6

ENERGY ON THE MOVE

So many devices we use rely on energy. Our televisions need an antenna to receive a TV signal; our mobile phones don't work if we are out of signal range; we see and hear because our brains interpret light and sound. Many other devices rely on the energy of heat or electricity. To work as they should, these devices need the transfer of energy as well as the energy itself.

6.1 TRANSFERRING ENERGY

Energy is transferred from one object to another. The type of energy determines how this transfer occurs. In terms of heat, this energy can be passed through three ways: convection, conduction and radiation. Convection and conduction occur through materials – think about how heating a pot of water over a stove will cause all of the water to be hot, not just the bottom of it, or how a metal tripod becomes hot after heating it with a Bunsen burner. Radiation does not need any material to go through, not even air! We feel hot when we stand in the sunlight.

Students:

» explain the processes of conduction and convection of heat energy

» explain the transmission of sound in different mediums

6.2 ENERGY AND WAVES

Heat is not the only form of energy that can be transferred. Whilst heat energy uses particles to transfer, some energy, such as sound, uses particles as well as waves. Waves are described as a movement of energy with no net movement of particles. Think about a Mexican Wave – whilst the wave is passed from one side of the stadium to another, people only move up and down in their chairs rather than running all the way around the stadium. Waves we cannot see work in the same way.

Students:

» identify situations when waves transfer energy

» describe qualitatively the features of waves in terms of wavelength, frequency and speed

» relate the properties of different radiation in the electromagnetic spectrum to their everyday uses, including communication technology

» describe the occurrences and uses of absorption, refraction and reflection of light

6.3 ENERGY AND ELECTRICITY

Electrical energy is a very important form of energy, especially in this day and age. Imagine living without anything electrical! But what is electrical energy? Is it a particle or a wave? How is it transferred between substances? The understanding of electricity applies to your everyday life too – how do we 'save' electricity? Why do we need to save it?

Students:

» describe voltage, current and resistance in terms of energy applied, carried and dissipated

» describe the relationship between voltage, resistance and current

» compare series and parallel circuits

» outline examples where scientific or technological development have involved teams of specialist scientists

6.1 TRANSFERRING ENERGY

Energy is never lost or used up. When energy is transformed (changed from one form to another), the total amount of energy stays exactly the same. We say it is conserved. This is one of the most important laws in science: the law of conservation of energy. So why is it that when our homes are heated in winter, they don't stay warm when we switch the heating off? Energy is quickly lost to the surroundings and seems to disappear. To keep our house warm, we have to keep supplying energy.

HOW HEAT ENERGY MOVES IN MATERIALS

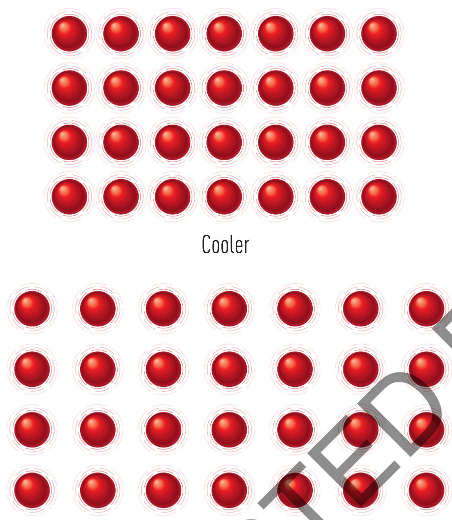

Figure 6.1 Atoms of a metal vibrate faster when they are heated and spread out as a result.

Metals are not molecular substances. They consist of atoms lined up in rows and columns, with each atom close to its neighbours. This regular arrangement of atoms is called a **lattice structure**. The atoms are fixed in place in this arrangement; however, they are able to vibrate. When a metal is hot, its atoms vibrate faster than when the metal is cold. Heat energy increases the kinetic energy of the atoms. As the atoms vibrate faster they bump into one another because they need more space to vibrate. As a result they do spread out slightly. It is this spreading of atoms that results in the expansion of heated metals.

ACTIVITY 6.1.1: INVESTIGATING HOW HEAT SPREADS

What you need: hotplate and wood block (or Bunsen burner, tripod, retort stand and clamp), metal rod (about 30 cm), wax, ruler, felt-tip pen, stopwatch, glass stirring rod (optional)

1. Measure along the metal rod, using the pen to mark every 1 cm for a length of 10 cm.
2. Place small blobs of wax on the rod at each mark.
3. Place the marked end of the rod on the edge of the hotplate and rest the other end of the rod on the wooden block. If using the Bunsen burner, support the unmarked end with a retort stand and clamp. Position the marked end of the rod on the edge of the tripod so just the tip is positioned in the Bunsen burner flame (blue or yellow flame will work).
4. Predict the shape of a graph of time taken to melt the wax (vertical axis) against distance from the heated end (horizontal axis).
5. Begin heating and time how long each blob of wax takes to melt. Record your data in a table and construct the graph described in step 1.
   - How do you think the heat was carried along the rod to each blob of wax?
   - How accurate was your prediction?

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Heating by conduction

Consider what happened when we heated the metal rod with the hotplate or burner:

- As the hotplate or Bunsen burner heated up, it produced thermal energy.
- The hot molecules moved quickly and bumped into the slowly vibrating atoms of the cold metal of the rod.
- Energy passed to the slowly vibrating atoms in the rod, causing them to vibrate faster.
- The quickly vibrating atoms in the rod bumped into metal atoms nearby, transferring energy to them and making them vibrate faster. This eventually heated the whole rod.
- When the rod heated up, heat energy was transferred to the blobs of wax along it.
- The wax molecules vibrated fast enough so that the wax melted to become a liquid.

This is an example of heating by **conduction**.

Although the energy moved through the metal of the rod and into the wax, the atoms in the metal did not leave their positions – metal atoms did not move into the wax. During heat conduction, it is the vibrations of the individual atoms that are passed on.

Thermal conductors and insulators

A thermal conductor is any material that allows **thermal energy** to easily pass from one particle to the next, and hence for thermal energy to 'flow' through it. All metals are conductors, although some are better conductors than others. Thermal insulators are materials that slow down the transfer of thermal energy. Their molecules don't allow the energy to pass very easily from one molecule to the next. Socks, jumpers and blankets, which keep us warm in cold weather, are insulators. They make it difficult for our body heat to escape, thus insulating us against the cold. Insulation in the roof and walls of a house prevents heat gain and loss during summer and winter. So insulation can hold heat in or keep it out.

Heating by convection

Think about what happens when a saucepan of water is heated on a gas flame:

Figure 6.2 Convection currents are created in a saucepan of water when it is heated. The heated water molecules (shown in red) rise while the cooler ones (shown in blue) sink.

- Energy transfers by conduction from the hot saucepan to the water molecules that are touching the metal.
- The water molecules in contact with the metal are moving faster than the molecules in the water above. Because they are moving faster, they take up slightly more space, and are less dense than the water above them.
- The heated water molecules near the bottom of the saucepan begin to rise, leaving room for the cooler water molecules to sink down and take their place.
- The heated water molecules take thermal energy with them as they move.

This is an example of heating by **convection**.

Thermal energy moves by convection in liquids and gases. When air or water is hot, the molecules are moving faster than when they are cold. Tiny currents, called convection currents, carry the thermal energy. **Convection current** is the movement of hotter or colder particles within a liquid or gas.

Because most of the energy transfer in liquids takes place by convection (where hot liquid rises), we heat liquids from below.

When air is heated, it either occupies more space or the pressure increases (if the air is contained in a space). We say the air expands – the molecules don't get bigger,

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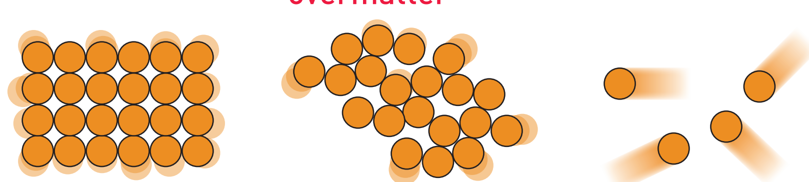


Figure 6.3 Particles move further apart and move faster when they are heated. This increase in space between molecules decreases the density of the substance, which allows it to rise (remember that less dense things float on top of more dense things).

EXPERIMENT 6.1.1: INVESTIGATING HEATING BY CONVECTION

Aim
To investigate heating water by convection.

Materials
- Bunsen burner
- Tripod
- Water
- Heatproof mat
- Beaker (600 mL)
- Potassium permanganate crystals (or a few drops of food colouring)
- Dropper or pipette

Method
1 Set up the equipment as shown in Figure 6.4.

2 Fill the beaker with water. Put individual crystals of potassium permanganate on the bottom of the beaker, at the edge (not in the centre). Alternatively, add a drop of food colouring to the bottom of the full beaker using a dropper or pipette.

3 Heat the water gently over the Bunsen burner and observe the movement of the crystals. (If possible, use a small flame and no heatproof mat between the Bunsen burner and the beaker – you can do this with pyrex beakers.)

4 Note the path the coloured water takes from the burner to the top of the water and back down again.

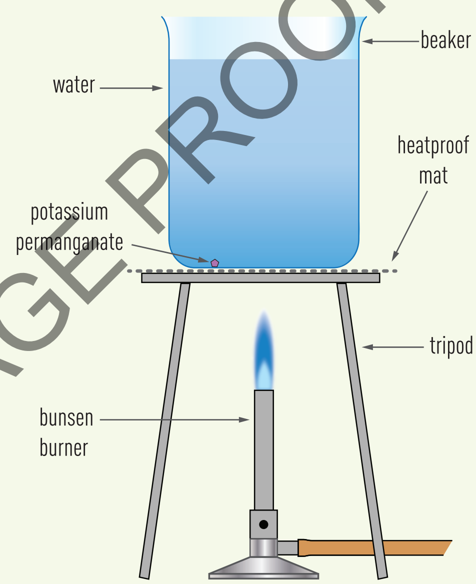


Figure 6.4 Experimental setup

Results
Draw a labelled diagram showing the movement of the coloured water.

Discussion
1 Describe the movement of the coloured water.

2 Why do you think the coloured water moved like this?

3 What was happening to the particles in the water when the water was being heated?

Conclusion
What do you know about heating water by convection? Write a sentence to address the aim.

DEEPER UNDERSTANDING

Staying warm in the Arctic Circle

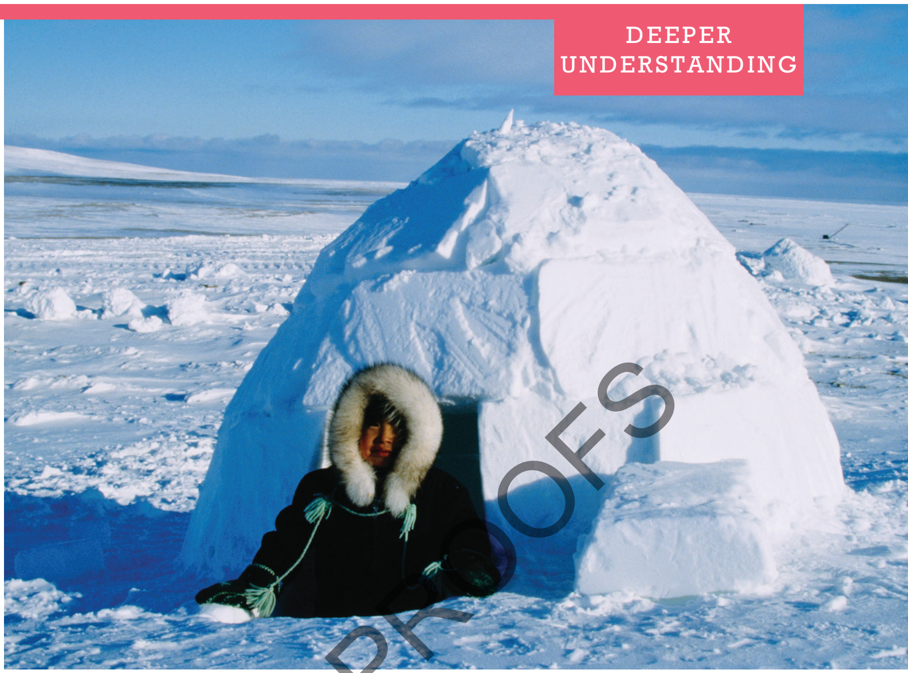


Figure 6.5 The design of an igloo minimises air circulation.

Traditionally, the Inuit people of North America built small igloos as temporary winter hunting shelters. They placed large blocks of ice, which only melted slowly, in a circular foundation and then stacked smaller blocks of ice on top to create a dome shape. Only a small hole is left for air ventilation. Without modern appliances, the Inuit relied on preventing warm air leaving the igloo to keep these temporary icy homes as warm as possible. To do this, they had no windows or doors, and any gaps in the walls of ice were filled with snow. The entrance was from an underground tunnel or was slightly below ground level to prevent the wintry wind from entering.

The inside of the igloo was insulated with fur skins to form a barrier between the ice and the energy generated within the igloo. Seal oil lamps were used to heat the igloo, and body heat was shared by staying as close as possible to the other people in the igloo.

Heating by radiation

Heat transfer through radiation is very different to how heat transfers through conduction and convection. You feel heat radiation many times in winter when you stand in front of a fireplace or a heater. The heat transfers to you without the rising and falling of particles, as in convection, and without the solid material, as in conduction. You may think this heat is going through 'nothing', but air itself is still there. Radiation also occurs when the Sun's light reaches the Earth and it heats the Earth. When you stand outside in the Sun, it is warmer than standing in the shade. This is due to the radiation of the heat given off by the Sun.

The energy from the Sun must travel through space to reach the Earth. Radiation of heat is passed by waves rather than particles.

You will learn more about the radiation of heat when you examine the electromagnetic spectrum (section 6.2).

QUESTIONS 6.1.1: HOW HEAT ENERGY MOVES IN MATERIALS

Remember

1 Explain what happens to molecules when they are heated.
2 From your everyday experience, recount some examples of where good thermal insulators are needed. Identify the materials used in each situation. Now give some examples where good thermal conductors are needed. Identify the materials used.
3 Compare the difference between conduction and convection.

Apply

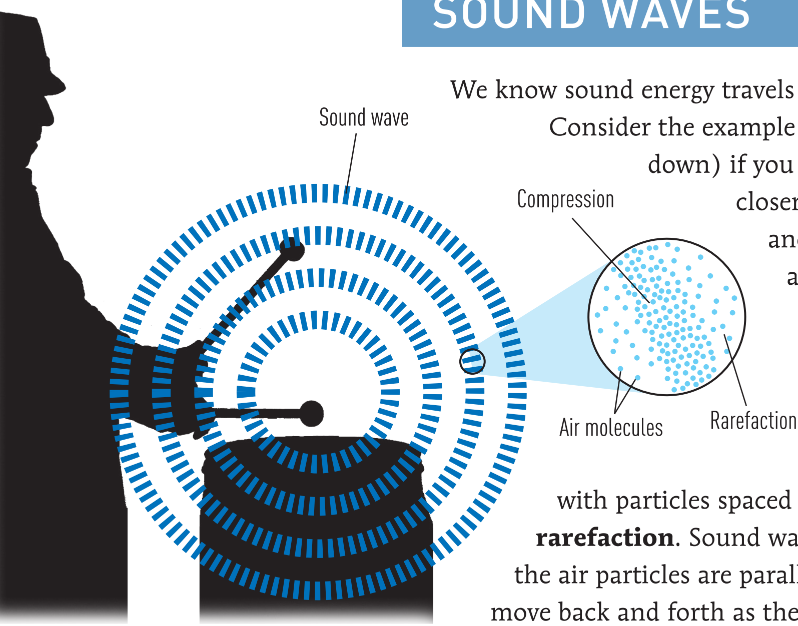
4 Modern saucepans have a copper bottom, steel sides, a plastic handle and a glass lid. Explain why each of these materials is used for a particular part of each saucepan.
5 Explain how particle theory relates to the heating/cooling of substances.

SOUND WAVES

We know sound energy travels because we can often hear it a long way from its source. Consider the example of playing a drum. A drum skin vibrates (moves up and down) if you hit it. The vibrations push the surrounding air particles closer together in one place and force them further apart in another. In this way, the air particles around the drum are also made to vibrate. This causes the air particles next to those air particles to vibrate, and so on, until the air close to your ears eventually vibrates and causes your eardrum to vibrate too. That's when you hear the sound.

The air with the particles forced close together is referred to as a **compression**, whereas the air with particles spaced further apart (that is, the air is less dense) is called a **rarefaction**. Sound waves travel as a **longitudinal wave** – the vibrations of the air particles are parallel to the direction of travel of the wave. The air particles move back and forth as the vibration passes through the air. A sound wave moves out in all directions from the place where the vibration began.

As the waves move further away from their source, more and more air particles share the original energy. Eventually, their energy is so small that the sound fades out. As neighbours will confirm, the closer you live to a drummer, the louder they seem!



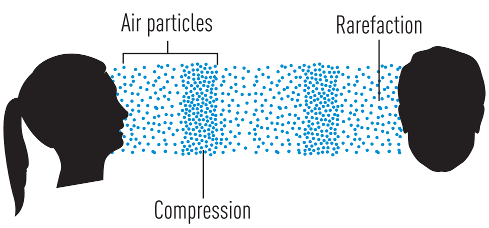


Figure 6.6 (a) When a drummer hits a drum skin, a sound wave is produced. (b) Air particles behave in a similar way between a speaker and a listener.

EXPERIMENT 6.1.2: SLINKY SPRING 1

Aim
To use a slinky spring to model the compressions and rarefactions of a sound wave.

Materials
- Slinky spring
- Clear space on the floor

Method
1 Two volunteers need to hold the spring, with one person at each end.
2 On the floor, slowly stretch the spring out slightly beyond its normal length.
3 One person pushes their end of the spring firmly towards their partner. This will create areas where the coils are pushed together (compressions) and areas where the coils are stretched out (rarefactions). These areas will travel along the spring to the other end. The person at the other end needs to hold the spring firmly and still in order to feel a compression arrive. In this way a wave will travel along the spring (Figure 6.7).
4 Try to make the wave have more or less energy by changing how hard you push the end. Try to keep the speed of the wave the same. Pushing harder is the same as making a sound louder. Pushing less hard models a softer sound.

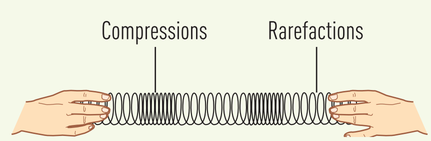


Figure 6.7

Results

Record your observations, including labelled diagrams where appropriate.

Discussion

1 Explain what happened when the wave reached the other end of the spring.
2 Do you know what this wave behaviour is called in real life? Think of what happens to sound waves as they hit a hard surface. Explain what you hear.

Conclusion

Write a conclusion for this experiment that addresses your aim.

DEEPER UNDERSTANDING

Sonar

In all wars since World War I, reflected waves have been used to detect enemy submarines under water. In a similar way to radar (radio waves), sonar sends out sound waves and records how long the sound takes to reflect back after striking an object (like an echo). The longer the sound takes to return, the further away the object is. An exact location of a submarine can be calculated by knowing how fast sound travels in water. This information, along with the time taken for the sound to return, detects the location of a submarine. Sonar is still widely used today and can help map the ocean floor, check the depth of water and locate schools of fish.

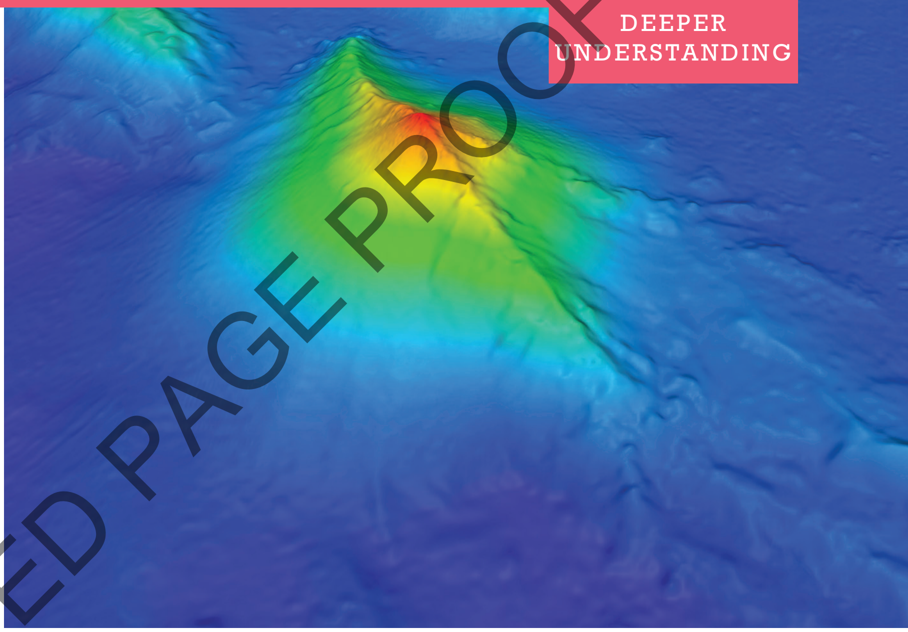


Figure 6.8 Sonar is used to map volcanoes on the ocean floor.

ACTIVITY 6.2.1: SILENCE THAT SOUND!

This is a whole-class activity.
What you need: all of the materials shown in Figure 6.9.

1 Assemble the materials as shown in Figure 6.9.
2 Switch on the radio or ring the bell throughout this demonstration.
3 Use a vacuum pump to gradually remove air from the bell jar for several minutes.
4 Gradually reintroduce the air.
  - Describe the sound coming from inside the bell jar before the vacuum pump is turned on.
  - Explain what happens to the loudness of the sound as the air is removed.
  - How does the sound change when the air is let back into the jar?

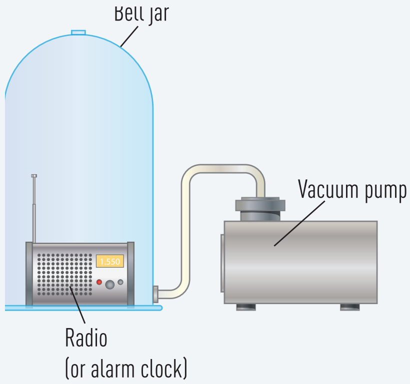


Figure 6.9 Activity setup.

Sounds of silence

If you are a drummer, you have probably been told more than once to 'keep the noise down!' But is there somewhere you could play your drum kit as hard and as loud as possible with absolutely no sound being heard? The answer is yes, but it's not a place you can get to easily.

A famous sci-fi movie was advertised with the tagline 'In space, no one can hear you scream'. The movie-makers were right. In outer space, you can play your drum kit without anyone hearing a sound – but you wouldn't hear it either. You could even see an explosion without hearing a thing. This is because sound needs something to travel through; it needs a substance, or **medium,** containing particles that can be vibrated to create the sound waves. The medium could be a solid, a liquid or a gas.

In solids, the particles are very close together, so any vibrations caused by sounds are quickly transferred to other particles. Sound travels the fastest in solids due to the minuscule spacing between particles. In liquids, the particles are still close together but not as close as in solids – this means sounds are also transmitted quickly, but not as quickly as in solids. In gases, the particles are far apart and vibrations are passed on slowly as a result. In outer space, there are so few particles of gas, and they are so far apart, that they cannot be made to vibrate. So, outer space is silent.

Temperature also affects particle spacing in solids, liquids and gases – the cooler the substance the closer the particles, so this has an effect on the speed of sound too. Lower temperatures cause faster speeds of sound.

Table 6.1 Speed of sound in solids, liquids and gases

State of matter	Substance	Approximate speed of sound (m/s)
Solid	Glass	4540
	Copper	3900
	Steel	6100
	Wood	3500
Liquid	Pure water	1480
	Salt water	1590
Gas	Air	340
	Oxygen	320
	Helium	970

Describing sound

You can sing high. You can sing low. You can talk in a funny voice if you want to, because you can alter the pitch of the sound coming from your vocal cords. Pitch describes how high or low a sound seems to us – it is not a measurement. High-pitched sounds are caused by faster vibrations (more sound waves being created every second); low-pitched sounds have slower vibrations (fewer sound waves per second). The number of sound waves per second, called the **frequency** of a sound wave, is measured in a unit called Hertz (symbol Hz). For example, five sound waves created every second equals 5 Hz. High-pitched sounds have a high frequency such as 1000 Hz. Low-pitched sounds have a lower frequency such as 100 Hz.

Figure 6.10 Middle C (shown in red) played on a piano creates vibrations at a frequency of 256 vibrations every second; its frequency is 256 Hz.

EXPERIMENT 6.2.1: SLINKY SPRING 2

Aim
To use a slinky spring to demonstrate the frequency of longitudinal waves.

Materials
Slinky spring
Clear space on the floor

Method
1 As in Experiment 6.1.2, two volunteers need to slowly stretch the slinky spring out slightly beyond its normal length along the floor. One person pushes and pulls back their end of the spring firmly towards their partner to create a longitudinal wave (compression wave), setting up compressions and rarefactions.
2 Set up a wave that travels at one wave per second (1 Hz). Remember, the number of waves per second is called the frequency of the sound.
3 Increase the number of waves per second. Try to create at least four waves per second. You have just modelled a wave of higher frequency.
4 Try to reduce the number of waves until there is only one wave every 2 seconds, or 0.5 waves per second (0.5 Hz). This model represents a lower frequency sound.

Results
Draw labelled diagrams of the waves you created, carefully indicating how the waves show that different frequencies have been achieved.

Discussion
1 Describe what you notice about how far apart the waves are (the distance between the compressions) when they are travelling at the higher frequency.
2 Identify if the distances between the compressions are bigger or smaller at the lower frequency (0.5 Hz).
3 Discuss whether a vibration is made up of a compression, a rarefaction or both.

Conclusion
Write a conclusion for this experiment that addresses your aim.

ACTIVITY 6.2.2: IS SCHOOL BAD FOR YOUR HEALTH?

Before conducting this survey of the noise levels around your school, predict which you think will be the noisiest and quietest areas.
What you need: one sound level meter per group, map of school, metre ruler

WARNING
> Never expose yourself to very loud noise or yell into someone's ear. When you are measuring loud sounds at your school and testing the volume of your classmate's yell, stand 1 m away from the source of sound.

1 Your teacher will identify various parts of the school, including the library, and allocate them to the various groups.
2 Visit your allocated part of the school and measure the sound levels inside rooms and outside.
3 When outside and far away from any classes, check the loudness levels of the individual voices in your group. First, a group member should speak as softly as possible and another person should measure the sound level at 1 m. Then, measure a loud yell, again at 1 m distance. Collect these results for each person in the group.

4 Collect the results of all groups into a class table.
- What units did you use for the sound levels?
- What was the average of your group for a loud yell?
- What would you recommend about yelling in someone's ear?
- Find the average noise level in classrooms. Which rooms were the noisiest?
- List the loudest and quietest places in your school. Were your predictions accurate?
- How reliable were your results? Give a reason for your answer.

QUESTIONS 6.1.2: SOUND WAVES

Remember

1 Identify how particles in air are arranged in:
  a compression
  b rarefaction

2 If a longitudinal wave travels from left to right, explain in which direction the particles of the medium are vibrating.

3 Work with a partner. Explain to your partner how the sound waves created by hitting a cymbal reach your ears. Use the following terms:
air particles, *close together*, *compression*, *ear*, *rarefaction*, *sound wave*, *spread out*

Apply

4 Outline how a sonar echo is similar to light striking a mirror.

5 If a nearby star was to explode, explain why we wouldn't hear the noise of the explosion on the Earth.

6 Of the two springs shown in Figure 6.11, identify which demonstrates a lower frequency. Explain your answer.

7 Imagine you have three tuning forks of frequencies 250 Hz, 500 Hz and 1000 Hz. Identify the fork that would:
  a sound the deepest
  b have the highest pitch

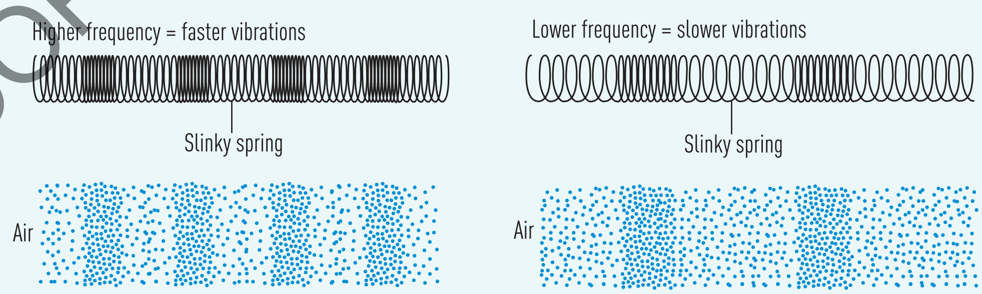


Figure 6.11

Research

8 Use the Internet or a reference book to confirm the speeds of sound for each material in Table 6.1. Do they correspond with the values given in the table? Account for any major differences.

9 Bats navigate by echolocation. Find out a little bit about this. How is it different to sonar? How is it similar?

TRANSFERRING ENERGY

6.1 CHECKPOINT

Remember and understand

1 Identify the two main processes in which energy can be transferred by heating. Use a labelled diagram to explain how the particle model of matter explains each type. [2 marks]

2 Explain which energy transfer process is happening when you touch something hot. [1 mark]

3 In scientific terms, explain:

a what we mean when we say we 'use' energy [1 mark]

b whether energy is 'lost' [1 mark]

4 An ice block sitting on a saucer is melting (see Figure 6.12).

a Identify what is happening to the water molecules as the ice melts. Draw a diagram to illustrate your answer. [2 marks]

b Where does the energy to melt the ice come from? Explain how the energy is transferred to the water molecules in the ice. [2 marks]

5 Copy and complete: [5 marks]

Sound is created by v____________. The v____________ create c____________ and r____________ due to the movement of the particles, as the sound w__________ passes through the medium. The w__________ travels through the substance and is known as a l____________ wave. The greater the vibration, the higher the p____________ of the sound, which means it sounds l____________. Sound waves must have a m____________ to pass through.

6 Recall what the frequency of a sound refers to. [1 mark]

Apply

7 When you store a container of ice cream in your freezer, the temperature in the freezer is so low (about −20°C) that the ice cream is solid and difficult to scoop out. Running hot water over the metal scoop does not help much, but soaking the scoop in hot water for several minutes does help. Explain why this is a more successful way of scooping out the ice cream. [1 mark]

8 Conduct a survey using a portable tape recorder or media player with a microphone. Ask at least ten different people, 'What is sound?' Record your voice asking the question at the start and then record their answers. Play back their answers and write down the things people understand correctly and also their misunderstandings about sound. Next to the misunderstandings, write the correct idea about sound that you have learned. [3 marks]

9 If radio communication between astronauts broke down on the Moon, would it help if the astronauts shouted at each other with their helmets touching? Explain why or why not. [2 marks]

10 Explain how sound pitch and frequency are related. Is there a difference between the two terms? [2 marks]

Analyse and evaluate

11 Describe, in terms of particle motion, why:

a convection can only occur in fluids (liquids and gases) and not solids [1 mark]

b when energy transfers by convection or conduction, the substance through which the energy transfers also gets heated [1 mark]

c good insulators are usually solids [1 mark]

d energy can transfer between two objects only from the warmer object to the cooler one [1 mark]

Figure 6.12

- **e** neither convection nor conduction is a way of transferring energy through empty space [1 mark]

12 In some countries, double-glazed windows are used for heat and sound insulation. They consist of two sheets of glass with a thin gap of air between them. Evaluate how this makes them better insulators than single-glass windows. [1 mark]

13 Molecular substances and metals both expand when they are heated.

- **a** Explain why air expands when it is heated. [1 mark]
- **b** Explain why a metal expands when it is heated. [1 mark]
- **c** Analyse what is the same in both explanations. What is different? [1 mark]

14 Have you ever swum in the sea or a lake and noticed that the water is warmer near the surface, even in shallow areas, at the end of a hot day? Use a diagram to explain why convection currents don't work very well to heat water when the heat source is above. [3 marks]

15 A grand piano can be played with the lid open or closed. Most often, concert pianists will play with the lid open towards the audience. Discuss why you think they would choose to do this. Analyse what effect this might have on the sound produced by the piano. [2 marks]

16 The table shows the speed of sound at different temperatures.

Air temperature (°C)	Speed of sound (m/s)
0	330
10	336
20	342
30	348

- **a** Using graph paper, draw a graph of the speed of sound (vertical axis because it is the dependent variable) at various air temperatures (horizontal axis because it is the independent variable). Start the speed scale at 320 m/s. Draw a trend line (a smooth line of best fit) on your graph that passes through as many points as possible. [2 marks]
- **b** Assess how well the data fits the trend line. [1 mark]
- **c** Explain what happens to the speed of sound as the temperature increases. Propose a reason why this is the case. [2 marks]
- **d** Use your graph to determine the speed of sound at 5°C. [1 mark]
- **e** Use your graph to calculate the temperature of the air, if the speed of sound is 351 m/s. [1 mark]

17 A sound wave of frequency 600 Hz is travelling at a speed of 340 m/s. Calculate its wavelength. Show your working. [2 marks]

18 Research the differences and similarities between audible sound, ultrasound and infrasound. Display your answer using a Venn diagram or a mind map. Acknowledge your sources of data and information in a bibliography. [2 marks]

Critical and creative thinking

19 Create a range of clothing to demonstrate some fashions across the globe. Your clothing range should show the various ways people are able to stay warm or keep cool, depending on the climate of their country. You will need to think about conductors and insulators of thermal energy. [3 marks]

Making connections

20 Investigate how homes in Australia and other countries are insulated. What types of materials are commonly used? How is heat gain into a house reduced in hot climates? How is heat loss from inside the house reduced in cold climates? [4 marks]

TOTAL MARKS
[/55]

ENERGY AND WAVES

6.2

When lightning strikes, a huge electric spark is created. The energy in the electricity rapidly heats the cold air around it. The air expands rapidly and then crashes into the surrounding cold air, making the sound of thunder. Even though the light from the electric spark and the sound of the thunder are made at exactly the same time, and both travel as a wave, we always hear the thunder after seeing the lightning – sometimes several seconds later. This is because the two waves are quite different. Light waves travel at least a million times faster than sound waves! Light travels at about 300 million metres per second, whereas sound in air travels at only about 300 metres per second. The light from the spark reaches our eyes long before the sound reaches our ears.

LIGHT WAVES AND VISIBLE LIGHT

What is light? Ancient civilisations believed that light was emitted from the eye and this enabled us to see. We now know that light entering our eye enables us to see. Like sound, light is a form of energy that travels in waves. In fact, light waves travel in a series of changing electric and magnetic fields. For this reason, light is also called **electromagnetic waves** or electromagnetic **radiation**. Electromagnetic waves are almost always the result when electrons in atoms vibrate or lose energy.

Transverse waves

Light waves are different to sound waves. In light waves, the vibrations are at right angles to the direction of travel of the wave. We call these waves **transverse waves**.

The distance between two adjacent crests (peaks) on a transverse wave is called the **wavelength**. It is the same as the distance between two consecutive troughs (dips) or between any two consecutive matching points on the wave. At a different wavelength, the nature of the electromagnetic wave changes. In visible light, this change of wavelength is seen as different colours.

The height of the wave from the midline to the top of a crest, or to the bottom of a trough, is called the **amplitude**. The amplitude of a wave determines the intensity or brightness of the light.

Figure 6.13 Vibrations in a transverse wave are at right angles to the wave's direction of travel.

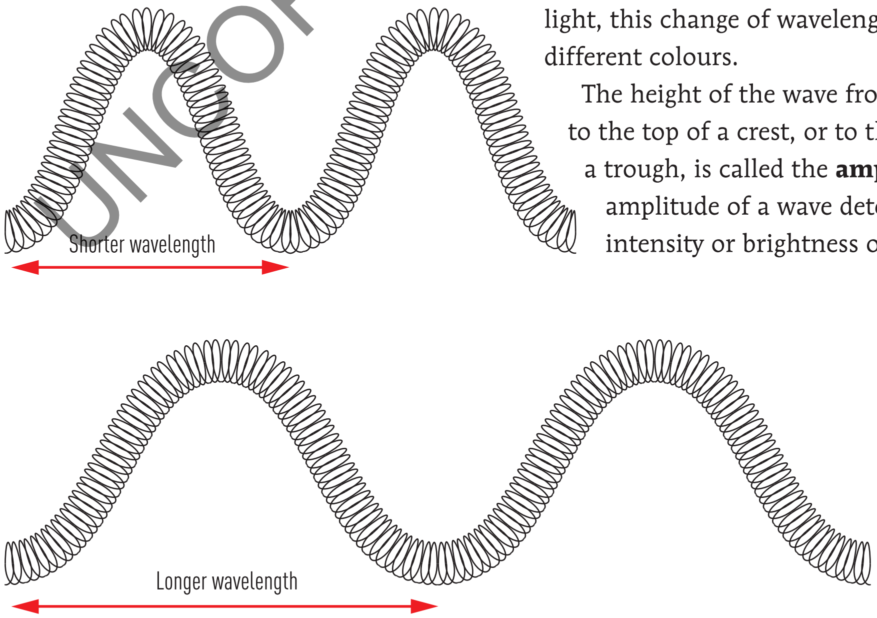


Figure 6.14 The wavelength of a transverse wave is measured from any point on the wave (usually a peak or trough) to the next corresponding point.

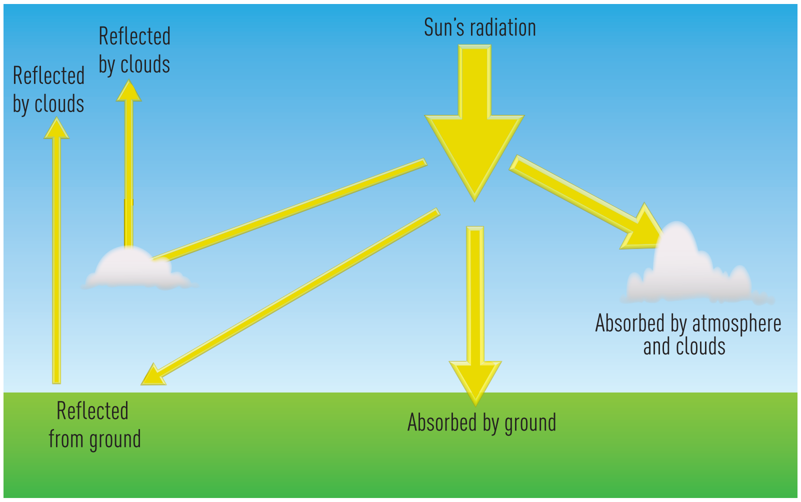


Figure 6.15 Radiation from the Sun does several things on the Earth, depending on weather conditions.

Light moves in a way that is similar to a wave moving across water. However, it does not disturb a substance as a water wave does. Unlike sound waves, light waves don't need a medium in which to travel, due to their electromagnetic nature. They don't pass their energy from particle to particle like sound waves do.

Light is not necessarily absorbed when it meets a substance – it may be reflected or transmitted. For example, radiation from the Sun is transmitted through the atmosphere; some is reflected from the tops of clouds, the ground absorbs some and the ground reflects some.

EXPERIMENT 6.2.2: SLINKY SPRING 3

Aim

To use a slinky spring to model a light wave as a transverse wave.

Materials

- Slinky spring
- Clear space on the floor

Method

1 Two volunteers hold the spring, one at each end. On the floor, slowly stretch the spring out slightly beyond its normal length. One person flicks their end of the spring firmly to one side and back again. This will create a sideways 'pulse' in the spring (a bit like an ocean wave). The person at the other end needs to hold the spring firmly and still. The pulse will travel along the spring to the other end (Figure 6.16).

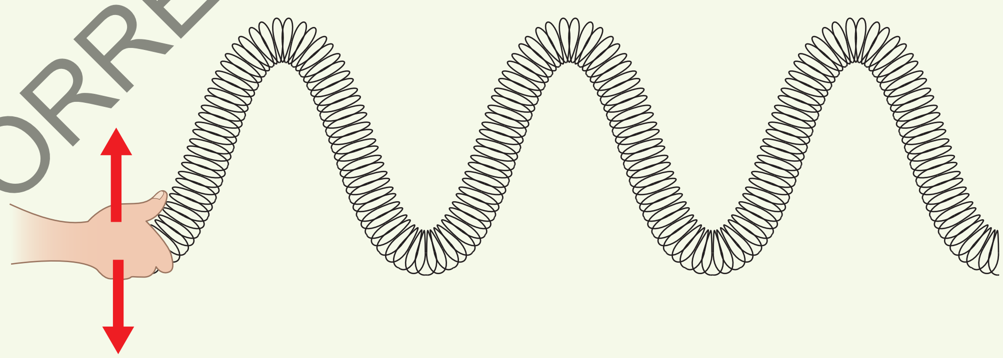


Figure 6.16

2 Continue this flicking of the spring to create a continuous transverse wave. Can you see the peaks and troughs of the wave?

3 Make the wave have more or less energy by changing how hard you flick the end of the spring sideways. Try to keep the frequency of the wave the same.

4 Increase the number of waves per second. You have just modelled a wave of higher frequency.

5 Try to reduce the number of waves. This model represents a lower frequency wave.

Results

Draw labelled diagrams of the waves you created, carefully indicating how the waves show that different wavelengths have been achieved.

Discussion

1. Is a wave a peak or a trough, or both? Explain your answer.
2. Explain what the link is between frequency and the distance between the peaks of the wave.
3. Outline what else in your world behaves as a transverse wave.

Conclusion

Write a conclusion for this experiment that addresses your aim.

SCIENCE SKILLS

Using the wave equation *(additional content)*

The speed of a wave through a particular substance depends on its frequency and wavelength. It is given by the fundamental wave equation:

$$v=f\lambda$$

where v = speed of the wave (m/s)
f = frequency of the wave (Hz)
λ = wavelength of the wave (m)
This can also be written as:

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

This means the fundamental wave equation triangle can be used to work out the speed, frequency or wavelength of a wave. Using your finger, cover the quantity you want to calculate. The two quantities remaining will make up the formula (Figure 6.17).

Example

A sound wave of wavelength 0.5 m travels at a speed of 400 m/s. What is its frequency?

Solution

Cover f with your finger and the equation becomes:

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

Substitute the numbers into the equation and calculate:

$$f=\frac{400}{0.5} = 800 \text{ Hz}$$

Your turn

1. A sound wave travels at a speed of 350 m/s and has a frequency of 70 Hz. What is its wavelength?
2. Light waves travel at 3×10^8 m/s. If the light wave has a particular wavelength of 400 nm (400×10^{-9} m), calculate its frequency.

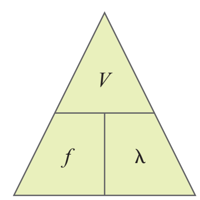


Figure 6.17 The fundamental wave equation triangle.

Colours of the rainbow

Visible light can be separated into an infinite range of different colours and shades, but there are generally considered to be seven basic colours: red, orange, yellow, green, blue, indigo and violet. Sir Isaac Newton came up with this concept. It was said he included the seventh colour, indigo, for good luck. The colour sequence is easy to remember as ROY-G-BIV. This infinite range of colours is called the **visible spectrum**. The splitting of white light into these colours is called **dispersion**. Each colour of light has a unique range of wavelengths.

ACTIVITY 6.2.3: DISPERSING LIGHT

What you need: Hodson light box, white sheet of A4 paper, glass prism

1 Place the light box on the sheet of white A4 paper and use the glass prism to refract (bend) a single beam of white light to produce a spectrum of colours.
2 Copy and complete Figure 6.18, labelling the colours.
   - Can you distinguish the colour indigo (between blue and violet)?
   - Does red or violet have a longer wavelength? How do you know?
   - Identify which colour bent the most. Why?
   - Identify which colour bent the least. Why?

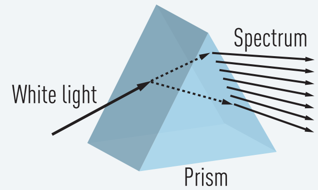


Figure 6.18 Dispersion can be demonstrated using a triangular prism and the double refraction of white light to separate the colours. Light refracts at the edges of the prism.

An object appears a particular colour because it is reflecting a narrow range of wavelengths while absorbing the other wavelengths. So a red object appears red because it absorbs yellow, orange, green, blue, indigo and violet, but reflects red, which is detected by our eyes. A coloured filter works in a similar way. A green filter will allow green light to pass through, but absorbs all other wavelengths of light. So what colour would a red object look if you shone green light on it?

STUDENT DESIGN TASK

Investigating coloured light

In this task you will investigate the absorption and reflection of different coloured light using different coloured filters and objects, and relate this to the appearance of coloured objects. You may investigate one of the following questions, or one of your own.

1 Plants absorb light as energy to fuel photosynthesis. The catalyst chlorophyll that absorbs the light also gives plants their green appearance. Which wavelengths (colours) of light does chlorophyll absorb and reflect?
2 Light bends as it passes from the air into the water, as you saw in Activity 6.2.3. Only the wavelengths of light that bend the most will penetrate deep under the ocean. Many deep-sea creatures are coloured red when you bring them to the surface. What colour would red creatures appear when they are deep under water?

Questioning and predicting

Choose a question to investigate and write a relevant aim and a hypothesis as an 'If … then … ' statement.

Planning

You will need a Hodson light box, a range of coloured filters and a range of coloured objects to examine.

Design an appropriate method that will test how different coloured objects look under different coloured light in relation to your aim and hypothesis.

Conducting

Carefully follow your method to carry out your experiment. Record detailed observations in an appropriate format.

Processing, analysing and evaluating

- Identify any trends in your results.
- Determine if your hypothesis was supported or disproved.
- Identify any problems you encountered during the experiment and suggest a modified method to overcome these issues.

Communicating

Present your finding as a scientific report, ensuring that all sections of the report are included in the correct order and that you write using the appropriate scientific language and tone.

QUESTIONS 6.2.1: LIGHT WAVES AND VISIBLE LIGHT

Remember

1 Draw two slinky springs, one showing a light wave of short wavelength and the other with a long wavelength. Explain which has a higher frequency and which has a lower frequency.

2 Define these terms:

  a visible spectrum

  b wavelength

  c dispersion

  d wave equation

3 Recall what type of wave light is.

Apply

4 Is a Mexican wave a transverse or longitudinal wave? Explain your answer.

5 Suggest a way to 'undisperse' a rainbow. Why will it work?

6 How does a rainbow form?

Research

7 Are there any cultures that recognise different colours of the rainbow to the ROY-G-BIV that we use? Find out a little more about why other cultures use different colours to describe the colours in a rainbow.

WAVES WE CANNOT SEE

Figure 6.19 In a household radiator, energy from the movement of the particles in the heating element becomes infrared radiation (heat radiation).

The light we see, visible light, is only one of the many types of radiation in the **electromagnetic spectrum**. What are some other types of radiation, and what do we use them for?

Electromagnetic spectrum

When you go outside, you are being exposed to radiation. Radiation can be in forms such as radio waves, ultraviolet waves, microwaves, X-rays, infrared waves and, of course, visible light.

These different types of electromagnetic radiation all travel at the same speed, but they have different wavelengths and therefore different frequencies.

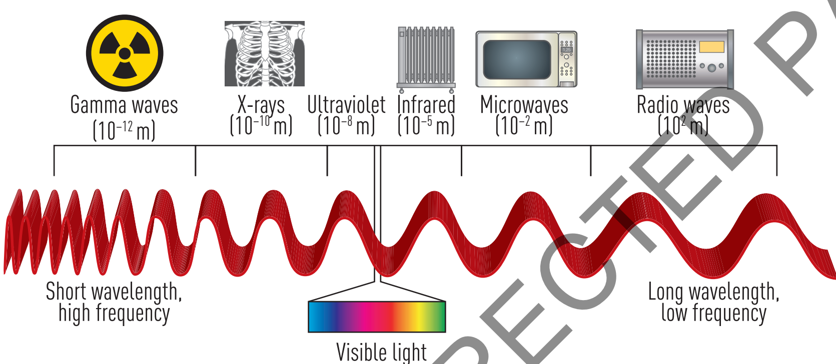


Figure 6.20 The electromagnetic spectrum. Typical wavelengths of each wave type are provided in brackets.

Radio waves

There is special type of telescope that analyses radio waves from space, called a radio telescope. Australia has its very own radio telescope at Parkes in New South Wales. Short-wavelength radio waves are used by television and radio stations. These waves rely on 'line of sight' when travelling through space and atmosphere. Radio waves have very long wavelengths (some are several kilometres long) but their frequency and energy are low.

Figure 6.21 The Parkes Radio Telescope, nicknamed 'the Dish', was the subject of a movie about the telescope's role in the 1969 *Apollo* Moon landing.

Microwaves

Very short wave radio waves are also known as microwaves. In a microwave oven, the water molecules in food vibrate at the same frequency as microwaves. The microwaves are converted into heat by the water molecules, which then cook food fast and effectively. Microwaves are also used in satellite communications systems, radar, and mobile phone networks. When you turn on your mobile phone, it sends a microwave signal out in all directions. One of these signals is picked up by the closest mobile phone tower, which registers your phone and sends a signal back. Phone calls and texts come to your phone along this link.

Infrared radiation

Infrared radiation has a frequency just below the visible spectrum's red end. Infrared waves are released when atoms vibrate, and so infrared waves are related to heat energy. All objects contain vibrating atoms, so they all release infrared waves. The atoms in hotter objects vibrate faster, therefore they release more infrared radiation than colder objects. Infrared radiation is used as a communications method for many remote controls for devices such as televisions, DVD players and air conditioners. Infrared cameras can detect body heat and can be used by police helicopters to locate suspects at night.

Ultraviolet radiation

Ultraviolet radiation is another type of electromagnetic radiation close to visible light. Humans need a little bit of ultraviolet radiation to make vitamin D, which our bones need. Vitamin D is produced by our skin. However, too much ultraviolet radiation can cause sunburn and possibly skin cancer. Ultraviolet radiation can kill bacteria, so it is used for sterilising equipment.

X-rays

X-rays can penetrate softer parts of the human body and so we can make images of bones. Computed tomography (CT or CAT) scans also involve X-rays, and can be useful in cancer diagnosis and treatment.

Gamma rays

The most harmful electromagnetic waves are gamma rays, because they have the highest frequency and therefore the highest energy. However, they have the lowest, or shortest, wavelength. Gamma rays can cause cancer, but they are also very useful in its treatment. A gamma camera in a hospital takes pictures of the human body to help diagnose some diseases. Radiotherapy delivers doses of gamma radiation to tumours in the body, to try to shrink or kill cancer cells.

Speed of light

Light waves, and in fact all electromagnetic waves, travel extremely fast: 300 000 kilometres per second (or 300 million metres per second) in a vacuum. This value is known as the speed of light, and is given the pronumeral *c*. Light waves can also travel through other mediums such as air, water and glass, where they slow down slightly. This slowing down of light can often cause an optical illusion to occur. This is known as refraction.

Figure 6.22 Heat lamps in a bathroom produce radiant heat, mainly through infrared waves.

Figure 6.23 A typical X-ray image of a human torso.

QUESTIONS 6.2.2: WAVES WE CANNOT SEE

Remember

1 In terms of wavelength and frequency, identify the difference between ultraviolet light and infrared radiation.
2 Outline what the typical wavelength of radio waves is.
3 Explain why a car radio station fades out on a long road trip.

Apply

4 Recommend some precautions you think are necessary when treating people using radiotherapy.
5 Evaluate the advantages that radio telescopes might offer astronomers over telescopes that rely on visible light.
6 Different radio and television stations have a characteristic transmission number, for example, Triple M in Sydney is 104.9 mHz.
   a Explain what these numbers mean.
   b Why do the stations need this number?
   c Using $c = 3 \times 10^8$ m/s, calculate the wavelength of this wave.
7 Outline what advantages microwave ovens offer over conventional ovens.
8 Discuss how the police might use radiation to locate a child who is wandering lost in the bush at night.
9 Explain why a television remote control must be pointed at the television set to work correctly.

HOW LIGHT BEHAVES

Light behaves in different ways with different objects. When you look in a mirror, you see an image of yourself – light has been reflected. If you look through a window, you can see what is on the other side but you might also be able to faintly see yourself. Although most of the light is transmitted (passes through) the window, a small amount is also reflected. Opaque objects, such as a wooden tabletop, don't allow any light to pass through them – the light is absorbed or reflected. Substances such as water can distort what we see by refraction.

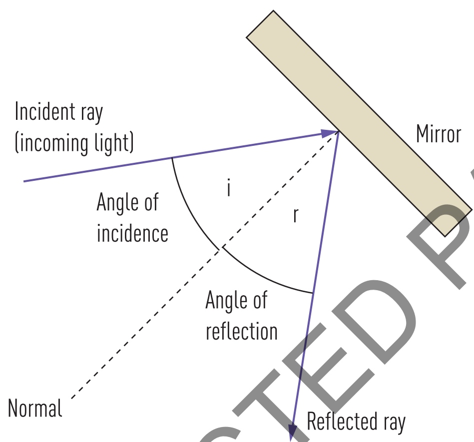


Figure 6.24 When light reflects off a mirror, the angle of incidence and the angle of reflection are the same.

Reflection

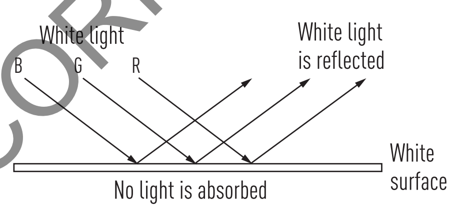
Reflection is the bouncing of light off a solid material. If an opaque material is shiny enough or has a shiny coating, it will reflect light in an ordered way and we see a clear **image**. The best example is a **plane mirror** (flat mirror). Light behaves in a predictable way when it reflects from a flat opaque surface, no matter how rough or smooth. Scientists have devised rules or laws to describe this behaviour. One of the laws of reflection is:

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

These two angles are measured from an imaginary line called the normal (Figure 6.24). This line is at right angles (90°) to the surface.

Reflection and colour

Why do coloured objects appear coloured? The colour the material appears to be depends on the light it reflects. When white light (such as sunlight) falls on an opaque surface, the energy of some colours may be reflected. Light of other wavelengths may be **absorbed** by interacting with the electrons of the surface.



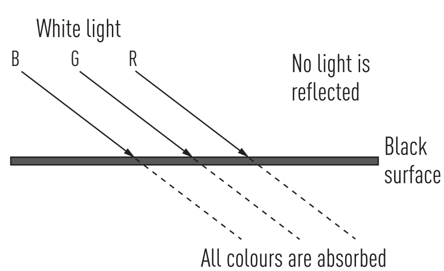
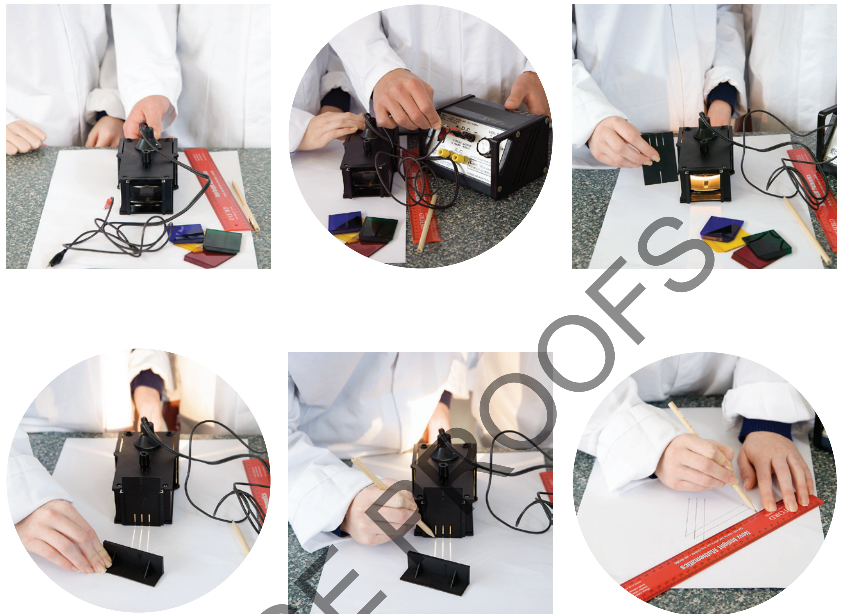


Figure 6.25 (a) A white surface reflects all visible light and looks white. (b) A black surface absorbs all visible light and so looks black – no colours are reflected.

Using a Hodson light box

A Hodson light box is often used to experiment with light.

1 Place the Hodson light box on a piece of white A4 paper.
2 Plug the light box into either the AC or DC sockets of a power supply. The voltage dial controls the brightness of the light globe.
3 Slide a slit former into the opposite end of the light box to where the mirror flaps are. Usually, a single-slit or a three-slit former is used.
4 Aim the light ray at the target, in this case a plane mirror.
5 Use a sharp pencil to mark the incident and reflected rays with dots.
6 Remove the light box and join the dots with thin, straight pencil lines.



EXPERIMENT 6.2.3: REFLECTION FROM PLANE MIRRORS

Aim

To investigate the first law of reflection: angle of incidence equals angle of reflection.

Materials

- Hodson light box kit, including plane mirror
- Power supply
- Sheet of white A4 paper
- Blu-Tack
- Ruler
- Pencil
- Protractor

Method

1 Rule a straight pencil line across the centre width of the A4 paper. The mirror surface will be placed along this line.
2 Use the protractor to draw a line at 90° in the centre of the first line (this is the normal).
3 Position the back edge of the plane mirror along the first pencil line. Keep it in place with Blu-Tack.
4 Set up the Hodson light box, darken the room and aim a single incident ray at the centre of the mirror where the normal begins. Mark the position of the incident and reflected rays with a pencil.
5 Move the light box to a different angle and aim another incident ray so it hits the mirror at the same place as it did the first time. Mark the incident and reflected rays again.
6 Repeat step 5 until five sets of lines are obtained.
7 Remove the light box and draw lines with a ruler to show the positions of matching incident and reflected rays.
8 Carefully use the protractor to measure the five angles of incidence and the matching five angles of reflection. Line up the 0° line of the protractor along the normal each time and read the angles between the normal and the incident rays, and between the normal and the reflected rays.

Results

Record your results in a suitable table.

Discussion

1 Explain why the back edge and not the front edge of the plane mirror was lined up on the pencil line.

2 Compare your angles of incidence to your matching angles of reflection. Are they close to being equal?

3 List some sources of error in this experiment.

Conclusion

Write a conclusion for this experiment and have it checked by your teacher.

Reflection off curved mirrors

Figure 6.26 A curved mirror, which is placed in blind corners to help give a wider angle of view. Note the reflected image is actually distorted as it has a 'bubbled' look.

Not all mirrors are necessarily plane mirrors (that is, flat). If you have ever been to a circus, sideshows usually contain curved mirrors that make your body appear long, short or otherwise distorted. Curved mirrors are also used in cars and shops to help see a wider field of view (see Figure 6.26). A different type of curved mirror is used as a makeup or shaving mirror, which helps to magnify (see Figure 6.27).

Reflections off curved mirrors still obey the laws of reflection (including the law stating that the angle of incidence is equal to the angle of reflection). However, because the surface is no longer flat, there are many different angles that the incidence ray enters.

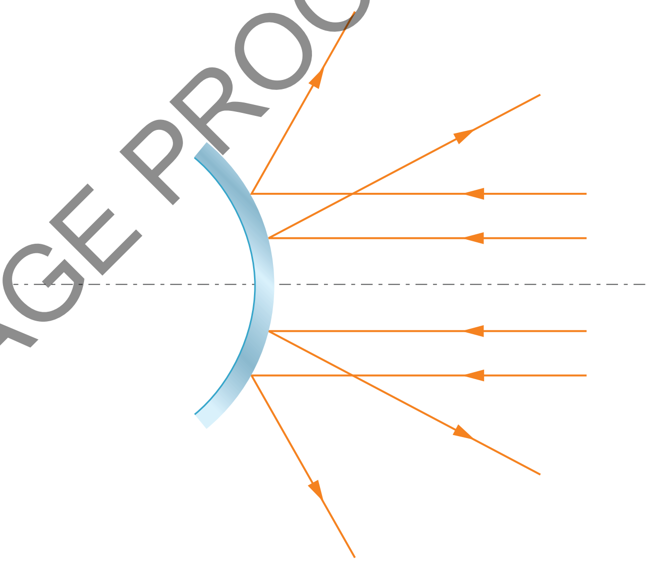


Figure 6.28 A convex mirror. The red lines show the path of the light with the incidence rays coming towards the mirror whilst the reflected the rays leave the surface of the mirror. Can you imagine where the lines for the 'normal' would be?

Figure 6.27 A small makeup mirror is usually slightly curved to allow for some magnification to occur.

Two different types of curves are possible: a convex curve and a concave curve.

Convex mirrors diverge, or spread out light, which means you can generally see more than you typically would with a plane mirror. They are also known as fish-eye mirrors or divergent mirrors.

Concave mirrors converge light, that is, they are able to focus light. Concave mirrors can also be used to focus other forms of electromagnetic radiation. Satellite dishes are concave – they don't focus light but they help focus radio waves.

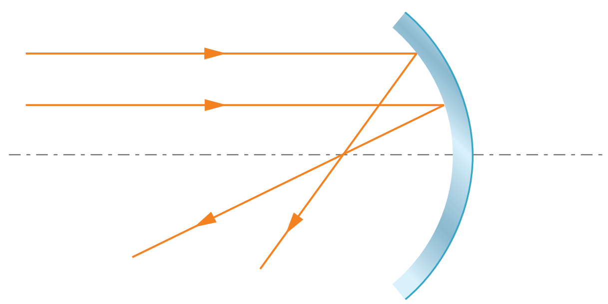


Figure 6.29 A concave mirror. The red lines show the path of the light. The incidence rays are coming into the mirror and the mirror reflects them through a point where they converge (come together). This point in a concave reflection is called the **focus**.

Refraction in everyday life

When light strikes a transparent (see-through) material, it enters the material and may change direction as it does so. This 'bending' of light as it passes from one transparent material to another is called **refraction**. Often when light is refracted, our view is distorted.

Refraction explains a lot of phenomena we are familiar with in everyday life.

1. Swimming pools and the ocean look shallower than they really are. The depth we see is called the **apparent depth**.
2. Refraction makes straight objects appear disconnected.
3. Refraction makes underwater objects appear closer to the surface than they really are.
4. Refraction explains the cause of mirages.
5. Refraction explains how lenses work.

Figure 6.30 This person looks shorter in the water because the apparent depth is less.

Figure 6.31 This pencil looks bent because the apparent position of the pencil is different from the real position.

Refracted rays

The amount of refraction (bending of light) depends on the optical densities of the mediums. The optical density, which is different to the physical density of an object, has to do with the amount of light an object transmits. Materials with different optical densities have different **refractive indexes** (n). The higher the optical density, the slower the light travels through it.

The bent ray is called the **refracted ray** and its angle with the normal is the **angle of refraction**. The way the light bends depends on which medium has the higher optical density.

When a ray of light travels from a less dense medium into a denser medium, such as from air into water, it slows down and consequently bends and becomes closer to the normal. This can be remembered using the mnemonic LMC.

first medium Less dense (L)
second medium More dense (M)
light bends Closer to normal (C)

When a ray of light travels from a denser

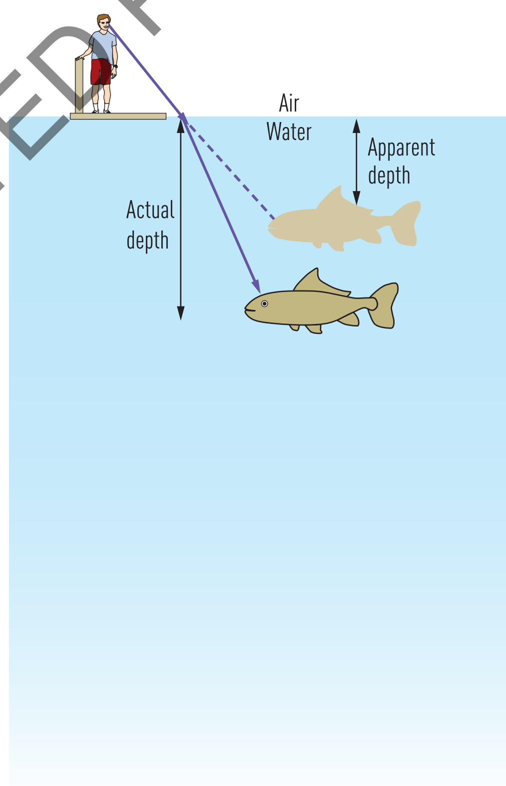


Figure 6.32 This fish would look closer to the observer than it really is because the light has entered a denser medium.

Figure 6.33 A mirage is a visual effect but does not exist. The air above the land is heated by the land and is less dense than the cool air above it. The blue light from the sky bends into the viewer's eyes, so we see a blue, watery image on the land – this is the mirage.

medium into a less dense medium, such as from glass into air, it speeds up and bends away from the normal.

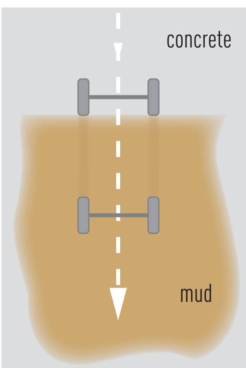
A way of remembering this is using the mnemonic MLA.

first medium More dense (M)
second medium Less dense (L)
light bends Away from normal (A)

Generally, liquids have a higher optical density than gases, and solids have a higher density than liquids. The light bends because it changes speed. The lower the optical density, the faster the light travels in the medium. The only time light doesn't refract is when it enters a new medium along the normal. It still changes speed but there is no bending of the light.

This behaviour can be understood through an analogy. Imagine a truck driving from concrete onto mud. If it is driving straight towards the mud, and both of its front wheels hit the mud at the same time, the truck will slow down, but it will still travel straight. If the truck hits the mud at an angle, the tyre which hits the mud first will change direction and cause the entire truck to change direction as it becomes bogged and travels slower. See Figure 6.36.

Total internal reflection is a very special case of refraction where the angle of refraction is so large that all the light becomes trapped within the substance.



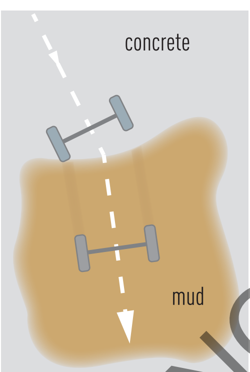


Figure 6.36 The speed of the wheels of the truck changes as they move across different mediums. If both front wheels move into the mud at the same time, the truck continues in a straight line (a). If one wheel hits the mud first, it spins more slowly than the wheel on the concrete and so turns the truck (b).

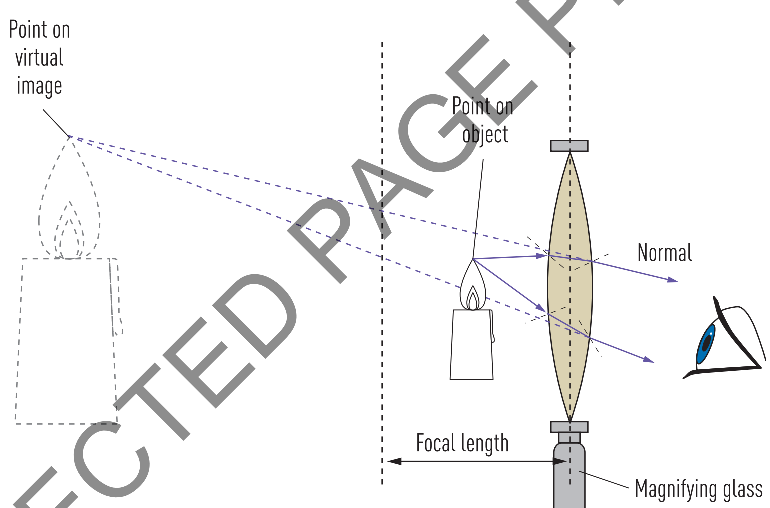


Figure 6.34 For objects closer to the lens than the focal length, a magnified, upright and virtual image is produced. This is how a magnifying glass works.

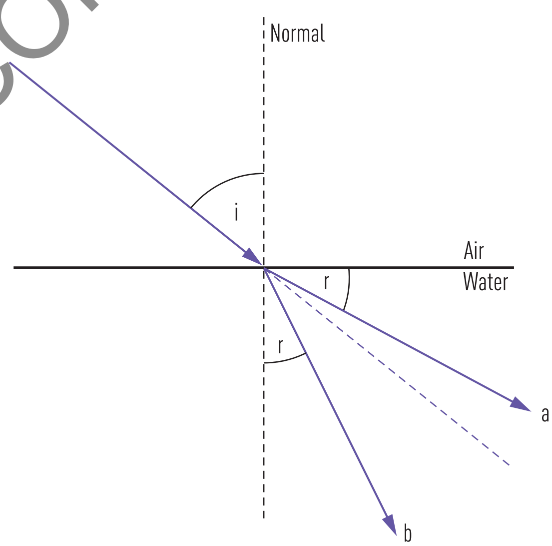


Figure 6.35 (a) Light entering a less optically dense medium bends away from the normal. (b) Light entering a more optically dense medium bends towards the normal.

EXPERIMENT 6.2.4: REFRACTION OF LIGHT

Aim

To investigate the path of light rays during the process of refraction.

Materials

- Hodson light box kit, including perspex block
- Power supply
- Sheet of white A4 paper
- Blu-Tack
- Ruler
- Pencil
- Protractor

Method

1 Place the perspex block in the centre of the A4 paper. Trace around its outside with your pencil.

2 Remove the block and use the protractor to construct a normal to one of the long sides of the block (that is, draw a line at 90º to the side of the block).

3 Position the block on the paper again. Keep it in place with some Blu-Tack.

4 Set up the Hodson light box, darken the room and aim a single incident ray at the face of the block along the normal line. Does the light bend as it enters and exits the block?

5 Move the light box so the ray is aimed at the face of the block at an angle of approximately 45°. Mark the position of the incident ray and the ray that exits the block on the other side with pencil dots. Ignore any reflected rays this time.

6 Remove the block and turn off the light box.

7 Join the end of the incident ray to where it exits the block on the other side using a ruler.

8 Construct a normal to the face of the block where the ray exits.

9 Use the protractor to measure the four angles of the light ray with a normal on your diagram. To do this, line up the 0º line of the protractor along the normal each time and read the angles between the normal and the incident rays and between the normal and the refracted rays.

Results

Record your results in two tables for refraction from air to perspex and refraction from perspex to air.

Discussion

1 Explain your observations when the incident light travelled along the normal.

2 Compare your angles of incidence to your angles of refraction. Why are they not equal in each case?

3 Do your results support the rules of light passing from a less dense medium into a denser medium and vice versa? Explain your answers.

4 Identify some sources of error in this experiment.

Conclusion

Write a conclusion for this experiment.

DEEPER UNDERSTANDING

Optic fibres

Optic fibres have revolutionised communications systems. Instead of always relying on copper wires to carry electrical signals, we now use bundles of optic fibres to carry light signals for landline telephone calls, the Internet and networking of computers. An **optic fibre** is a very thin cable of glass or plastic that carries light. By sending the information as controlled pulses of light, a single fibre less than a millimetre thick can carry thousands of landline telephone calls at once.

The advantages of optic fibres over copper wires are less signal loss, greater carrying capacity and immunity to electromagnetic interference. Hence, long distances can be covered with fewer repeater (booster) stations. A single optic fibre carries much more data than a copper cable, so optic fibres save space, and crossed messages (a form of interference) cannot happen. Optic fibres do not generate heat like the current in a copper wire and are non-electrical, so they don't pose a fire risk and can be used around high voltages. The National Broadband Network of fibre optic cables is currently under construction.

Optic fibres work on the basis that the light passing through the fibres is totally internally reflected within the core of the fibre. This means there is minimal signal loss, and theoretically transmission can occur at the speed of light.

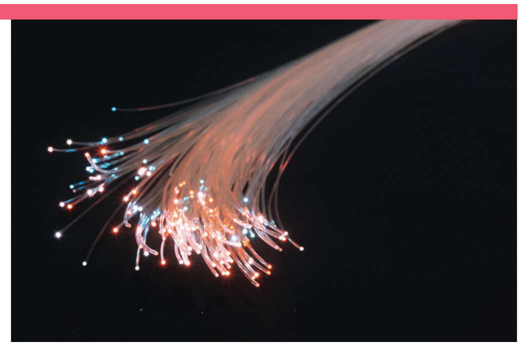


Figure 6.37 Optic fibres are used to carry digital light signals and they have various applications.

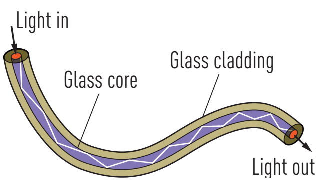


Figure 6.38 Light zigzags inside an optic fibre at the boundary of the core and the cladding, being totally reflected (so there is no loss of light).

DEEPER UNDERSTANDING

Models of light

You have learned about light as a transverse wave. Some experiments with light show that it has a particle nature as well as a wave nature. The fundamental light particle, or quantum, is called the photon. The 17th-century astronomer and mathematician Sir Isaac Newton proposed the particle model of light.

Models are a good way to think about how light behaves in different situations. For example, the idea of bending light is based on the wave model, and we use the particle model when we think about reflection. Another model, the ray model of light (where light is drawn as light or rays), is a simple way to draw light. However, *these are only models* – in reality, light behaves in much more complex ways.

QUESTIONS 6.2.3: HOW LIGHT BEHAVES

Remember

1 Construct a table that explains where to draw or measure the normal, incident ray, angle of incidence, reflected ray and angle of reflection.

2 Identify three everyday examples where refraction takes place.

3 What is the name given to the point where light converges in a concave mirror?

4 Recall the difference between a concave mirror and a convex mirror. Draw a diagram to help you explain.

Apply

5 Identify and list the similarities and differences between reflection and refraction.

6 Draw a diagram to demonstrate how a light ray bends when it travels from water (less dense) into diamond (more dense).

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ENERGY AND WAVES

6.2 CHECKPOINT

Remember and understand

1 Explain why humans need a little bit of ultraviolet light. [1 mark]

2 Describe the uses of infrared light. [1 mark]

3 Identify different types of electromagnetic radiation that make up the electromagnetic spectrum. Explain in point form how they are different from each other. [3 marks]

4 Identify three places where reflection occurs. [3 marks]

Apply

5 Identify and list the advantages of optic fibres over copper wires for communications. [2 marks]

6 Sound is a wave, but it cannot travel through a vacuum (empty space). Light can travel in a vacuum. Propose why this is. [1 mark]

7 Identify what type of electromagnetic radiation would be suitable for use in transmitting information. Justify your choice. [2 marks]

Analyse and evaluate

8 More Australians are being diagnosed with vitamin D deficiency every year. So, is it healthy to get a bit of a suntan? Think about this, share your ideas with a partner and then discuss the various issues as a class. Write a brief discussion about whether it is healthy to get a slight suntan. [2 marks]

9 Sound waves leave a loudspeaker. Using scientific terms, explain how we hear this sound. [2 marks]

Critical and creative thinking

10 Explain to a year 7 student the difference between the absorption, reflection and refraction of light. Use language they will understand and include an everyday example in your answer. Your answer can be written, verbal or use ICT and diagrams. [3 marks]

11 Construct a model that demonstrates refraction. You need to use two surfaces, either of different heights or different textures, and a large ball bearing (like a marble) or a pair of toy wheels connected with an axle. Explain what each part of your model represents. [3 marks]

12 Construct an illusion model of a straight rod dipping into a container of water. Bend the rod where it enters the water so the part underwater appears to be straight. [3 marks]

Making connections

13 Think back to Activity 6.2.1, with the radio (or alarm clock or bell) in the bell jar.

a You could still see the radio (or alarm clock or bell) in the bell jar, even though you could not hear it. Explain what this says about the way light travels. [2 marks]

b Investigate what you can infer about the ability of light energy to travel through outer space. [2 marks]

TOTAL MARKS
[/30]

6.3 ENERGY AND ELECTRICITY

Electrical energy is fundamental to our modern lives. We use electrical energy every day at home and at school. Our MP3 players, mobile phones, tablets and laptops rely on the energy stored in their batteries to work, and without it we would find life to be very different, and certainly less entertaining. Have you ever tried to recharge your mobile phone without an energy source? Is it impossible? So, what is electricity and how do we use it?

ELECTRIC CIRCUITS

The pathway travelled by electrical energy is called an **electric circuit**. As electrically charged particles move around an electric circuit, they carry electrical energy from an energy source, such as a battery, to the device that uses the energy, such as a torch bulb. This movement of negatively charged particles results in an electric current.

What are these particles? Think back to the basic atomic model: protons and neutrons within the centre of the atom (the nucleus), then electrons orbiting around the outside. Protons and neutrons are big and heavy and are trapped within the centre of the atom, whilst electrons are tiny and are able to move away from the atom. An electrical current can be established through the movement of electrons through the circuit.

This is, obviously, very hard to imagine. Analogies are often used in science to describe concepts that are difficult to visualise. Here's one for electric circuits:

Imagine a mountain with only one ski run. Skiers line up at the bottom of the mountain, get taken up to the top using chairlifts, then ski across the slope before coming down the ski run. They then need to ski across the slope again before lining up to use the chairlift.

Now imagine it is a very busy day and there is a line for the chairlift and the ski run. The skiers aren't waiting though – they are evenly spaced out and the number of them taken up by the chairlift balances exactly with the number coming down the slope.

The chairlift gives each individual skier energy (in the form of gravitational potential energy). Each skier loses that potential energy when they come down the slope. In the entire process, the skier is not changed.

For each individual skier, it may take them five or so minutes to go up the chairlift, ski across the slope, then down the ski run and then across the slope back to the chairlift, but there are always skiers everywhere.

This is exactly the case with electricity. The electrons are the skiers, moving through an electrical circuit. The chairlift is like a power source – a place where electrons gain electrical potential energy. As the electrons move across a wire (as a skier moves across a slope), no energy is lost or gained. Electrons will use up electrical potential energy when they come across a resistor, such as a light bulb. Where in the skier's case, gravitational potential energy is transformed into kinetic energy and heat, in electricity, electrical potential energy is transformed into heat, light or sound.

Simple circuits

A simple circuit can be constructed with two pieces of wire, a resistor (such as a light bulb) and a power supply. You may remember constructing these circuits before.

ACTIVITY 6.3.1: BASIC CIRCUITS

You will need: 2 lengths of wire, light bulb, switch, power pack and alligator clips.

1 Connect the equipment, as per Figure 6.39.

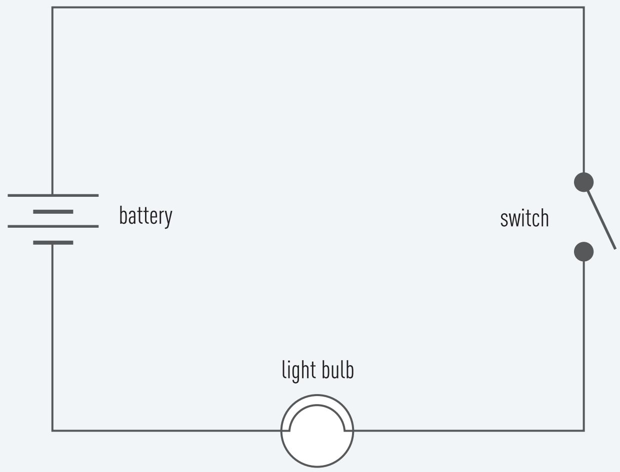

Figure 6.39 A basic circuit.

2 Place the power supply on 2V, close the switch and see what happens.

3 Repeat with increasing voltage.

4 When two or more resistors or light bulbs are connected together, there are a few different ways to connect them.

- What did you find out about the way a circuit must be connected to ensure the electricity flows all the way around?

All circuits have a few things in common:

- A power source – could be a power pack, battery cell or a connection to mains power.
- A component that requires energy – could be a globe, buzzer or motor.
- Connecting wires – the electrons need a substance to travel through.
- A completed circuit without breaks – electrons cannot flow unless there is a complete path from the power source through the circuit back to the power source.
- A switch – this breaks the circuit (when open) and stops the flow of electrons and controls the circuit.

When there are multiple components in a circuit, there are a few different ways they can be wired together. The positions of components in a circuit relative to each other can change the amount of energy they receive and how they function.

SCIENCE SKILLS

Drawing circuit diagrams

Circuits are represented using **circuit diagrams** in the same way that scientific diagrams are used to represent scientific laboratory equipment. Each component is represented by a specific symbol (Figure 6.40). Connecting wires are usually shown as straight lines, and where different wires meet at junctions they are often shown as being joined at right angles. The power source is represented as a pair of parallel lines of different lengths. The longer line represents the positive terminal (often indicated by a plus symbol) and the shorter line represents the negative terminal. These terminals of the battery cell (or other power source) are where the wires are connected.

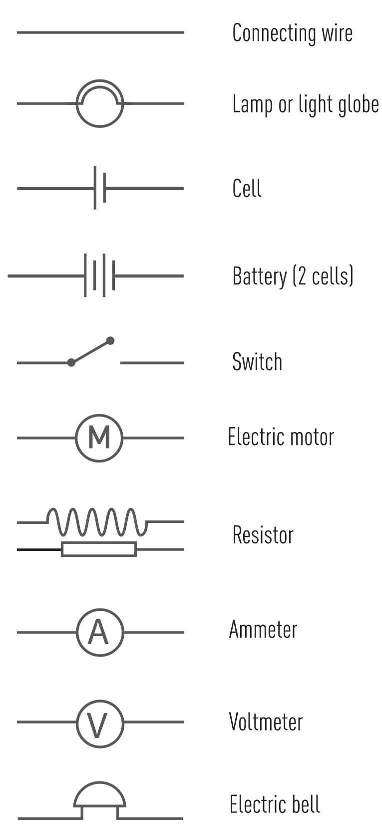

Figure 6.40 Some common symbols for circuit diagrams.

The circuit illustrated in Figure 6.41a includes a globe, a battery, connecting wires, a switch and an ammeter to measure the electric current. Drawing illustrations like this to represent a circuit is time consuming and difficult if you are not a great artist. The circuit diagram of the same circuit (Figure 6.41b) is much simpler, clearer and easier for most of us to draw.

Tips for drawing circuit diagrams:

- Use a pencil so it is easy to fix any mistakes.
- Use a ruler for the connecting wires.
- Each diagram should be about quarter of a page in size so all the components can be clearly drawn.

Your turn

Draw a simple circuit containing one battery cell, a switch, an electric bell and connecting wires.

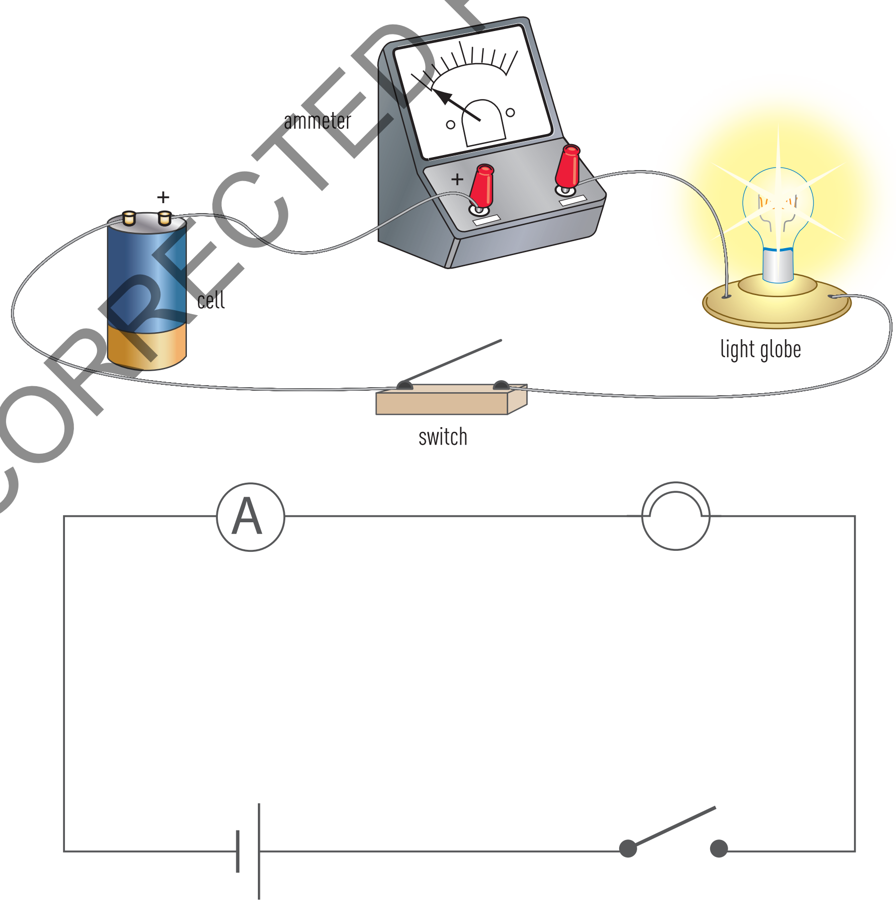

Figure 6.41 (a) An illustration of a simple circuit. (b) A circuit diagram of the same circuit.

ACTIVITY 6.3.2: MAKING SERIES AND PARALLEL CIRCUITS

Find out how many different ways you can connect two globes in a circuit.

What you need: 2 × 1.2 V globes and holders, variable power supply, 8 connecting wires (with banana plugs or alligator clips), switch, ammeter

1 Construct four different circuits, placing the switch so that it controls:
   - a both globes (that is, with both globes either on or off at the same time)
   - b one globe only, with the other on all the time
   - c the other globe only, with the first globe on all the time
   - d Follow steps 2 and 3 before you disconnect each circuit.
2 Draw the circuit diagrams to show where the switch was placed in each circuit.
3 Connect an ammeter at different places in each circuit and measure the current at each point. Record your measurements in a table.
   - What did you find out?

Series and parallel circuits

When we look at two light bulbs connected in a circuit, two different types of connection are possible.

In a **series circuit**, the globes are connected side by side so the current goes through one globe and then the other (Figure 6.42).

What would happen if the circuits in your house were series circuits? A problem in one part of the circuit would cause appliances in other parts of the house to stop working. Parallel circuits avoid this problem. If one appliance fails, others will still work, and some appliances can be on while others are off (by using switches).

A parallel circuit has two or more branches and the current splits between the branches (Figure 6.43) and comes back together afterwards. The sum of the currents in the branches of a parallel circuit is equal to the current in the unbranched part of the circuit. You will learn more about current and the differences between these two circuits a little later.

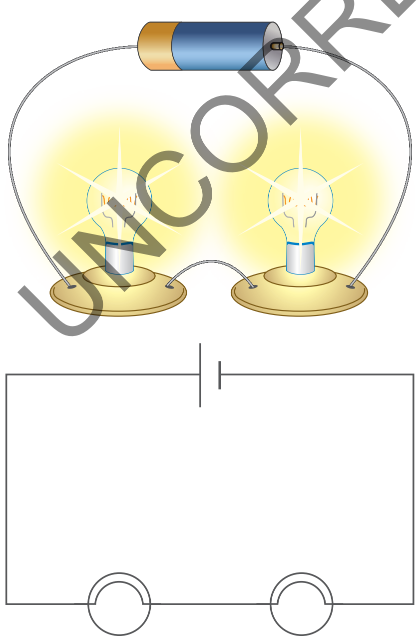

Figure 6.42 A series circuit.

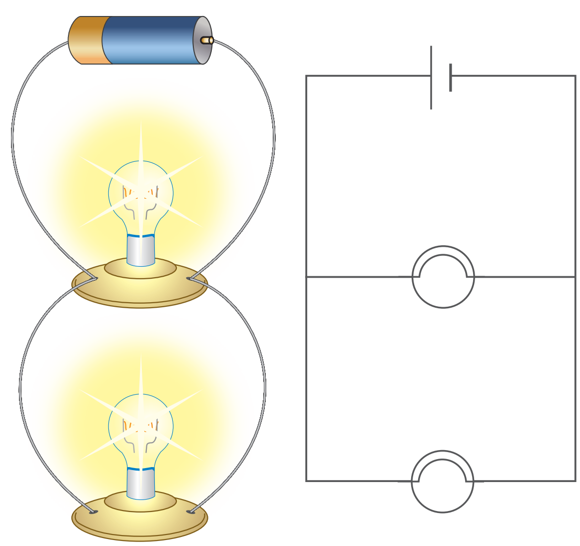

Figure 6.43 A parallel circuit.

QUESTIONS 6.3.1: ELECTRIC CIRCUITS

Remember

1 Identify if household appliances are connected in series or in parallel. How do you know? Why is this the standard wiring?

2 People often complain when they put up their Christmas tree lights that a whole row of them no longer work.

  a Does this suggest the globes are connected in series or parallel? How do you know?

  b Draw a circuit diagram showing the wiring of some of the globes.

3 Identify which of the globes in Figure 6.44 will light up.

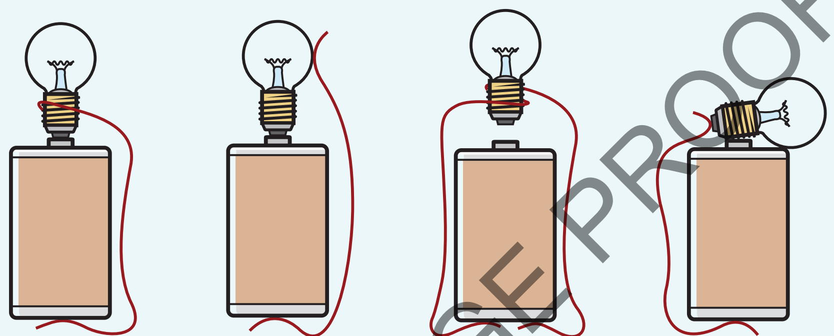

Figure 6.44

Apply

4 Double adaptors and power boards enable you to connect additional appliances onto a power point.

  a Identify if these are series or parallel connections. Explain your answer.

  b If you try to operate several appliances at one time from the same power point using power boards or double adaptors, you are likely to overload the circuit. Explain why.

5 Explain how the skier analogy could explain what happens when a light bulb blows in a circuit and no longer conducts and changes electricity.

6 Consider what would need to be added to the skier analogy to simulate a switch in a simple circuit.

7 Explain what can be added to the skier analogy to explain:

  a A parallel circuit

  b A series circuit

Voltage

Voltage is a measure of the potential energy that electrons have. In a 1.5 V battery, each unit of charge gets 1.5 joules of energy as it passes through the battery.

Voltage is more accurately called the **potential difference** and has the unit **volts** (symbol V). It is measured using a voltmeter. To measure the potential difference of a current, voltmeters are set in parallel across the two points in a circuit that you want to measure. (You will do this in Experiment 6.3.1 when you measure the voltage drop across the resistor by connecting the voltmeter before and after the resistor.)

This electrical potential energy is similar to the gravitational potential energy that skiers gain when travelling up a chairlift. In the skiing analogy, the chairlift is the battery in a circuit. This potential energy is used up in the circuit, but only if there is a resistance.

Figure 6.45 Each unit of charge in this battery has 1.5 joules of energy.

Electric current

Electric current, the flow of charge, is measured by counting the number of electrons that go past some point in the circuit in one second. Electrons are very small and therefore a huge number of them are likely to go past any given point. We give another unit to 6.241×10^{18} electrons. Just as 12 items are called a dozen, 6.241×10^{18} electrons are known as one coulomb. 1 coulomb passing a given point in 1 second is known as an **ampere** (symbol A). Current is measured in amperes. You may often hear it being called amps.

The ampere is a large quantity of current, so smaller units such as the milliampere (1000 mA = 1 A) are often used. An ammeter is a meter that measures the current travelling through a particular point in an electric circuit. The ammeter must be connected into the circuit in series so the current flows through it. Another way of thinking of an ammeter is a barrier that the skiers have to go through. It counts the number of skiers that go through it.

Figure 6.47 An ammeter is used to measure electric current.

Resistance

The amount of current flowing in a circuit is determined by the resistance of the circuit. The electrical **resistance** of a material is a measure of how easily electrons move through it. Resistance has the unit called **ohms** (symbol Ω).

In the skiing analogy, the resistance would be how hard the snow is. If the snow is particularly hard, you will need to do more work, and use up more energy to ski properly. If the snow is soft, you can ski down the slope relatively easily.

But keep in mind that the higher the ski run, the higher the chairlift would have to go. Notice that the chairlift will take you to the top of the ski run, and no further. You cannot get off the chairlift half way between the ski run either. This is the same with resistance and voltage. The electrical potential energy provided by an energy source must balance the resistance of an object connected in the circuit, otherwise the circuit will not work.

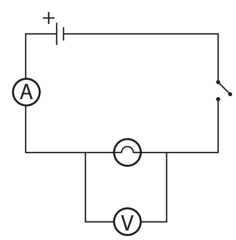

Figure 6.46 A voltmeter is used to measure voltage in a circuit. It is shown in a circuit diagram by a 'V' within a circle. An ammeter is used to measure the current in a circuit. It is shown by an 'A' within a circle.

As electric current moves through the wires of an electric circuit, the electrons collide with the atoms in the wires and some of their electrical energy is changed into heat. The heat produced by a computer that has been running for a while is an example of this resistance. This is why many connecting wires are thick and made from good conductors. Sometimes, the heat

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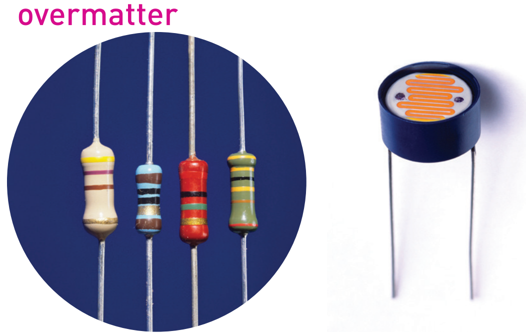

Figure 6.48 Many types of resistor are available. (a) The resistance of carbon resistors is indicated by the coloured bands on their plastic case. (b) The resistance of a light-dependent resistor (LDR) varies depending on the brightness of the light shining on it. This makes LDRs useful in sunset sensors that control automatic lighting circuits, like street lights or security lights.

SCIENCE SKILLS

Understanding resistor colour codes

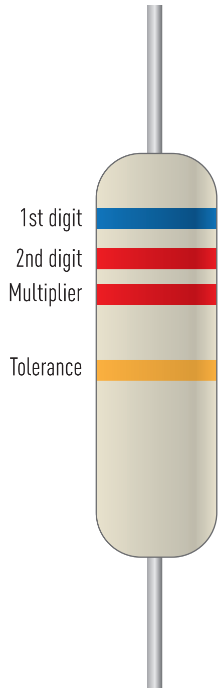

Figure 6.49 What is the value of this resistor?

Carbon resistors sometimes have four colour-coded bands on their case. These bands are part of a code that allows you to work out the resistance of the part and the tolerance. The fourth band is the tolerance band, which gives you an indication of the accuracy of the resistor. A gold band as the fourth band means 5% accuracy, a silver band means 10% accuracy and no fourth band means 20% accuracy. The lower the percentage, the more accurate the resistor.

To read the three other bands, put the tolerance band on the right and start at the other end. The first two bands form a two-digit number according to their colour (Table 6.2). The third band tells you how many zeros to put after that number.

Look at the resistor in Figure 6.49. What does its code mean?

1. Read the tolerance band (at one end). This band is gold, so the resistor has 5% accuracy.
2. Read the other three bands starting at the opposite end. The first band is blue, so it has a value of 6.
3. The second band is red, so it has a value of 2. Consequently, the number is 62.
4. The third band is also red, meaning two zeros need to be placed after the number. Therefore, the number is now 6200.
5. Resistor values are always coded in ohms, so the value of this resistor is 6200 ohms or 6.2 kilo-ohms.

Table 6.2 Resistor colour codes

Colour	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

QUESTIONS 6.3.2: CURRENT, VOLTAGE AND RESISTANCE

Remember

1. Recall the name given to a large quantity of electrons.
2. What is another definition for an ampere? (Think about it in terms of number of electrons)
3. Define 'resistance' in terms of electrical circuits.
4. Explain what happens to the electrical energy carried by electrons as they flow through an electric circuit.
5. Identify the quantity that is a measure of the electrical energy carried by each unit of charge in an electric circuit.

Apply

6. Create an analogy of your own that explains the relationship between voltage, resistance and current.
7. Copy and complete the table below to summarise the key facts about voltage, current and resistance.

	Voltage	Current	Resistance
Definition			

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OHM'S LAW

Georg Ohm, a German physicist, discovered the relationship between voltage, current and resistance. He found that if the resistance is fixed and the voltage is increased, then the current is increased too. Likewise, if the voltage is decreased, the current is also decreased. If one of them is changed, the other one changes the same way.

This relationship is known as **Ohm's law**:

$V = IR$

where R = resistance (ohms)

V = voltage (volts)

I = current (amps)

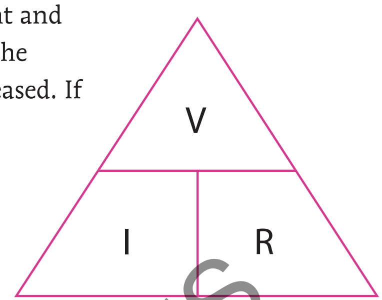

Figure 6.50 The Ohm's law triangle.

NUMERACY BUILDER

Using Ohm's law to find resistance

Example

Find the value of a resistor that has a voltage drop of 6 V across it when a current of 50 mA flows through it.

1 Check the units: 6 V is in volts and so can be used unchanged. 50 mA (milliamps) needs to be converted to amps. 'milli' means 0.001 (or × 10^{-3}), so 50 mA = 50 × 0.001 = 0.05 A.

2 Use the Ohm's law triangle to find the correct formula. You want to find resistance, so use your fingertip to cover the R – the other two letters show you the formula to use (Figure 6.50). The V is over the I, so we use:

$$R=\frac{V}{I}$$

3 Substitute the numbers for V and I:

$$R=\frac{6}{0.05}$$

4 Do the calculation:

$$R=\frac{6}{0.05}=120\ \Omega$$

5 Answer the original question:

6 The resistance of the resistor is 120 Ω.

If you are given units that are not the standard units used in the table, you will need to convert them.

Your turn

This law can also be used to work out the voltage or the current. What is the voltage drop across a resistor with a value of 180 Ω and a current of 50 mA? (Remember to cover the V to get the correct formula with the R and I. If the letters are next to each other, you multiply them.)

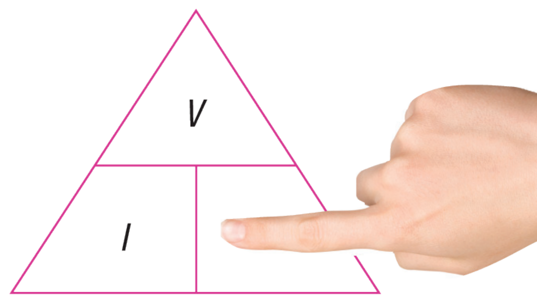

Figure 6.51

EXPERIMENT 6.3.1: INVESTIGATING OHM'S LAW

Aim

To investigate the voltage drop across and the current flow through a resistor, and then calculate an average value of the resistance.

Materials

- Power supply
- Ammeter
- Voltmeter
- 10 Ω resistor
- 3 other resistors with masking tape over their coloured bands
- Connecting wires
- (Note: The resistor's fourth band is not used for measuring, it is the tolerance band.)

Method

1 Identify the 10 Ω resistor. It should be colour-coded brown, black, black.

2 Connect the circuit as shown in Figure 6.52. Use the DC terminals of the power supply and start with the dial on 2 V.

3 Switch on the power supply, take the readings on the ammeter and voltmeter, and switch the power off again quickly and straight away (so you don't overheat the resistor).

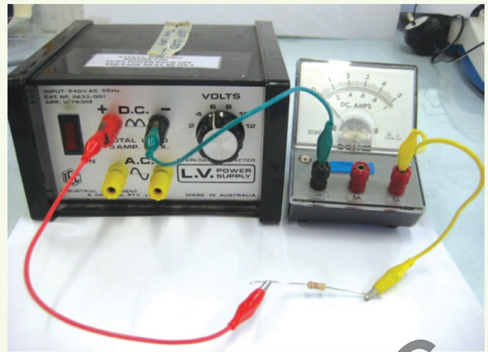

Figure 6.52 Circuit setup.

4 Change the dial on the power supply to 4 V and repeat step 3. Then change the dial to 6 V and repeat.

5 Copy and complete the results table.

Resistor	Voltage (V)	Current (mA)	Current (A)	Volts ÷ amps

6 Repeat the experiment for the other three resistors, without reading their coloured bands.

7 Complete the results table for each of the three masked resistors and calculate their resistance.

8 Remove the masking tape and determine the resistance values from the coloured bands of the resistors.

Results

Include your results table in this section.

Discussion

1 From your results table, what can you infer about the values in the last column for each resistor?

2 Identify what quantity the last column calculates.

3 For the three masked resistors, examine how close the values you obtained were to those marked with their coloured bands.

4 Can you outline the difference as a percentage of the average?

5 Which value, the one obtained by reading the coloured bands or the one obtained from your calculations, gives the more accurate measure of a resistor's resistance? Explain your answer.

Conclusion

What do you know about Ohm's law? Write a statement that addresses your aim.

Series and parallel circuits

How do series and parallel circuits fit into Ohm's law and the concepts of resistance, current and voltage? Let's revisit the concepts:

- Resistance is how much resistance a particular circuit component has against the move of electrical energy. Higher resistance depends on the components themselves.
- Current is how many electrons are passing through a particular point in a circuit at any one time. This was analogous to how many skiers pass through the gate for the chairlift.
- Voltage is potential difference – this is how much energy is supplied by the power supply, and also how much energy is used up by the circuit.

Now let's apply these ideas to a series circuit and a parallel circuit.

In a series circuit, the electrons flow all around, so the current passing through each component is the same whilst the voltage through the circuit is the sum of the voltages across each component. In a parallel circuit, the voltage across each of the components is the same, as each individual component is supplied with the same voltage as whatever the power supply outputs. The total current in a parallel circuit is the sum of the current through each component.

QUESTIONS 6.3.3: OHM'S LAW

Remember

1 Recount the three equations that can be obtained from the Ohm's law triangle.

Apply

2 Calculate the current flowing through a 44 Ω resistor when it has a voltage drop of 11 V across it.

3 Calculate the voltage drop across a 25 Ω resistor when a current of 50 mA flows through it.

4 Calculate the value of a resistor that has a voltage drop of 8 V across it when a current of 0.4 A flows through it.

5 Explain what the value of a resistor is that has three coloured bands (excluding the tolerance band) of:

a red, white, black

b yellow, green, red

c brown, blue, orange

CLEAN COAL TECHNOLOGY – IMPROVING ELECTRICITY GENERATION

In Australia, coal is burnt in most power stations to produce electricity. When coal burns, it emits gases such as carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). Carbon dioxide is a big contributor to the enhanced greenhouse effect, while sulfur dioxide and nitrogen dioxide cause damage to the environment as acid rain. Although there are emerging renewable technologies available, such as solar power and hydropower, coal remains a relatively cheap and plentiful energy resource in Australia. Whilst some scientists and engineers are working on alternative energy production, other scientists and engineers are working on a number of technological developments to improve the way we use coal.

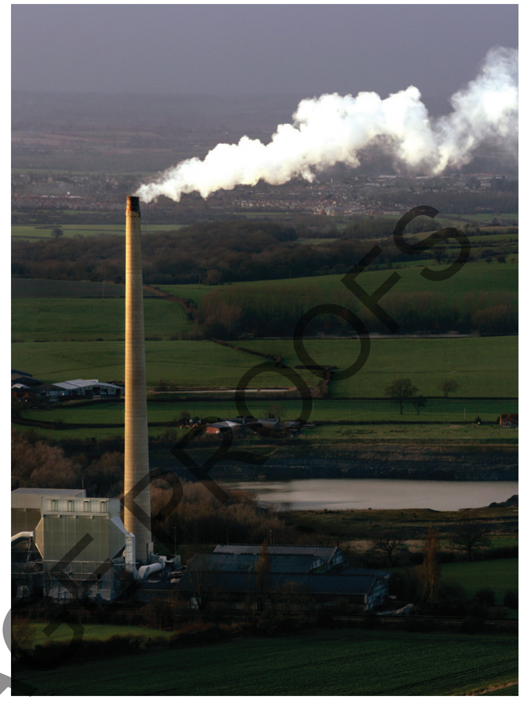

Figure 6.53 Electrostatic precipitators trap solid particles, preventing solid particles from leaving via stacks such as the one shown, which is emitting steam.

Treating coal and coal emissions

Coal washing removes unwanted chemicals in the coal. Crushed coal is mixed with a liquid, which allows the impurities to separate and settle. The waste gas emitted when the coal is burnt can be sprayed with a mixture of limestone and water in a 'wet scrubber'. This removes sulfur dioxide. Special burners reduce the creation of nitrogen oxides by limiting the oxygen involved in the combustion process. Electrostatic precipitators remove solid waste particles by giving them an electric charge and capturing them on collection plates.

Turning coal into gas

The integrated gasification combined cycle (IGCC) system changes coal into gas. Steam and hot pressurised air combine with coal and force the carbon molecules apart. The result is syngas, a mixture of hydrogen gas and carbon monoxide gas, which is then cleaned and burned in a gas turbine instead of a coal power station. This is a more efficient process than burning coal to heat water, which turns to steam and then turns a turbine.

Carbon capture and storage

Carbon capture and storage (CCS) refers to the collection and storage of carbon dioxide emissions from power stations. Scientists have so far developed several technologies for capturing carbon dioxide. Flue-gas separation removes carbon dioxide using steam and condenses the steam into a concentrated stream. This produces carbon dioxide that can be used in other industries. Oxy-fuel combustion involves burning coal in enriched or pure oxygen. This creates a gas composed mainly of carbon dioxide and water, without the other normal waste gases.

Secure containers are used to store the collected carbon dioxide. Two storage options are being explored: under the ocean or under the ground. Ocean storage injects liquid carbon dioxide 500 to 3000 metres under the ocean, where it dissolves. Geologic storage injects carbon dioxide into depleted oil or gas fields, or into deep geologic structures.

ACTIVITY 6.3.3: HOW MUCH ENERGY AM I USING, AND CAN I USE LESS?

One of our most valuable resources is within ourselves: the ability to make wiser choices. One such wise decision is to reduce our electricity consumption. If each one of us made the effort, the electrical resource requirements of our cities would be reduced.

The electrical energy we use at home is measured in kilowatt hours (kWh). The cost to a householder of each kWh varies around Australia and between different companies. Let's say it is approximately 20 cents per kWh.

To find out how many kilowatt hours you use in your house, you will need to examine your electricity meter. If you don't have access to your electricity meter, you can use the last electricity bill and calculate the average energy usage in a day.

This activity takes a minimum of three days to complete and should be done with the help of an adult. You might like to consider taking photographs throughout the investigation to use in your final report.

1 Record the reading on your electricity meter at a time you are able to repeat the next day (for example, 7.00 pm).

2 Keep a list of the electrical appliances your household uses during the next 24 hours.

3 Record the reading on the meter at exactly the same time the next day.

4 Calculate the number of kilowatt hours your household used in that 24-hour period by subtracting the second reading from the first.

5 Calculate the approximate cost of this electricity, assuming that each kWh costs 20 cents.

6 Choose four appliances in the house and read their electricity label. It might be on the back of the appliance or on its base. This should give details of the power an appliance uses. For example, if a microwave oven has a 1000 W rating it uses 1 kW (1 kilowatt = 1000 watts). This means that if the microwave is used for 1 hour, it uses 1 kWh of energy.

7 Estimate how long each of the four appliances is used for each week. Multiply the power rating of the appliance (in kW) by the estimate of the time it is used per week (in hours). For example, the microwave oven may be used for 2 hours per week total (5 minutes per use, used 24 times per week). The energy it uses would be:

energy = power × time/ = 1 kW × 2 h/= 2 kWh

8 Use the total amount of energy each of the four appliances you chose uses each week to calculate the amount of energy that all four of them use together each week.

9 Estimate the cost of using these four appliances each week (remember to use 20 cents per kWh). You might like to copy and adapt the following table.

Appliance	Power (W)	Power (kW)	Time used (h)	Energy (kWh)	Cost ($)
Microwave	1 000				
Refrigerator	0.168		24		

10 Total cost per week for both appliances = ____________________

11 Identify how people in your house could reduce the amount of electricity used at home in time for the next bill. Be specific for each member of your household.

12 Record the reading on the electricity meter and then ask household members to do as many of the things you listed for step 10 as possible over the next 24 hours. Record these changes and check the meter again at the same time the following day.

13 Assess if there is any difference in the amount of energy used by your household as a result of your changes. Calculate the difference in energy usage and calculate how much money was saved.

14 Analyse what your household could do to reduce your electricity usage over a longer period of time.

15 Explain what you and your household have discovered during this challenge.

16 Combine all your findings into an inspiring presentation to your class. Use a format of your choosing.

QUESTIONS 6.3.4: CLEAN COAL TECHNOLOGY – IMPROVING ELECTRICITY GENERATION

Remember

1 Recall the definition of 'emissions'.

2 Identify two waste gases apart from carbon dioxide that result from burning coal.

Apply

3 Draw a flow chart to show how coal can be converted into a gas, which is burnt to produce electricity.

4 Discuss what dangers might be posed by injecting CO_2 deep under the ocean or deep under the Earth's surface.

ENERGY AND ELECTRICITY

6.3
CHECKPOINT

Remember and understand

1 Draw a circuit diagram for a circuit, showing a power supply, a globe, several wires and a switch. [2 marks]

2 Label each component in the circuit in you drew in the above question. [2 marks]

3 Identify what an ammeter is and what it measures. [2 marks]

4 If you don't connect the conducting wires to a globe correctly, the globe doesn't light up. This means the energy from the electrons is not being used in the globe. Explain what is happening in terms of the electrons. [1 mark]

5 Identify two places where parallel circuits are used. [1 mark]

6 Explain when series circuits are used, giving the reason why they are used instead of parallel circuits. [2 marks]

Apply

7 Draw a circuit diagram showing a battery and a switch, with a globe either side of the switch. Does it matter where in the circuit the switch goes? [3 marks]

8 Explain how the resistance of resistors can be read using the four-band system. [2 marks]

9 Outline three techniques that help to make coal-fired electricity generation cleaner. [3 marks]

Analyse and evaluate

10 The lights in Figure 6.54 are connected in series. Explain what happens if one globe fails. [1 mark]

11 Power lines carry electricity from power stations to cities and towns at very high voltages. Should the wires be thick or thin? Explain your answer. [2 marks]

12 Is the circuit in Figure 6.55 a parallel or series circuit? Explain your answer. [1 mark]

13 Calculate the current flowing through a 30 Ω resistor when it has a voltage drop of 12 V across it. [1 mark]

14 Calculate the voltage drop across a 50 Ω resistor when a current of 25 mA flows through it. [1 mark]

15 Calculate the value of a resistor that has a voltage drop of 18 V across it when a current of 0.3 A flows through it. [1 mark]

16 Choose a clean coal technology. Research what type of scientists, engineers and technology are involved in its process. Outline the key parts of their roles. [4 marks]

Critical and creative thinking

17 A storm has blown a tree over onto the main power line to your neighbourhood. As a result, your electricity supply is cut. Describe your day without electricity. [2 marks]

18 Use the skiing analogy to explain what happens in a:

a simple series circuit with two light bulbs [1 mark]

b simple parallel circuit with two light bulbs [1 mark] overmatter

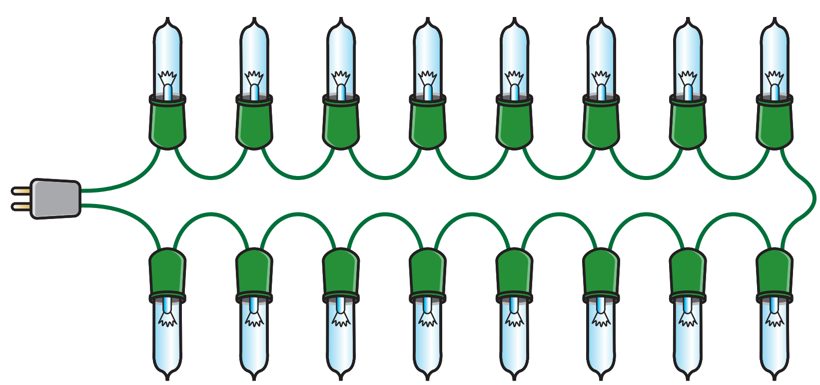

Figure 6.54

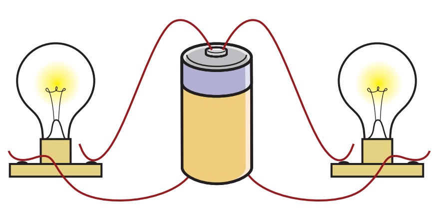

Figure 6.55

TOTAL MARKS
[/40]

6 CHAPTER REVIEW

1 Fill in the gaps using the words in the Word Bank below:

The law of conservation of __________ states that energy is not created or destroyed. It is _________________ from one form to another. Energy can also be transferred. In the case of heat, this energy is transferred through ___________________, conduction or __________________. Waves are another way that energy can be transferred. The energy carried by the ____ is transferred through waves. Light waves, a form of ____, can be reflected and refracted to help serve special purposes.

Electrical energy is very important to our everyday lives. Three main measurements of electrical energy are:

- _____________________ – energy applied
- Resistance – energy dissipated
- Current – energy ______________________

The three measurements can be related through _______________________.

WORD BANK

Carried	Electromagnetic radiation	Ohm's law
Convection	Electromagnetic spectrum	Transformed
Energy		Radiation
		Voltage

Explain the processes of conduction and convection of heat energy

2 Explain how particles in solids and gases behave when they conduct heat energy. [1 mark]

3 Describe how particles behave in convection currents. [1 mark]

4 Outline why solids and liquids can't carry heat energy through convection. [1 mark]

5 Explain why liquids can't carry heat energy through conduction. [1 mark]

6 Compare convection and conduction to radiation in terms of transfer of heat energy. [2 marks]

Identify situations when waves transfer energy

7 Define the term 'wave'. [1 mark]

8 Identify at least two forms of energy that can be transferred by waves. [2 marks]

Describe qualitatively the features of waves in terms of wavelength, frequency and speed

9 Explain the difference between the frequency, wavelength and speed of a wave. [3 marks]

10 Recall the equation that relates frequency to wavelength and velocity. [1 mark]

11 Identify the units used in the wave equation for:

a frequency [1 mark]

b wavelength [1 mark]

c velocity [1 mark]

Explain the transmission of sound in different mediums

12 Sound waves rely on the particles in a medium to carry the energy. Explain how the particles carry the wave. [1 mark]

13 Solids carry sound waves the fastest and gases carry sound waves the slowest. Analyse why the speed of the waves is different in different mediums. [2 marks]

14 Define the terms 'rarefaction' and 'compression'. [2 marks]

Relate the properties of different radiation in the electromagnetic spectrum to their everyday uses, including communication technology

15 Describe how microwaves are different to ultraviolet radiation. What properties does each type have? [2 marks]

16 Give two examples of how infrared waves are used in everyday life. [2 marks]

17 Outline the difference between electromagnetic radiation and electromagnetic spectrum. [1 mark]

Describe the occurrences and uses of absorption, refraction and reflection of light

18 Recall the law of reflection covered in this topic and provide three examples where reflection occurs. [4 marks]

19 Explain how light can be refracted. [2 marks]

20 Describe how the absorption of light gives rise to colours. [2 marks]

Describe voltage, current and resistance in terms of energy applied, carried and dissipated

21 Explain what current is. [1 mark]

22 Identify the unit and the symbol used to describe resistance. [1 mark]

23 Recall one of the analogies used to describe voltage, current and resistance and evaluate the appropriateness of that analogy. [2 marks]

Describe the relationship between voltage, resistance and current

24 Recall Ohm's law. [1 mark]

25 In a simple circuit, describe what the effect on the current will be if the voltage of the power supply is increased, while the resistance of the circuit remains the same. [2 marks]

Compare series and parallel circuits

26 Compare and contrast series and parallel circuits in terms of voltage, current and resistance. [2 marks]

27 Using terms such as potential difference and electrical energy, explain what happens to components connected in parallel. [3 marks]

28 Evaluate the main benefit of connecting a set of lights in series rather than in parallel. [1 mark]

Outline examples where scientific or technological development have involved teams of specialist scientists

29 Outline why higher energy efficiency is an important concept in today's society. Present your findings as a piece of persuasive writing or persuasive multimedia presentation, designed to convince a sceptic. [3 marks]

6 CHAPTER REVIEW

TOTAL MARKS
[/50]

6 CHAPTER REVIEW

KEY WORDS

absorbed
ampere
amplitude
angle of incidence
angle of reflection
angle of refraction
apparent depth
circuit diagram
compression
conduction
convection
convection current
dispersion
electric circuit
electric current
electromagnetic radiation
electromagnetic spectrum
electromagnetic waves
focus
frequency
image
lattice structure
longitudinal wave
medium
ohms
Ohm's law
optic fibre
parallel circuit
plane mirror
potential difference
radiation
rarefaction
reflection
refracted ray
refraction
refractive indexes
resistance
series circuit
thermal energy
transverse wave
visible spectrum
voltage

overmatter

RESEARCH

Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your findings to your class in a format of your own choosing. Your presentation should last for about three minutes. In a multimedia presentation, sound must be part of the presentation. If you interview someone as part of your research, you must present the content of your interview with your report.

Supersonic planes

What does 'supersonic sound' mean? What is the difference between a supersonic jet and a normal jet aircraft? What are some of the problems with supersonic planes? Why was the Concorde removed from air travel service?

Blue sky

Why is the sky blue during the day but often red at sunrise and sunset? What optical processes produce these colour displays? Are there any other natural colourful displays that can occur in the sky? What produces them?

Speed of light

What is the speed of light? How is it measured and how was it discovered? What applications does it have in science? Why can't objects travel as fast as the speed of light?

Night vision goggles

Night vision goggles allow soldiers to see at night and spot the enemy before they are spotted themselves. They give an army a tactical advantage, but how do they work? Will they work in a totally dark environment? Do they have any disadvantages to the soldiers using them?

Large moon

Sometimes when the moon is close to the horizon, it is very large. Some sources put this down to 'relative sizing', that is, you can compare the moon to the size of the buildings and it seems large. But this is actually incorrect. Why does the moon look so big when it is close to the horizon? Draw a picture to show this.

REFLECT

Me

1 How important are heat, light, sound and electricity to your quality of life?

2 What new skills have you learned in this chapter?

My world

3 How important do you think light is for life on the Earth?

4 How are light and heat different to each other?

My future

5 How might the impact of various energy forms (like heat, light and wind energy) change in the future?

6 How might energy-related careers change over the next 50 years?

Green buildings

During the past few years, a sustainability movement has begun in the building industry. It is called green building, and the aim is to develop a sustainable property industry by adopting 'green' building practices, technologies, designs and operations. Green building councils have been established throughout the world to develop and support green building principles and standards, and to rate and certify buildings. These systems consider issues such as building management, indoor environment quality, energy use, transport, water use, types of materials, land use, emissions and innovation. In NSW, the Building Sustainability Index (BASIX) sets energy and water reduction targets for new houses. BASIX is an online program whereby the building designer enters data such as the location of the building, size and building materials into the BASIX program. This data is analysed and a score is determined against the energy and water targets.

Research sustainable building design and build a labelled model of a house or office block showing the features it incorporates to demonstrate sustainable design.

- Identify what 'passive' features the building uses for heating and cooling.
- Assess whether the building uses natural light effectively.
- Discuss if the building utilises green power and what power alternatives are available.
- Explain how the building harvests rainwater and what the water is used for in the building and gardens.
- Does the building generate its own energy? Explain how.
- Critically analyse how the placement of the building makes the best use of its site.
- Demonstrate what knowledge you have gained to verify that green buildings can reduce our carbon footprint

Figure 6.56 Building designs that utilise sunlight, direction and insulation can reduce the carbon footprint by using less electricity as air conditioning does not need to be used to cool and heat the building.

Figure 6.57 Many buildings now have solar panels and other renewable ways to generate electricity.

Figure 6.58 Incorporating a garden into the side of a building helps with insulation.