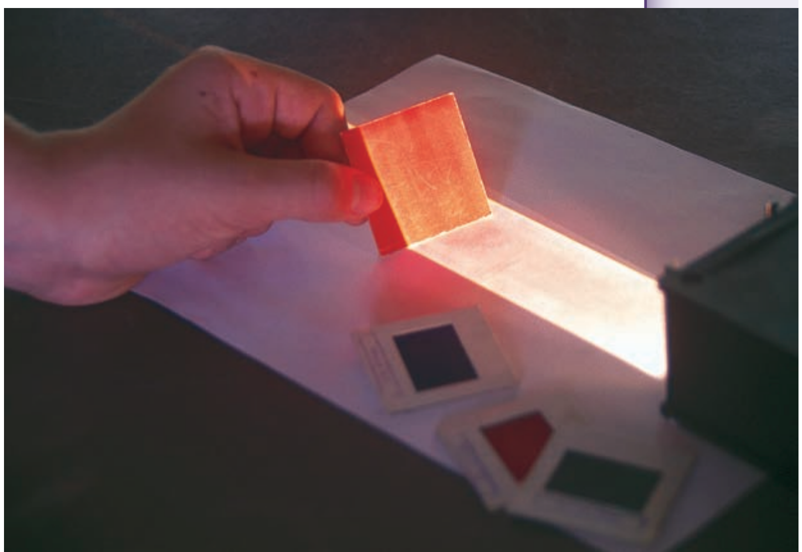
2 Predict what will happen when you put a red filter between the light and the prism.
Try it and record your observations.

3 Try other filters and record your observations.

PART B Coloured objects

1 Shine a full beam of light from the ray box onto a piece of red card. Then place different coloured filters in the ray box and record the colour of the card in each light.
Draw up a table and record your results in the table.

2 Repeat Step 1 with the other coloured cards.



Discussion

1 How do the results in Part A Step 1 help you decide which colour of the spectrum is refracted the most? Which one is refracted the least?

2 Which colours are transmitted and which are absorbed when white light is shone through a yellow filter?

3 Which colours of the spectrum would you see if white light was shone through a red filter and then a green filter? Explain your answer.

4 Explain, using the words *absorb* and *reflect*, why a blue card is blue in white light.

5 What would you see if you placed the blue card in red light? Explain your answer.

Making colours

There are two main ways of making colours. The first way is to shine different coloured lights together. The other way is to mix different coloured paints or pigments together.

Activity

Your teacher will set up three slide projectors (or light boxes) in a darkened room. Each projector will have a different coloured filter, red, green and blue, and the spots of colour will overlap on a white screen.

- What colour do you see when red light and green light overlap? As a challenge, try to suggest why this happens.
- What colours would you see if the screen was red instead of white?

Addition

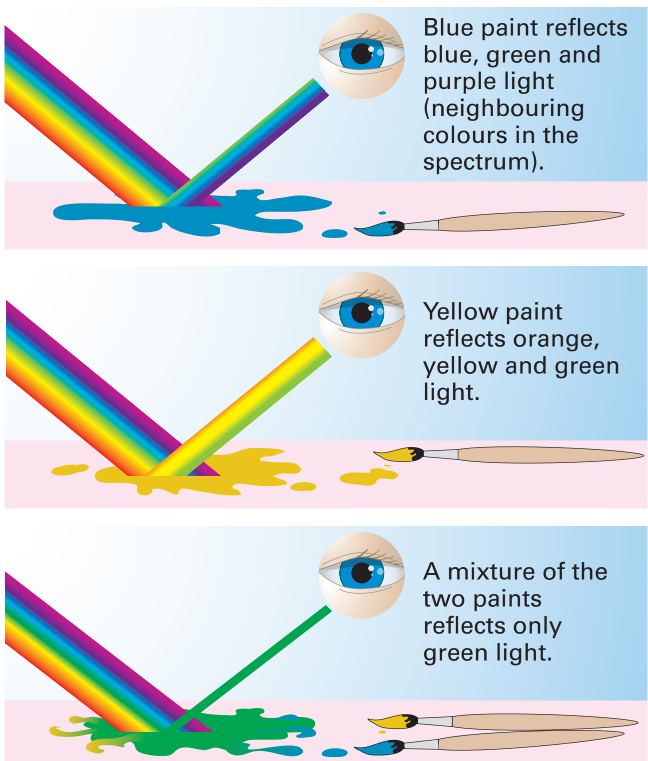
Making colours by adding different coloured lights together is called **addition**. White light can be made by shining red, green and blue lights together as shown below.

Subtraction

The method of making colours by mixing various paints together is called **subtraction**, because each paint colour subtracts or absorbs colours from white light. For example, blue paint reflects blue light and absorbs the rest.

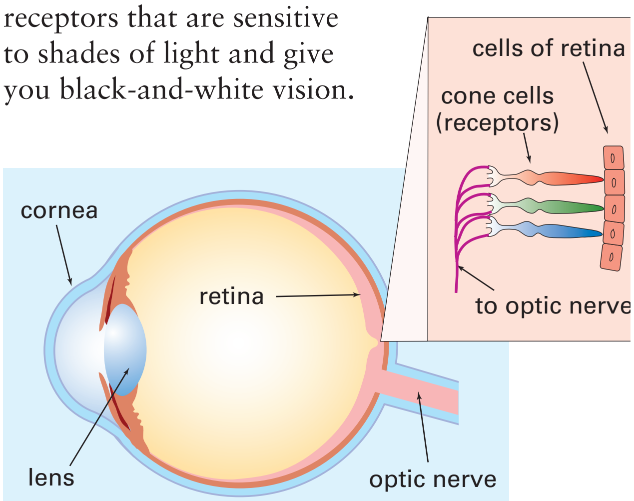
Suppose 5-year-old Emily has seven pots of paints, and each one is a different colour of the spectrum. When she mixes them all together, she ends up with a black mess. What happens is that each of the seven paints absorbs its colour from white light. When they are all mixed together, all the white light is absorbed and none is reflected. So the mixture looks black.

The diagram below shows how green is the only colour reflected when blue and yellow paints are mixed. All the other colours are absorbed.

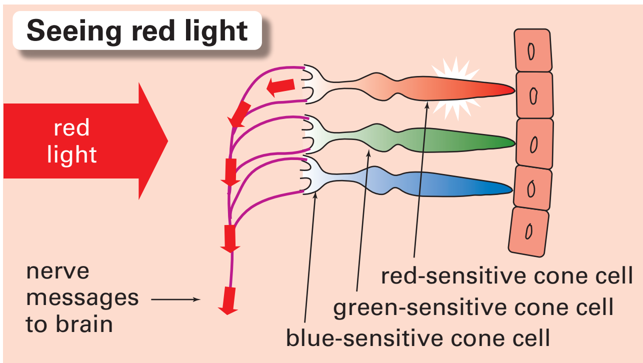


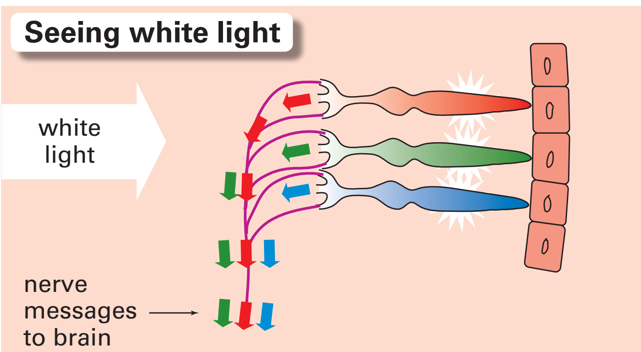
Seeing colours

The retina that lines the inside of the human eye contains receptors that are sensitive to colours and give you colour vision. There are other receptors that are sensitive to shades of light and give you black-and-white vision.



The colour vision receptors are called *cone cells*. There are three types of cone cells—one type is sensitive to blue light, another to green light and the third to red light. The diagrams below show how you see colours.





Colour blindness

Colour blindness is a condition that causes people to have trouble distinguishing between certain colours. The most common form of colour blindness is red–green colour blindness. People with this condition cannot see, or they confuse, shades of red, green and brown.

The condition is usually inherited, which means it is passed on from parents to children. In Australia, about 9% of males and about 0.4% of females have some form of colour blindness.

Each of the cone cells in the retina contains a type of light-sensitive pigment. One type of pigment is sensitive to blue light, another to green light and the third to red light.

In people with defective colour vision, one or more of the light-sensitive pigments functions poorly, or, in severe colour blindness, is absent altogether. Generally it is the red-sensitive and green-sensitive pigments in the cones that function poorly, giving rise to red–green colour blindness.

WEBwatch

Go to **www.OneStopScience.com.au** and link to the following websites.

Colour blindness
This website describes colour blindness and lists some of the everyday problems colourblind people put up with.

Ishihara tests for colour blindness
This website contains the Ishihara colour charts to test for red/green colour blindness.

Use the websites above to answer these questions.

1 Does a colourblind person see only in black and white and shades of grey?
2 Is there a cure for colour blindness?
3 Describe three everyday frustrations for colourblind people.
4 Use the Ishihara colour charts to test your colour vision.

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Lights, colour, action!

Colour is a vital part of any stage play or film, and it can be used to produce a response from an audience. For example, the blue light on the characters in Fig 13 gives an impression of coldness and sadness, while the red light in Fig 14 gives warmth and excitement to the scene.

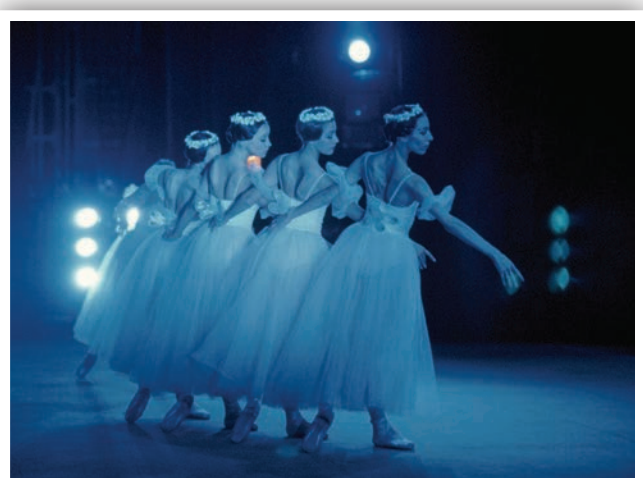


Fig 13 The blue light used in this scene gives a feeling of serenity and sadness.

Fig 14 The red light used in this scene gives a feeling of warmth and excitement.

The coloured lights for theatre or film-sets are made by using coloured filters or gels that are attached to spotlights. The lights can be used to flood the stage with a particular colour, as in the two scenes in the photos, or they can be used to focus on particular characters.

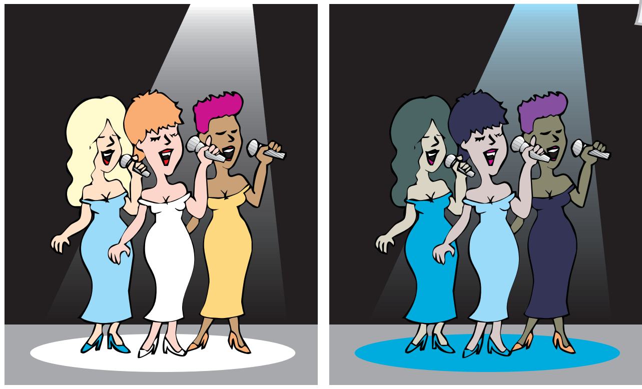


Fig 15 The colours of objects on stage change with different coloured spotlights.

The three characters in Fig 15 are dressed in different colours. Notice how the character dressed in yellow seems to have 'disappeared' in blue light, and you tend to focus your attention on the other two characters.

The character in yellow seems to disappear because her yellow clothes absorb the blue light and do not reflect any light. The character in blue, on the other hand, reflects all the blue light and does not absorb any light.

Using different coloured lights and characters dressed in different coloured clothes, the lighting director can create special effects on stage where characters come in and out of attention.

Questions

1 Suggest why red light flooding the stage gives a feeling of excitement and action. Do any other colours give the same effect?

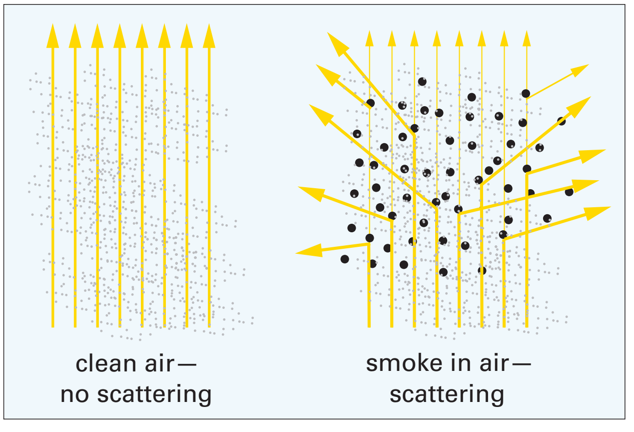
2 Look at the singer in the middle in Fig 15. Explain why the colour of her dress and hair change in blue light.

3 Suppose you were designing the lighting for a scene that is set around a haunted house. Which coloured filters would you use? Why?

4 Why would it be best for the characters in the scene in Fig 13 to wear neutral-coloured clothes (such as white or grey) rather than reds, oranges and yellows? Use the words *reflect* and *absorb* in your answer.

Why is the sky blue?

When a beam of light passes through smoke or dust, some of it bounces off the tiny particles and is reflected towards your eyes. This is why you can see the beam. This bouncing of light from particles such as smoke or dust is called **scattering**. You cannot see a beam of light in clean air because the particles of air are too small to scatter the light.



The air around the Earth contains tiny bits of dust. These are too small to see, but they are big enough to scatter light. Blue light is scattered more by the dust than red light is. As the light from the sun comes through the atmosphere, the blue light is scattered. This scattered blue light bounces from dust particle to dust particle, spreading blue light through the whole sky. This is why the sky normally appears blue.

Why are sunsets red?

When the sun is low on the horizon, the light has more air to pass through as it travels through the atmosphere. Also the lower part of the atmosphere close to the horizon contains much more dust, so the blue light is scattered and the red light reaches your eyes. This is why sunsets are red. The dustier or smokier the atmosphere, the redder the sunset.

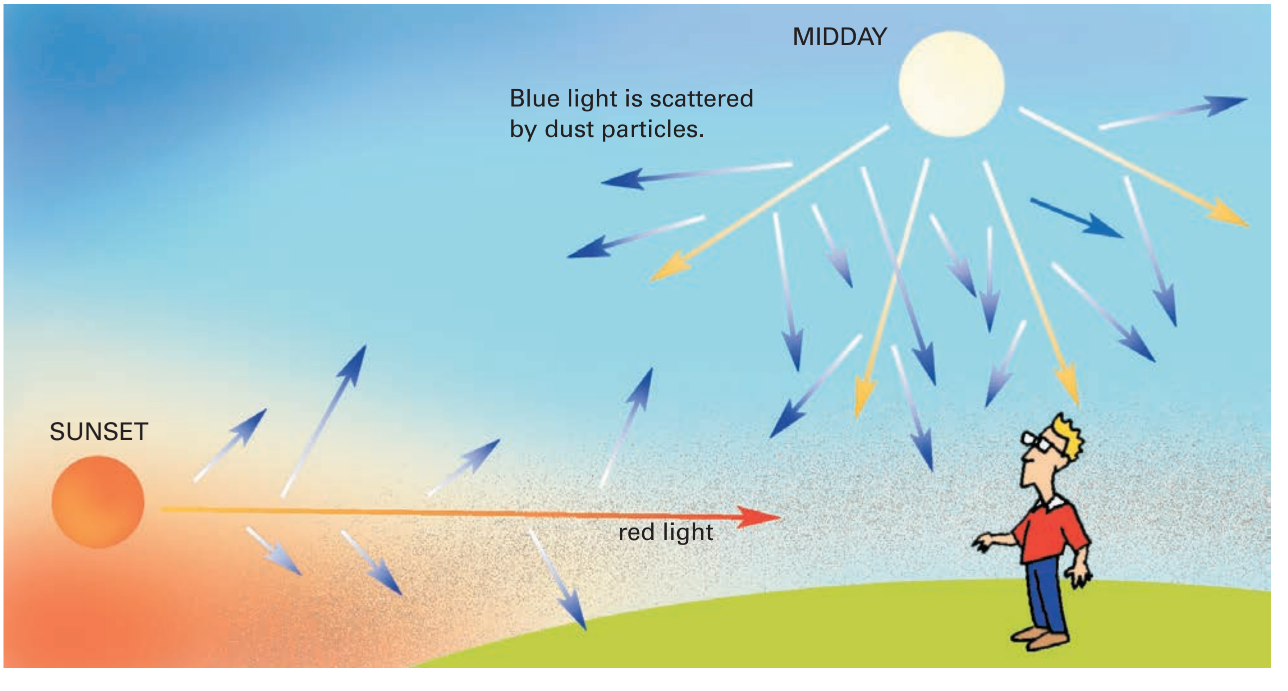
Questions

1 Why do suspensions scatter light but solutions do not?

2 a Why can you see the beam of light from a car's headlights when driving at night in fog?

  b Suggest why yellow lights are more effective than white lights when driving on foggy nights.

3 Suggest why sunsets are redder on cloudy or dusty days than on fine, clear days.



Check

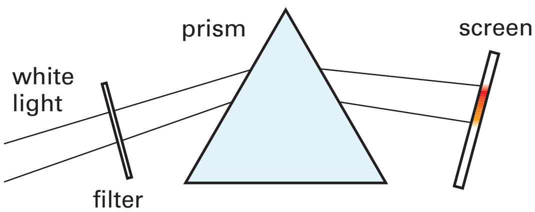
1 Go back to your answer for the second question in Getting started on page 28. Use the words *dispersion* and *spectrum* to explain why you see a rainbow of colours.

2 Use the words *absorbed* and *reflected* to explain why a banana looks yellow in white light.

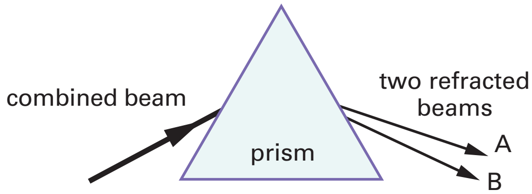
3 What colour would a bunch of green grapes be in red light? Why?

4 A beam of white light shines through a blue filter. Use the words *transmitted* and *absorbed* to explain what happens to the colours in the white light.

5 A beam of white light passes through a filter and then through a prism. The prism disperses the light, and the different colours shine on a white screen. Use the information in the diagram below to work out the colour of the filter.



6 A combined beam of red and blue light hits a glass prism. On the other side of the prism, two separate beams of light are observed.
   a Why did this happen?
   b Which beam, A or B, on the diagram below is red? Give a reason for your answer.



7 Why is the method of creating colours by mixing various coloured paints called subtraction?

8 Suppose green light is shone into your eyes.
   a How do you see green light?
   b Suppose a red light and a green light are shone together into your eyes. Predict what colour you would see. Which type of cone cells would not be detecting a colour?

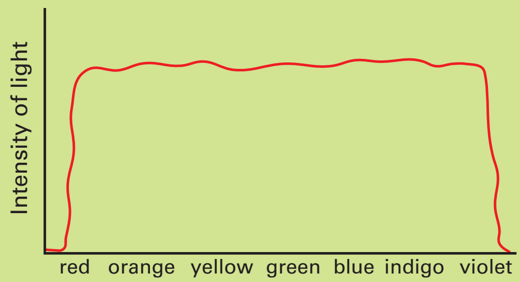
Challenge

1 A beam of light shines through a green filter. A red filter is then placed in front of the green filter. What will happen?

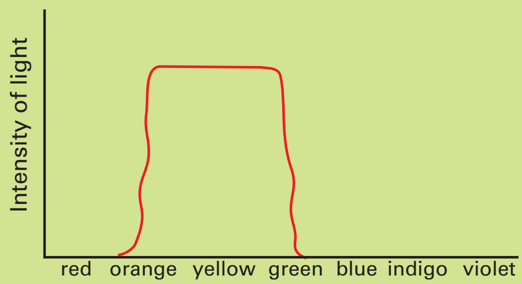
2 Some people believe that there are only six colours in the spectrum. Use library resources to find out which colour is in dispute.

3 When white light was detected by a light probe connected to a datalogger, graph 1 was obtained. It shows that white light contains equal intensities of all the spectral colours.
   a When a coloured filter was placed in the path of the light, graph 2 was obtained. Infer the colour of the filter.
   b Predict and draw the shape of the graph you would get if a violet filter was placed in the beam of white light.

Graph 1



Graph 2



2.3 Light and sound waves

In the first section you learnt that sound and light are both forms of energy. How do these forms of energy travel from place to place?

Sound waves

Consider the following experiences.

- If you put your ear to a metal railing, you can hear the sound of someone tapping on it a long way away.
- When you are at the beach swimming underwater, you can hear the sound of a motorboat more than a kilometre away.
- The photo below shows an electric bell inside a large jar. The bell is heard when the switch is pressed. However, if all the air is pumped out of the jar, you cannot hear the bell. (Your teacher may set this up for you.)

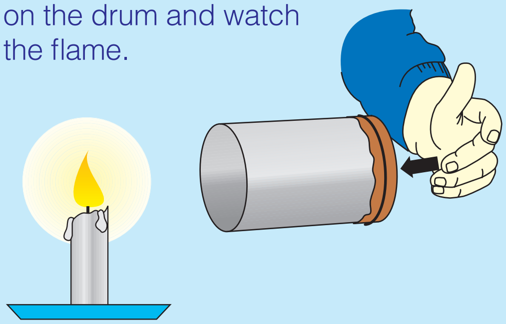
Sounds travel in solids, liquids and gases. This is why you can hear sounds in a metal railing, in water and in air. But when the air is pumped out of the jar, no sounds are heard.

Activity

To observe an effect of sound waves travelling through the air, your teacher will set up the following equipment, or you could set it up at home.

You will need a candle and a drum. (You could use a large can open at both ends with a rubber skin tied over one end.)

1. Make sure there is no wind in the room. Light the candle. Hold the open end of the drum close to the flame. Tap the skin on the drum and watch the flame.



2. For a more dramatic effect, hit the drum skin with a drumstick.

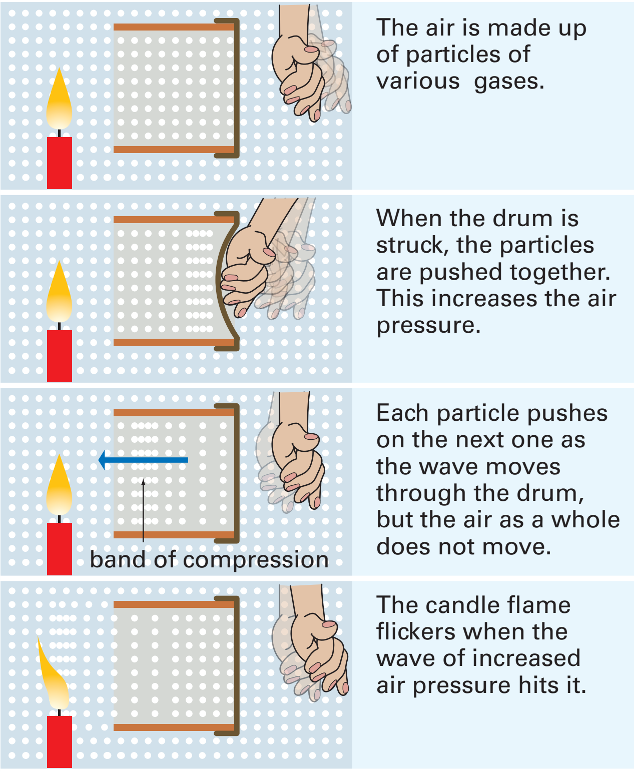
   How do you think sound waves are responsible for the movement of the candle flame?

Sounds are made by vibrating objects. The vibrating strings on a guitar make sounds, as does the vibrating skin on a drum when it is struck. These vibrations are carried through the air as *sound waves*.

The activity showed that the sound from the drum travelled through the air. The air 'pushed' on the candle flame and made it flicker. These 'pushes', or sound waves, are the way sounds travel in air.

You may also have noticed that a soft tap on the drum made a soft sound and produced a small flicker in the flame. A harder hit on the drum made a louder sound and produced a larger flicker in the flame.

Sound waves are made up of bands of high and low air pressure. The energy from the vibrating source is transferred from one air particle to another as the sound waves travel.

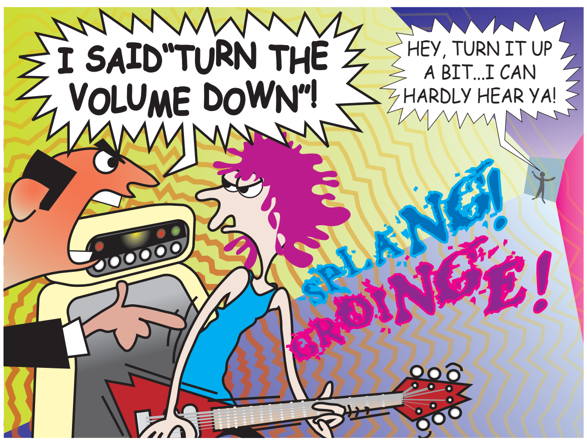


Working with technology

To see how sound waves are carried through the air, open the Sound waves animation at www.OneStopScience.com.au.

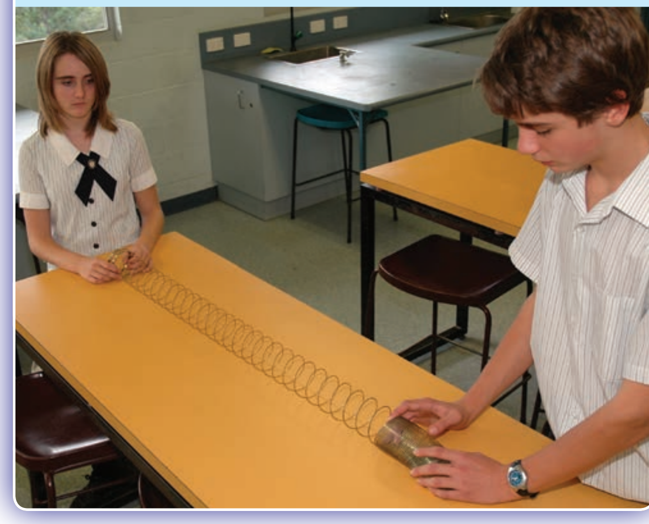
OneStopScience

Sound waves spread out in all directions through the air from the source of the sound. As they do this, the energy in the waves gradually decreases and the sounds become fainter.



Activity

Your teacher may show you how you can model sound waves in a slinky spring. The waves travel through the spring as compressions.



The speed of sound

When someone shouts at you from the far end of the schoolground, you hear the sound instantly. From this you can conclude that sound travels very rapidly in air.

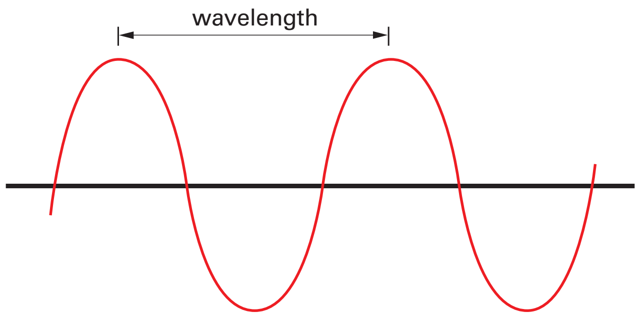
Sound travels at 330 metres per second in air at 0°C. However, it travels even faster in other substances. The table below gives the speed of sound in various substances.

Substance	Speed of sound (m/s)	Speed of sound (km/h)
air (at 0°C)	330	1 188
air (at 15°C)	342	1 231
oxygen (at 0°C)	317	1 141
water (at 0°C)	1 410	5 076
water (at 15°C)	1 450	5 220
lead (at 20°C)	1 200	4 320
copper (at 20°C)	3 500	12 600
iron (at 20°C)	5 100	18 360
granite (at 20°C)	6 000	21 600
wood (at 20°C)	about 5 000	about 18 000

Light waves

Light from the sun is a type of radiation that comes to us in the form of waves called *electromagnetic waves*. Unlike sound waves, light waves do not transfer their energy through the particles of gases, liquids or solids. Light waves can travel through the vacuum of space.

The various types of electromagnetic waves are different because they have different wavelengths.



Light is just a small part of the **electromagnetic spectrum**. Microwaves, infrared radiation and X-rays are other parts.

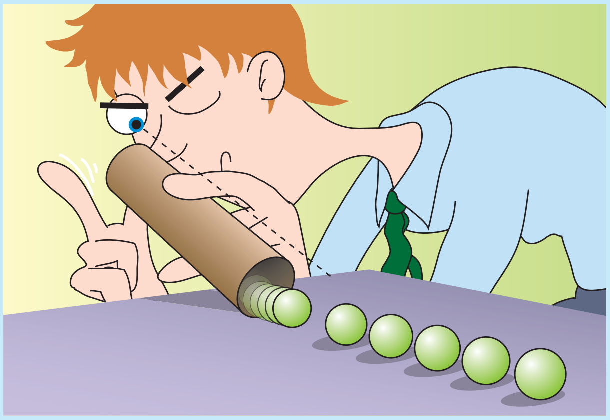
Visible light has a wavelength of about 0.000 000 5 m, while radio waves have very long wavelengths of about 10 m. The radiation with the shortest wavelength is gamma radiation, a very high-energy radiation that causes injury to the cells of living things. Generally, the shorter the wavelength of the radiation, the higher the energy of the waves.

Activity

Models for light and sound

On the previous page you used two models to explain how sound behaves—a theoretical particle model and an actual spring model.

- Suggest ways of making an actual particle model to show how sound travels. You might like to use marbles or styrofoam balls attached to pieces of string.



- Use your model to explain to other people the properties of sound.
- Devise a second model to explain how light travels.
- What are the limitations of your models?

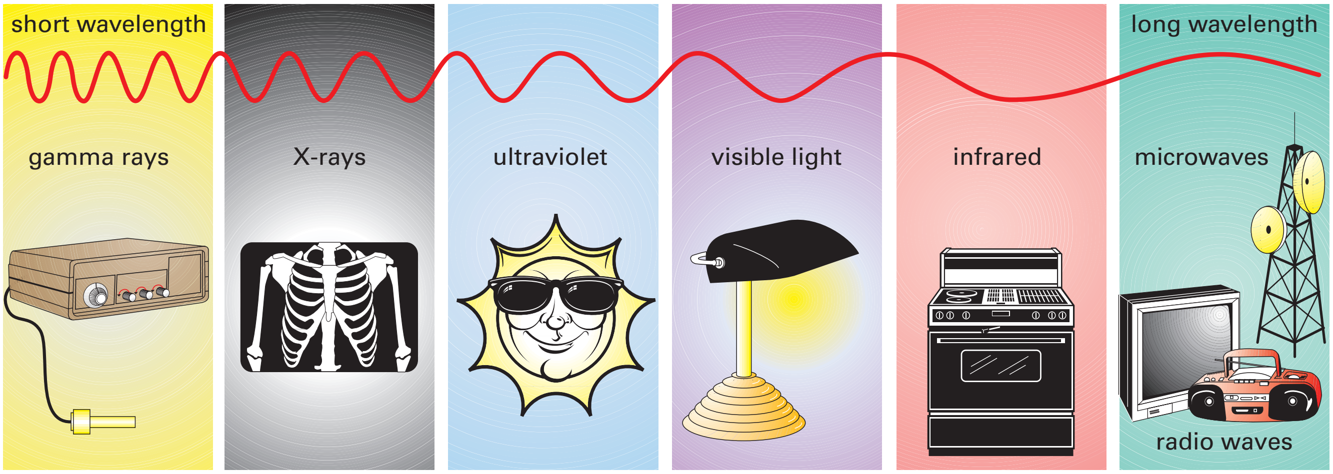


Fig 16 The electromagnetic spectrum. The short wavelength waves carry more energy than long wavelength ones.

Why sailors wear polaroids

Polaroid is a brand name for a type of sunglasses that reduce glare from reflected light, particularly the light reflected from water. The lenses in these sunglasses contain special filters called *polarising filters* which reduce the light reflected from surfaces. How do these polarising filters work?

Fig 17 A scene taken without a polarising filter on the camera lens (top) and the same scene taken with a polarising filter (bottom).

Polarised light

When you flick a rope up and down, you can make regular vertical waves in the rope. If you flick it sideways, you can make horizontal waves.

Light rays behave like the waves in a rope. A ray of light contains waves that vibrate vertically, horizontally and in all planes in between. So if you switch on a light, billions of light rays are emitted, all vibrating in different planes.

A polarising filter is a transparent substance that allows light waves that vibrate in only one particular plane to pass through.

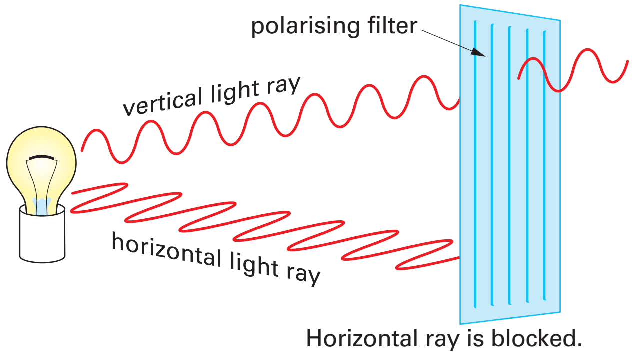


Fig 18 Only the light rays that vibrate vertically are able to pass through this polarising filter.

When light is reflected from water or wet roads, it is often polarised; that is, the reflected light waves are in one plane only. Most of these reflected polarised waves vibrate horizontally. So the lenses in polarising sunglasses contain filters which allow only vertically polarised light through and block the horizontal waves. This is how your polarising sunglasses reduce glare when you are at the beach or driving along wet roads.

Inquiry

1 Go outdoors and look at the reflections from still water, glass, a wet surface or grass through a polarising filter. Observe what happens when you slowly rotate the filter.

2 Reflected light from water or glass is polarised, but the reflected light from shiny metals is not. Use a polarising filter to test this.

3 Hold two pairs of polarising sunglasses up to the light, one in front of the other. Slowly rotate one and you will find that at a certain position no light can be seen. Why?

Light waves and refraction

In the first section of this chapter, you learnt that light refracts when it passes from one transparent substance to another. This is because light slows down as it passes from air to glass.

Light, like all types of electromagnetic radiation, travels at incredible speed—about 300 000 000 m/s or 3×10^8 m/s. This is about a million times faster than the speed of sound. No wonder you see the lightning before you hear the thunder of a distant thunderstorm!

The speed of light in glass is 1.98×10^8 m/s—about 1.5 times slower than in air. When light passes from air to glass at an angle, it slows down and bends towards the normal.

How far away is that thunderstorm?

You can use the fact that light travels nearly one million times faster than sound in air to calculate how far away a thunderstorm is.

It takes sound 3 seconds to travel 1 km in air. So when you see the lightning flash, count the seconds by saying 'one thousand, two thousand ...' then calculate how far away the storm is.

WEBwatch

Go to **www.OneStopScience.com.au** and follow the links to **Lightning and Thunder** to find out more about lightning and thunder.

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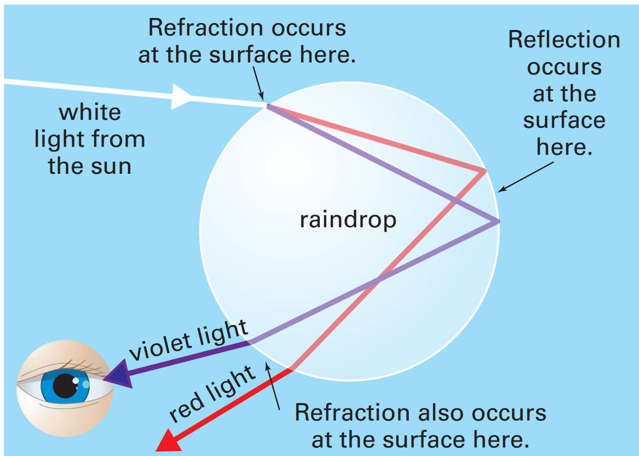
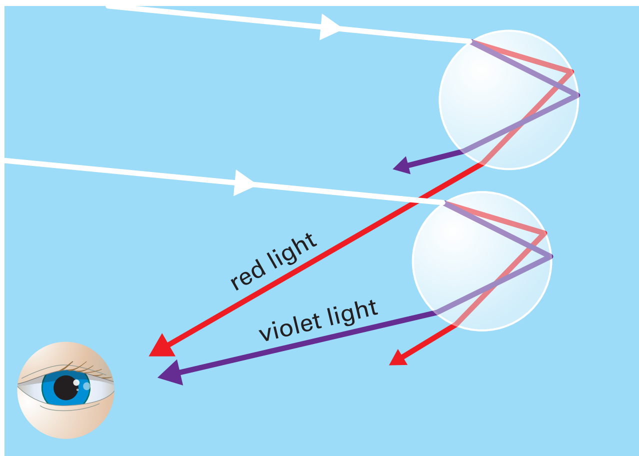
How a rainbow forms

A drop of water has the same effect on light as a prism does—it is dispersed into the spectrum of colours. But why is violet light refracted more than red light?

It has been found that different colours of light have slightly different speeds in the same substance. For example, the speed of red light in water is 2.280×10^8 m/s, while that of violet light is slower, at 2.255×10^8 m/s. This slight difference in speed means that violet light bends more than red light when it passes through a drop of water.

When sunlight hits a raindrop at a particular angle, the white light is dispersed into the spectral colours. These colours come out of the raindrop at different angles. Because of this, your eye only sees one colour from each drop (see the top diagram). The red light in the rainbow comes from the droplets highest in the sky and the violet light from the droplets lowest in the sky. So red should be on top of the rainbow and violet underneath. Check this in the rainbow photo on page 39.





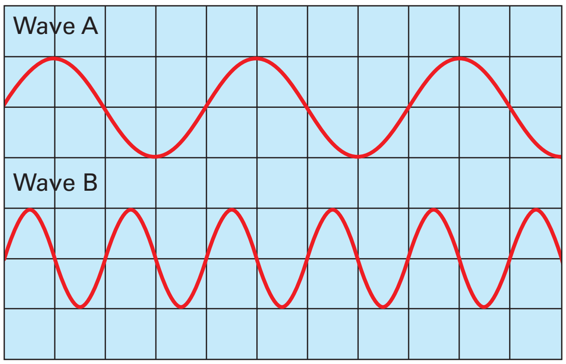
Check

1 Sound cannot travel through:
- A wood
- B fresh water
- C outer space
- D the ocean
- E the Earth's crust

Justify your answer.

2 Decide whether each of the statements below is true or false by referring to the table of speeds of sound on page 48. For each case, give reasons for your decision.
- a Sound travels faster through gases than through liquids.
- b Sound travels faster through warm air than through cold air.
- c Sound travels at the same speed through all gases.
- d Sound travels faster through metals than through non-metals.

3 Two waves were drawn on centimetre square graph paper.
- a Which wave has the longer wavelength?
- b What is the wavelength of wave A?



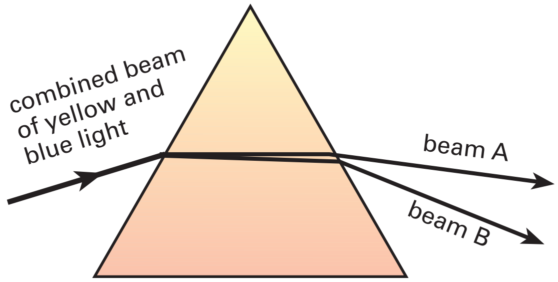
4 Why do you hear thunder after you see the lightning in a far-off storm?

5 Light is one type of electromagnetic radiation. Name three others.

6 Look at the electromagnetic spectrum at the bottom of page 49.
- a Which types of radiation can be detected by the human body?
- b Which receptors do you use to detect them?
- c Which types of radiation can be used for communicating with other people?
- d Which type of radiation is commonly referred to as heat?

7 Using your knowledge of sound and light, write a paragraph outlining the similarities and differences between them.

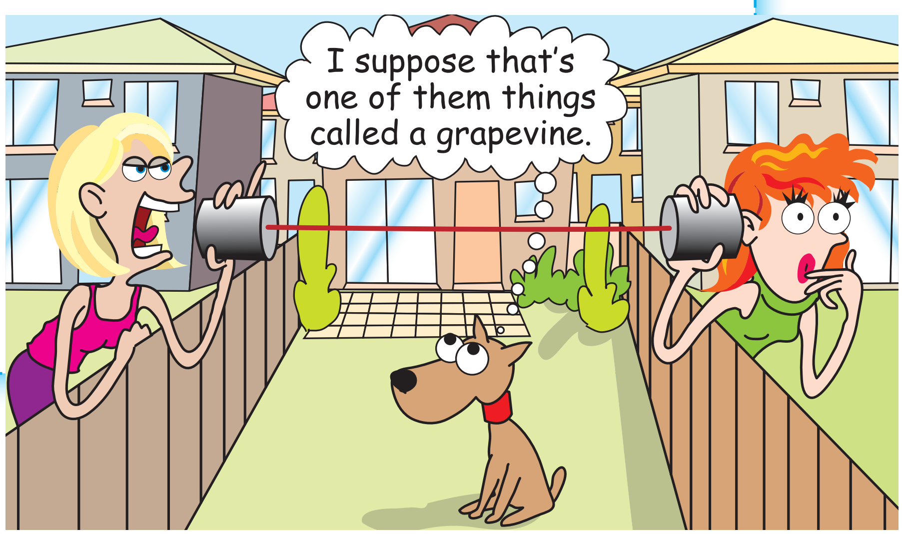
8 A combined beam of yellow and blue light was shone onto a prism. Two separate beams emerged from the other side. Use your knowledge of light waves to explain why beam B is blue.



9 How does the candle and drum demonstration on page 47 show that sound is a form of energy?
Use the particle model to explain why there is more energy in a loud sound than in a soft one.

10 Design an experiment to show that light, unlike sound, does not need a substance such as air in which to travel.

11 A string telephone can be made from two metal cans and some string. Suggest why:
- a the telephone works only when the string is stretched tight
- b the telephone does not work when a third person touches the string.



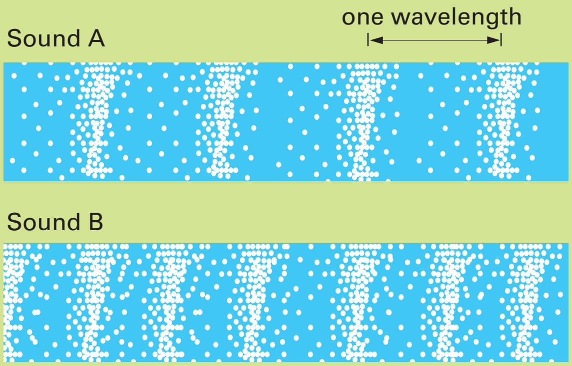
Challenge

1 Sam is a long way away from you and he is trying to tell you something. He rolls up a piece of cardboard in the shape of a cone and speaks through it. You can now hear him. Explain in terms of sound waves why this happens.

2 Suggest why you can hear sounds better when the wind is blowing towards you than when it is blowing away from you.

3 In a science fiction movie, the goodies destroy an enemy spacecraft in deep space with laser guns, and they hear it explode as they fly past. What is wrong with this scene?

4 The diagrams below show two different sounds. Different sounds have different wavelengths. The wavelength of sound is the distance between the bands of compression of the particles.



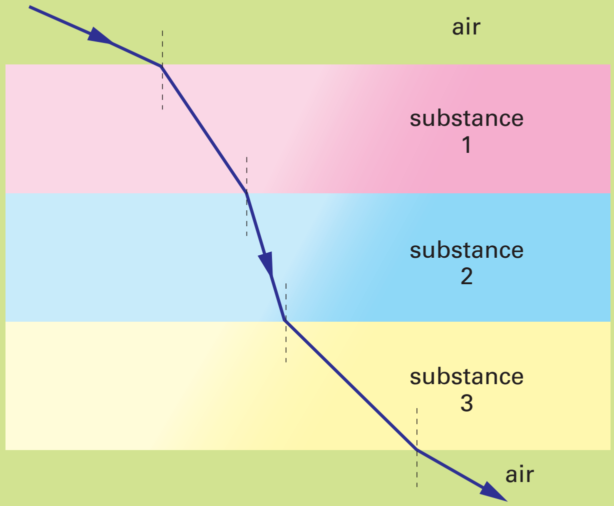
a Which sound has the shorter wavelength?

b High-pitched sounds have shorter wavelengths than low-pitched sounds. Which sound has the higher pitch: A or B?

c Hold a ruler over a bench and flick it. It vibrates and makes a sound. Notice how the ruler vibrates. Increase the length of the ruler and flick it again. Look at the way it vibrates and listen to the pitch.

d How do you think the wavelength, the speed of vibration and the pitch of the sound are related?

5 The diagram below shows a ray of light passing from air through three different transparent substances.



a Does light travel faster or slower in substance 1 than in air? Give a reason for your answer.

b In which substance is the speed of light closest to that in air?

6 On page 48 the particle model was used to explain how sound waves travel in air. Use the model to explain why sound travels faster in liquids than in gases, and even faster in solids.

7 A person fires a gun and hears an echo from a cliff after 5 seconds. If the temperature is 15°C, use the speed of sound on page 48 to calculate how far away the cliff is.

8 Suppose someone is talking about you in the next room. When you put your ear to the wall, you can hear what the person is saying.

a Try to explain in terms of waves why you can hear sounds through the wall but cannot see light through it.

b Which types of radiation can pass through walls? (Hint: Refer to the electromagnetic spectrum on page 49.)

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

1 Reflection is a ______ of light and sound. Another property of light is that it travels in ______.

2 The ______ states that the angle of ______ is equal to the angle of reflection.

3 ______ of light occurs when a beam of light passes from one ______ substance into another, eg from air to water. The amount of refraction depends on the substances.

4 White light can be ______ by a prism into the colours of the ______.

5 A coloured object reflects some colours and ______ the rest. The colour you see depends upon the colours that are reflected.

6 Different colours can be made by mixing different coloured lights (addition) or by mixing paints (______).

7 Sound waves are produced by ______ objects and travel through gases, liquids and solids.

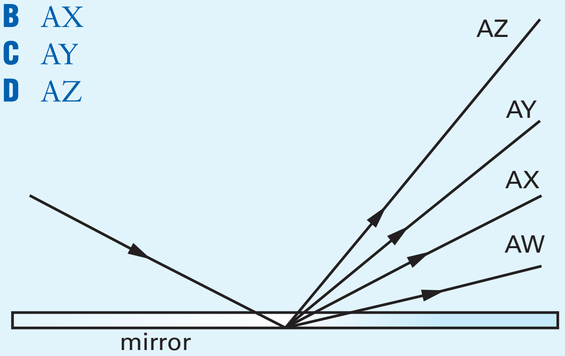
8 Light is a form of ______ radiation that can travel as waves through a ______. The speed of light is much greater than the speed of sound.

absorbs
dispersed
electromagnetic
incidence
law of reflection
property
refraction
spectrum
straight lines
subtraction
transparent
vacuum
vibrating

Working with technology: **Try doing the Chapter 2 crossword at www.OneStopScience.com.au.** OneStopScience

REVIEW

1 A ray of light hits a mirror. The path of the light ray after it is reflected is shown by light ray:
A AW
B AX
C AY
D AZ

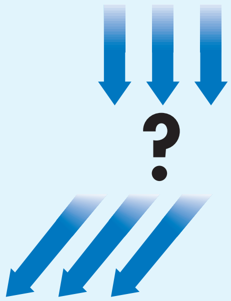


2 Ian is using a fine spray to water his seedlings. When he sprays the water into the air, he sees the colours of a rainbow. The rainbow is caused by:
A the reflection of light
B the transmission of light
C the absorption of light
D the dispersion of light

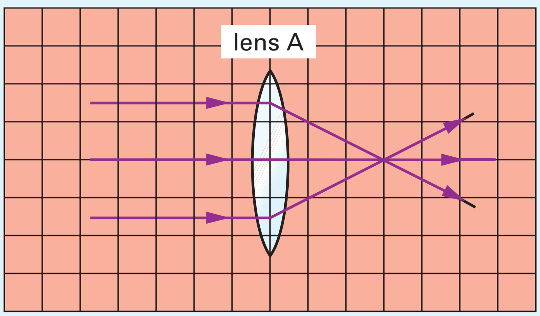
3 Each of the drops of water in question 2 is acting like a:
A glass prism
B lens
C plane mirror
D concave mirror

4 Three parallel light rays shine through a transparent object and are refracted as shown below. Which shaped object will cause this refraction?

A a rectangular glass block
B a converging lens
C a diverging lens
D a triangular glass prism



5 Three parallel light rays shine onto a converging lens. The scale drawing below shows the results. Each square of the grid is 5 cm × 5 cm.



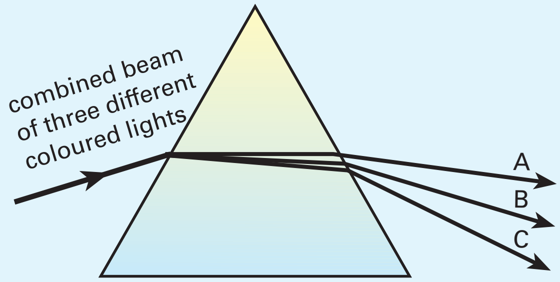
a What is the focal length of the lens?
b Suppose lens A is replaced with another converging lens, B. This lens has a focal length of 25 cm. What is the shape of lens B compared with that of lens A?

6 A beam of light consisting of red, green and violet light shines on a white screen. A coloured filter is placed over the beam. Green light is seen on the screen.

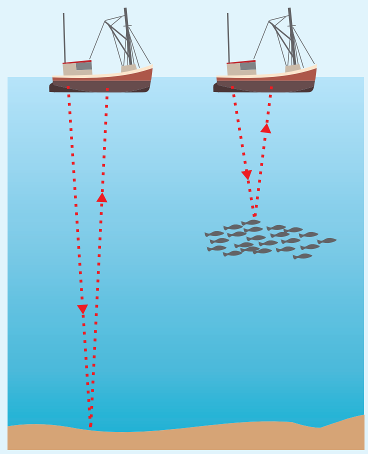
a Which colours are being transmitted?
b Which colours are being absorbed?
c Infer the colour of the filter.

7 Which colour light is shining in your eye when all three types of receptors in your retina are sending messages to your brain? Explain your answer.

8 A combined beam of three different coloured lights is shone through a prism. Two of the coloured lights are green and red. The other coloured light is either yellow or blue. The diagram below shows the results. If beam C is green, work out which colour beams A and B are. Explain your answer.



9 Echo sounders send sound waves through water to determine its depth. They can also be used to find the depth of shoals of fish. Suppose a reflected sound wave returns after 0.1 seconds, and a second one returns after 0.2 seconds. The fisherman believes that one echo came from a shoal of fish. (The speed of sound in water at 15°C is 1450 m/s.)



a Which echo came from the shoal of fish?
b How far below the ship is the shoal of fish?
c Suppose the temperature of the water decreases with depth. How would this affect the calculations?

Check your answers on page 295.

Working with technology

Go to www.OneStopScience.com.au to access interactive activities to help you revise this chapter.

OneStopScience

Science as a Human Endeavour

Inventing the microscope

Over 400 years ago, a young Dutch child named Zacharias Janssen was playing with his father's lenses when he suddenly screamed. The church spire he saw was so large it seemed to be coming towards him. When he grew up, Zacharias became a spectacle-maker like his father Hans. He remembered the fright he received as a child and began combining lenses to make small objects bigger. In 1595, he invented the first compound microscope, probably with help from his father. It consisted of two tubes, with one fitted neatly inside the other. There was a lens at each end, and one lens magnified the already enlarged image from the other. The microscope was focused by sliding the tubes back and forth.

The English scientist Robert Hooke improved on Janssen's microscope. When he examined a thin slice of cork (the bark of an oak tree) through his microscope, he was astonished to see a block-like pattern inside the cork. Hooke called these blocks *cells* because they looked like the little cubicles where monks studied and prayed. Amazed by this, other scientists were soon examining parts of all kinds of plants and animals. They found that all the specimens they examined were built from rows and rows of cells. These cells were different shapes and sizes, and some could even move about.

A Dutchman named Antonie van Leeuwenhoek (LAY-ven-HOEK) read about Hooke's work and began making his own single-lens microscopes. When he placed a small live fish in front of the lens and held it up to his eye, he could see blood surging through the blood vessels in the fish's tail. He took a drop of water from the bottom of a pot plant and observed it with his microscope. To his amazement he saw tiny single-celled animals that he called 'cavorting beasties'. Leeuwenhoek was the first person to observe bacteria—in plaque he collected from his own teeth and 'two old men who had never cleaned their teeth in their life'. He even noticed that the bacteria in the plaque were killed when he drank hot coffee.

After Hooke and Leeuwenhoek, microscopes were made with higher and higher magnifications, but it was not possible to go beyond a magnification of ×1500. In 1931, a German named Ernst Ruska made an *electron microscope*. Instead of light he used a stream of electrons that could be focused using electrical or magnetic fields. Electron microscopes can magnify objects up to one million times, and for the first time scientists could observe viruses and the details of cell structure. Scanning electron microscopes can take 3D pictures of the various structures in the human body; for example, blood cells (page 77) and muscle fibres. The photo below shows a head louse with an egg (nit) clinging to a human hair.

Question

Use the information on this page to write one or two paragraphs that describe how developments or improvements in technology have transformed science.