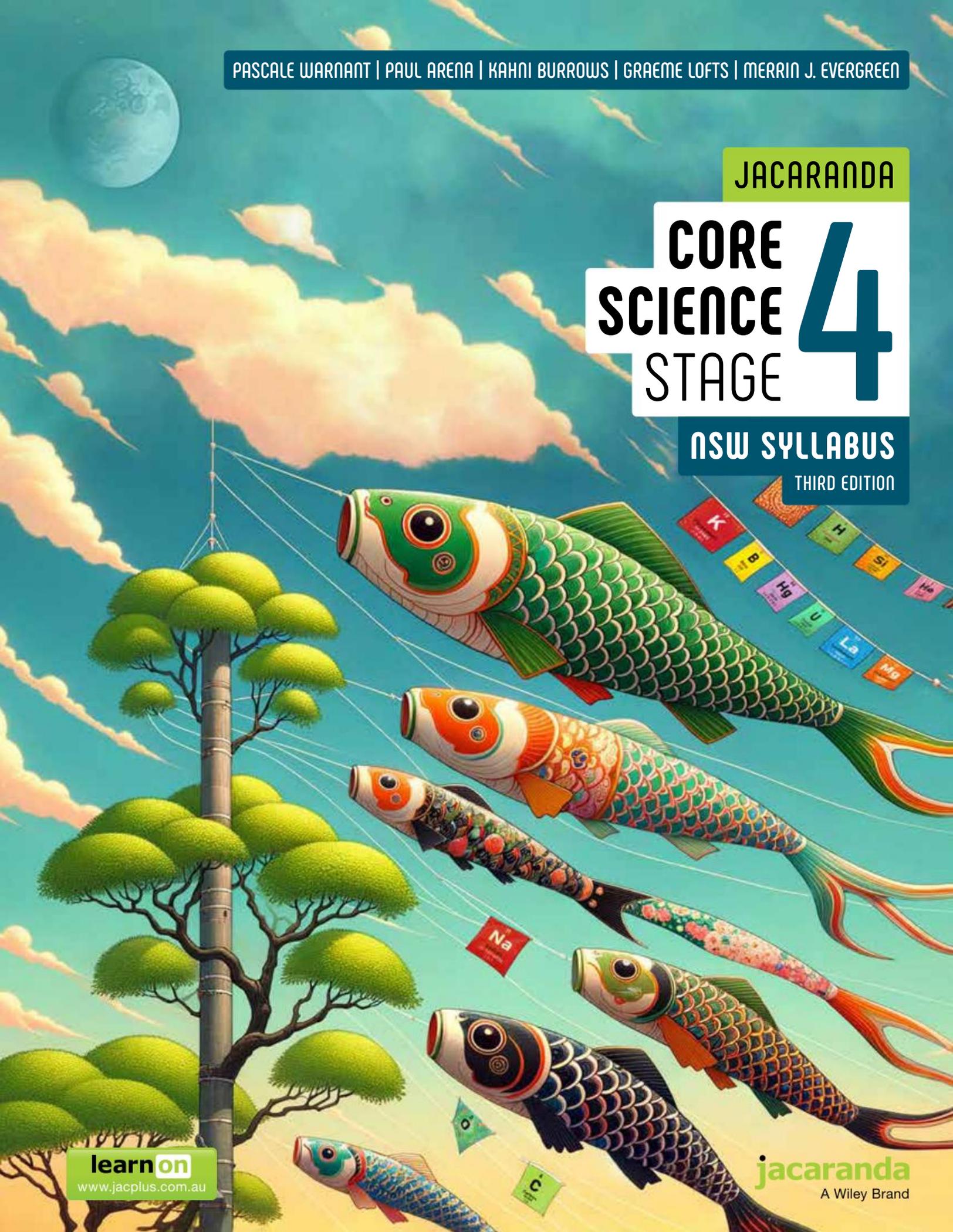PASCALE WARNANT | PAUL ARENA | KAHNI BURROWS | GRAEME LOFTS | MERRIN J. EVERGREEN

JACARANDA

CORE SCIENCE STAGE 4

NSW SYLLABUS

THIRD EDITION

jacaranda
A Wiley Brand

1 Investigating

LESSON SEQUENCE

LESSON 1.1 Overview

1.1.1 Why learn this?

The word 'science' comes from a Latin word that means 'knowledge'. For thousands of years, scientists have been trying to learn as much as they can about the world. Long ago, before we had the amazing technology we have today, scientists were called philosophers and used their best thinking to explain what they saw around them.

Now, scientists use special equipment to investigate and add to what we know about the world. But science isn't just a big list of facts; it's about exploring and discovering! As a young explorer, you'll learn how to investigate things scientifically, so that what you find out is based on good thinking and real evidence.

FIGURE 1.1 Forensic scientists use science to help investigate and solve crimes.

ACTIVITY: Engaging with investigating

1. Look around the laboratory. Identify five features special to this working environment.
2. Identify five everyday devices that have been invented with the assistance of science.
3. Do you know anyone working in science? Describe what they do.
4. Think of a really important scientific discovery. Discuss with a partner why you think it is so significant.
5. These two pieces of equipment are used for measuring volumes of liquids.
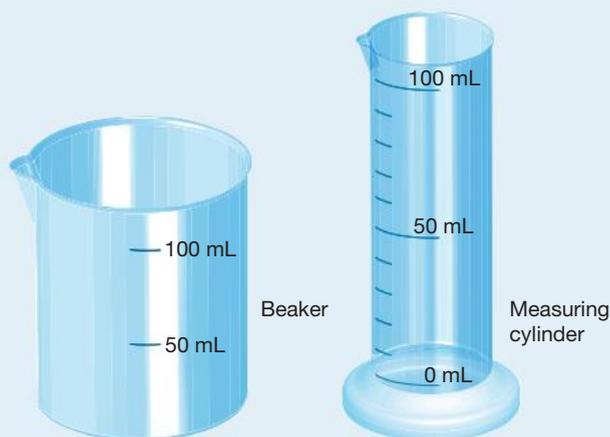
Identify an important difference between them, other than their shape. Outline when each should be used.

6. Some of the skills that scientists use are the same as those used by detectives in solving a crime. Careful observations are required before any conclusions can be drawn. Look carefully at the drawing and describe what you think has happened.

LESSON 1.2 What do scientists do?

LEARNING INTENTION

In this lesson you will recognise how scientific knowledge can be represented in branches of biology, chemistry, physics and geology, and consider how modern scientific knowledge is interdisciplinary and transdisciplinary.

1.2.1 Different types of scientist

You can find scientists just about anywhere. They could be in a desert finding out how plants survive without water. They could be digging deep into the ice in Antarctica. You might find a scientist searching for fossils on a rocky shore, counting rare animals in a rainforest or monitoring electricity in a power station. Some scientists work in laboratories, searching for a cure for a disease. Others work in the chemical industry. You might even find a scientist in space.

There are many types or disciplines of study in science. A few are shown in figure 1.2.

FIGURE 1.2 There are many disciplines of science.

Earth science

Geologists study rocks and mountains.

Seismologists study earthquakes.

Palaeontologists study fossils and ancient rocks.

Vulcanologists study volcanoes.

Biology

Biologists study living things.

Botanists and **horticulturists** study plants.

Zoologists and **veterinarians** study animals.

Microbiologists study microscopic living things.

Chemistry

Chemists study the structure and properties of substances.

Pharmacists work with chemicals that are used to treat illness and disease.

Metallurgists study the chemical properties of metals.

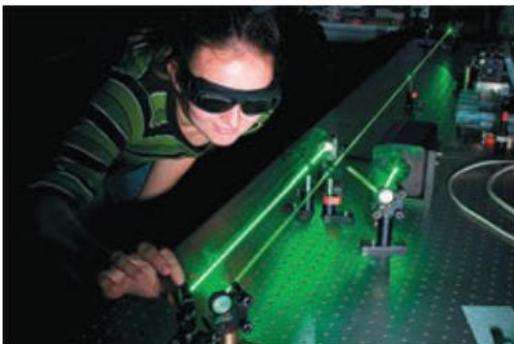**Environmental chemists** study the impact of human-made substances in our air, water and soil.

(continued)

FIGURE 1.2 There are many disciplines of science. *(continued)*

Physics

Physicists study things like movement, heat, nuclear energy, light and electricity.

Mechanical engineers design and construct machines and tools for a variety of purposes.

Astronomers study objects found in the sky, including stars, moons, galaxies and meteorites.

Aerodynamics scientists study the way air moves around objects such as cars and aircraft.

1.2.2 A mix of science

Some scientists work in areas that involve more than one scientific field. Such sciences are said to be **interdisciplinary**.

For example, a biochemist is a scientist who studies the chemical processes inside living organisms. They use knowledge from both biology and chemistry in their work.

FIGURE 1.3 Some sciences are a mix of scientific fields.
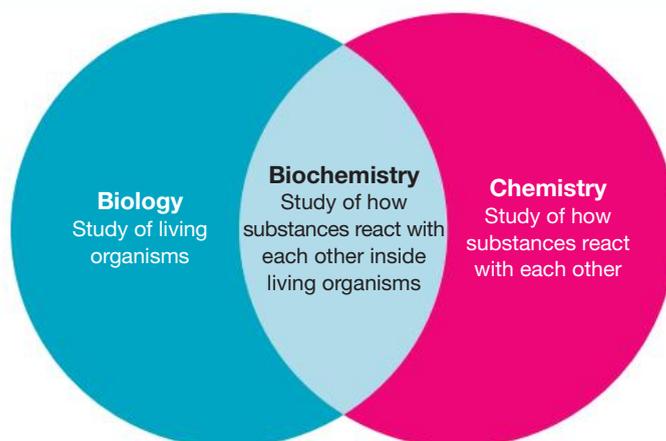
Biology
Study of living organisms

Biochemistry
Study of how substances react with each other inside living organisms

Chemistry
Study of how substances react with each other

1.2.3 Specialist scientists

Within each discipline of science, scientists specialise in a specific area. For example, in psychology, **neuropsychologists** study the different areas of the brain to better understand brain functions such as memory and learning. **Sports psychologists** advise athletes on self-image and on maintaining the motivation to persist and succeed in their chosen sport.

FIGURE 1.4 Scientists from different fields, such as chemistry, physics and biology, analyse and improve the performance of athletes in different ways.

Engineers or **chemical engineers** may be involved in producing a lightweight but powerful tennis racquet for modern-day players. Like many other players, de Minaur currently chooses the Wilson Blade 98.

Sports psychology helps athletes train their minds for greater success in the sports arena. Alex de Minaur has received advice from sports psychologists on setting goals, motivation and concentration.

Industrial chemists look for ways to make better materials. De Minaur's tennis outfit is made of a blend of polyester and cotton. The blend of these two fibres makes the fabric more breathable and durable.

The branch of physics that studies how people move is called **biomechanics**. Scientists use video and computer technology to analyse every part of a player's swing to suggest improvement.

The branch of biology that studies the function of the human body is **physiology**. De Minaur suffered a hip injury and withdrew from the first round at the Olympic Games in 2024. These types of injuries often require healthcare from a **physiotherapist**, who uses physical techniques to help treat conditions and injuries.

Physicists study how objects move and the importance of **forces** such as **friction**. They research the performance of the different types of balls. For example, tennis balls with coarser covers slow down more quickly in their flight through the air.

Researchers in physics have helped tennis players adjust their game to suit different playing surfaces. On a grass court, players are encouraged to serve as fast as possible to produce a fast, low bounce. On clay courts, players need to reduce the speed of the serve and put more spin on the ball. This produces a slower, higher bounce that is difficult to return.

1.2.4 Scientists working together

Quite often, different types of scientists will need to work together to solve a problem. This is certainly true in criminal investigations, where the solving of a crime may rely on the observations and conclusions of scientists from many disciplines.

FIGURE 1.5 Investigating a crime scene involves many types of science.

1.2.5 Scientists solving problems over time

Science advances because scientists build on the knowledge of the pioneering scientists who came before them.

DISCUSSION

In 1675, Sir Isaac Newton wrote to fellow scientist Robert Hooke, saying:

"If I have seen further, it is by standing on the shoulders of Giants."

Discuss what you think Newton meant by this.

Can you give examples where the work of one person has contributed to the success of another?

FIGURE 1.6 Our understanding of how objects move, The Theory of Motion, has been developed over many centuries.

I derived a theory of black holes from Einstein's Theory of General Relativity that predicted they would give off something now called 'Hawking radiation'.

Stephen Hawking
1942–2018

My theories of relativity showed that Newton's laws don't describe the motion of objects travelling near the speed of light or in regions of exceptionally strong gravity.

Albert Einstein
1879–1955

I formulated a theory of gravity that improved on Galileo's theory of motion and which mathematically supported Kepler's laws of planetary motion.

I agreed with Copernicus that the Earth moves around the sun. I came up with three mathematical laws that precisely described the orbits of the planets and the moons of Jupiter that Galileo had discovered.

My work supported Copernicus's heliocentric theory. I disproved Buridan's impetus theory and came up with a better explanation for motion.

Isaac Newton
1642–1727

Johannes Kepler
1571–1630

Galileo Galilei
1564–1642

I theorised that the Earth and the other planets move around the sun.

I theorised that thrown objects stop rising because they run out of a substance called 'impetus'.

Nikolaus Copernicus
1473–1543

Jean Buridan
1301–1358

The development of penicillin

In 1928, Scottish bacteriologist Alexander Fleming was working on an experiment when he discovered that some mould spores in the air had contaminated one of his Petri dishes growing bacteria. He observed that the bacteria had stopped developing where the mould had landed. Fleming **inferred** that there was some substance in the mould that was affecting the bacteria. He named the substance **penicillin**.

Fleming realised that penicillin could be a cure for bacterial diseases, but was not able to isolate the penicillin from the mould. He published his discovery in a British science journal.

In 1938, Australian-born scientist Howard Florey read Fleming's paper and saw its potential for treating the many bacterial infections that killed so many people worldwide. In 1939, Howard Florey, Ernst Chain and their colleagues at Oxford University in the United Kingdom, successfully purified the mould so that it could be used as a commercial **antibiotic**.

Penicillin was the first antibiotic to be widely used, and it is still used for the treatment of serious bacterial infections. Fleming, Florey and Chain were jointly awarded the 1945 Nobel Prize for Medicine for the parts they had each played in the development of penicillin.

FIGURE 1.7 A photo of Fleming's original Petri dish, showing the effect of the mould *Penicillium notatum* on the bacteria

Penicillium notatum mould

Region of bacteria where growth has been stopped

Active *Staphylococcus* bacteria
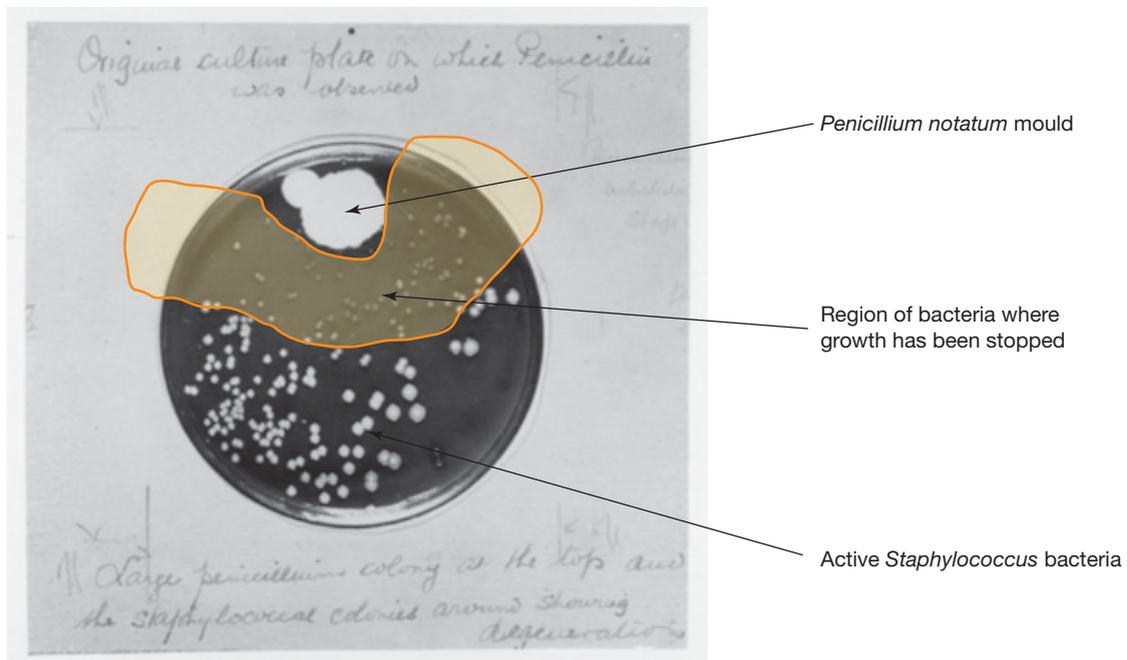
From amber to electricity

From around the sixth century BCE, the Ancient Greeks observed that amber (fossilised tree sap) was able to pick up small grains of sand and dust and lift hair fibres after it was rubbed with fur.

For centuries this remained a curiosity, until in1600 William Gilbert theorised that there was some sort of force acting between the rubbed amber and the particles it picked up. He used the term **electricity** to describe this force, because the Greek word for amber was *elektron*.

FIGURE 1.8 Amber attracting pieces of paper

In 1660, Robert Boyle expanded on Gilbert's work and identified that the electrical force could pull charged objects together or push them apart.

Electric charge was able to be stored in a device called a **Leyden jar**, invented by the Dutch scientist Pieter van Musschenbroek in 1746.

In 1752, the American scientist Benjamin Franklin proved that lightning bolts were made of electricity. He famously flew a kite attached to a metal wire during a thunderstorm and collected the electricity in a Leyden jar.

FIGURE 1.9 Artist's impression of Benjamin Franklin and his son performing the kite experiment

1.2 Activities

learn on

1.2 Quick quiz **on**	**1.2 Exercise**

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4	2, 5, 7	3, 6, 8

Remember and understand

1. Select the correct terms to complete the following sentence: A botanist is a *biologist / chemist / physicist* who studies *animal cells / plants / clouds*.
2. What important observation did Alexander Fleming make that led to the development of the first antibiotic?
3. What hypothesis did Benjamin Franklin test in his experiments on electricity?

Apply and analyse

4. Place the following theories in order from earliest to latest.
   I. Buridan's impetus theory
   II. Galileo's laws of motion
   III. Newton's laws of motion
   IV. Einstein's Theory of Special Relativity
5. Is the following statement true or false?

   Biomechanics combines the study of physics and biology.
6. Science helps elite sportspeople perform to the best of their ability. What is the role of sports psychology in improving the ability of elite athletes?
7. How might firefighters use science in their daily work?

Evaluate and create

8. Read the main section of a daily newspaper, either online or offline. Find an article in which a scientist is referred to or quoted. For this article, **identify**:
   a. the scientist's name
   b. the discipline or specific field of science they study
   c. which organisation they work for
   d. what the newspaper article is about and why the scientist has been included in the article.

# LESSON 1.3 The science laboratory

LEARNING INTENTION

In this lesson you will identify, assemble and use appropriate equipment and resources to perform an investigation safely.

1.3.1 Getting to know the science lab

Scientists often conduct experiments in a laboratory (also known as a lab). The science laboratory in your school is different from other classrooms. It is filled with a range of equipment to help you undertake scientific investigations safely.

ACTIVITY: Getting to know your lab

- Sit quietly for a minute or two and look around the science laboratory.
- List as many differences as you can between the science laboratory and other general classrooms at your school.
- Draw a map of the science laboratory, labelling each of the following items if they are present.
  - Student tables and work benches
  - Teacher's desk or demonstration bench
  - Gas taps
  - Sinks
  - Fume cupboard
  - Eye wash and safety shower
  - Fire extinguisher
  - Fire blanket
  - Broken glass bin
  - Rubbish bin
  - Doors
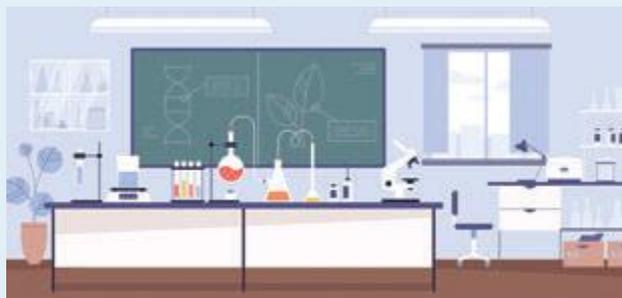
1.3.2 Laboratory equipment

Some of the equipment that you are likely to use in science is listed in table 1.1 and illustrated in figure 1.10.

TABLE 1.1 Common laboratory equipment

Equipment	Use
Beaker	Container for mixing or heating liquids and other substances
Bosshead	Holds the clamp to a retort stand
Bunsen burner	Heats substances
Clamp	Holds objects at the required height on a retort stand
Conical flask	Container for mixing substances or collecting filtered substances
Evaporating dish	Container for heating small amounts of substances over a Bunsen burner
Filter funnel	Used with filter paper to filter substances
Gauze mat	Supports a container over a Bunsen burner while it is heated
Heatproof mat	Protects benches from damage
Measuring cylinder	Used to measure the volume of a liquid accurately
Retort stand	Used with a clamp and bosshead to hold equipment at the required height
Safety glasses	Protect eyes
Spatula	Used to pick up small amounts of solid substances

Stirring rod	Used to stir mixtures
Test tube	Container for holding, heating or mixing small amounts of substances
Test-tube holder	Holds a test tube while it is being heated
Test-tube rack	Holds test tubes upright
Thermometer	Measures temperature
Tongs	Used to hold small objects while they are heated or to pick up hot glassware
Tripod	Supports a gauze mat over a Bunsen burner
Watchglass	Holds small quantities of solids

FIGURE 1.10 Some equipment that you are likely to use in the science laboratory

1.3.3 Investigating safely

ALWAYS …

- follow the teacher's instructions
- wear safety glasses and a laboratory coat or apron, and tie back long hair when mixing or heating substances
- point test tubes away from your eyes and away from your fellow students
- push in chairs and keep walkways clear
- inform your teacher if you break equipment, spill chemicals, or cut or burn yourself
- wait until hot equipment has cooled before putting it away
- clean your workspace — don't leave any equipment on the bench
- dispose of waste as instructed by your teacher
- wash your hands thoroughly after handling any substances in the laboratory.

FIGURE 1.11 It is important to use appropriate safety equipment in a laboratory.

NEVER …

- enter the laboratory without your teacher's permission
- run or push in the laboratory
- eat or drink in the laboratory
- smell or taste chemicals unless your teacher says it's OK. When you do need to smell substances, fan the odour to your nose with your hand.
- leave an experiment unattended
- conduct your own experiments without the teacher's approval
- put solid materials down the sink
- pour hazardous chemicals down the sink (check with your teacher)
- put hot objects or broken glass in the bin.

FIGURE 1.12 Experiments should not be left unattended.

1.3.4 Working with dangerous chemicals

Your teacher will tell you how to handle the chemicals in each experiment. At times, you may come across warning labels on the substances you are using.

TABLE 1.2 Information about dangerous chemicals in the lab

Label	Why is this chemical dangerous?	What safety measures do I need to take?
	Corrosive substances can cause severe damage to skin and eyes. Acids are examples of **corrosive** substances.	Always wear gloves and **safety glasses** when using chemicals with this symbol.
	Flammable substances are easily set on fire. For example, methylated spirits is a **flammable** substance.	Always keep chemicals with these labels well away from flames such as lit matches and Bunsen burners.
	Chemicals with this label can cause death or serious injury if swallowed or breathed in. They are also dangerous when touched without gloves, because they can be absorbed by the skin. Mercury is a **poisonous** substance.	You should always wear gloves and **safety masks** when using chemicals with this symbol. Your teacher will instruct you if you need to use these chemicals in a **fume cupboard**.

1.3.5 Heating substances

In school laboratories, heating is usually done with a **Bunsen burner**. A Bunsen burner flame provides heat when a mixture of air and gas is lit.

FIGURE 1.13 a. The components of a Bunsen burner **b.** The yellow visible flame is known as the safety flame and is less hot than the blue flame.

(a)

Barrel

Gas hose

Collar

Airhole
(gas jet inside)

Base

(b)

Blue heating flame

Yellow safety flame
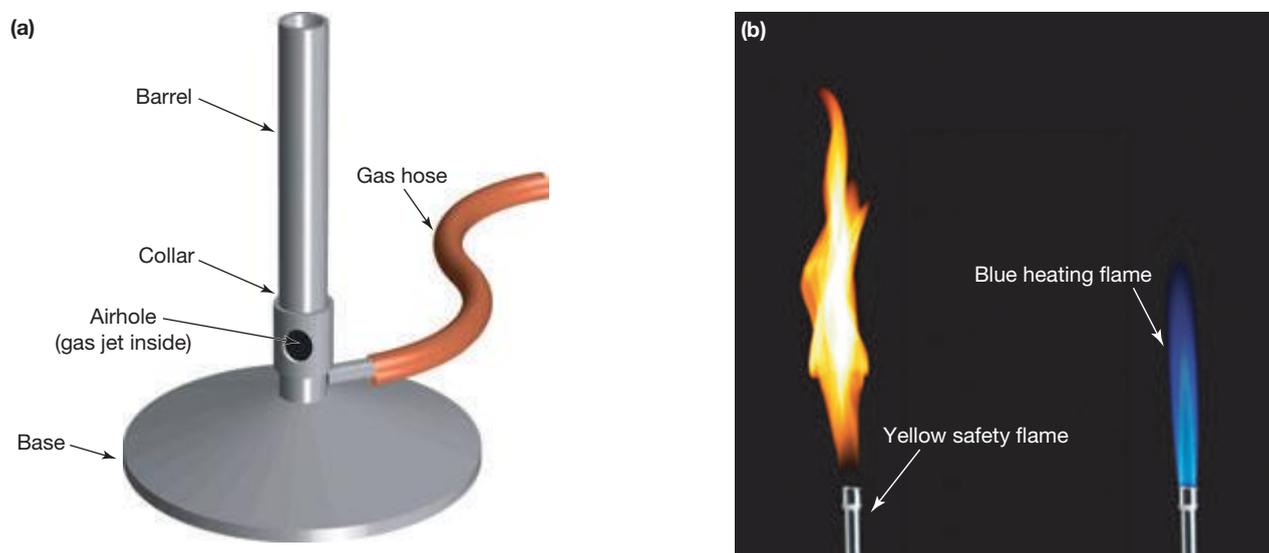
KEY IDEAS

The following steps describe how to use a Bunsen burner safely.
1. Place the Bunsen burner on a heatproof mat.
2. Check that the gas tap is in the 'off' position.
3. Connect the rubber hose to the gas tap.
4. Close the airhole of the Bunsen burner collar.
5. Light a match and hold it a few centimetres above the barrel.
6. Turn on the gas tap and a yellow flame will appear.
7. Adjust the flame by moving the collar until the airhole is open and a blue flame appears.
8. Remember to close the collar to return the flame to yellow when the Bunsen burner is not in use.

FIGURE 1.14 The process of lighting a Bunsen burrner

Connect hose to gas tap. → Close air hole. → Hold lighted match above burner. → Turn gas tap on. → Once lit, open air hole.
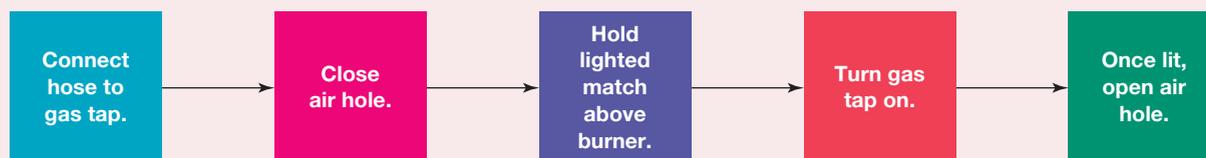
The Bunsen-burner flame

Aim

To determine which Bunsen-burner flame is hotter

Materials

- Bunsen burner
- heatproof mat
- matches
- tongs
- pieces of porcelain
- safety glasses
- clock or watch

CAUTION: Before you use your Bunsen burner, ensure you are wearing safety glasses, your Bunsen burner is on a heatproof mat and long hair is tied back.

Method

1. Light the Bunsen burner according to the guide above.
2. Open the airhole.
3. Using the tongs, hold a piece of porcelain over the flame with the airhole open.
4. Record how long it takes for the porcelain to turn red-hot.
5. Let the porcelain cool on the heatproof mat.
6. Examine the surface of the porcelain and record any changes to its surface.
7. Close the airhole.
8. Hold another piece of porcelain in the yellow flame.
9. Record how long it takes for the porcelain to turn red-hot.
10. Place the porcelain to cool on the heatproof mat and turn off the Bunsen burner.
11. Examine the surface of the porcelain and record any changes to its surface appearance.

Results

Flame colour	Time to turn porcelain red-hot	Appearance of surface after heating
Blue		
Yellow		

Discussion

1. Describe the flame when the airhole is open. What colour is it? Does it make a noise?
2. Describe the flame when the airhole is closed. Is it easy to see?
3. Does the porcelain turn red-hot in the yellow flame when the airhole is closed?
4. Do you notice anything else about the porcelain after heating in the yellow flame?
5. Which flame would be the best to use if you were heating a beaker over a Bunsen burner? Explain your choice.

Conclusion

Write a sentence summarising which Bunsen-burner flame is the hottest.

The hottest part of the flame

Aim

To determine the hottest part of a blue flame

Materials

- Bunsen burner
- heatproof mat
- matches
- safety glasses
- nichrome wire
- tongs
- pin

CAUTION: Before you use your Bunsen burner, ensure you are wearing safety glasses, your Bunsen burner is on a heatproof mat and long hair is tied back.

Method

Part A

1. Use a pin to hang an unburnt match over the barrel of a Bunsen burner.
2. Light the Bunsen burner according to the guide above.
3. Turn the collar to produce a blue flame.
4. Turn the Bunsen burner off and remove the match and pin with tongs.
5. Examine the match and record your observations of its appearance.

Unburnt match

Pin
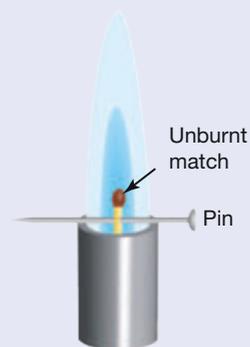
Part B

1. Re-light the Bunsen burner and turn the collar to produce a blue flame again.
2. Use the tongs to hold the wire across the flame, close to the barrel of the Bunsen burner and observe the wire.
3. Move the wire up a little and continue observing.
4. Record your observations of what happens to the wire as it is moved.
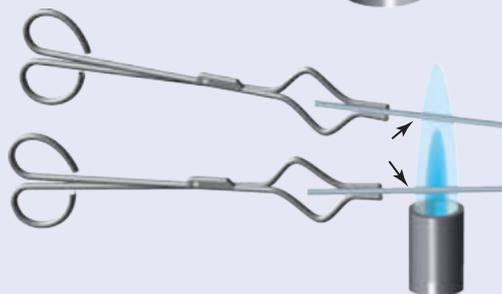
Results

	Observations
Part A	
Part B	

Discussion

1. What happens to the match hanging over the barrel? Explain why.
2. What colour does the wire become when held across the flame?
3. Is the colour of the wire different when it is held at the top of the flame?
4. Draw a diagram of the Bunsen-burner flame, labelling the parts that are hottest.
5. Students often heat substances in a test tube with a Bunsen burner. Why would it be unwise to position the test tube at the base of a blue flame?
6. Why is the yellow flame often called the safety flame?

Conclusion

Write a sentence describing what part of a blue flame is the hottest.

Heating containers

There are some rules that must be followed when using heating containers:

- Beakers and evaporating dishes can be placed straight onto a gauze mat for heating.
- Never look directly into a container while it is being heated.
- Wait until the equipment has cooled properly before handling it.

**FIGURE 1.15** The equipment used to heat substances and containers

Gauze mat
Bunsen burner
Beaker
Tripod
Heatproof mat
Evaporating dish
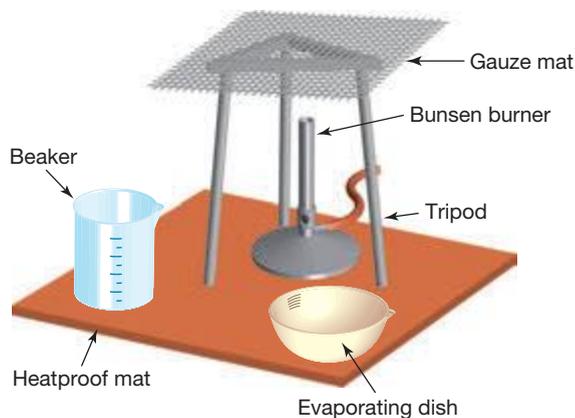
INVESTIGATION 1.3

Heating a substance in a test tube

Aim

To practise heating a liquid in a test tube safely

Materials

- 100 mL beaker
- Bunsen burner and heatproof mat
- matches
- safety glasses
- test tube
- test-tube rack
- test-tube holder
- food colouring
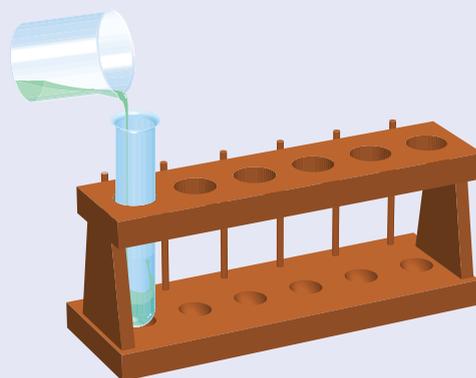
CAUTION: Before you use your Bunsen burner, ensure you are wearing safety glasses, your Bunsen burner is on a heatproof mat and long hair is tied back.

Method

1. Carefully pour water from a beaker into a test tube to a depth of about 2 cm, as shown in the diagram above. Add a drop of food colouring to make it easier to see.
2. Light the Bunsen burner correctly and heat the test tube gently in the blue flame.
3. Make sure that the open end test tube points away from you and other students.
4. Move the base of the test tube gently in and out of the flame. This prevents the liquid from splashing out of the test tube.
5. Keep the test-tube holder away from the flame.
6. Once the liquid has started boiling, stop heating and turn off the gas to the Bunsen burner. Place the test tube in the test-tube rack. Leave it there until it has cooled, before emptying it and cleaning up.
7. Record any changes that you observed inside the test tube as you heated the water.

Changes observed	

Discussion

1. Why should the test-tube holder be positioned at the top of the test tube?
2. Why is the blue flame used for heating?
3. Describe any safety precautions to take when heating substances in a test tube that you did not have to take when heating a substance in a beaker.

Conclusion

Write a summary of the skills you practised to heat a substance in a test tube safely.

FIGURE 1.16 Review this image of students in a science laboratory. Can you find at least 20 dangerous activities occurring? There may be more!.

1.3 Activities

1.3 Quick quiz on	**1.3 Exercise**

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4, 6	2, 5, 7, 9	3, 8, 10

Remember and understand

1. Match each piece of laboratory equipment with its purpose.

a. Heatproof mat	**1.** Porcelain container for evaporating small amounts of substances over a Bunsen burner
b. Evaporating dish	**2.** Used with clamps and bossheads to hold equipment at the required height
c. Test-tube rack	**3.** Protects benches from heat damage
d. Retort stand	**4.** Holds test tubes upright

2. **MS** Which three of the following pieces of equipment are used when heating objects?
   A. Bunsen burner   **B.** Heatproof mat
   C. Watchglass   **D.** Safety glasses
   E. Spatula

3. Is the following statement true or false?

   You should always wear gloves when working with corrosive substances to prevent severe damage to the skin should the chemical be spilled.

4. Is the following statement true or false?

   If it is safe to smell a chemical, the appropriate technique is to place the flask containing the chemical just below the nose.

5. Complete the following sentence. The safety flame of a Bunsen burner is _____ and is obtained by _____.

Apply and analyse

6. Which item of equipment would you use to measure exactly 10 mL of water?

7. **MC** Which of the following is an example of a violation of a lab safety rule?
   A. Tasting chemicals   **B.** Smelling contents of a test tube directly
   C. Hair not tied back   **D.** Eating food in the lab
   E. All of the above

8. **Describe** where you would find the hottest part of the Bunsen-burner flame.

9. **MC** Which of the following is an appropriate safety measure if using a chemical with this label?
   A. Keep it away from flames
   B. Avoid use altogether
   C. Dilute with water
   D. Wear safety glasses and gloves
   E. Ventilate the room

CORROSIVE
8

Evaluate and create

10. Select one of the safety rules for using a Bunsen burner and choose a strategy for publicising your message. Create a safety poster about your chosen rule.

LESSON 1.4 Making observations

LEARNING INTENTION

In this lesson you will use a variety of analog and digital measuring devices in scientific investigations to compare the range, sensitivity and accuracy of observations provided by those instruments.

Observations are bits of information we collect by using our senses, like seeing or hearing. We can also use tools to measure things and help us observe even more details.

Observations can be either **qualitative** or **quantitative**.

TABLE 1.3 Different types of observations

Type of observation	Description	Examples
Qualitative	An observation that uses description and words	• The red kangaroo sheltered under a tree during the hottest part of the day. • The mixture became cloudy. • The solution smelled like rotten eggs.
Quantitative	An observation that involves a numerical measurement	• The male red kangaroo had a mass of 85.3 kg. • The water took 5 minutes and 10 seconds to reach boiling point. • The temperature of the solution increased by 5 degrees.

DISCUSSION

Are there some observations that can be only quantitative? Are there cases where the observations can be only qualitative? Discuss as a group and decide whether examples can be found to support each statement.

1.4.1 Making quantitative measurements

Common quantities that are measured in experiments include length, time, mass and temperature. Accurate measurements allow us to observe if the quantities change during an experiment and by how much they change.

Scientists around the world measure using the **metric system**, a decimal system (based on units of 10) that uses metres, litres and kilograms as base units to measure distance, volume and weight.

FIGURE 1.17 A fitness test is carefully measured and analysed by a **biomechanist**. Note that the markers attached to the subject's body are being imaged on the computer.

TABLE 1.4 Metric versus imperial units

Quantity	Metric unit	Imperial unit
Length	metre	foot
Time	second	second
Mass	kilogram	pound

In 1999, NASA's Mars Climate Orbiter crashed into the surface of Mars instead of going into orbit around the planet. The reason for this really expensive mistake was that the designers of the orbiter did their calculations using metric units, but the company that built the orbiter used a different measurement system called the imperial unit system. However, both teams assumed that they were using the same system when they were communicating with each other.

The result was that the orbiter was travelling on the wrong pathway when it was approaching Mars, causing the loss of a 9-month mission that had been years in the planning!

1.4.2 Analog and digital measuring instruments

Many different types of instruments are used to gather scientific measurements (called **data**). Measuring devices can be either **analog** or **digital**.

Analog measuring devices are usually marked with a series of lines; some of these lines will have numbers next to them. These lines and numbers together are called a **scale**. A ruler and a glass thermometer are examples of analog measuring instruments.

Digital measuring devices do not have a scale; instead, they provide a value that appears directly on the device's screen. The main advantage of digital measuring devices is that they are easier to read and more accurate than analog devices.

Electronic kitchen scales and digital thermometers are examples of digital measuring devices.

TABLE 1.5 Either analog or digital instruments can be used to make quantitative measurements.

Quantity	Device that can be used to measure the quantity	
	Analog	Digital
Length	Ruler	Digital calipers
Mass	Pan scales	Digital scales
Time	Clock with a second hand	Stopwatch
Temperature	Glass thermometer	Digital thermometer

CASE STUDY: Data loggers

A **data logger** is a very useful digital device that can measure many different quantities. The measurement recorded by a data logger depends on the sensor that is connected to it. The sensor does the measuring and sends the information to the data logger. There are a number of different sensors available; for example, if a temperature sensor is attached to the data logger, temperature is measured and recorded.

Data loggers are useful devices because they generally measure quantities very accurately. For example, they may record temperature accurately to 0.1 °C. Some data loggers can also store thousands of individual measurements and allow them to be downloaded to a computer to be converted to tables and graphs.

FIGURE 1.18 A data logger and temperature sensors

DATA SCIENCE 1: Data science in context

Monitoring classroom temperature and humidity

The objective

Learn how to analyse data collected over time to understand trends and make predictions about classroom conditions

The task

Imagine you have a device in your classroom that logs temperature and humidity every hour. By analysing this data, you can understand how classroom conditions change throughout the day and see how this might affect concentration and comfort levels.

The data in the table below simulates hourly temperature and humidity readings taken from a data logger in a classroom over a school week (Monday to Friday).
- **Timestamp:** the day and hour of the reading
- **Temperature (°C):** the classroom temperature at that time
- **Humidity (%):** the classroom humidity level at that time

Timestamp	Temperature (°C)	Humidity (%)	Timestamp	Temperature (°C)	Humidity (%)
Monday 8:00	21.2	49.7	Wednesday 13:00	25.4	46.6
Monday 9:00	21.8	50.9	Wednesday 14:00	25.1	46.6
Monday 10:00	21.9	49.1	Wednesday 15:00	24.5	47.1
Monday 11:00	23.3	48.9	Wednesday 16:00	24	50.0
Monday 12:00	23.8	48.3	Wednesday 17:00	23.6	48.2
Monday 13:00	24.3	46.9	Wednesday 18:00	23.4	46.9
Monday 14:00	25.1	44.8	Wednesday 19:00	23.7	48.6
Monday 15:00	24.6	46.5	Wednesday 20:00	23.2	47.3
Monday 16:00	23.5	48.3	Wednesday 21:00	23.2	46.8
Monday 17:00	23.2	46.8	Wednesday 22:00	22.5	51.0

Monday 18:00	24.1	47.3	Wednesday 23:00	21.4	49.1
Monday 19:00	23.1	46.9	Thursday 0:00	28.8	43.2
Monday 20:00	22.5	48.9	Thursday 1:00	27.7	44.7
Monday 21:00	21.9	49.6	Thursday 2:00	27.7	45.1
Monday 22:00	21.9	49.0	Thursday 3:00	27.4	46.4
Monday 23:00	21.6	51.4	Thursday 4:00	27.2	44.7
Tuesday 0:00	28.8	42.7	Thursday 5:00	27.7	43.4
Tuesday 1:00	28.9	42.5	Thursday 6:00	27.1	46.4
Tuesday 2:00	28.3	42.2	Thursday 7:00	25.9	46.3
Tuesday 3:00	27.2	45.2	Thursday 8:00	21.1	50.7
Tuesday 4:00	28	44.6	Thursday 9:00	20.9	48.8
Tuesday 5:00	27.2	44.7	Thursday 10:00	22.3	49.3
Tuesday 6:00	26.3	45.1	Thursday 11:00	22.6	49.0
Tuesday 7:00	26.5	46.7	Thursday 12:00	23.7	48.1
Tuesday 8:00	21.2	48.1	Thursday 13:00	24.6	46.4
Tuesday 9:00	21.7	49.1	Thursday 14:00	25.9	46.5
Tuesday 10:00	21.7	50.1	Thursday 15:00	24.9	47.5
Tuesday 11:00	23	49.3	Thursday 16:00	23.5	48.8
Tuesday 12:00	23.6	47.6	Thursday 17:00	24.3	46.6
Tuesday 13:00	24.7	48.0	Thursday 18:00	23.9	48.1
Tuesday 14:00	24.8	46.8	Thursday 19:00	23.5	49.9
Tuesday 15:00	24.9	45.6	Thursday 20:00	22.7	47.9
Tuesday 16:00	24.4	48.6	Thursday 21:00	22.1	48.3
Tuesday 17:00	23.7	48.9	Thursday 22:00	22.2	49.4
Tuesday 18:00	23.6	47.3	Thursday 23:00	22	50.0
Tuesday 19:00	23.3	49.7	Friday 0:00	28.8	45.2
Tuesday 20:00	22.8	50.1	Friday 1:00	28.4	46.8
Tuesday 21:00	21.2	50.7	Friday 2:00	28.5	43.1
Tuesday 22:00	22.2	48.7	Friday 3:00	27.4	45.4
Tuesday 23:00	21.9	47.3	Friday 4:00	27.5	45.5
Wednesday 0:00	28.7	44.2	Friday 5:00	27.5	44.7
Wednesday 1:00	29.2	42.9	Friday 6:00	26.6	44.0
Wednesday 2:00	27.8	44.1	Friday 7:00	26.5	46.5
Wednesday 3:00	28.4	44.4	Friday 8:00	21.1	48.7
Wednesday 4:00	27.3	45.4	Friday 9:00	21.6	49.9
Wednesday 5:00	27.3	45.9	Friday 10:00	21.6	49.7
Wednesday 6:00	26.6	45.2	Friday 11:00	22.5	47.6
Wednesday 7:00	26.5	44.1	Friday 12:00	24.2	48.0
Wednesday 8:00	21.1	50.1	Friday 13:00	25	47.8
Wednesday 9:00	21.5	49.4	Friday 14:00	24.3	46.4
Wednesday 10:00	21.3	49.3	Friday 15:00	25.8	46.7
Wednesday 11:00	22.3	48.1	Friday 16:00	24.3	51.2
Wednesday 12:00	23.9	48.1	Friday 17:00	24	48.7

1. **Explore the data.**
   Discuss the following.
   - What is the temperature range during the day?
   - How does the humidity change throughout the day?
2. **Plot temperature and humidity trends.**
   Use a simple plotting tool (e.g. Excel) to create:
   - a **scatter plot** of temperature over time to see how it changes across the day
   - a **scatter plot** of humidity over time for comparison.
3. **Identify patterns and make observations.**
   - Are temperatures higher in the afternoon compared to the morning?
   - Does humidity increase or decrease as the temperature rises?
   - Discuss why these patterns might happen (e.g. more people in the room, sun warming the room).
4. **Data analysis.**
   - Calculate the average temperature and humidity for each day. How do they compare?
   - Identify the times of the maximum (highest) and minimum (lowest) temperature each day. At what time do each of these usually occur?
5. **Make predictions.**
   Using the data, predict the following:
   - What might the temperature and humidity be like in the first hour of the next school day?
   - How might the temperature change if there was a longer school day or an extra recess?

✦ 1.4.3 Reading scales

Analog devices such as rulers, measuring cylinders or glass thermometers are each marked with a **scale** or set of numbered markings. When reading a scale, it is important to determine what each of the markings on the scale represents.

SAMPLE PROBLEM 1 Reading a scale

What are the temperatures measured by thermometers A and B shown here?

THINK	WRITE
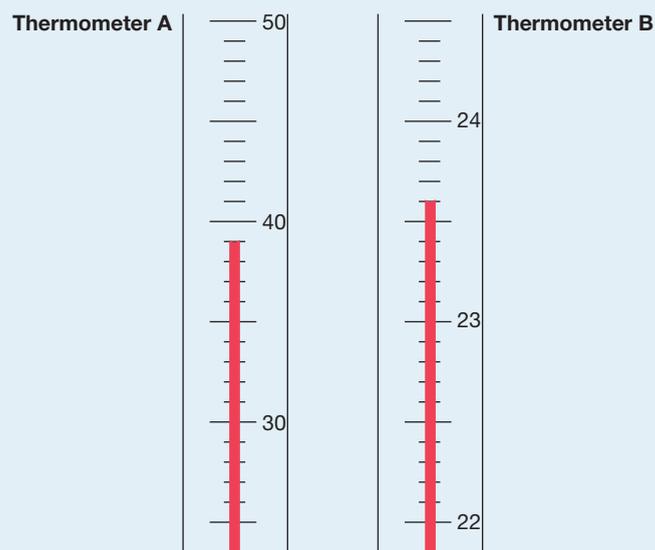
Thermometer A

1. First, look at the numbered measurement lines. We can see that they go up in jumps of 10 degrees: 30 degrees, 40 degrees, 50 degrees and so on. Therefore, the temperature shown by the red line will have a value higher than 30 degrees but less than 40 degrees.

2. Next, count how many divisions lie between any two consecutive numbered lines; there are 10 divisions between the 30-degree and 40-degree marks (the same is true for between 40 degrees and 50 degrees).

3. As there are 10 divisions that are spaced out over the 10 degrees difference; this means that each division must be equivalent to 1 degree.

4. Count how many divisions above the 30-degree mark the red line finishes. It ends at 9 divisions above the 30-degree mark.

5. As each division equals 1 degree, the temperature must be 30 degrees + (9 × 1) degrees = 39 degrees.

39 °C

Thermometer B

1. This time, the numbered measurement lines are increasing by 1 degree at a time. We can also see that the temperature shown by the red line is between 23 degrees and 24 degrees.

2. There are 10 divisions between the 23-degree and 24-degree marks.

3. This means that each division on this thermometer is equal to 0.1 degree (= 1 degree /10 divisions).

4. The red line finishes at the sixth division after the 23-degree mark.

5. As each division is equal to 0.1 degrees, the temperature reading will be 23 degrees + (6 × 0.1) degrees = 23.6 degrees.

23.6 °C

1.4.4 Parallax error

When reading the scale on an analog measuring device, measurements should always be made with your eye in line with the reading you are taking. When scales are read from a different angle, the reading is not accurate — it will be either lower or higher than the true reading. This type of reading error is called **parallax error**.

WORKING SCIENTIFICALLY: Parallax problems

Place a matchstick with the head in line with the 0 mark of a ruler. Observe where the end of the matchstick lies on the ruler if you look at it with your eyes near the head. Observe again from directly above the match end. Is there a difference between the two lengths?

▶

FIGURE 1.19 Measuring a matchstick

Measuring
correctly

Measuring
incorrectly
results in a
parallax error.
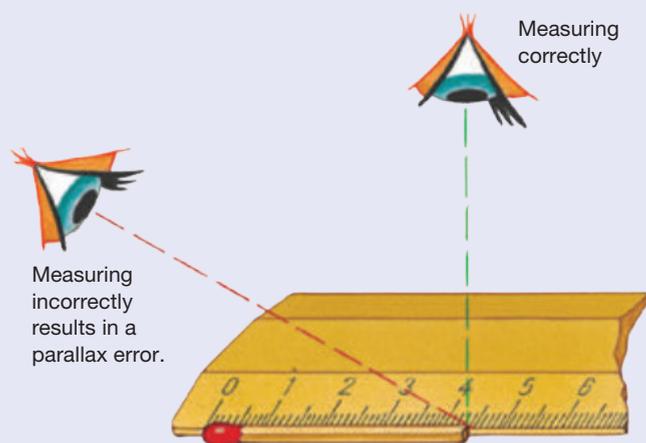
SC4-WS-01 Uses scientific tools and instruments for observations

1.4.5 Measuring length

Scientists measure the lengths of different objects accurately to compare sizes and estimate growth. The biologists in figure 1.20 are measuring the mass and condition of a tranquillised polar bear as part of a study aimed at conserving these animals in their Arctic home.

FIGURE 1.20 Measuring mass and condition

The standard unit for length is the metre (m). But length can also be measured in millimetres (mm), centimetres (cm) or kilometres (km). Table 1.6 shows how to convert between some common units of measurement.

TABLE 1.6 Converting measurements

Length	Volume
1 kilometre (km) = 1000 metres (m) 1 metre (m) = 100 centimetres (cm) 1 centimetre (cm) = 10 millimetres (mm)	1 litre (L) = 1000 millilitres (mL) 1 millilitre (mL) = 1 cubic centimetre (cm^3)
Mass	**Time**
1 kilogram (kg) = 1000 grams (g)	1 hour (h) = 60 minutes (min) 1 minute (min) = 60 seconds (s)

DISCUSSION

In ancient Egypt, length was measured using cubits and digits.
- A cubit was equal to the distance between a person's elbow and the tip of their middle finger.
- A digit was equal to the width of a person's index finger.

How accurate would this system be if you had to measure the length of a textbook or your lab bench? Would everybody get the same answer?

1.4.6 Measuring volume

Liquids in containers such as measuring cylinders are often curved at the top edge. The curve is called a **meniscus**. The edges of the meniscus may curve up or down. We always measure the volume of liquids from the middle flat section of the meniscus.

FIGURE 1.21 Meniscus illustrated

60 mL
55
50
45
40
Reading = 57 mL

60 mL
55
50
45
40
Reading = 56 mL
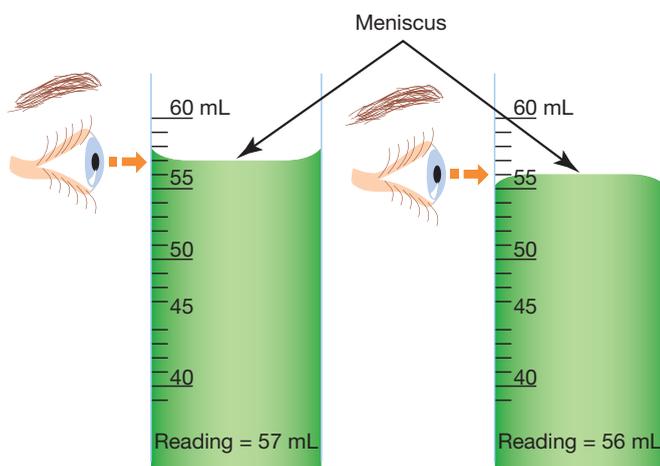
FIGURE 1.22 Water (left) has a meniscus that curves downwards, while the meniscus of mercury (right) curves upwards.

ACTIVITY: Observing a meniscus

Observe the meniscus formed by the surface of different liquids (such as water, honey, glycerine, cooking oil, methylated spirits) when you pour them into a measuring cylinder. Are some more curved than others?

1.4.7 Measuring temperature

The units of temperature are **degrees Celsius** (written as °C). Water boils at 100 °C and freezes to form ice at 0 °C.

CASE STUDY: Hot and cold

The highest air temperature ever measured on Earth is 56.7 °C. This measurement was taken in 1913 in the USA. The lowest temperature ever measured was in 1983 in Antarctica. That temperature was −89.2 °C.

The highest air temperature ever recorded in Australia is 50.7 °C.

FIGURE 1.23 Antarctica, 1983

Temperature is usually measured with a **thermometer** or a **data logger**. The analog thermometers used in schools are sealed glass tubes filled with alcohol, which is dyed red so that they are easier to read.

KEY IDEAS

The following steps describe how to use a glass thermometer safely.
- Read the thermometer with your eye level with the top of the alcohol column to avoid parallax error.
- If measuring the temperature of a liquid, make sure that the liquid fully covers the thermometer bulb.
- Do not rest the bulb of the thermometer on the bottom of a container being heated, as the bottom may be hotter than the rest of its contents.
- **Never** use the thermometer as a stirring rod.
- **Never** rest a thermometer near the edge of a bench where it is likely to fall off.

WORKING SCIENTIFICALLY: Using scientific tools

Use a thermometer or data logger to measure the temperature of:
a. the air inside the school laboratory
b. the air outside the school laboratory
c. icy water in a small beaker
d. cold tap water in a small beaker
e. warm tap water in a small beaker
f. your armpit (take care, the thermometer is a delicate instrument).

CAUTION: Do not put the thermometer in your mouth!

Compare your answers with those of other people in your class. Why might some of their answers differ from yours?

WS **SC4-WS-01** Uses scientific tools and instruments for observations

1.4.8 Measuring mass

Mass is usually measured in kilograms (kg); however, in the science laboratory, you will often measure smaller masses and so you will use smaller units, grams (g) or milligrams (mg). You will usually use **electronic scales** to measure mass accurately.

KEY IDEAS

The following steps describe how to use an electronic scale.
1. Turn the scales on.
2. Adjust the balance reading to zero by pressing the tare button (this is often marked with just a 'T').
3. Place the object to be measured on the scales.
4. Read the mass from the digital display.

INVESTIGATION 1.4

Estimating mass

Aim

To accurately measure and record the masses of some common objects

Materials

- electronic scales
- pen
- safety glasses
- watchglass
- teaspoon
- watch
- 100 mL beaker
- 50 mL water
- sugar

Method

1. Estimate the masses of each of the following items: pen, watch, a pair of safety glasses, 50 mL of water and 2 teaspoons of sugar. Record your estimates in grams (g).
2. Use electronic scales to measure the masses of the pen, watch and safety glasses. Record your measurements.
3. The water and the sugar cannot be put directly on the pan. Record the masses of the beaker and the watchglass on their own.
4. Add 50 mL of water to the beaker. Record the combined mass of the water and the beaker. Subtract the mass of the beaker alone from the combined mass. Do the same with 2 teaspoons of sugar in the watchglass. Alternatively, put the empty container on the electronic scales before adding the water or sugar, and press 'tare'.

Results

1. Draw a table like the one shown below and enter the values of your estimates and measurements.

Item	Estimated mass (g)	Measured mass (g)	Difference (g)	Percentage error (%)
Pen				
Watch				
Safety glasses				
50 mL water				
2 teaspoons of sugar				

2. In the 'Difference' column of the table, record the difference in grams between the measured mass and the estimated mass for each item. If the estimated mass was lower than the measured mass, place a minus sign (−) in front of the number.
3. For each item, calculate the percentage error using:

$$\frac{\text{difference (g)}}{\text{measured mass (g)}} \times 100 = \text{percentage error}$$

Enter these values into the last column of the table.

Discussion

1. Which was your most accurate estimation?
2. By what percentage did your least accurate estimation vary from the measured mass?
3. Is it easier to estimate larger or smaller masses? Explain why you think this is the case.

Conclusion

Write a sentence describing why instruments are needed for accurate measurement of quantities.

1.4.9 Measuring time

We use clocks and watches to tell the time, but scientists often need to record how long an event takes. To do this accurately, they use stopwatches or electronic counters. The standard unit for measuring time is the second (s).

Familiarise yourself with a stopwatch. There is generally a start/stop button and a reset button. Push the reset button when you wish to start timing in a new experiment, and when you have finished timing your experiment and need to return your stopwatch to zero.

FIGURE 1.24 A stopwatch can be used to record time accurately.

INVESTIGATION 1.5

Timing a fall

Aim

To practise timing an event

Materials

- stopwatch
- pen

Method

1. Time how long it takes for a pen to fall from the top of the bench to the ground. Repeat two more times.
2. Calculate the average time taken for the three trials.
3. Repeat your experiment but swap roles within your group so that each member has a turn timing, recording and managing (such as saying 'go' when it's time to start the drop).

Results

Record your results in a table like the one below.

Name of student timing	Time taken (s)			
	1	2	3	Average

Discussion

1. Was the time taken to fall the same in each trial? Can you explain why?
2. Explain why it is useful to calculate an average.
3. Explain why you used a stopwatch in this experiment instead of the second hand of a clock or watch.

Conclusion

Describe what you learned about using a stopwatch accurately in this investigation.

Recording observations in a table

Aim

To record observations from experiments

Materials

- test tubes
- 50 mL beaker
- eye-dropper
- vinegar
- sodium carbonate
- methylated spirits
- starch suspension
- safety glasses
- test-tube rack
- spatula
- drinking straw
- sodium bicarbonate
- copper sulfate
- limewater
- iodine solution

CAUTION: Safety glasses should be worn while conducting these experiments.

Method

Activity 1

1. Pour vinegar into a clean test tube to a depth of about 1 cm.
2. Add a spatula-full of sodium bicarbonate.
3. Record your observations.

Activity 2

1. Quarter-fill two clean test tubes with water.
2. Add a dry spatula-full of sodium carbonate to one test tube. Shake the tube until the sodium carbonate dissolves.
3. Add a dry spatula-full of copper sulfate to the other test tube and shake it until the crystals dissolve.
4. Pour the contents of the second test tube into the first.
5. Record your observations.

Activity 3

1. Use an eye-dropper to put one drop of methylated spirits onto the back of your hand.
2. Blow air gently across the back of your hand.
3. Record your observations.

Activity 4

1. Quarter-fill a very small beaker with limewater.
2. Gently blow out through a drinking straw into the limewater. Be careful not to share straws.
3. Record your observations.

Activity 5

CAUTION: Take care not to get iodine solution on your skin or clothes.

1. Put a few drops of starch suspension in a clean test tube.
2. Add a drop of iodine solution.
3. Record your observations.

Results

Use a table like the one shown to display a summary of what was done and the observations you made for each activity.

Activity	Summary of what was done	Observations
1		
2		
3		
4		
5		

Discussion

1. What senses did you use in making your observations?
2. Outline two safety precautions involved in this investigation.
3. Explain why it is important to use small quantities of chemicals when doing experiments like these.
4. Explain why it is useful to present the observations in a table.
5. In activity 4, you had to pour limewater into the beaker. If you took more limewater than required, explain why it is not a good idea to return any unused limewater to the original bottle.

Conclusion

Write a sentence describing which of the observations in the investigation were qualitative and which were quantitative.

1.4 Activities

learnon

1.4 Quick quiz on	**1.4 Exercise**

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4, 7, 9	2, 5, 8, 10	3, 6, 11

Remember and understand

1. Is the following statement true or false?

   A measuring cylinder is an example of an analog measuring instrument.
2. What is a parallax error?
3. How do you avoid a parallax error?
4. **Outline** a way to achieve an accurate measurement of the mass of a quantity of water.

Apply and analyse

5. What is the temperature measured by this thermometer?
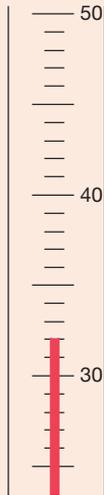
6. What is the temperature measured by this thermometer?
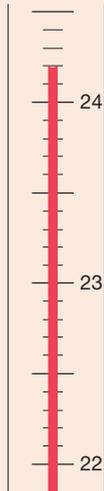
7. What is the temperature measured by this thermometer?
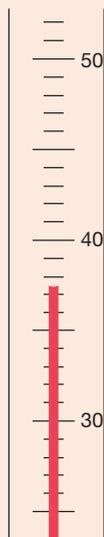
8. **Identify** whether each of the observations in the table is quantitative or qualitative.

Observation	Qualitative	Quantitative
The plant in sunlight grew faster than the plant in shade.		
The nail had a mass of 1.3 grams.		
The air temperature is 28 degrees.		
The mouse has brown spots.		

9. Convert 120 grams into kilograms.
10. Luke measured the mass of a beaker of water as 240 grams. He poured out the water and measured the mass of the beaker as 105 grams.

    Calculate the mass of the water in grams.

Evaluate and create

11. Which of your five senses is the most important for making observations in science investigations, and which is the least important?

    Give reasons for your answers.

LESSON 1.5 Reporting on investigations

LEARNING INTENTION

In this lesson you will present your investigation findings and ideas in the form of a scientific report, including using relevant scientific terms, diagrams and graphical representations.

1.5.1 Experiment reports

Once scientists have completed an investigation, they need to communicate to other scientists what they did, their qualitative and quantitative observations and their conclusions. This is done using a **scientific report**.

KEY IDEAS

The format of a scienctific report should be as follows.

Aim: This is what you intended to do in the investigation.

Materials: This is a list of all the equipment and chemicals that were used.

Method: This is the procedure followed in the investigation, described as a series of steps. It may be useful to include a labelled diagram of the set-up of equipment used. Be sure to include what you were actually recording in the experiment.

Results: This is a presentation of your data, and it may include qualitative observations. Data are usually organised into tables and presented as graphs.

Discussion: In this section, scientists explain their results — why they think they obtained the results they did. They may refer to the research of other scientists. They may also describe any problems encountered in the investigation and make suggestions for improvements.

Conclusion: This is a summary of the overall findings, and must relate to the aim of the investigation.

FIGURE 1.25 A good quality report of an experiment

Dissolving sugar	
Aim	To find out how much sugar will dissolve in hot water compared with cold water
Materials	• Beaker • Heatproof mat • Bunsen burner • Tripod • Gauze mat • Matches • Spatula • Stirring rod • Sugar • Water
Method	1. A spatula was used to add sugar to 100 mL of cold water in a beaker. The sugar was stirred and more added until no more would dissolve. The amount of sugar dissolved was recorded. 2. The mixture of sugar and water was heated with a Bunsen burner for 4 minutes and the extra amount of sugar that could be dissolved was recorded. The equipment was set up as shown in the following diagram.

Results				
	Water temperature	**Initial amount of sugar added**	**Extra sugar added**	**Total amount of sugar dissolved**
	Cold water	2 spatulas	1 spatula	3 spatulas
	Hot water	2 spatulas	7 spatulas	9 spatulas

Discussion	More sugar can dissolve in hot water than in cold water. This experiment could be improved by using a thermometer to measure the temperature of the water. The sugar could be measured more accurately by adding smaller amounts at a time, or weighing it.
Conclusion	Three times as much sugar dissolves in hot water as in cold water.

✦ 1.5.2 Drawing laboratory equipment

Scientific drawings can be used in laboratory reports to show how equipment was set up. It is important for the drawings to be clear and easy to understand. When drawing scientific diagrams, you should:
- always draw in pencil
- use a ruler to draw straight lines
- label the equipment drawn
- draw only a cross-section of the equipment
- not draw lines closing the top of open glassware.

Some examples of equipment drawn scientifically are shown in figure 1.26.

FIGURE 1.26 Diagrams in scientific reports should be simple. In each case here, the apparatus is shown on the left and the diagram of this apparatus on the right.

Tripod and gauze mat

Beaker

Test tube

Bunsen burner and heatproof mat

Conical flask

Retort stand, bosshead and clamp

Filter funnel and filter paper
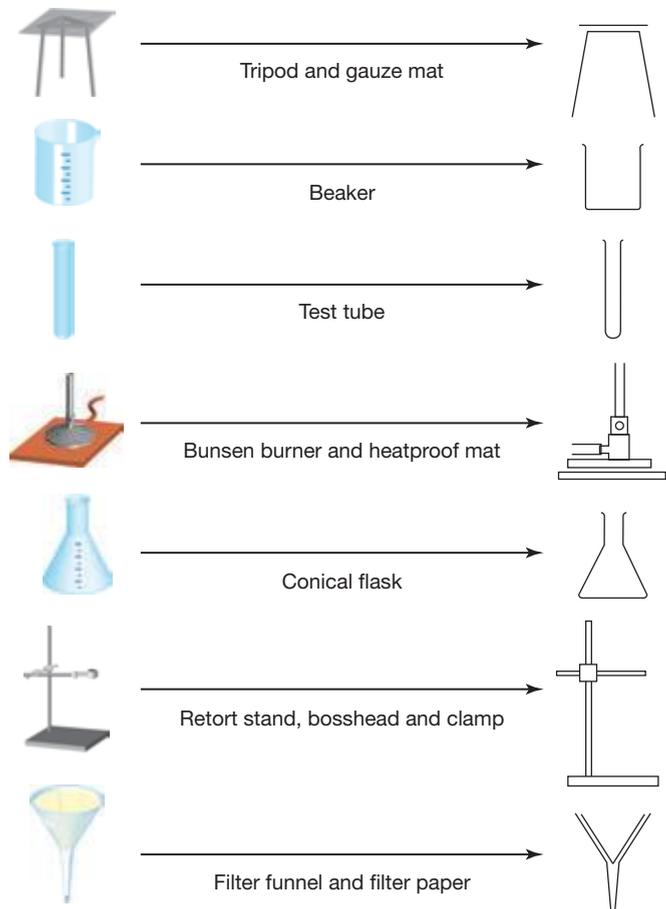
DISCUSSION

Do you have to be a talented artist to be able to draw a neat scientific diagram? Discuss ways in which you can produce a clear labelled diagram of your equipment even if you are not a good at drawing.

1.5.3 Recording observations in tables

When recording observations, it is helpful to organise the data in a table. Information presented in this way is often easier to read. Graphs can then be constructed from the table to make it even easier to see patterns in the data.

The heading for each column is a clear label of what has been measured.

Always include the units used in the headings.

Distance (cm)	Time for ant to travel between markers (s)
0	0
2	3
4	7
6	8
8	12

Enter the data in the body of the table. Do not include units in this part of the table.

Use a ruler to draw lines for rows, columns and borders.

1.5.4 Graphing

Graphs are used to make data easier to interpret. The type of graph used depends on the type of data to be displayed.

TABLE 1.7 Types of graphs

Type of graph	When is it used?	Example
Pie graph or pie chart	For showing the parts that make up a whole	A pie chart can be used to show the percentages of different substances in Earth's crust. Calcium (4%), Other (10%), Iron (5%), Oxygen (46%), Aluminium (8%), Silicon (27%)
Bar or column graph	To display data that can be placed in categories	A column graph can be used to show the number of students in a class with a particular hair colour. *Number of students* vs *Colour of hair* (Black, Brown, Red, Blond)
Scatter plot	To show how a measurement changes	A scatter plot can be used to show how quickly a plant grows over time. Data points are plotted on the graph and a line is drawn which best matches the positions of the data points. This line of best fit may be a straight line or a curve. Avoid playing 'dot-to-dot'. A line of best fit can be used to predict what might happen in the future. Lines of best fit Data point Lines of best fit are useful for predicting values between those that you actually observed. *Height of plant (cm)* vs *Number of weeks*

Graphing temperature

Aim

To observe how the temperature of water changes while it is heated over a Bunsen burner

A scatter plot is a useful way to present the results of an experiment and helps to identify any trends or patterns in the results. A line of best fit can be drawn on the scatter plot and used to predict values that occur between, or outside, those measured during an experiment.

Materials

- 100 mL measuring cylinder
- 250 mL beaker
- Bunsen burner
- heatproof mat
- matches
- tripod
- gauze mat
- retort stand, bosshead and clamp
- thermometer or data logger and temperature sensor
- stopwatch
- safety glasses

Method

1. Use a measuring cylinder to measure 100 mL of water.
2. Pour the water into the beaker.
3. Set up the equipment as shown in the diagram. Make sure that the bulb of the thermometer is not on the bottom of the beaker or out of the water.
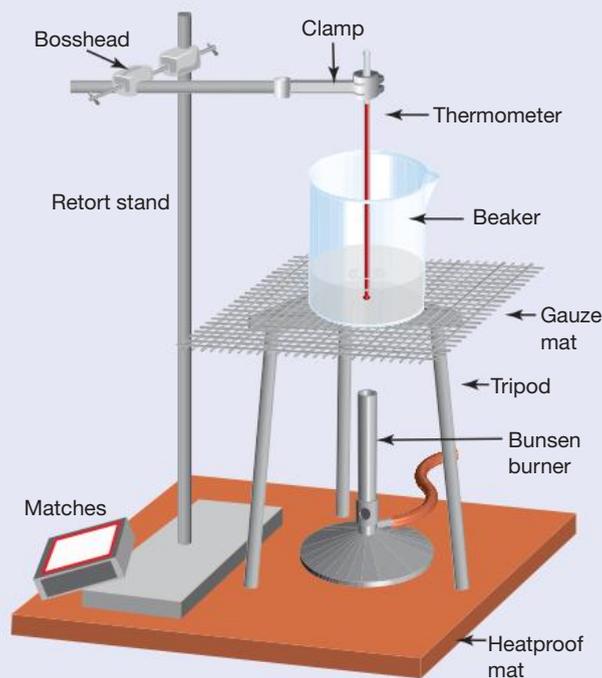
4. Wait for a minute to allow the thermometer to adjust to the water temperature.

5. Measure the initial temperature of the water and record it in a table like the one shown below. The initial temperature is recorded when time is 0 minutes.

Time (min)	Temperature (°C)	Time (min)	Temperature (°C)
0		6	
1		7	
2		8	
3		9	
4		10	
5			

6. Put your safety glasses on.
7. Light the Bunsen burner according to the guide in section 1.3.5.
8. Open the airhole and heat the beaker over a blue flame.
9. Measure and record the temperature of the water every minute for 10 minutes.
10. Turn off the Bunsen burner and allow the equipment to cool.

Results

1. Plot the data you have collected on a sheet of graph paper using labels like those below. Don't forget to give your graph a title.
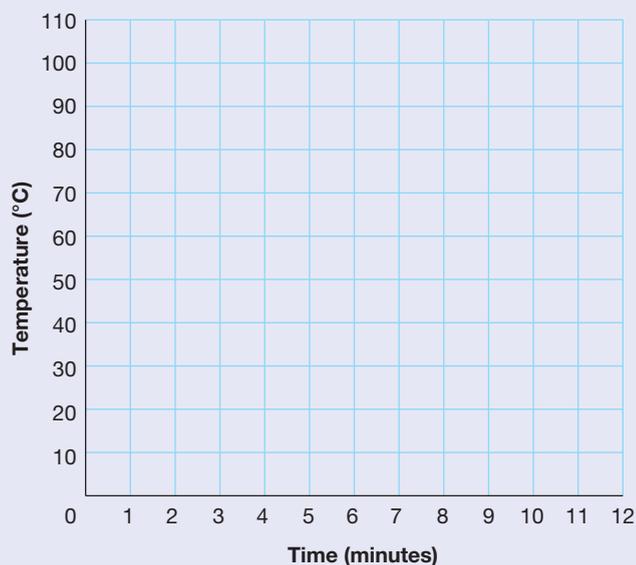
2. Complete the graph by drawing a smooth line near as many points as possible to show the overall trend in the water temperature over time.

Discussion

1. Describe in words how the temperature increases over time.
2. Explain why you didn't record the starting temperature of the water as soon as it was poured into the beaker.
3. How does your graph compare with those of other groups? If your graph is different, give a possible explanation for this.
4. The line of best fit can be used to predict values that occur between, or outside, those measured during an experiment. Looking at your graph, predict what would happen to the temperature of the water if you continued heating for another two minutes.

Conclusion

Write a sentence describing the shape of your graph and state the change in temperature of the water over the 10-minute period.

1.5 Activities

1.5 Quick quiz on	1.5 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4	2, 5, 8	3, 6, 7

Remember and understand

1. **MS** Select all the rules for drawing the equipment used in an experiment from the options provided.
   A. Use a pencil
   B. Draw in 3 dimensions
   C. Use a ruler to draw straight lines
   D. Shade in glassware
   E. Label the equipment drawn
2. Place the following in the correct order for the sections of a scientific report.

   Aim, Conclusion, Discussion, Materials, Method, Results, Title
3. Match each section heading of a laboratory report with the information contained in that section.

a. Materials	**1.** Suggestions for improvements to your experiment
b. Procedure	**2.** The data collected
c. Conclusion	**3.** A description of how the experiment was undertaken
d. Discussion	**4.** A list of the equipment used
e. Results	**5.** A statement saying what you discovered by doing the experiment

4. Select the correct terms to complete the sentences.

   The *aim / method* section of a scientific report is a statement of what you intended to find out in the experiment.

   The *aim / method* section is a list of steps explaining how the experiment was performed.

Apply and analyse

5. Why is it useful to present observations in a table?
6. **Identify** one reason that we might use line graphs to present the results of an experiment.

7. Consider the figure below. The computer screen shows data collected by a data logger for an experiment in which water is heated to boiling point in a beaker. A temperature sensor was used to take the measurements.

If you were at this computer, you could scroll through every temperature measurement in the table.

The computer has graphed all these data.

a. MC How often did the data logger collect temperature readings?
   A. Each minute
   B. Each second
   C. Each 0.1 second
   D. Each 0.001 second
b. Identify the number of individual temperature readings the data logger has stored.
c. Identify the approximate time at which heating of the water began.
d. MC **Identify** the temperature of the water when heating began.
   A. 23 °C
   B. 32 °C
   C. 50 °C
   D. 100 °C
e. Identify the approximate temperature of the water when heating finished.
f. Identify the time at which the water began to boil.
g. MC **Calculate** the rate (in degrees per second) at which the water temperature rose between 100 and 400 seconds.
   A. 0.19 °C/s
   B. 30 °C/s
   C. 58 °C/s
   D. 300 °C/s

Evaluate and create

8. Draw a neat scientific diagram showing the equipment set-up for the following experiment. You may use an online program to help you draw.

Muddy salt water is being poured from a 100 mL beaker into a filter funnel (with filter paper). The filter funnel is resting in the opening of a 150 mL conical flask.

LESSON 1.6 Designing investigations

LEARNING INTENTION

In this lesson you will describe how observations of natural phenomena can be used to make inferences and testable predictions. You will also identify that scientific theories and laws are based on repeated experiments and observations that describe or predict a range of natural phenomena.

In many of the experiments you have done so far, the aim and the method you need to follow have been provided for you. In some cases, though, you will need to design your own experiments as part of your investigation.

Let's look at some important principles to consider when designing investigations.

1.6.1 Inferences

After making some initial observations, scientists make an **inference** about what has happened. Many inferences can often be made for the same set of observations.

ACTIVITY: Inferences

Consider the picture. What inferences can you make? What observations led you to these inferences?

FIGURE 1.27 Observations and inferences

1.6.2 Hypotheses

After making an inference, scientists will come up with a **hypothesis**.

Here are some examples of hypotheses.
- Wearing makeup causes your skin to get pimples.
- The rate at which coffee in a cup gets colder depends on the shape of the cup.
- Plants grow faster in full sunlight than in shady positions.
- Bees prefer flowers that are red rather than white.

Each of these can be tested in an experiment, and the results of the experiment will either **support** the hypothesis or cause the hypothesis to be **rejected**.

1.6.3 The scientific method

The word *science* comes from the Latin word *scientia*, meaning 'to know'. Scientists of all kinds gain knowledge through a process of making observations and conducting experiments to come up with explanations for those observations. This process is called the **scientific method**.

The scientific method can be described in a series of steps, as shown in figure 1.28.

FIGURE 1.28 Belly button lint and the scientific method
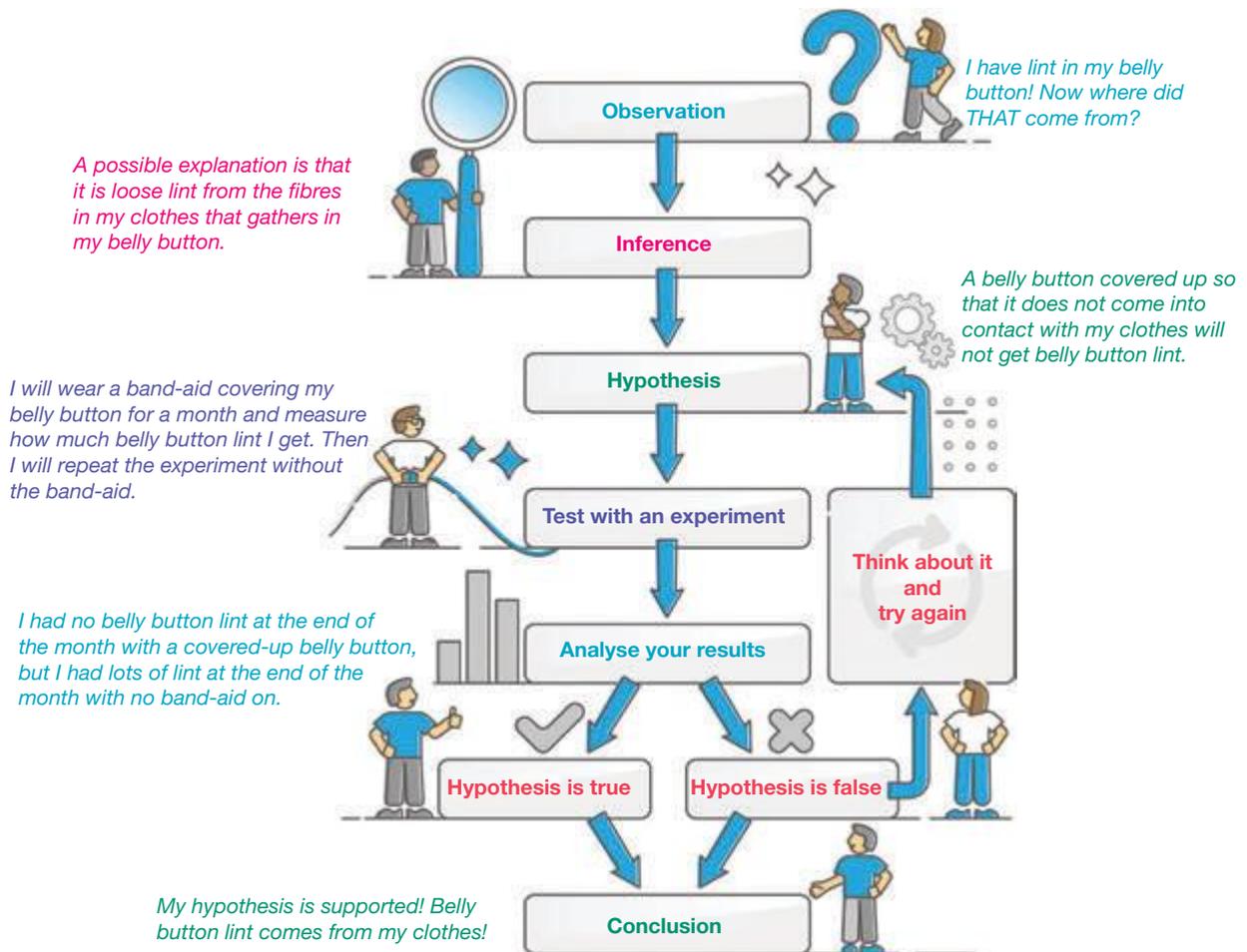
Observing and inferring

Aim

To observe the changes that occur in a burning candle

Materials

- large beaker
- short candle
- lid or watchglass
- matches
- electronic scales

Method

1. Weigh the candle and lid (or watchglass) using electronic scales, and record your results.
2. Light the candle.
3. Observe the candle for several minutes and record as many observations as you can while it is alight. (Michael Faraday, a nineteenth-century scientist famous for his discoveries in electricity and chemistry, was able to make 53 observations of a burning candle!)
4. After several minutes, place an upturned beaker over the candle and continue to record your observations.
5. Weigh the candle and lid (or watchglass) again and record your results.

Beaker
Candle
Watchglass

Results

List your observations in a table similar to that shown below. Note whether the observation was qualitative or quantitative.

	Observations	Qualitative or quantitative?
Before the beaker is placed over the candle		
After the beaker is placed over the candle		

Discussion

1. How many observations did you record? What was the greatest number recorded by a member of your class?
2. What change occurred in the mass of the candle and lid? Is this an example of a quantitative observation or a qualitative observation?
3. What inferences can you make as to why the mass of the candle may have changed?
4. Write a hypothesis that allows you to test one of your inferences.

Conclusion

Describe the difference between your observations and your inferences.

1.6.4 Laws and theories

Scientific laws and **scientific theories** are very different things.

Laws	Theories
Predict what will happen	Explain how or why things happen
Can be proven experimentally or mathematically	Are hypotheses that have been repeatedly supported by evidence but cannot be proven
May often be written in the form of mathematical equations	May be replaced by other theories that are a better explanation for observations

It is important to note that theories cannot become laws.

DISCUSSION

Which of the following have you heard about?
- The Law of Gravity
- The Theory of Evolution
- The Laws of Motion
- The Theory of Relativity
- The Distributive Law
- The Greenhouse Theory

Discuss what people mean when they say something is 'just a theory'. Do they mean that it isn't always true? What is the difference between a theory and a law?

1.6.5 Fair tests

An important part of any investigation is to consider all the factors, or **variables**, that may affect the outcome of an experiment.

In a fair test, only one variable is changed at a time and all other variables are controlled, or kept the same. If this wasn't the case, it would be impossible to tell which variable caused the result we are studying.

The phrase 'Cows Moo Softly' can be useful in remembering how to plan a fair test:
- **C**hange one thing
- **M**easure something
- keep everything else the **S**ame.

When designing fair tests, you might find it helpful to use a table like table 1.8 to identify all the variables.

TABLE 1.8 Investigation: Does the height from which a ball is dropped affect the height of its bounce?

Independent variable (What I will change)	Dependent variable (What I will measure)	Controlled variables (What I will keep the same)
• The height from which the ball is dropped	• The height of the ball's bounce	• The type of ball • How much air is in the ball • The type of surface onto which it is dropped • Dropping the ball from a stationary point

DISCUSSION

Dana loves playing tennis, and it seems to her that the Schmick brand of tennis ball bounces higher than the Swish brand. She wants to test this hypothesis experimentally.

What variable will be the independent variable? What will be the dependent variable?

Discuss what variables Dana would need to control (keep the same) throughout her testing to make it a fair test. Are there any variables that are beyond her ability to control?

1.6.6 Including a control

In some investigations, it is important to include a **control**. A control is a **trial** of the experiment in which the independent variable being tested is not applied. Results from the control are compared with those obtained when the independent variable has been included. This allows us to test whether the independent variable we are investigating really has an effect, or whether other variables that we may not have thought of could be playing a part.

For example, Toby is going to test whether powdered laundry detergent gets his clothes cleaner than liquid laundry detergent. A suitable control would be a trial in which no laundry detergent is used at all.

FIGURE 1.29 The laundry test

1.6.7 Reliability

If the results obtained are similar for each trial using the same independent variable value, then we say the results are **reliable**.

Errors often arise in experiments. The most common errors are **one-off errors** (or **random errors**). These may happen because the experiment was not done in the same way in every trial. The results of these errors are just as likely to be too high as too low.

Examples of one-off errors include:
- the person timing the drop of a ball is distracted and is late stopping the stopwatch
- the distance a paper plane travels is being measured when, suddenly, there is a gust of wind that pushes against the plane
- the person weighing powder on a digital scale forgets to subtract the mass of the powder's container during one of the trials, so the weight recorded for that trial is too high.

KEY IDEAS

The following steps help avoid random errors affecting your conclusions.
1. Tests should be repeated several times (at least three) and the average value found.
2. When repeating tests, they should be done in exactly the same way each time.
3. If reading scales, ensure that there is no parallax error.
4. If there was a significant difference between your results for each test, you may need to review the way in which the experiment was done.

DISCUSSION

When doing the official weighing-in for a match, a boxer is found to have a mass of 95 kg. However, the scales he used in the changing room five minutes before showed him to be 93 kg. What is the most likely explanation for the difference in weight? Discuss how you could find out which of the scales to believe.

CASE STUDY: The smoking gun

It is vital that all people timing a race start their stopwatches at the same time. For this reason, they start to time when they see the smoke first appear from the starter's gun. In important events such as at the Olympic Games, the timing is started and stopped by a system of sensors and computers.

FIGURE 1.30 All stopwatches must be started at the same time when timing a race.

DATA SCIENCE 1: Data science in context

Using data

To investigate whether a ball being wet affects how high it bounces, you could compare the height of a wet ball's bounce with that of a dry ball dropped from the same height. Conducting two sets of five trials for each condition, and finding the average height in each case, might give the following results.

TABLE 1.9 The tennis ball test

Trial	Height of bounce (cm)	
	Dry tennis ball	Wet tennis ball
1	70	70
2	65	62
3	68	60
4	69	63
5	72	65
Average	69	64

a. Would you say the results presented in the table are reliable? Identify any results in the table that seem inconsistent.
b. What conclusion would you make based on the average results?
c. What conclusion would you have drawn based on the results of trial 1 only?

CASE STUDY: Experimental design and Louis Pasteur

To properly test an idea, a fair test of a hypothesis needs to be made. In a fair test, all factors should remain the same except one: the independent variable. In a simple experiment, you change one independent variable at a time and observe what happens.

Observations of maggots appearing in rotten meat and mould forming on bread led the fourth-century BCE philosopher Aristotle to infer that living things could suddenly be created from non-living things. He called this theory 'spontaneous generation'. Many scientists continued to believe this theory for 2000 years.

However, the spontaneous generation theory was dealt a serious blow by the work of the French scientist Louis Pasteur in 1859. Pasteur had been filtering air through wads of gun cotton when he observed that the gun cotton was getting filled with microbes.

He inferred that the microbes must have been in the air. He designed an experiment to test his **hypothesis** that the microbes growing on old food came from the air not the food.

In his experiment, Pasteur's **independent variable** was whether the meat broth in the flask remained sealed away from air or not.

His **dependent variable** was the number of microbes that grew in each flask after a set period of time.
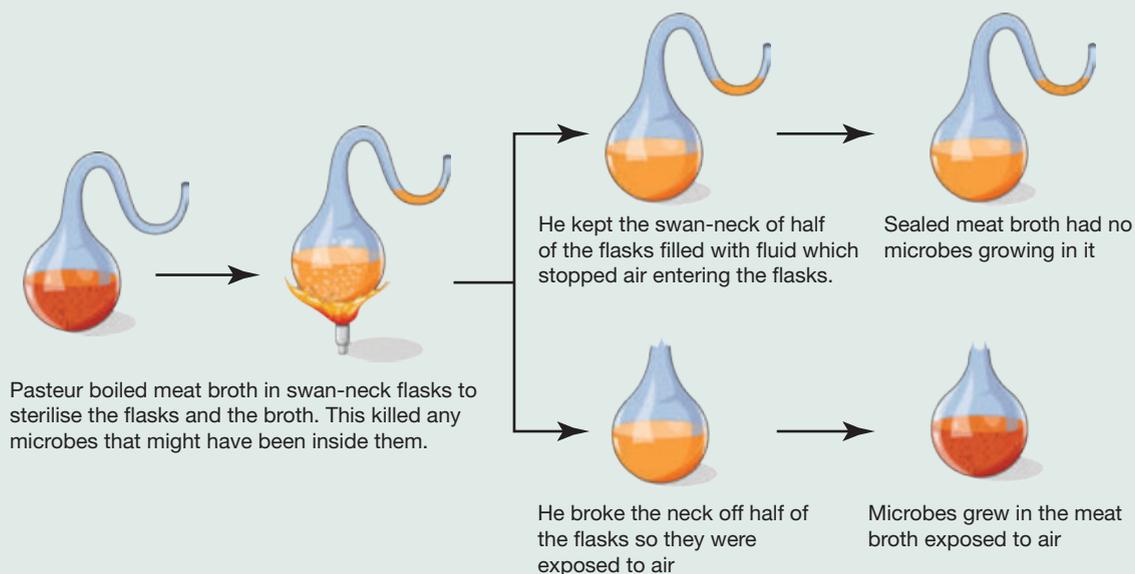
FIGURE 1.31 Louis Pasteur

Some of the variables that he controlled were:
- the size and volume of flask used
- the period of time that the meat broth and flasks were boiled for at the start to sterilise them
- the volume of meat broth added to each flask
- keeping the flasks in the same area/environment.

FIGURE 1.32 The Pasteur experiment

Pasteur boiled meat broth in swan-neck flasks to sterilise the flasks and the broth. This killed any microbes that might have been inside them.

He kept the swan-neck of half of the flasks filled with fluid which stopped air entering the flasks.

Sealed meat broth had no microbes growing in it

He broke the neck off half of the flasks so they were exposed to air

Microbes grew in the meat broth exposed to air

The **result** of his experiment was that microbes grew in the meat broth in the flasks open to the air, but not in the ones which remained sealed by the fluid in the swan-neck.

He **concluded** that the microbes in the air became trapped in the fluid in the bent section of the neck, and so could not travel into the meat broth.

Because microbes grew in the flasks exposed to the air but not in the others, this experiment supported Pasteur's hypothesis that germs arrived from the air outside the flask.

INVESTIGATION 1.9

Stopping the growth of bacteria

Aim

To investigate whether preservatives can stop the growth of bacteria

Materials

- chicken stock cube
- vinegar
- beaker (1 L)
- salt
- hot tap water (750 mL)
- masking tape
- stirring rod
- pen or marker
- 3 beakers (250 mL)
- teaspoon

Method

1. Place a chicken stock cube in a 1 L beaker and add 750 mL of hot tap water.
2. Stir the solution with a stirring rod until it is consistent.
3. Pour 200 mL of the mixture into each of three 250 mL beakers.
4. Add one teaspoon of vinegar to one small beaker and use the pen and masking tape to label the solution 'vinegar'.
5. Add one teaspoon of salt to another small beaker and label the solution 'salt'.
6. Label the third beaker 'control'.
7. Place the three small beakers on a warm windowsill for seven days.

Results

Large amounts of bacteria will make the solutions go cloudy.

Examine the three beakers after two days and again after seven days. Record your observations in a table like the one below. Describe the degree of cloudiness of each solution.

Beaker	Observations	
	After 2 days	**After 7 days**
Vinegar		
Salt		
Control		

Discussion

1. What was (a) the independent variable and (b) the dependent variable in this investigation?
2. What role did the control play in this experiment?
3. Salt is one of the most widely used of all food preservatives. Suggest a hypothesis relating to salt that could be tested by this experiment.
4. Which preservative was the most effective at stopping bacterial growth?

Conclusion

Write a brief statement explaining whether your hypothesis (from question 3 in the Discussion) was supported by the results of this experiment.

Floating in salty water

Aim

To investigate whether the salinity of water affects how high an object floats in water

The water in the Dead Sea, a lake near Jordan in the Middle East, has an unusually high salinity; in fact, it is nine times more saline than the ocean. Tourists flock to the lake because it is believed the water has health benefits and to experience the water's unusually high buoyancy.

Materials

- 100 mL measuring cylinder
- small test tube
- cork or rubber stopper
- cotton thread
- permanent marker
- scissors
- table salt
- teaspoon or spatula

Method

1. Fill the measuring cylinder to the 100 mL mark with tap water.
2. Make a 'diving bell' by half-filling a test tube with tap water; seal the top with a stopper.
3. Tie a piece of cotton thread securely around the top of the test tube so it can be carefully moved in and out of the measuring cylinder.
4. Check that the test tube floats off the bottom but not higher than halfway up the measuring cylinder. If not, adjust the volume of water in the test tube.
5. Put the diving bell in the measuring cylinder and mark the position of the *bottom* of the diving bell on the measuring cylinder's scale. Record this value.
6. Carefully remove the diving bell.
7. Add a level teaspoon of table salt to the measuring cylinder and dissolve it in the water by shaking carefully or stirring.
8. Put the diving bell back in and mark and record its position.
9. Repeat this experiment using a second, a third and, finally, a fourth teaspoon of salt.

Cotton thread

Measuring cylinder

Diving bell

Water and dissolved salt
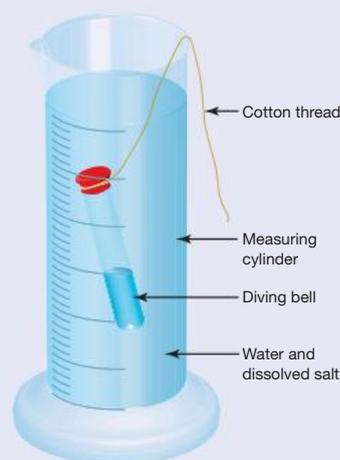
Results

1. Design a suitable table to record your results — you will need a column indicating the number of teaspoons of salt added and a column listing the position of the diving bell (using the scale on the measuring cylinder).
2. Draw a line graph of salinity (teaspoons of salt added) on the x-axis versus the height of the diving bell (reading on the measuring cylinder) on the *y*-axis, and draw a smooth line of best fit.

Discussion

1. Identify the independent variable and the dependent variable in this experiment.
2. Identify the control in this experiment.
3. What variables were controlled throughout this experiment? (Remember – this will not be the same as the control variable.)
4. What happens to the height of the diving bell as the number of teaspoons of salt added is increased?
5. Repeating this experiment would be very time-consuming so, to check the reliability of your findings, compare your results with those of other groups. The easiest way to do that is to compare others' graphs with yours. Describe any differences that stand out between your results and those of other groups.

6. List the most likely causes of error in your experiment. In each case, state how this error could be avoided if the experiment was done again.
7. Use your graph to predict the position of the diving bell if six teaspoons of salt were added. (This sort of prediction beyond the values used in the experiment is called **extrapolation**.)

Conclusion

Write a conclusion to the experiment about whether the salinity of water affects how high an object floats in water.

1.6 Activities

1.6 Quick quiz on	1.6 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4, 7, 9	2, 5, 8, 10	3, 6, 11

Remember and understand

1. Is the following statement true or false?

   Only one variable at a time should be changed in experiments, so that it is possible to assess the effect of just that one variable on the outcome.
2. **MC** Which of the following statements is NOT a hypothesis?
   A. Red cars get hotter interiors than white cars when parked in the sun.
   B. Dogs are better pets than cats.
   C. Tea cools at a faster rate than coffee.
   D. Sugar is more soluble in water than salt.
3. Place the following steps of the scientific method in their correct order.

   Observation, Inference, Hypothesis, Experiment, Analyse results, Determine whether the hypothesis is supported or rejected, Conclusion
4. Is the following statement true or false?

   In science, a theory can never become a law.
5. Is the following statement true or false?

   Louis Pasteur tested the hypothesis that food spoiled when left open in the air.
6. What three characteristics did the control used by Louis Pasteur in his experiments have?

Apply and analyse

7. **MS** Which two of the following variables might affect how quickly a pot plant grows?
   A. The amount of light received
   B. The colour of the pot
   C. The nursery from which it was purchased
   D. The species of plant
8. Imagine that you are conducting an experiment to test the effectiveness of different washing powders at removing mud stains from cricket shirts.
   a. **MC** Which of the following would be an independent variable in your experiment?
      A. Amount of mud on cricket shirt
      B. Temperature of the water
      C. Brand of washing powder
      D. Amount of washing powder

b. MC Which of the following would be a dependent variable in your experiment?
  A. Amount of mud on cricket shirt
  B. Brand of washing powder
  C. Amount of washing powder
  D. Visibility of stain remaining after washing
c. MC Which of the following would be controlled variables in your experiment?
  A. Temperature of the water
  B. Visibility of the stain after washing, visibility of the stain before washing
  C. Amount of washing powder, visibility of the stain after washing
  D. Time shirt is washed for, amount of washing powder, temperature of the water
d. MS Which of the following variables in your experiment could be measured quantitatively? Select all that apply.
  A. Brand of cricket shirt
  B. Amount of mud on cricket shirt
  C. Temperature of the water
  D. Brand of washing powder
  E. Amount of washing powder
  F. Time shirt is washed for
9. Simon and Jessie conducted an experiment to find out how effectively two plastic cups maintain the temperature of near boiling water. Their data are shown below.

Time (min)	Temperature (°C)	
	Simon's cup	Jessie's cup
0	90	90
10	47	58
20	29	39
30	22	31
40	20	26
50	20	23

Estimate the temperature of the water in Simon's cup 15 minutes after timing commenced.
10. Catherine and Celine are trying to find out whether ceramic or glass cups are better for keeping water hot. The illustration shows their experiment in progress.
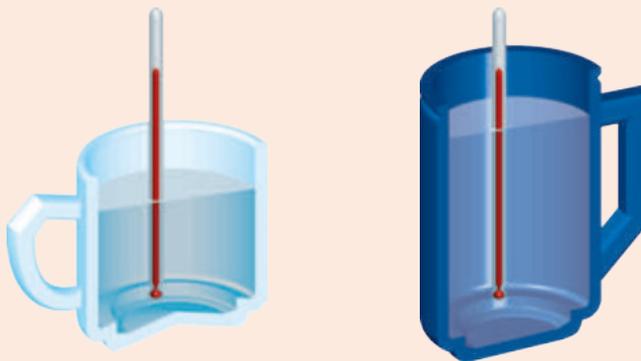
a. The temperature of the water is the *dependent / independent* variable and the type of cup is the *dependent / independent* variable.
b. **Identify** two errors in their experimental design.
c. Write a step-by-step outline of the procedure that they could use to find out which cup keeps water hotter.

Evaluate and create

11. Design an experiment to **investigate** what conditions affect the time taken for seeds to germinate.

LESSON 1.7 Review

1.7.1 Topic summary

<To come>

1.7.2 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	🟢	🟡	🔴
1.2	I can recognise how scientific knowledge can be represented in branches of biology, chemistry, physics and geology.			
	I can consider how modern scientific knowledge is interdisciplinary and transdisciplinary.			
1.3	I can identify, assemble and use appropriate equipment and resources to perform an investigation safely.			
1.4	I can use a variety of analog and digital measuring devices in scientific investigations to compare the range, sensitivity and accuracy of observations provided by those instruments.			
1.5	I can present investigation findings and ideas in the form of a scientific report, including using relevant scientific terms, diagrams and graphical representations.			
1.6	I can describe how observations of natural phenomena can be used to make inferences and testable predictions.			
	I can identify that scientific theories and laws are based on repeated experiments and observations that describe or predict a range of natural phenomena.			

on Resources

on **Post-test**	Topic 1 Post-test
eWorkbook	Quick quiz
	Summary
	Reflection
Digital document	Key terms glossary

1.7 Activities

Remember and understand

1. Match the following scientists with their field of work.

a. Physicist	1. Studies living things
b. Chemist	2. Investigates the formation of rocks and mountains
c. Biologist	3. Studies the night sky
d. Astronomer	4. Investigates movement and light
e. Earth scientist	5. Studies how substances react together

2. **MS** Which three of the following are parts of a Bunsen burner?
   A. Gas hose
   B. Barrel
   C. Collar
   D. Bosshead
   E. Conical flask
   F. Test tube rack
   G. Evaporating basin

3. Match the piece of laboratory equipment with its correct use.

a. Bosshead	1. Holds test tubes upright
b. Conical flask	2. Container used for heating small amounts of substances over a Bunsen burner
c. Test-tube rack	3. Holds a clamp to the retort stand
d. Evaporating basin	4. Container used for mixing substances or collecting filtered substances

4. a. When lighting a Bunsen burner, light the match *immediately before / while / immediately after* turning on the gas.
   b. When using a thermometer to measure the temperature of a liquid as it is heated, place the bulb of the thermometer *at the bottom / near the centre / at the top* of the beaker.

5. When heating a test tube, hold the test tube using _____ at the top of the test tube and _____ over the flame.

6. **MC** **Identify** which of the following is an important safety rule in the science lab.
   A. When smelling chemicals, place your nose carefully over container.
   B. Dispose of all materials in the rubbish bin.
   C. When reading the volume of a liquid, always read the top of the meniscus.
   D. Point test tubes away from your eyes and away from your fellow students.

7. Place the following important steps involved in using a Bunsen burner into the correct order.
   I. Light a match and hold it over the barrel.
   II. Adjust the flame by moving the collar until the airhole is open.
   III. Connect the rubber hose to the gas tap.
   IV. Turn on the gas tap and a yellow flame will appear.
   V. Close the airhole of the Bunsen burner collar.

8. **MC** The equipment used for measuring the volume of liquids includes:
   A. conical flask, beaker, measuring cylinder.
   B. measuring cylinder, crucible, beaker.
   C. watchglass, filter funnel, conical flask.
   D. evaporating basin, test tube, beaker.

9. **Convert** the following quantities to standard units.
   Note: Use numerals to write your answers.
   a. 240 cm = _____ m
   b. 650 mL = _____ L
   c. 3500 g = _____ kg

10. **Identify** the temperature measured by the thermometer shown below.
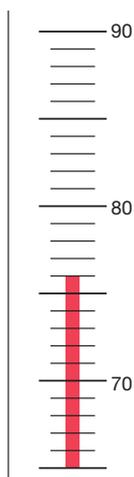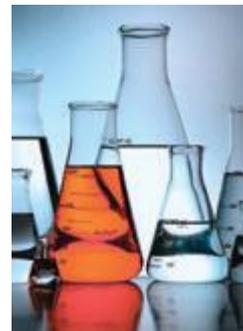
11. **MC** Luke was tired of being bitten by mosquitoes. He counted several bites each evening when he sat outside to have dinner. He had heard that a burning citronella candle was a good way to keep mosquitoes away.

    If you were to design an experiment using the principles of fair testing to test Luke's idea, identify the independent variable.
    A. The type of candle used
    B. The number of mosquito bites on Luke
    C. The time of night the candle is burned
    D. A plain unscented candle

12. The graph shows how far from the starting point a snail moves in an experiment.

   a. How far from the starting point was the snail 7 minutes after timing began?

   b. **MC** During which times did the snail not move at all?

   A. None — it was always moving
   B. Between the second and third minutes
   C. Only at the very beginning
   D. During the first and fifth minutes

   c. **MC** What does the graph tell us about the snail's movement between 7 and 8 minutes after timing began?

   A. The snail was slowing down.
   B. The snail was moving back towards the start.
   C. The snail had stopped moving.
   **D.** The snail was travelling down a slope.
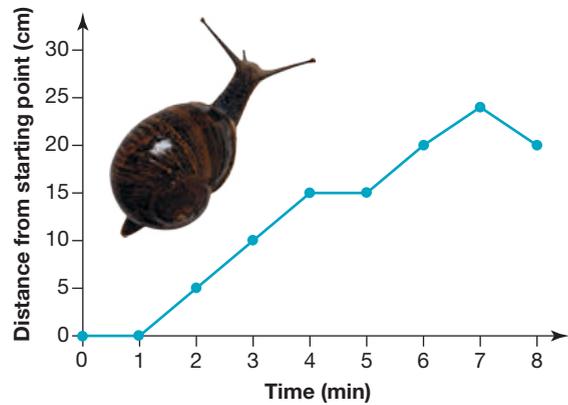
13. The following table shows the winning times for the men's 400 m freestyle swimming event at various Olympic Games from 1908 to 2016.

Year	Name, Country	Time (min:s)
1908	Henry Taylor, Great Britain	5:36.8
1920	Norman Ross, USA	5:26.8
1932	Buster Crabbe, USA	4:48.4
1948	Bill Smith, USA	4:41.0
1960	Murray Rose, Australia	4:18.3
1972	Bradford Cooper, Australia	4:00.27
1984	George DiCarlo, USA	3:51.23
1996	Danyon Loader, New Zealand	3:47.97
2000	Ian Thorpe, Australia	3:40.59
2004	Ian Thorpe, Australia	3:43.10
2008	Taehwan Park, Korea	3:41.86
2012	Yang Sun, China	3:40.41
2016	Mack Horton, Australia	3:41.55

   a. Is data available for each Olympic Games every 4 years?
   b. What was the winning time in seconds for Taehwan Park, Korea, in 2008? Round off to the closest second.
   c. **Discuss** how the winning times have changed over the 108-year period and suggest two reasons for the change in winning times.
   d. **Discuss** how times for the men's 400 m freestyle might change over the next 40 years.

**14.** **MC** The liquid level in the measuring cylinder shown is:
   A. 34 mL.
   B. 38 mL.
   C. 40 mL.
   D. 42 mL.
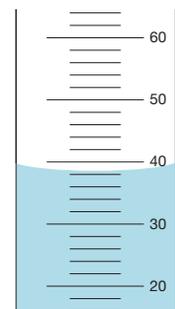
15. Draw a scientific diagram of the experiment below, suitable for inclusion in a report. Label each part of your diagram.
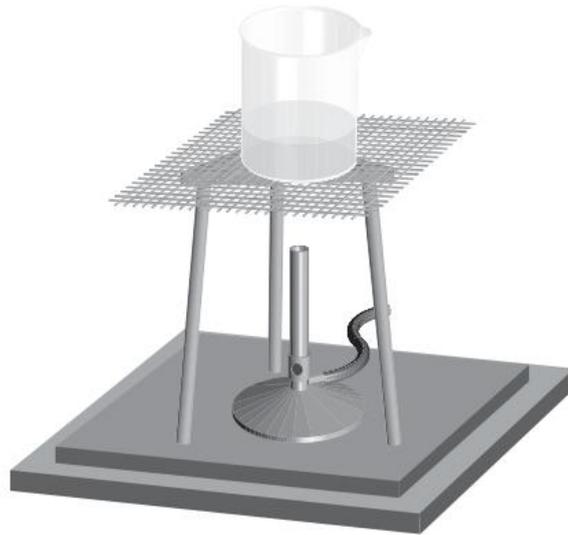
16. A student wanted to investigate which brand of paper towel was the most absorbent. Identify the following variables for the experiment.
  a. The independent variable
  b. The dependent variable
  c. Two important controlled variables

17. Copy and colour the thermometer below to show a temperature of 14 °C.
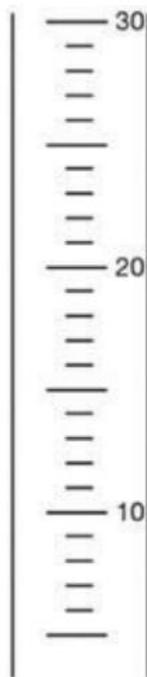
18. A group of students carried out an investigation to study the types of birds that visited the school playground during lunch time. They recorded 5 native miners, 2 cockatoos, 7 Indian mynahs and 3 pigeons. What is the most suitable type of graph to present their data? Give a reason for your answer.

19. A group of students investigated the time taken for a headache tablet to dissolve in a glass of water as the temperature of the water was increased. They obtained the following results.

Temperature (°C)	15	20	25	30	35	40
Time (s)	60	40	30	20	15	10

Draw a line graph of this data, including a curve of best fit.

20. Look at the photograph.
   a. What qualitative observations do you think the scientist can make from this experiment?
   b. **Propose** two different quantitative observations the scientist might make during this experiment.
   c. **Propose** what the aim of this experiment might be.

21. **Construct** a table with three columns headed 'Observation', 'Inference' and 'Prediction'. In the table, write each of the statements below under the correct heading and in their correct sequence, so that a scenario is followed across each row.
   - I am afraid of heights.
   - A snail has eaten holes in the leaves of my African violet plant, but hasn't touched the flowers.
   - I will experience similar symptoms if I stand at the top of another building, a cliff or a bridge.
   - My charger cable is faulty.
   - Snails eat leaves, but not flowers.
   - My phone doesn't charge when I plug it in.
   - When visiting the top deck of Sydney Tower, my heart started beating more quickly and loudly, my palms sweated and I felt a bit dizzy.
   - If I put a different flowering plant in place of my African violet each night, the snail will eat only the leaves of each plant, and ignore the flowers.
   - If I use another charger cable, my phone will charge.

22. Four students each measured the temperature in the same classroom using a thermometer. Their results are shown in the table.

Student	Temperature (°C)
1	23.5
2	24.0
3	25.0
4	22.0

   a. **Construct** a bar graph of these results.
   b. **Propose** some possible reasons for the differences between measurements.

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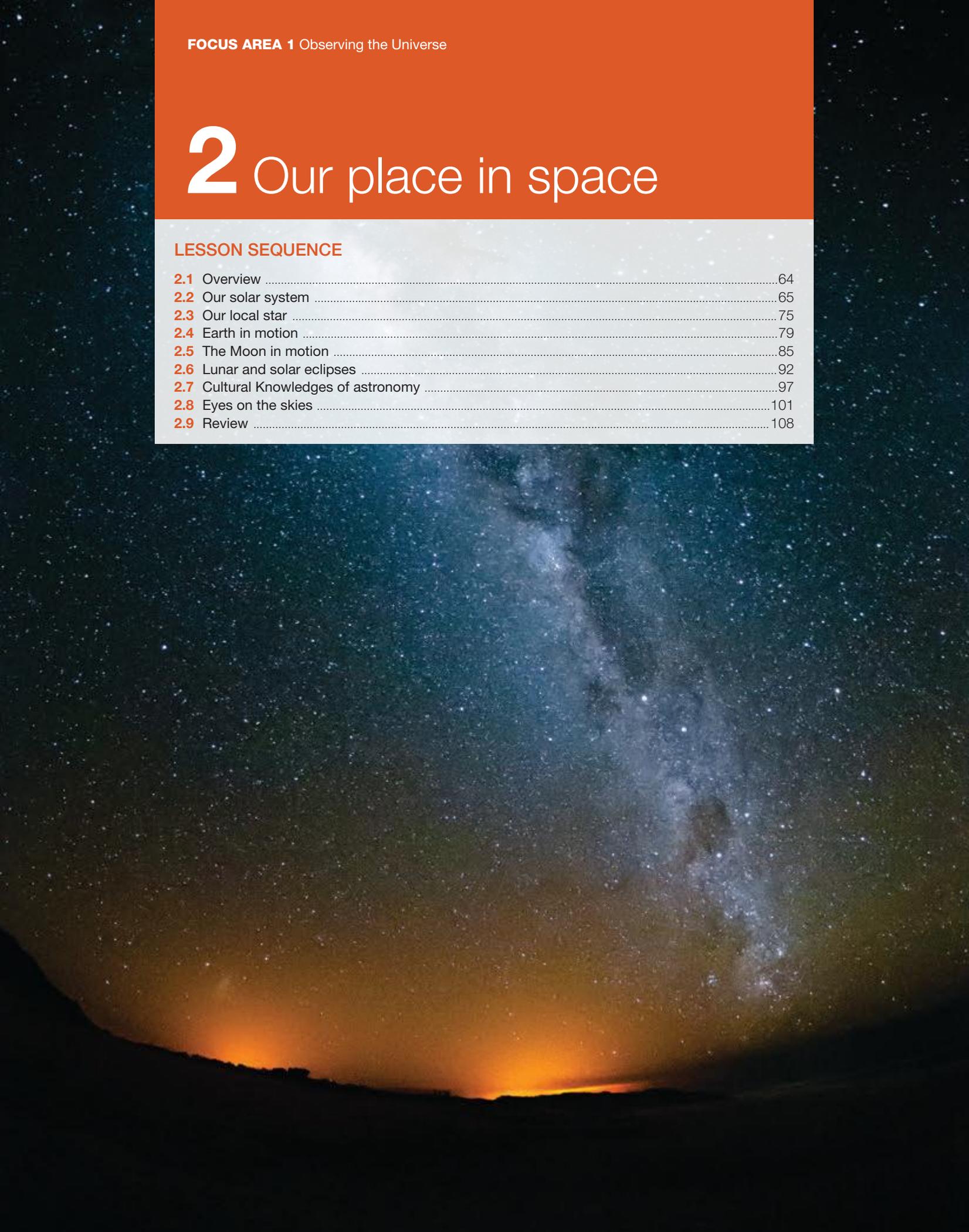Track your students' results

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2 Our place in space

LESSON 2.1 Overview

2.1.1 Why learn this?

When you look up at the night skies, what do you see?

If you live in a large city, chances are you aren't going to see a lot up there. You'll see the Moon of course, and probably Venus, which is the brightest of the planets we can see with the naked eye. You might even, if you live in the suburbs, see the stars making up the constellations of the Southern Cross and the brighter stars of Orion.

FIGURE 2.1 The night sky we see far away from civilisation is the same night sky seen by humans for tens — if not hundreds — of thousands of years. In trying to understand what we observe, we create models of our Universe that change as we improve our observational tools.

In the darkest skies of Earth, far from civilisation, we are seeing the same skies that have been watched for tens of thousands of years by Aboriginal and Torres Strait Islander Peoples, the ancient Greeks, the Babylonians, African tribesmen and Chinese scholars. Like today, they saw patterns to the way the Sun and the Moon moved, and in how the Moon's face changed over the course of weeks. They knew there was some sort of relationship between these changes and the swelling and falling ocean tides. They watched for certain stars to appear on the horizon signalling the coming of the cold seasons or the wet seasons.

They came up with explanations for what they observed that placed our world firmly in the centre of everything. It was only in the last few hundred years that we have come to realise just how big the Universe really is and how very small a part of it we are.

learn on

on **Pre-test**	Topic 2 Pre-test
eWorkbook	Topic 2 eWorkbook
	Student learning matrix
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 2.2 Our solar system

LEARNING INTENTION

In this lesson you will compare historical and current solar system models to show how models are modified or rejected due to new scientific evidence.

2.2.1 Modelling the solar system

From ancient times, humans used their observations of the day and night skies to infer how the Sun, Moon, stars and the five planets visible to the naked eye (Mercury, Venus, Mars, Jupiter and Saturn) moved relative to Earth.

The ancient Greeks provided many of the early ideas from which modern astronomy was developed. The early models of the Universe were mostly **geocentric** (where Earth was the centre of the system) or **heliocentric** (where the Sun was the centre of the system). The biggest problem for each model was explaining **retrograde motion**. Retrograde motion is where a planet appears to move eastward with respect to the stars over a period of many nights.

FIGURE 2.2 From July to September 2003, the planet Mars appeared to travel backwards relative to the stars in the background. This is an example of retrograde motion.
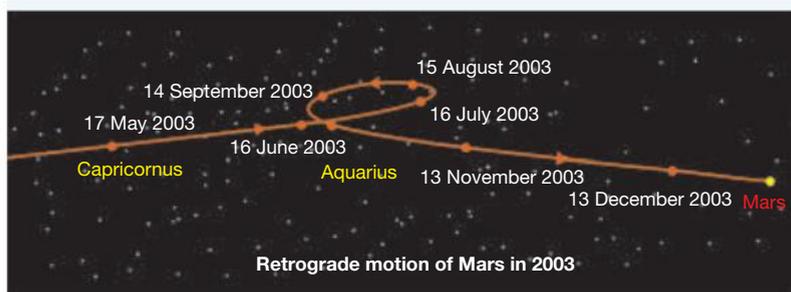
The models of the solar system that were developed over the centuries were modified or even thrown out altogether as advances in technology allowed increasingly more detailed observations to be made.

TABLE 2.1 Early ideas of astronomy

Aristotle
Fourth century BCE
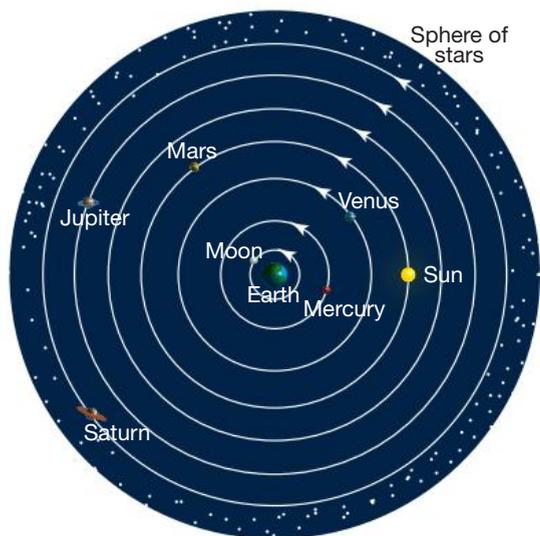
The model:
- Earth is the centre of the Universe.
- Earth is surrounded by a series of transparent crystal spheres — these carry the Sun, the Moon and planets in perfect circles around Earth.
- The outermost sphere is filled with stars.

Aristarchus of Samos
Third century BCE
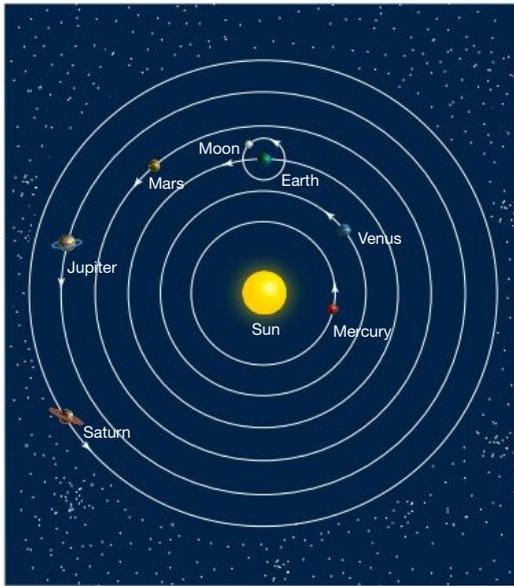
The model:
- The Sun is the centre of the Universe.
- The Moon moves in a circle around Earth.
- Earth and other planets move in circles around the Sun.
- Earth rotates on its axis over the course of a day.
- The stars are other suns, but they are very far away.

Claudius Ptolemy
85–165 CE
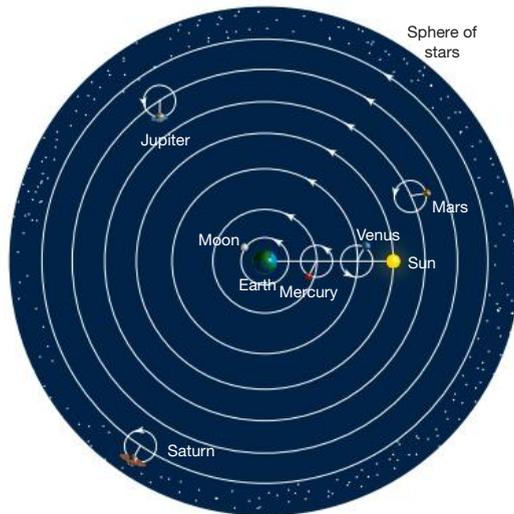
The model:
- Modified Aristotle's model
- Explained retrograde motion by theorising that the planets travelled in small circular orbits (epicycles), while also orbiting around Earth

(continued)

TABLE 2.1 Early ideas of astronomy *(continued)*

Nicolaus Copernicus
1473–1543
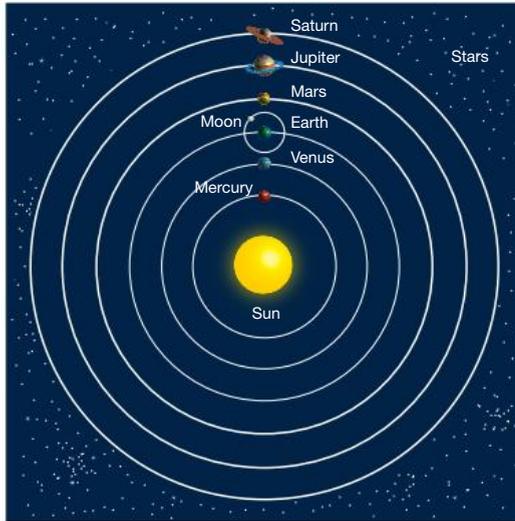
The model:

- Supported the model of Aristarchus
- Rejected Ptolemy's model because its predictions of planetary position in the sky were wildly inaccurate
- Theorised that the greater the radius of a planet's orbit, the longer it took for the planet to orbit around the Sun. This explained retrograde motion without needing Ptolemy's epicycles.

Johannes Kepler
1571–1630
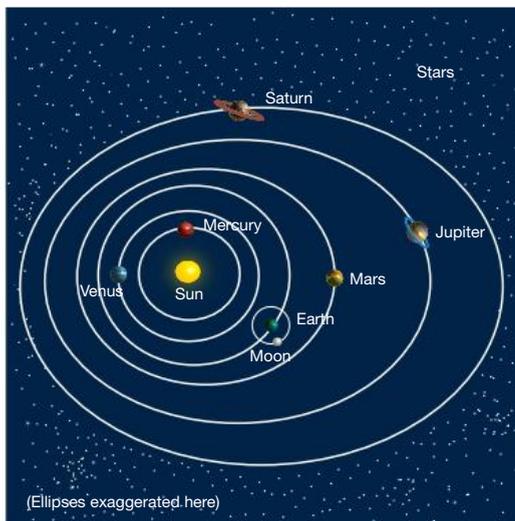
The model:

- Supported Copernicus's heliocentric model of the solar system but found it was no better at predicting planetary position than Ptolemy's model
- The orbits of the planets are ellipses (squished circles), not perfect circles.
- The planets do not travel at a constant speed in their orbit.

While Galileo did not propose his own model of the Universe, his observational, experimental and theoretical work provided the evidence that eventually led to rejection of the Aristotelian–Ptolemaic geocentric model of the Universe.

When Galileo heard about a new optical device, the telescope, in 1609, he quickly built his own version, used it, and later used more sophisticated telescopes to systematically study the night sky.

He observed the Moon and described the lunar surface as uneven, with craters and mountains. This was the first time anyone had publicly suggested that a celestial object was not perfect.

Galileo's observations of the planet Jupiter over successive nights revealed four star-like objects in a line with it. The objects moved from night to night, sometimes disappearing behind or in front of the planet. Galileo correctly inferred that these objects were moons of Jupiter and orbited it just as our Moon orbits Earth. Earth was clearly seen not to be at the centre of all planetary motion — further evidence for the heliocentric theory.

FIGURE 2.3 Galileo Galilei
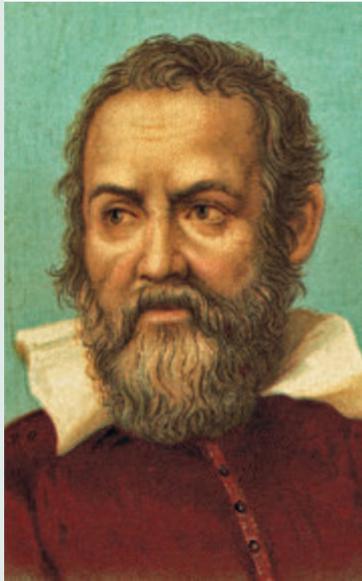
FIGURE 2.4 The moons of Jupiter as drawn by Galileo on successive nights.
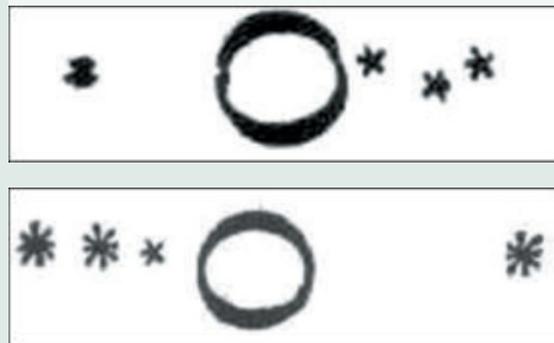
2.2.2 A collection of rocks and gas

The main components of our solar system are a central star (the Sun) and eight planets that travel around the Sun.

- The four inner planets — Mercury, Venus, Earth and Mars — are classified as **terrestrial planets** (terrestrial means 'like Earth'). They are small and solid.
- The four outer planets — Jupiter, Saturn, Uranus and Neptune — are classified as **gas giants**. These huge planets do not have a solid surface.

The order of the planets from the Sun is as follows: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

We can use a mnemonic device to help us remember this order, such as:

My Very Excellent Mum Just Served Us Noodles.

FIGURE 2.5 The planets of the solar system with their sizes drawn to scale (but not their distances from the Sun)
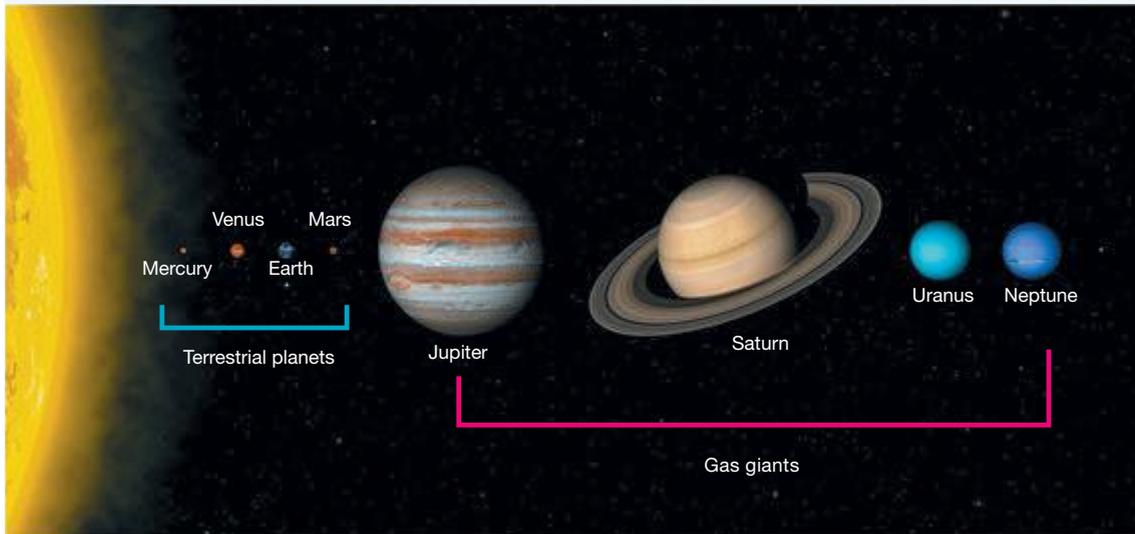
CASE STUDY: The problem with Pluto

From the time of its discovery in 1930, Pluto was considered the ninth and outermost planet of our solar system.

However, in the early 2000s, astronomers found several rocky objects similar in size to Pluto were also orbiting the Sun although at a much greater distance from it. The discovery of these objects — now named Eris, Sedna and Quaoar — created debate among scientists about whether they were to be regarded as planets or not.

In 2006, an international committee of astronomers agreed to a definition of a planet.

To be considered a planet, a celestial body must:
1. be in orbit around a star, while not itself being a star
2. be large enough in mass for its own gravity to cause it to be nearly spherical in shape
3. travel in an orbit that does not overlap with other objects, including planets.

Pluto has a highly elliptical orbit, and it sometimes crosses over the orbit of Neptune, so it failed this third condition.

FIGURE 2.6 Pluto was disqualified as being one of our solar system's major planets and instead reclassified as a dwarf planet.

As a result, Pluto was disqualified as being one of our solar system's major planets and instead reclassified as a **dwarf planet**. Eris, Sedna and Quaoar are also dwarf planets.

2.2.3 Orbiting the Sun

Each planet travels around the Sun in a path called an **orbit**. The orbits of the planets are nearly circular but are better described as **ellipses** (think of them as slightly squashed circles).

The time a planet takes to go once around the Sun is called its **orbital period**. The orbital period of Earth is 365.25 days – this is called an Earth year.

All the planets in our solar system spin, or rotate, as they orbit the Sun. The time taken for a planet to make one full rotation is called its **rotational period**. The rotational period of Earth is equal to 24 hours (or one 'Earth day').

Many of the planets have **moons** that are in orbit around them.

The planets in our solar system are kept in their orbits by the force of **gravity** exerted on them by the Sun. Similarly, the moons around each planet are kept in their orbits by the gravitational pull of their parent planet.

FIGURE 2.7 The solar system showing elliptical orbits
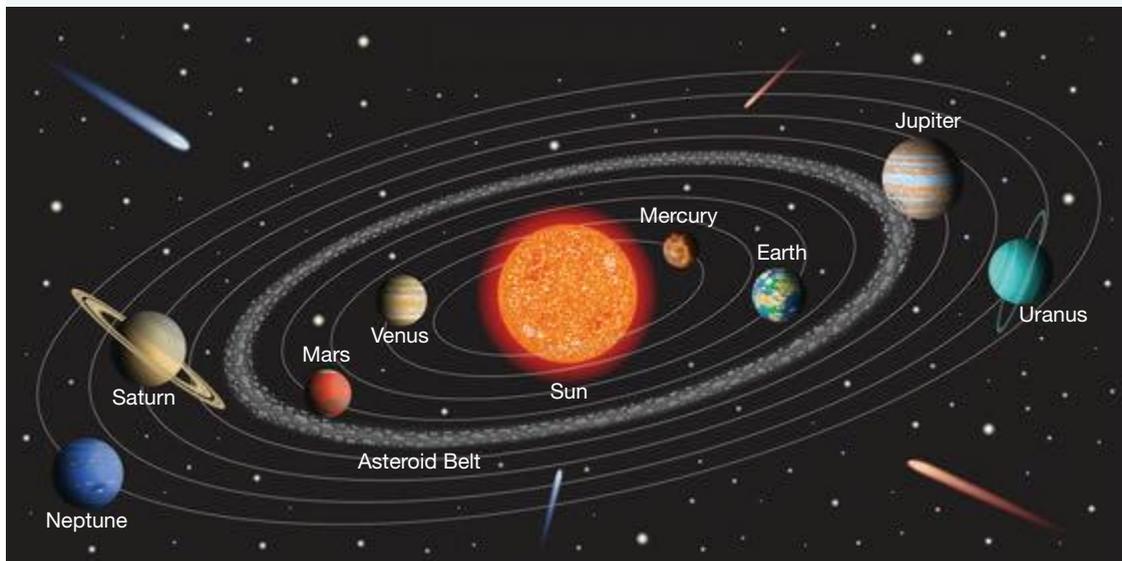
TABLE 2.2 Key features of the planets of the solar system

Planet	Period of orbit	Period of rotation	Gravitational force	Average surface temperature (°C)	Number of satellites
	(compared with Earth)				
Terrestrial planets					
Mercury	88 days	59 days	0.38	−180 to 420	0
Venus	225 days	243 days	0.91	450	0
Earth	1 year	1 day	1.00	22	1
Mars	687 days	24.5 hours	0.38	−120 to −30	2
Gas giants					
Jupiter	12 years	10 hours	2.9	−140	At least 95
Saturn	29 years	11 hours	1.3	−170	At least 146
Uranus	84 years	17 hours	0.93	−210	At least 28
Neptune	165 years	16 hours	1.2	−220	At least 16

ACTIVITY: The scale of the solar system

Materials

- cardboard
- marking pens
- trundle wheel

- basketball
- 2 golf balls (or table tennis balls)
- 2 marbles
- 2 peas
- 2 silver cachous (small shiny spheres used to decorate cakes)

Method

1. Make nine large cardboard labels for your class: one for the Sun and one for each planet.
2. Collect a basketball to represent the Sun, and each of the items listed in the table below to represent the planets, and move to a large outdoor area.
3. One student should be selected to hold the 'sun' and its label. Eight teams of students should also be selected to carry the 'planets' and their labels to the correct distances from the 'sun'. If you don't have a trundle wheel, assume that each pace is 1 metre long. (The model created here is not quite to scale for both planet size and distance from the Sun.)

Planet	Item representing planet	Distance from the 'Sun' (metres)
Mercury	Silver cachou	1.5
Venus	Pea	2.7
Earth	Pea	3.7
Mars	Silver cachou	5.7
Jupiter	Golf ball	20
Saturn	Golf ball	36
Uranus	Marble	72
Neptune	Marble	110

Discussion

1. Describe your model in words. Does it surprise you in any way?
2. Outline why this modelling exercise is useful in understanding the solar system.

CASE STUDY: The Moon

Before the invention of the telescope, humans thought that there was only one moon: ours. We have now observed moons around all the planets in our solar system except Venus and Mercury.

The largest moon in the solar system is Ganymede, one of the moons of Jupiter. It has a diameter of 5270 km, which makes it bigger than the planet Mercury! Our own moon, by comparison, has a diameter of 3475 km.

The smallest moon to be observed so far is Deimos, one of two known moons of Mars. This has a diameter of only 13 km!

FIGURE 2.8 Our Moon is not the largest in our solar system, but it isn't the smallest either.

What keeps the planets in the solar system?

Aim

To model the gravitational force of the Sun

Materials

- styrofoam ball
- one metre of thread
- sticky tape
- small metal nut or similar weight
- hollow plastic tube or empty biro case
- scissors

Method

1. Tape a piece of thread to a styrofoam ball or table tennis ball and pass it through a hollow plastic tube. Tie the other end to a large metal nut or similar weight. The ball represents a planet and the plastic tube represents the Sun.
2. Move to an area in the playground where you are several metres away from all other students. Hold the plastic tube in your hand and whirl the ball in a circle as shown in the diagram at right.
3. Cut the thread just below the plastic tube while the ball is being whirled and observe the motion of the ball.

Styrofoam ball (Earth)

Hollow plastic tube (Sun)

Thread

Metal nut
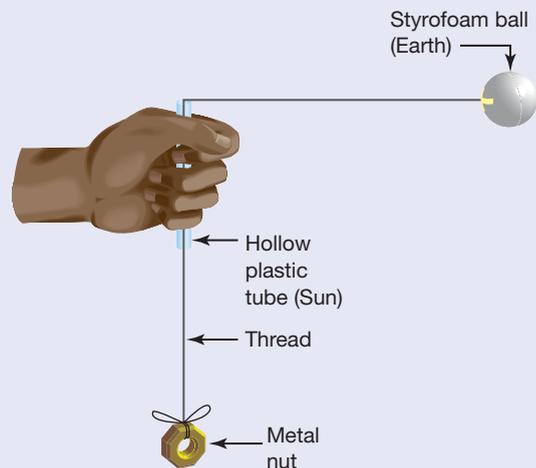
Results

Describe what happens to the motion of the ball when the thread is cut.

Discussion

1. What force prevents the ball in this activity from flying off into the distance while it is in orbit?
2. The planets are obviously not tied to the Sun with a string. What is the name of the force that keeps the planets from escaping from the Sun and the solar system?
3. What would happen to the planets if the Sun suddenly disappeared from the solar system?
4. Is the motion of the ball on the string a good representation of:
   a. the motion of the planets around the Sun
   b. the motion of the Moon around Earth?
   Explain why you think this.

Conclusion

Explain how the investigation is a model for the motion of the planets around the Sun.

ACTIVITY: PhET simulation — Gravity and orbits

Access the **PhET simulation: Gravity and orbits** interactivity in the Resources panel and use the simulation to move the Sun, Earth, Moon or a space station to see how it affects their gravitational forces and orbital paths.

2.2 Activities

2.2 Quick quiz **on**	2.2 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4, 7, 10	2, 5, 8	3, 6, 9

Remember and understand

1. Which two planets in the solar system do not have moons?
2. Is the following statement true or false?
   Uranus, Neptune and the dwarf planet Pluto were discovered much later than the other planets because they are the smallest planets.
3. **MC** In a model of the solar system, if a pea represents Earth, which object would best represent the Sun?
   A. A passionfruit pip
   B. A golf ball
   C. An apple
   D. A basketball
4. **MC** Which of the following astronomers developed models of the solar system that had the planets moving around the Sun? Select all options that apply.
   A. Aristarchus
   B. Aristotle
   C. Ptolemy
   D. Copernicus
   E. Kepler
5. Aristotle developed a model of the Universe. How does Aristotle's model differ from the current model of the solar system?

Apply and analyse

6. Is the following statement true or false?
   A geocentric model of the solar system would have made much more sense to early astronomers than a heliocentric one because the stars were visible in the night sky.
7. Why was Ptolemy's model of the solar system an improvement on previous models?
8. During the Renaissance, new theories about our solar system developed rapidly and previous ones were rejected. **Explain** why.

Evaluate and create

9. The table below shows the average surface temperature of several planets within our solar system.

Planet	Average distance from the Sun (compared to Earth)	Temperature (°C)
Venus	0.72	450
Earth	1	22
Jupiter	5.19	−140
Saturn	9.43	−170
Uranus	19.11	−210
Neptune	29.9	−220

   a. Plot a line graph of the distance of each planet from the Sun against their surface temperature.
   b. Refer to your graph to **explain** if there is a relationship between a planet's distance from the Sun and its average surface temperature.
10. Write a mnemonic of your own to remember the eight planets in order from the Sun.

LESSON 2.3 Our local star

LEARNING INTENTION

In this lesson you will identify the main features of our Sun and explain the occurrence of sunspots and why solar radiation can be helpful or harmful.

2.3.1 The Sun

We now know that the Sun is a star like the billions of others that make up our galaxy, the Milky Way. The heat and light that it produces are vital to life on Earth.

CASE STUDY: The Sun

The Sun has a diameter of 1.4 million km (about 109 times the diameter of the Earth) and it contains 99.8 per cent of the mass of our solar system.

Like all the planets, the Sun rotates around its own axis. It therefore has two poles and an equator. Because it is not solid, different parts of the Sun rotate at different speeds. At its equator, the Sun rotates once every 25 days. At the poles, it takes 34 days for a full rotation.

Light from the surface of the Sun takes eight minutes to reach Earth.

The Sun itself orbits a **black hole** at the centre of the Milky Way galaxy.

FIGURE 2.9 The Sun has a complex internal structure. The fusion of hydrogen atoms in the core produces helium atoms and generates light and heat that travel through several layers of the Sun before escaping from the surface.

Core: here the sun generates light and heat through a **nuclear fusion reaction.** This reaction requires immense heat and the core is believed to be about 15 million degrees. In this reaction, hydrogen atoms are fused together, producing helium atoms and a great deal of energy.

Radiative zone: light and heat radiating out from the core.

Corona: white-hot halo above the surface, most visible during solar eclipses
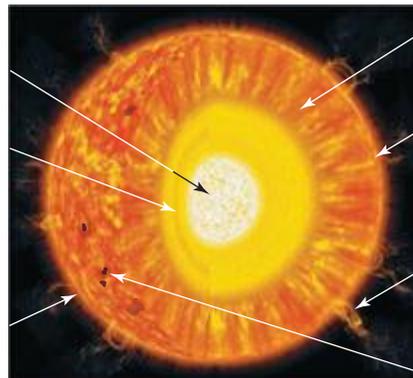
Convective zone: heat travelling in circular convection currents

Photosphere: visible surface of sun

Prominence: an eruption of glowing gas from the surface

Sunspots: darker, cooler areas on the surface of the sun. They can be very large - up to 50 000 kilometres in diameter. Sunspots typically last anywhere from a few days to a few months.

2.3.2 Sunspots

Sunspots appear dark against the surface layer of the Sun (**photosphere**) because they are sections of gas that are roughly 3000 degrees cooler than the surrounding region.

Sunspots occur over regions of intense magnetic activity. They can be very large (up to 50 000 km in diameter) and can last from a few days to a few months

INVESTIGATION 2.2

Observing sunspots

Aim

To observe sunspots

Materials

- cardboard
- tripod-mounted telescope

CAUTION: The Sun should never be observed directly, either with the naked eye or through a telescope or binoculars. Damage to the eyes can result from direct observation.

Method

1. Cut out a masking screen to fit over the front of the tube of the telescope.
2. Position the tripod and telescope so that it is directed towards the Sun, but **do not** look through the telescope to align it; rather, use the shadow cast on the ground as an indication of the correct position.
3. Hold or position a sheet of cardboard 0.5-1.0 metre behind the eyepiece of the telescope to capture the image of the Sun and to view any sunspots. You may need to adjust the eyepiece focus knob and the cardboard screen to obtain a sharp image. You may find it helpful to take photos of the image for use in reporting your results.
4. Repeat your observations again after three days and after seven days.
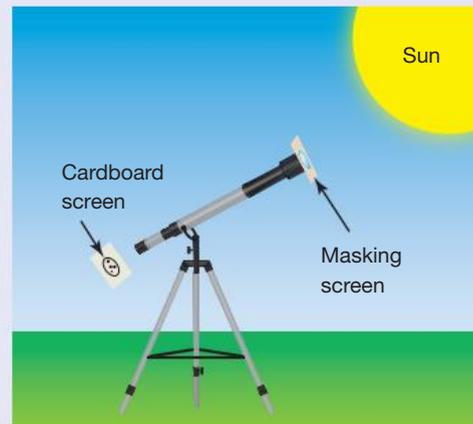
Results

Write your observations of the sunspots for the three days in the form of a table. Include the number of sunspots observed each day; you may also add photos or illustrations.

Discussion

1. Did you observe the same number of sunspots each day?
2. Were the sunspots in the same positions on the Sun each day? If not, infer why.
3. Are all the sunspots similar in size and colour? What does this tell you about the temperature of the sunspots?

Conclusion

Write a brief statement describing the effectiveness of this method for observing sunspots.

DATA SCIENCE 1: Data science in context

Sunspot activity

Objective

The number of sunspots observed on the Sun varies from year to year. In this activity, you will plot data and determine whether there is a pattern that could describe the number of sunspots over time.

Task

The following data were collected on the average number of sunspots recorded each year from 1970 to 2024.

Year	Average number of sunspots	Year	Average number of sunspots
1970	109	1998	65
1971	74	1999	94
1972	72	2000	120
1973	39	2001	111
1974	34	2002	104
1975	15	2003	64
1976	14	2004	41
1977	30	2005	30
1978	103	2006	15
1979	156	2007	8
1980	141	2008	3
1981	141	2009	3
1982	116	2010	16
1983	72	2011	81
1984	44	2012	84
1985	17	2013	94
1986	12	2014	114
1987	28	2015	70
1988	89	2016	40
1989	148	2017	22
1990	149	2018	4
1991	146	2019	6
1992	96	2020	10
1993	54	2021	36
1994	36	2022	83
1995	19	2023	125
1996	9	2024	154
1997	22		

- Plot the number of sunspots (vertical axis) against years (horizontal axis) on a sheet of graph paper.
- Join the data points with a ruler.

Discussion

1. Is there a pattern in the data?
2. Approximately how long is there between periods of high sunspot activity and periods of low sunspot activity?
3. Predict whether there will be many or few sunspots:
   a. this year
   b. the year you turn 18.

2.3.3 Solar radiation

The Sun provides the planets with heat, light and other forms of energy. The energy released from the Sun is called *solar radiation.* Solar radiation reaches all of the planets.

All the different types of energy coming from the Sun form the **electromagnetic spectrum**. This includes visible light, infra-red radiation, ultraviolet radiation, and even x-rays and gamma rays.

Life exists on Earth because the atmosphere allows the right amounts of each type of solar radiation to reach the surface. Most of the harmful radiation is absorbed by the **ozone layer**, a layer of the atmosphere sitting between 15 and 30 km above the Earth's surface.

FIGURE 2.10 Earth's atmosphere filters some of the electromagnetic radiation from the Sun.

Radiation from sun

Cosmic rays | Gamma rays | X-rays | UVC rays | UVB rays | UVA rays | Visible light | Infra-red | Microwaves

Ozone layer

Clouds

Dust, pollution

Earth's atmosphere

0.1% 4.9% 39% 56%

Proportion reaching Earth's surface

Ultraviolet radiation is needed by humans to help the body make vitamin D, essential for strong bone development.

Visible light is needed by plants so that they can grow and make their own food using a process called **photosynthesis.** Animals rely on plants as a source of food. Even animals that do not eat plants eat other animals that do eat plants.

Infra-red radiation provides Earth with heat. This heat keeps the atmosphere, Earth's surface and its water warm enough to support life.

DISCUSSION

In Australia, we are very aware of the damage that the Sun can cause to our skin.

Can you still get sunburnt on cloudy days? Is it possible to get sunburnt at night? Why do we seem to get sunburnt more often in the summer than in the winter?

CASE STUDY: UV radiation

While we need the ultraviolet radiation emitted from the Sun for making vitamin D, it is also the cause of sunburn and can lead to skin cancer.

UV radiation is not related to temperature, so you can still get sunburned on cool, cloudy days. The Bureau of Meteorology provides a daily forecast of the Sun's UV radiation intensity. This is called the UV index. It divides UV radiation levels into low (1–2), moderate (3–5), high (6–7), very high (8–10) and extreme (11 and above). In Australia, UV radiation levels are most intense from the beginning of September to the end of April, particularly between 11 am and 3 pm. When UV levels are 3 and above, sun protection is needed because the UV radiation is intense enough to damage the skin.

FIGURE 2.11 The daily forecast of the Sun's UV intensity allows us to predict the time of day when the sun's rays will be most damaging to our skin.

UV Alert: 8.20 am to 5.10 pm
MAX UV Index: 15

Extreme
Very high
High
Mod
Low

UV Index: 20, 15, 11, 8, 6, 3, 20

6 am   8 am 10 am 12 pm   2 pm   4 pm 6 pm 8 pm

2.3 Activities
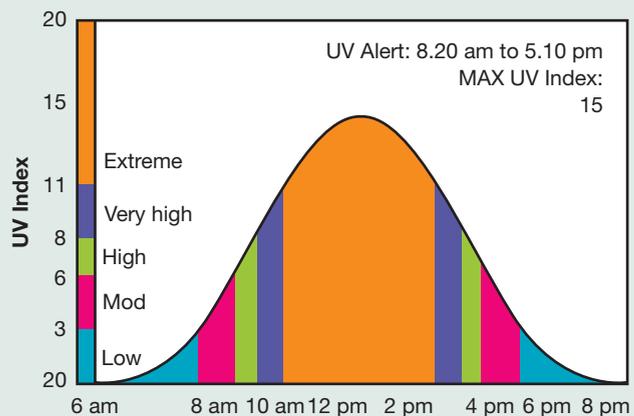
2.3 Quick quiz	on	2.3 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 5	3, 4, 6	7, 8

Remember and understand

1. Match the feature of the Sun with its correct description.

a. Core	**1.** Where fusion reactions occur
b. Photosphere	**2.** The visible surface of the Sun
c. Corona	**3.** Darker, cooler region on the Sun's surface
d. Sunspot	**4.** An eruption of glowing gas
e. Prominence	**5.** White hot halo of gas above the Sun's surface

2. Is the following statement true or false?
   All of the Sun's layers rotate at the same speed.
3. **Identify** four types of radiation emitted by the Sun that are filtered out by Earth's atmosphere.
4. Complete the following passage.
   The Sun generates light and heat through a nuclear _____ reaction in which _____ atoms are _____ producing _____ atoms and a great deal of energy. This fusion reaction requires the immense heat of the Sun's core, where the temperature is believed to be about _____. The energy produced in fusion travels out from the core through several layers of the Sun before it escapes into space as sunlight.

Apply and analyse

5. **Explain** why life on Earth would not be possible without the Sun.
6. **Explain** why you would need protection from the sunlight on Mars, even though it is very cold.
7. Objects that are heated will start to glow when their temperature gets over 525 degrees Celsius. **Explain** why sunspots appear black when they have temperatures above 3000 degrees Celsius.

Evaluate and create

8. Investigate why telecommunication problems occur when there are large numbers of sunspots. Create a diagram **explaining** your findings.

LESSON 2.4 Earth in motion

LEARNING INTENTION

In this lesson you will explain how seasons and the lengths of night and day are caused by the movement of Earth around the Sun and its rotation on its axis.

Have you ever wondered why it gets dark or why the Sun rises in Sydney before it does in Perth? Why is Australia in the middle of a hot summer in January while Europe experiences a cold winter? These things can all be explained by the movement of Earth through space.

2.4.1 Day and night

Earth rotates from west to east. Therefore, the Sun during the day and the Moon, planets and stars during the night seem to move in the other direction, from east
to west. On the east coast of Australia, the Sun rises over the Pacific Ocean.

❖ A tilted axis

As Earth moves in its orbit around the Sun, the relative lengths of day and night change.

In Australia, we have more hours of night than we do hours of daylight in the month of June. In December, we have more hours of daylight than darkness.

This is because Earth's axis is tilted at an angle of 23.5 degrees to its orbit.

FIGURE 2.12 Star trails. Stars appear to move in the night sky, but it is Earth that is rotating, as shown in this time-lapse photo.

FIGURE 2.13 Earth rotates from west to east. Continents facing the Sun are in daylight.
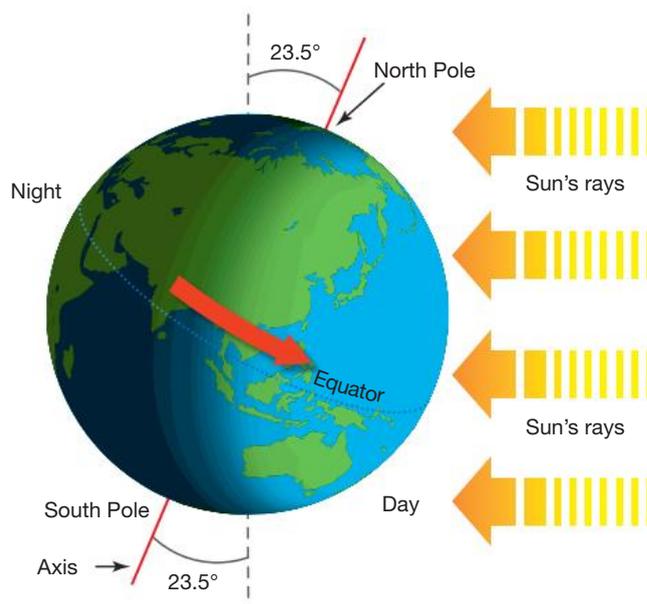
INVESTIGATION 2.3

Day and night across Earth

Aim

To model the day/night cycle

Materials

- polystyrene (or similar) sphere (about the size of a small rockmelon)
- metal or wooden skewer
- pen
- spotlight or bright torch

Method

1. Your sphere represents Earth. Draw a line around the centre to represent the equator. Label the Northern and Southern Hemispheres and mark in the North and South Poles.
2. Draw an outline of Australia and Africa on your sphere. Use an atlas to check the positions and approximate shape of each continent. Also, note the position of north.
3. Mark the four compass directions — north, south, east and west — around the outlines of each continent.
4. Gently push a skewer through the centre of your sphere from bottom to top through the 'polar regions'. This skewer represents Earth's imaginary axis.
   Note: Do this experiment in a darkened room. This will help you see more clearly the contrast between light and dark.
5. Turn on the spotlight in a dark room. Its light represents the Sun's light. Hold the skewer so it leans a little away from the vertical. This represents Earth's tilt.
6. Turn your sphere very slowly in the light, making sure you keep the skewer slightly tilted all the time. Turn it in an anticlockwise direction (as seen from above). Watch what happens from side on.
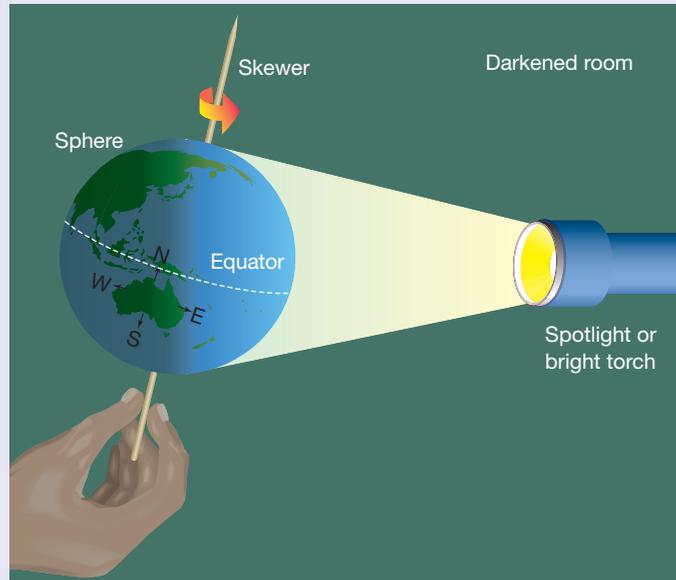
Skewer

Darkened room

Sphere

N

W

Equator

E

S

Spotlight or bright torch

Results

Record the observations you have made during this investigation.

Discussion

1. In which direction is the 'Earth' rotating — from east to west or west to east? Check the compass directions you marked on your sphere.
2. In which direction does the light of the 'Sun' seem to move around the 'Earth'? How does this explain the apparent movement of the Sun across the sky?
3. Where is Africa when Australia is lit up? Where is Australia when Africa is lit up? Explain why these continents experience daylight at different times.
4. How does this experiment help to explain why night falls in Perth about two hours later than in Sydney?

Conclusion

Write a statement describing how effective this model of the day/night cycle is.

CASE STUDY: Shape of Earth

Earth is spherical, but it is not a perfect sphere. The diameter of Earth measured across the equator is 12 760 km. However, if you measure the diameter between the two poles, the diameter is shorter by 40 km because Earth has a slight bulge at the equator.

The regions north of the Arctic Circle and south of the Antarctic Circle experience the greatest changes in the length of their days and nights over the course of the year. In Svalbard, Norway, the Sun sets in mid-November and does not come back over the horizon again until the end of January — this means that it has a night that is 2 months long! This swings the other way from the end of April to late August when the Sun never goes below the horizon, so it gets a 3-month long day. This is why the north of Norway is called the Land of the Midnight Sun.

INVESTIGATION 2.4

Day length in summer and winter

Aim

To explain why the number of daylight hours varies

Materials

- the equipment used for Investigation 2.3
- 2 pins with coloured heads

Method

Note: Do this experiment in a darkened room; this will help you see more clearly the contrast between light and dark.

1. Hold the skewer vertically. Push two pins into your sphere — one about where Sydney is and the other directly above it at the top of the sphere, near the skewer.
2. Set the torch up in a central place (such as on a table you can move around).
3. Stand to the left of the torch. Turn on the torch. Hold the skewer so it leans away to the left from the vertical. The southern half of your sphere should be leaning more toward the light.
4. Slowly turn your sphere in the light, making sure you keep the skewer slightly tilted. Turn it in an anticlockwise direction. observe how long the two locations marked with pins remain in the light.
5. Now stand to the right of the torch holding your skewer tilted to the left as before. This time the northern half of your sphere should be leaning more towards the light. Repeat what you did in the previous step.
6. Repeat the whole procedure above two more times. The first time, look at what happens at each of the poles. The second time, look at what happens at the equator.
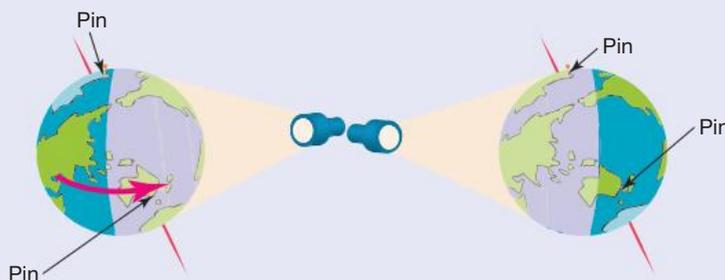
Results

Write your observations of how the daylight exposure at the two pins changes according to which direction the skewer is tilted. Also record your observations of what happens at the poles and the equator in each case.

Discussion

1. Which pin comes into the light first when the southern half of the sphere leans towards the light? Ask your partner which pin moves out of the light first.
2. What does this tell you about the number of daylight hours in each hemisphere when the southern hemisphere tilts towards the Sun?
3. Which pin comes into the light first when the northern half of the sphere leans towards the light? Ask your partner which pin moves out of the light first.

4. What does this tell you about the number of daylight hours in each hemisphere when the northern hemisphere tilts towards the Sun?
5. What is the approximate length of day and night at the equator in each season?
6. Suggest why the Sun never sets at certain times of year at the North and South Poles. Which season is the southern hemisphere experiencing when the South Pole has several months of darkness?

Conclusion

Based on what you have learned in this investigation, explain why the number of daylight hours varies with location.

2.4.2 Explaining the seasons

KEY IDEAS

- The time Earth takes to complete one orbit of the Sun is called a **calendar year**.
- There are 365.25 days in one year.
- To make the calendar simpler, each year is allocated 365 days, and every fourth year is called a **leap year**, with an extra day added (29 February), giving a leap year 366 days in total.

While Earth travels around the Sun, the tilt of the axis does not change. This means that, during part of the orbit, one hemisphere is tilted towards the Sun while the other hemisphere points away.

FIGURE 2.14 Winter and summer in the southern hemisphere

Southern hemisphere tilted away from the sun

Southern hemisphere tilted toward the sun

Fewer hours of daylight / less direct sunlight = Less heat

More hours of sunlight / more direct sunlight = More heat

Winter in southern hemisphere

Summer in southern hemisphere
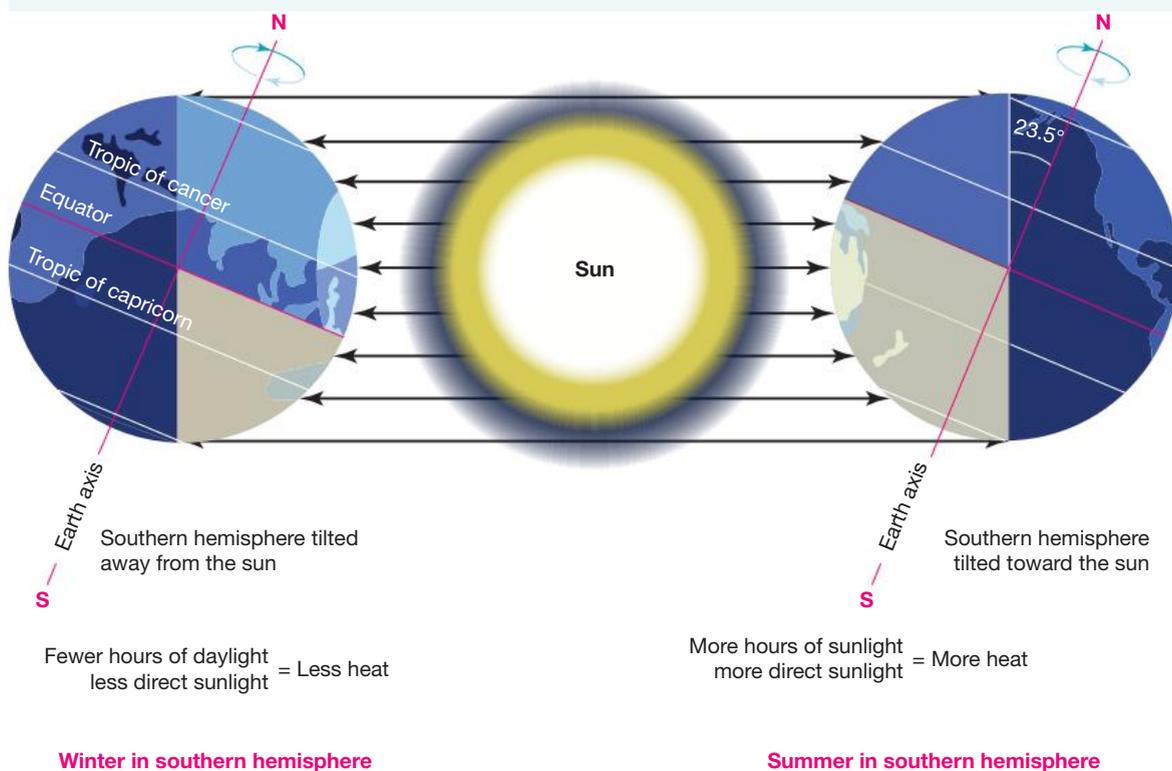
FIGURE 2.15 Because of the tilt of Earth, seasons change as Earth completes an orbit of the Sun.
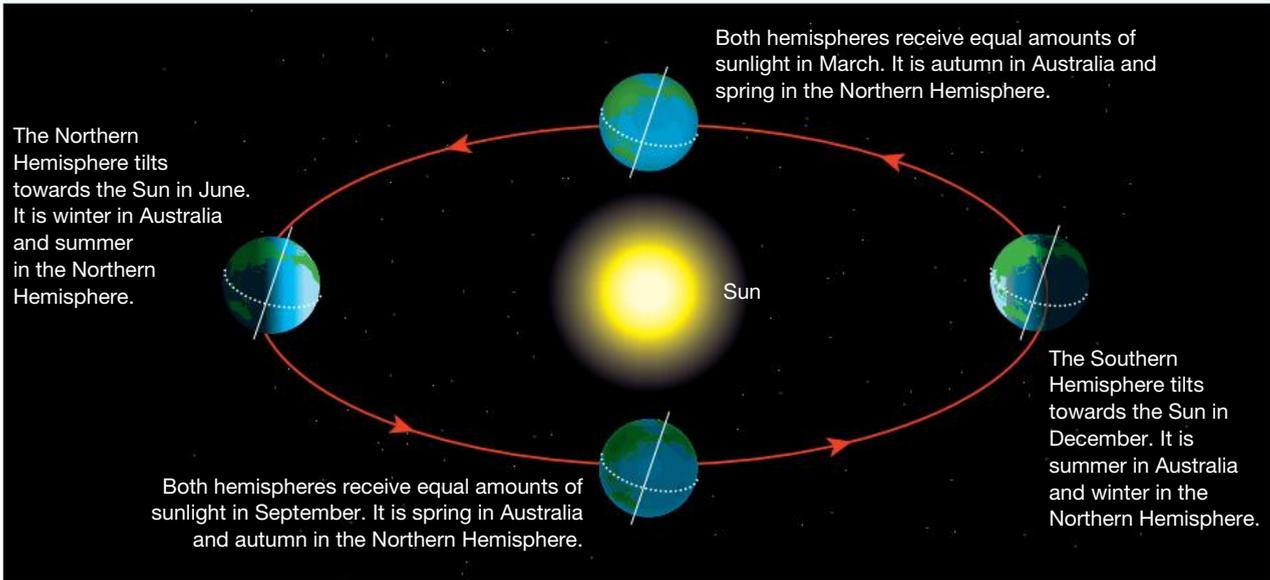
2.4 Activities

2.4 Quick quiz **on**   **2.4 Exercise**

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 4	3, 5, 6	7, 8

Remember and understand

1. Complete the following sentence.
   The position on Earth's surface that experiences the smallest variation in the number of daylight hours over the course of the year is _____
2. Complete the following sentence.
   The Sun never sets _____
3. Is the following statement true or false?
   We experience the seasons on Earth because Earth's orbit around the Sun is elliptical and in summer Earth is closer to the Sun.

Apply and analyse

4. **MC** If the axis of Earth was not tilted, then:
   A. we would not have seasons.
   B. we would have equal periods of day and night all year.
   C. we would not have leap years.
   D. it would take less time for Earth to complete its orbit.
5. **Explain** why there are 29 days in February every fourth year, but only 28 the other years.
6. **MC** What fraction of Earth's surface is lit by the Sun at any moment?
   A. 1/2
   B. 3/4
   C. It depends on the season.
   D. It depends on our position in Earth's orbit.

LESSON 2.5 The Moon in motion

2.5.1 Studying the Moon

The Moon is, by far, the brightest object in the night sky. Its presence and changing appearance when viewed from Earth have raised many questions, inspired myths and legends, shaped our calendar and even determined the dates of some religious holidays.

FIGURE 2.16 The Moon has several distinctive characteristics first observed through telescope by Galileo in the early seventeenth century.

Unlike the Earth, the moon has no **atmosphere.** There is no air and there is no flowing water on the surface. It does not experience wind or rain, This means that there is no erosion of its cratered surface.

Profile of the moon

- Natural satellite of the Earth
- Distance from Earth: 385 000 km (three days by spacecraft)
- Diameter at equator: 3475 km (Earth's diameter is 12 750 km)
- Period of orbit around Earth: about 29.5 days
- Period of rotation around its own axis: about 29.5 days
- Surface gravity: about one-sixth that of Earth
- Surface temperature: ranges from −175 ºC in darkness to 125 ºC in sunlight

These large dark, flat areas are known as "seas" even though they do not hold water. They are the result of ancient lava flows. These regions cover about 16% of the moon's surface

The lighter regions of the moon are called the "highlands". Some of the mountains in these regions reach heights of 6 km.

The moon's surface is covered in **craters** of different sizes. Astronomers believe these are the results of meteorites striking the surface.

Observing the Moon's surface

Aim

To observe the Moon using binoculars or a small telescope

Materials

- binoculars or small telescope

Method

1. Observe the Moon with a pair of binoculars or a small telescope. The best time to observe the Moon is during a quarter Moon (when about half of it is visible). Craters and mountains are difficult to see when there is a full Moon because they do not cast shadows.
2. Try to identify the seas (dark, smooth areas), mountainous areas and craters.

Results

Draw a labelled sketch of what you see.

Discussion

1. Which features were easiest to locate?
2. How do you think the craters were formed?

Conclusion

Describe how much more detailed your observations were using the telescope/binoculars than simply using the naked eye.

CASE STUDY: 'Months' from 'Moon'

The word 'month' comes from the Old English word *mona,* meaning 'moon'. In early calendars, a month was the length of time between full 'moons'. This period is called a lunar month. The modern calendar was not developed until the sixteenth century by Pope Gregory XIII. The Islamic, Hebrew and Chinese calendars are still based on the lunar month.

2.5.2 Phases of the Moon

The Moon is visible from Earth only because it reflects light from the Sun.

As the Moon orbits Earth, it rotates so that the same side of the Moon always faces Earth (it is tidally locked).

- Once in each lunar cycle, when viewed at night, the entire side of the Moon facing Earth is completely dark; this is called a **new Moon**.
- As the Moon continues its orbit of the Earth, more of the lit face of the Moon is visible from Earth. When roughly half of the face is lit, we see a **quarter Moon** and then a **gibbous Moon**.
- When the side facing Earth is completely bathed in sunlight, we see a **full Moon**.
- When the Moon moves on in its orbit, less of the lit face starts to become visible. Eventually, the near side is completely dark again and there is another new Moon, and so the sequence continues.
- During the period between a new Moon and a full Moon, the Moon is said to be **waxing**.
- As the phases move from full Moon to new Moon, it is said to be **waning**.

FIGURE 2.17 The diagram below shows how the phases change during the 29 ½-day lunar cycle, the period between one new Moon and the next.
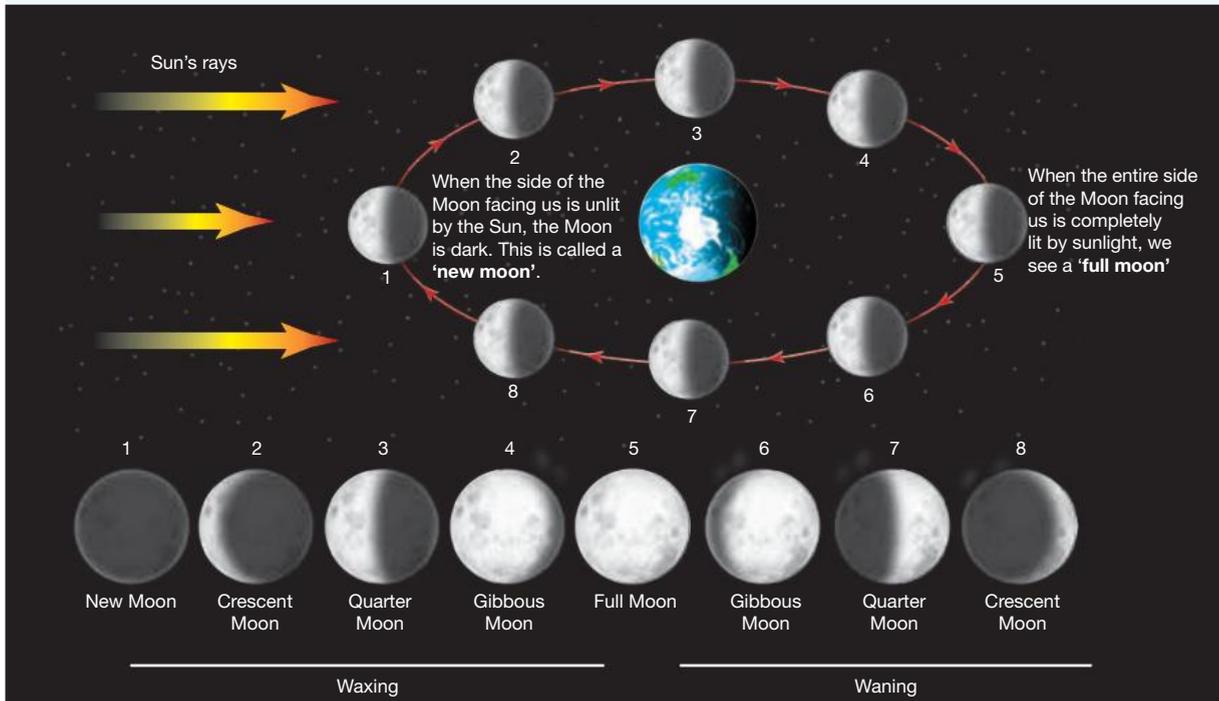
INVESTIGATION 2.6

Modelling the phases of the Moon

Aim

To model the phases of the Moon

Materials

- projector or bright torch
- large, light-coloured ball

Method

1. Select one student to act as Earth and another to hold the ball representing the Moon.
2. Darken the room and aim the projector or torch (the Sun) at the ball (the Moon). The student holding the 'Moon' walks around 'Earth' slowly in an anticlockwise direction, holding the same side towards 'Earth'.
3. Try to identify each of the eight phases of the Moon, as they are seen by the person representing Earth. Stop rotating briefly when each of the phases is identified so that the positions of the 'Sun', 'Earth' and 'Moon' can be recorded in a diagram.

Results

1. Sketch a plan view to show the positions of the 'Sun', 'Earth' and 'Moon' that result in:
   a. a full Moon
   b. a gibbous Moon
   c. a quarter Moon
   d. a crescent Moon
   e. a new Moon.

2.5.3 Ocean tides

Each day, the waters of Earth's oceans rise and fall against the coastlines of islands and continents. These changes in sea level are called **tides**.

Tides are caused mainly by the **gravitational pull** of the Moon on Earth's oceans.

Due to the Earth's rotation under the tidal bulges, two high tides and two low tides occur each day.

The period between high tide and low tide when the sea level falls is called the **ebb** tide.

The **flow** tide occurs when the sea levels rise between low tide and high tide.

FIGURE 2.18 Looking down on Earth from above the North Pole. As Earth rotates, different places experience high tide.

Low tide
The water that makes up the high tides is drawn from oceans in between.

High tide
As the Moon orbits the Earth, its gravity most affects the side of the Earth facing it – the closest side. The ocean bulges out on that side the most.

Moon

Earth

High tide
The Moon's gravity also attracts the Earth itself. This causes the Earth to pull away from the water surface on this side. As a result, these oceans also bulge out, though not quite as much as the side facing the Moon.

CASE STUDY: High and low tide in the Bay of Fundy

The **tidal range** in the Bay of Fundy, on the east coast of Canada — over 16 m — is the biggest in the world. The bay has a very wide mouth that allows a lot of water to rush in as the tide rises. But the bay gets much narrower further inland. The huge volume of water has nowhere to go but up!

FIGURE 2.19 Low tide at Bay of Fundy

FIGURE 2.20 High tide at Bay of Fundy

DATA SCIENCE 1: Data science in context

Tide data

Objective

To plot data on tide height and determine the tidal pattern

Task

The following data show the tide heights in Manly, NSW, at two-hourly intervals.

Date	Time	Tide height (m)	Date	Time	Tide height (m)
Wed. 28 Nov.	5 am	1	Thu. 29 Nov.	5 am	0.4
	7 am	1.5		7 am	0.9
	9 am	1.7		9 am	1.2
	11 am	1.3		11 am	1.2
	1 pm	0.7		1 pm	0.7
	3 pm	0.5		3 pm	0.4
	5 pm	0.8		5 pm	0.4
	7 pm	1.3		7 pm	1.1
	9 pm	1.7		9 pm	1.3
	11 pm	1.5		11 pm	1.2
Thu. 29 Nov.	1 am	0.8	Fri. 30 Nov.	1 am	0.8
	3 am	0.4		3 am	0.5

- Plot the data on a sheet of graph paper, showing the tide heights on the vertical axis and the date and time on the horizontal axis.
- Draw a smooth line of best fit based on your data.

2.5.4 Spring and neap tides

The Sun also exerts a gravitational pull on Earth's oceans, but its effect is much smaller than the Moon's. This is because the Sun is so much further away from Earth than the Moon.

During the **full Moon** and **new Moon** phases, the Sun, Moon and Earth line up. At these times, the gravitational pulls of the Moon and the Sun combine to make the ocean bulges larger. This results in high tides that are higher than usual and low tides that are lower than usual. These are called **spring tides**.

During the **first quarter** and **third quarter** phases of the Moon, the Moon and Sun are at right angles relative to Earth. Their gravitational pulls on the oceans work against each other so we see lower high tides and higher low tides. These are called **neap tides**.

FIGURE 2.21 Each month there are two spring tides and two neap tides during a full Moon and a new Moon.

2.5 Activities
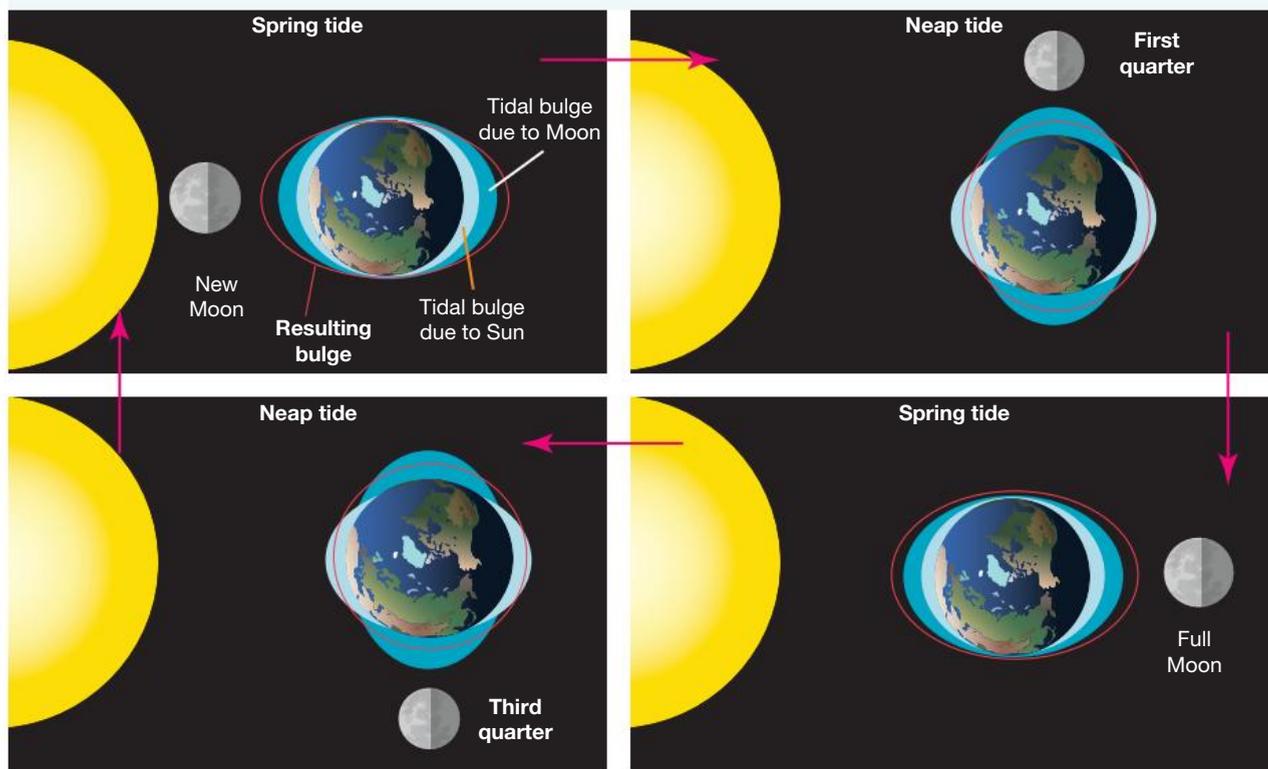
2.5 Quick quiz **on**	2.5 Exercise

Learning pathways

■ **LEVEL 1** 1, 2, 3	■ **LEVEL 2** 4, 5, 7, 9	■ **LEVEL 3** 6, 8, 10

Remember and understand

1. **Identify** the phases of the Moon during each of the numbered stages.
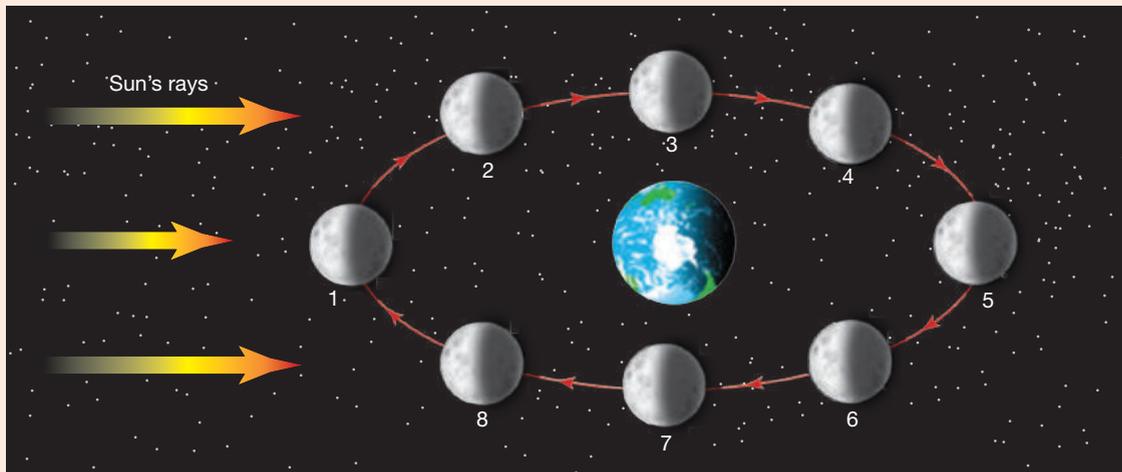
2. **MC** High tides occur approximately every:
   A. 6 hours.
   B. 8 hours.
   C. 12 hours and 25 minutes.
   D. 24 hours.
3. The tidal range is the difference in height between the high tide and the low tide at a particular location. If the height of the highest tide on a particular day was 6.5 metres and the tidal range was 4.2 metres, what is the height of the lowest tide?
4. **MC** The phase of the Moon that we see when Earth is between the Sun and the Moon is called a:
   A. full Moon.
   B. new Moon.
   C. quarter Moon.
   D. crescent Moon.
5. **Explain** why the Moon has a stronger gravitational pull on Earth than the Sun.
6. **Identify** whether a spring tide or a neap tide will be occurring in location relative to the Moon.

Apply and analyse

7. **Explain** why there are more craters on the Moon than on Earth, even though Earth is a bigger target.
8. **Explain** why we never see the far side of the Moon.

Evaluate and create

9. **Deduce** why one high tide on any given day is always greater than the other.
10. **Create** a diagram showing the surface of the Moon, displaying the sites of all of the missions that have landed there. Use different symbols for manned and unmanned missions.

LESSON 2.6 Lunar and solar eclipses

LEARNING INTENTION

In this lesson you will explain how solar and lunar eclipses result from the relative positions of the Sun, Moon and Earth, and use physical and virtual simulations to model eclipses.

Eclipses are the result of different alignments of the Moon, Earth and the Sun, where one object forms shadows on another.

2.6.1 Lunar eclipses

Lunar eclipses occur when Earth is between the Sun and the Moon, causing Earth's shadow to pass over the surface of the Moon. They only occur when there is a full Moon.

The darkest part of Earth's shadow on the Moon is called the **umbra**. The region where only some of the Sun's light is blocked by Earth is called the **penumbra**.

During a **total lunar eclipse**, the Moon and Earth are lined up so that the whole of the Moon's face is in the umbra for a while.

FIGURE 2.22 Total lunar eclipse
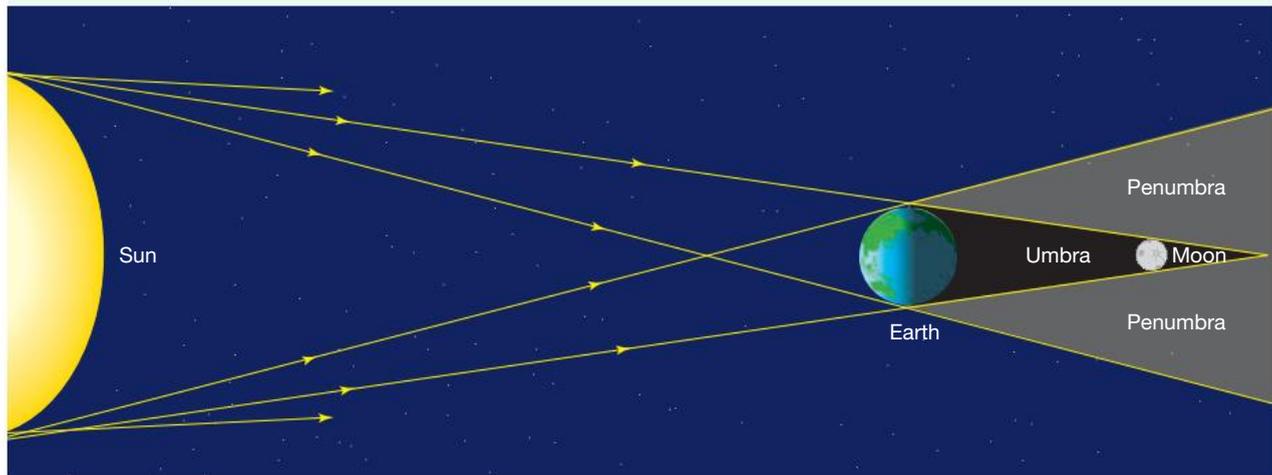
FIGURE 2.23 Earth's shadow makes the Moon appear to change phases during a total lunar eclipse. Note the red tinge of the Moon at the height of the eclipse.

ACTIVITY: The umbra and the penumbra

Place a piece of white paper on your desk and shine a strong light on it, such as the torch from your phone, or even just use the Sun coming through the window. Place your pen between the light source and your paper and observe what happens to the shadows formed on the paper as you move the pen closer to the paper.

In some positions, you will see a sharp dark shadow of the pen form. In others, you will see a shadow that is darker in the centre but surrounded by a softer, less dark shadow.

The dark shadow is called the **umbra** and the softer shadow that forms around it is called the **penumbra**.

EXTENSION: Blood moon

The Moon usually looks white because it reflects white light from the Sun; however, during an eclipse, the Moon takes on a red tinge. This is because, during a total eclipse, the only light that reaches the Moon first passes around the edges of Earth and so has passed through Earth's atmosphere. Earth's atmosphere scatters the blue light from the Sun, leaving mainly red light to illuminate the dimly lit Moon.
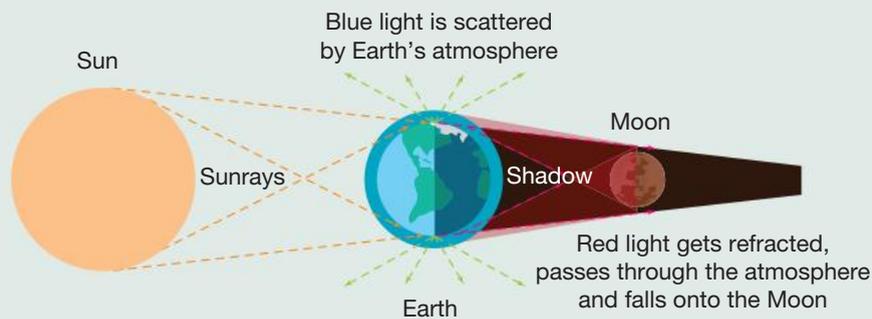
A **partial lunar eclipse** occurs when the Moon is not directly aligned with Earth and the Sun, causing only part of the Moon's face to be in the umbra.

FIGURE 2.24 Partial lunar eclipse
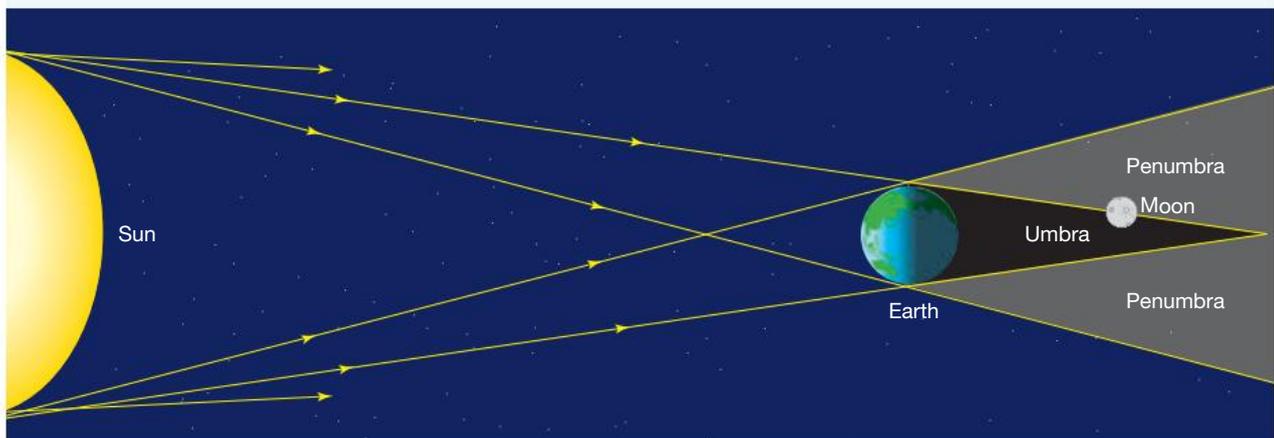
2.6.2 Solar eclipses

Solar eclipses occur when the Moon lies between the Sun and Earth. This means that the Moon's shadow falls on Earth. People on Earth within the **umbra** of the Moon's shadow see a total eclipse of the Sun. Those within the **penumbra** see a **partial solar eclipse**.

Total solar eclipses are not seen often as the Moon casts only a narrow shadow on Earth. The umbra may be only about 100 km wide. It may fall in the middle of the ocean. It may even miss the Earth altogether.

CAUTION: You must NEVER look directly at an eclipse of the Sun — even a total eclipse. You could permanently damage your eyes. Sunglasses will not protect you.

FIGURE 2.25 Total and partial solar eclipse
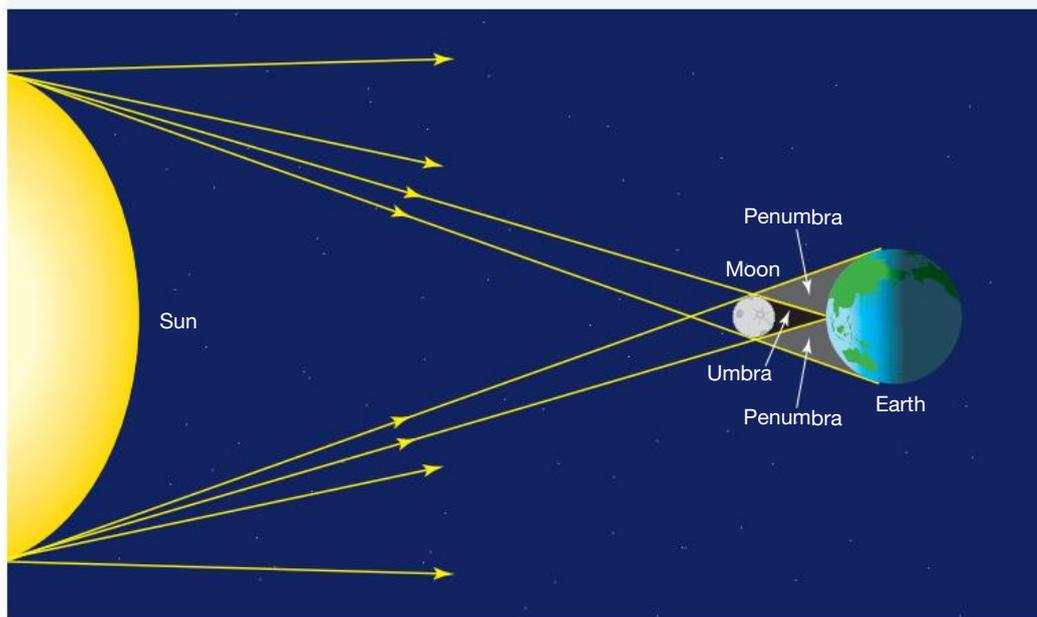
FIGURE 2.26 A total solar eclipse – the Sun's light is blocked as the Moon passes in front of it. The Sun's corona is visible in the middle photo.

Modelling solar and lunar eclipses

Aim

To model a solar and lunar eclipse

Materials

- projector
- globe
- tennis ball attached to string

Method

1. Darken the room and aim a beam of light at the globe.
2. To simulate a solar eclipse, suspend the tennis ball (Moon) between the projector (Sun) and the globe (Earth) as shown. Ensure that you keep your own shadow off the globe.
3. Rotate the globe a little (think carefully about which way to turn it) and note what happens to the shadow.
4. To simulate a lunar eclipse, move the tennis ball to the opposite side of the globe from the projector. Suspend it so that it is partly in the shadow of the globe.

Modelling a solar eclipse

Light from projector

Tennis ball
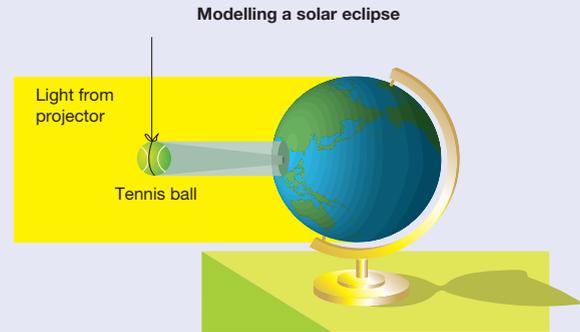
Results

1. Draw a labelled diagram to show the initial positions of Earth, Moon and Sun in your model of a solar eclipse. Note the positions of the umbra and penumbra if observed.
2. Draw a labelled diagram to show the initial positions of Earth, Moon and Sun in your model of a lunar eclipse. Again, note the positions of the umbra and penumbra if observed.

Discussion

1. During which phase of the Moon does a solar eclipse occur?
2. When you rotate the globe, does the shadow move from east to west or from west to east?
3. During which phase of the Moon does a lunar eclipse occur?

Conclusion

How well does this investigation model solar and lunar eclipses? What aspects of eclipses was it not very good at demonstrating?

CASE STUDY: Fire-breathing dragons

In ancient China, people believed that solar eclipses occurred when a giant dragon ate the Sun. They thought that if they made enough noise, they could frighten the dragon. The frightened dragon would then spit the Sun out, bringing daylight back.

2.6 Activities

2.6 Quick quiz **on**	**2.6 Exercise**

Learning pathways

■ **LEVEL 1** 1, 2	■ **LEVEL 2** 3, 4	■ **LEVEL 3** 5

Remember and understand

1. What type of eclipse is being modelled in the diagram?

Light from projector

Tennis ball
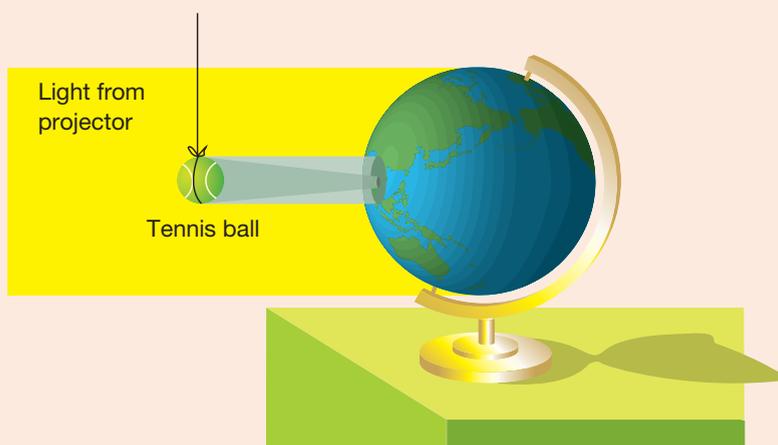
2. During which phase of the Moon does a solar eclipse occur?
3. **Explain** why total solar eclipses are much less frequent than partial solar eclipses.

Apply and analyse

4. At the time of a lunar eclipse, will Earth be experiencing a spring tide or a neap tide? **Explain** your answer.

Evaluate and create

5. Australia is set to experience several total solar eclipses over the next 50 years. Here are the upcoming events:

    July 22, 2028
    Path of totality: this eclipse will traverse central Australia, passing through cities such as Sydney, where totality will last approximately 3 minutes and 49 seconds.

    November 25, 2030
    Path of totality: the eclipse will cross parts of Australia, including regions in Western Australia, the Northern Territory, and Queensland.

    July 13, 2037
    Path of totality: this eclipse will pass over northern Australia, including areas in Queensland and the Northern Territory.

    December 26, 2038
    Path of totality: this eclipse will be visible in parts of South Australia and New South Wales.

    May 31, 2068
    Path of totality: this eclipse will be visible in parts of Western Australia.

    Draw a map showing the path of totality for each one.

LESSON 2.7 Cultural Knowledges of astronomy

LEARNING INTENTION

In this lesson you will describe how some Aboriginal and Torres Strait Islander Peoples predicted seasonal phenomena based on their observations of stars and phases of the Moon and explain how these groups used stars to identify specific weather phenomena. You will also investigate the similarities between their accounts and mainstream scientific explanations about the phases of the Moon and how the phases affect tides.

Aboriginal and Torres Strait Islander Peoples make up the oldest living continuous cultures in human history, having inhabited this land for over 60 000 years. During this time, certain Aboriginal and Torres Strait Islander Peoples have made detailed observations of the relative positions of the stars, Moon and planets in the sky and use them to predict the best times for hunting, fishing and collecting plants for food and medicine.

This information has been passed down through the generations in the form of stories that are told or sung, or illustrated using **petroglyphs**, and ochre paintings and dance. The stories vary across regions and from group to group but have many common elements.

2.7.1 The Dreaming Road

In the night sky, the Moon and planets can be found within a narrow band across the sky, known as the **zodiac** by the ancient Greeks. This region lies along either side of the **ecliptic** (the path taken by the Sun across the sky). The positions of the Moon and planets in the night sky are always close to the ecliptic.

The Yolŋu people of Arnhem Land in the Northern Territory this path as the 'Dreaming Road,' symbolising the journeys of celestial ancestors in cultural stories. The Sun, Moon and planets were seen as celestial beings, and the stories told about their interactions as they travelled along the Dreaming Road were a reflection of what was happening in the
sky above.

CASE STUDY: Walu the Sun-woman

The Yolŋu people of Arnhem Land explain the sunrise, sunset and movement of the Sun through the sky in terms of Walu the Sun-woman. Walu lights a fire each morning, which we see as the dawn. Holding her torch, she travels across the sky from east to west. At the end of her journey to the western horizon, she goes underground for her return journey east, back to her starting point at her morning camp. Walu uses red ochre to decorate her face and body; when some of the red dust falls onto the clouds, this creates the red sunrise and red sunset.

According to the people of the Tiwi Islands north of Darwin, the Sun-woman and her torch are followed by the Moon-man who carries a smaller torch and who is sometimes accompanied by his four wives (who represent the planets Venus, Mars, Mercury and Jupiter).

CASE STUDY: Retrograde motion

We have seen in lesson 2.2 that retrograde motion is the apparent backwards motion of a planet across the night sky over several weeks. In Wardaman (primarily south-west of Katherine, NT) traditions, this motion is caused by the planet spirit walking back along the Dreaming Road to chat to its friends before continuing its forward journey. Sometimes, a planet spirit will catch up with another and they will travel near each other chatting and walking together for a while. This explains a **planetary conjunction**.

2.7.2 The phases of the Moon

The accounts from many different Aboriginal and Torres Strait Islander communities show an understanding of the interactions between the Sun and the Moon, linking them to the phases of the Moon, the changing tides, and solar and lunar eclipses.

The changing appearance of the Moon over the course of a month is explained by many different stories featuring the Sun-woman and the Moon-man (or, in some cases, the Sun-man and the Moon-woman).

CASE STUDY: Ngalindi

The Yolngu people explain the phases of the Moon through the story of Ngalindi and his wives. At the time of the full Moon, Ngalindi is a fat, lazy man. His wives punish him by attacking him with an axe, and he is seen as a waning moon as parts of him are chopped off. Unable to escape his wives, Ngalindi dies of his wounds, and this is the time of the new Moon. He rises from the dead after three days and is seen as the waxing moon as he again grows round and fat. Two weeks later, his wives punish him again, and the cycle repeats.

A traditional Tasmanian Palawa story tells how the Sun-man and Moon-woman rise into the sky together but, because the Sun-man is faster than his wife, she drops behind. To encourage her to run faster and catch up with him, he shines more light on her every night until she is fully lit. This describes the waxing of the Moon from a new Moon to a full Moon.

The phases of the Moon are observed by Torres Strait Islander Peoples, so they know when to fish. Spring tides stir up sediment and make the water cloudy, making it harder to spot the fish. They prefer to fish when there is a neap tide instead. They know that the best time to fish is when the Moon is in either its first or third quarter.

CASE STUDY: The Moon's motion

Other Dreaming stories show that the Yolngu people knew about the relationship between tides and the Moon's motion. They explain that, at high tide, water fills the Moon as it rises. When the water flows back out of the Moon, the tides fall. The Moon is empty for three days before the tide rises again, when the Moon is again filled with water.

DISCUSSION

Consider the rock carvings shown below, which come from the Ku-ring-gai Chase National Park in Sydney's north.

Discuss what astronomical event is being shown here. What is the significance of the two figures? Is there any way that you could verify your theories?

FIGURE 2.27 Rock carvings, Ku-ring-gai Chase National Park, NSW

2.7.3 Predicting seasonal changes

Traditionally, certain Aboriginal and Torres Strait Islander Peoples used a variety of different astronomical indicators to predict changes in their environments. Seasons linked to the behaviour of animals and the fruiting and flowering season of plants are heralded by the appearance of certain stars, or formations in the skies. The brightness and clarity of stars also allow the prediction of seasonal change.

CASE STUDY: The Emu in the Sky

The Emu in the Sky is seen in the bright background of the Milky Way with its body, head and legs traced out by the dark regions. The position of the emu in the sky after sunset throughout the year is associated with the breeding cycle of the emu on the ground. The emu breeding season coincides with the time of the year when the celestial emu is rising above the horizon. Its appearance means this is the best time to gather emu eggs — a highly prized source of nutrition.

FIGURE 2.28 When the celestial emu is seen rising above the horizon after sunset, it is the season to gather emu eggs for food. In Ku-ring-gai Chase National Park (New South Wales), there is a petroglyph of the emu in the sky. Emu egg season coincides with the appearance of the celestial emu above the carving.
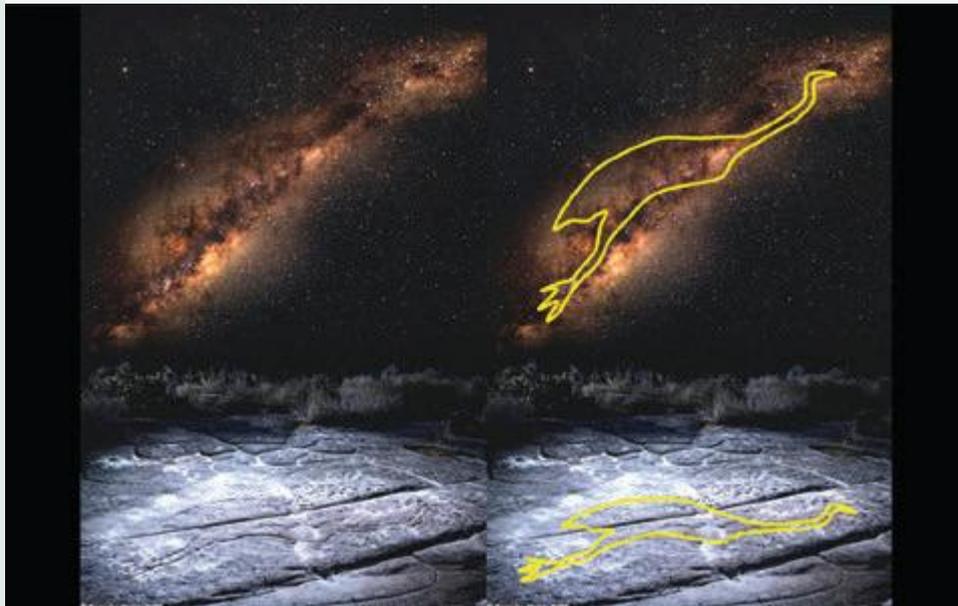
CASE STUDY: The Pleiades (or the Seven Sisters)

The star group called the Pleiades (or the Seven Sisters) is associated with many traditions across Australia.

For communities on the east coast, their appearance just before dawn in the east marks the start of the winter migration of whales from Antarctica to their breeding grounds in northern New South Wales and Southern Queensland. When the stars set in the west at dawn, the communities know that it is the time when whales will be moving back south to Antarctica with their calves.

For communities in central Australia, however, the rising of the Pleiades at dawn tells them it is time to look for dingo pups who are used for warmth on cold nights. The Pleiades are also linked to the harvest time for bush tomatoes, honey ants and thorny devils.

FIGURE 2.29 The position of the Pleiades near dawn is important for many different Aboriginal and Torres Strait Islander traditions across Australia.

2.7 Activities

learn on

| **2.7 Quick quiz** on | **2.7 Exercise** |

Learning pathways

| ■ **LEVEL 1** | ■ **LEVEL 2** | ■ **LEVEL 3** |
| 1, 2 | 3 | 4 |

Remember and understand

1. Complete the following passage.
   Aboriginal and Torres Strait Islander Peoples' seasons are organised _____ the traditional four-season calendar used by migrants to Australia. By observing the movement and position of _____ Aboriginal and Torres Strait Islander Peoples' developed_____. Each seasonal calendar has been developed over thousands of years for a specific environment, by the community living there. In many Aboriginal and Torres Strait Islander Peoples' traditions, each _____was indicated by the emergence of an important star or a group of stars in the sky.
2. **MS** Which two of the following phases of the Moon are traditionally considered the best for fishing?
   A. Full moon
   B. Third quarter
   C. First quarter
   D. New moon

Apply and analyse

3. **Explain** why there are no traditional stories associated with the movement of Uranus and Neptune across the sky, when there are many which describe the motion of Mercury, Venus, Mars, Saturn and Jupiter.
4. **MS** Which of the following events are connected to the position of the Pleiades in the night sky for Aboriginal and Torres Strait Islander Peoples communities in the Central desert? Select all that apply.
   A. Dingo pups are being born.
   B. Whales are migrating with their calves.
   C. Emus are nesting.
   D. Bush tomatoes are ready for harvesting.

LESSON 2.8 Eyes on the skies

LEARNING INTENTION

In this lesson you will explain how advances in telescope technology have increased our knowledge of our Universe.

A telescope is a device which allows distant objects to be observed more clearly.

Our understanding of the variety of celestial objects in the Universe relies on advances in telescope technology. Better telescopes allow clearer images of distant objects — even of objects in other galaxies — and give astronomers opportunities to observe phenomena that change our view of how our cosmos works.

2.8.1 Optical telescopes

The earliest form of optical telescope was made up of a tube of brass or wood with glass **lenses** of different sizes at either end. These lenses changed the path taken by the light rays from distant objects before they passed into the eye of the observer, and made the object look bigger.

FIGURE 2.30 By changing the path of the light rays travelling from a distant object to our eye, the lenses in a telescope make the object look bigger, allowing more details to be seen.
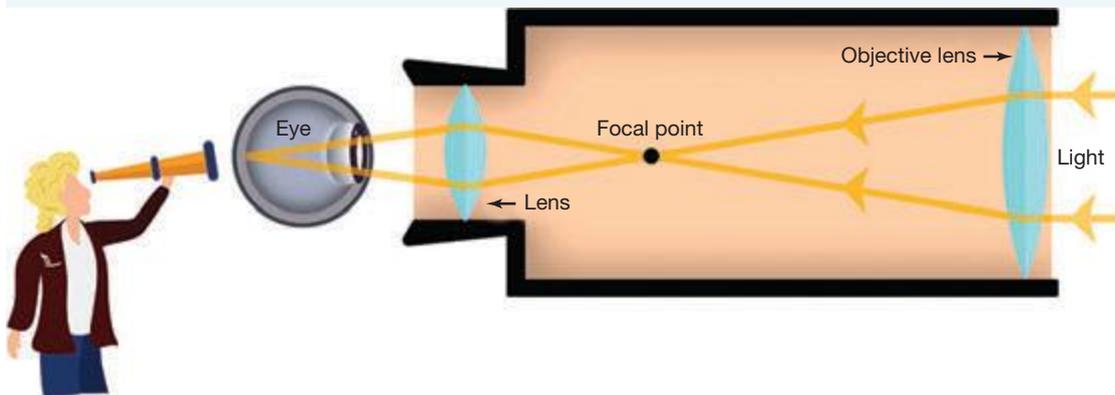
While Galileo did not actually invent telescopes (as many people believe) he was one of the first astronomers to use a telescope to observe objects in our solar system and record his observations. His discovery that the surfaces of the Moon and the Sun were not perfect, and that other planets had moons, led him to support the heliocentric model of Copernicus.

Today optical telescopes are much more sophisticated, using systems of mirrors and lenses to increase the amount of detail that can be seen on distant objects.

A telescope's ability to see finer detail is called its **resolution**. Telescopes with good resolution can distinguish objects that are close together in the night sky as being separate and distinct. The resolution of a telescope is affected by the telescope's diameter. Large diameter telescopes have the potential to see more distant objects as they have greater sensitivity, or light-collecting capacity, and so they have a higher resolution.

CASE STUDY: Alpha Centauri

Alpha Centauri was thought to be a single star up until 1689 when Jean Richaud observed through his telescope that it was a system made up of two stars close together (referred to as Alpha Centauri A and B). In 1915, telescopes had improved to the point that Robert Thorburn Ayton Innes was able to observe a third, much smaller star now called Proxima Centauri (or Alpha Centauri C).

FIGURE 2.31 Alpha Centauri AB — Proxima Centauri (or Alpha Centauri C) is too small to identify in this image.

Beta Centauri

Southern cross

Alpha Centauri AB
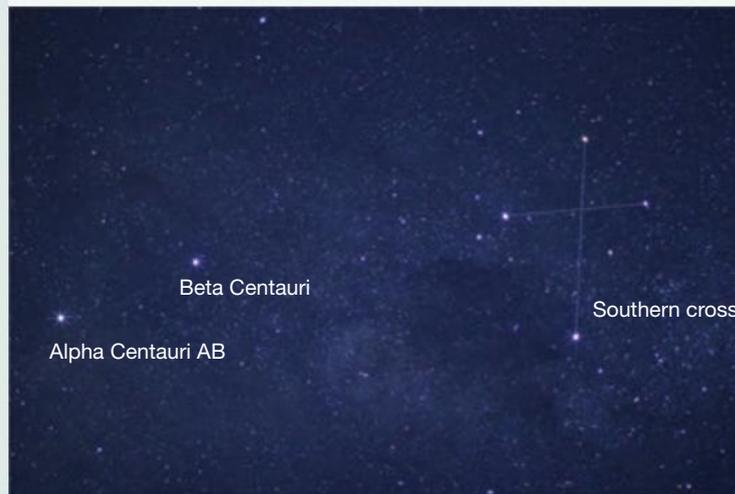
INVESTIGATION 2.8

Looking for detail

Aim

To compare the resolution of optical instruments and the naked eye

Wider diameter telescopes not only collect more light and so can see deeper into the Universe, they also provide better resolution, or ability to see finer detail. Telescopes with good resolution are able to distinguish close objects in the night sky as separate and distinct.

The diameter of the lens of our eye is approximately 10 mm. In this experiment you will be comparing the resolution of the eye with optical instruments, such as binoculars and the telescope.

Materials

- A4 sheet of cardboard
- ruler
- trundle wheel
- optical telescope
- thick black marker
- sticky tape
- pair of binoculars

Method

1. Measure and record the diameter of the lens or mirror of the binoculars and the telescope. Record this data along with the diameter of the human eye.
2. On a sheet of cardboard, draw two thick black lines approximately 2 cm long and with a gap of exactly 2 mm between them. These lines represent two stars that appear close to one another in the night sky.

3. Tape the sheet of cardboard to a wall or bench in open space in the playground.
4. Position a member of your group as an observer some distance from the 'stars', so that when viewed with the naked eye they appear as one single star.
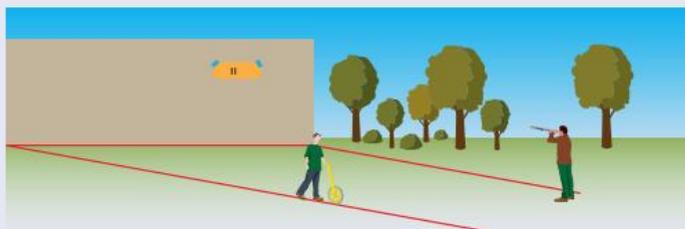
5. Ask the observer to slowly walk towards the stars until they appear as two separate and distinct objects. At this point, use a trundle wheel to measure the distance between the observer and the stars.
6. Repeat for all members of the group and calculate the average distance at which the observers were able to resolve the two stars.
7. Repeat this experiment with the observers using a small telescope or pair of binoculars.

Results

Enter your results in a table like the one shown. Add more rows if you have more than four people in your group.

Observer	Naked eye resolution distance	Resolution distance using telescope/ binoculars
1		
2		
3		
4		
Average		

Discussion

1. Which instrument provided the greatest resolution? Support your response with suitable data.
2. What advantages does a large diameter telescope provide when viewing the night sky?
3. Explain why the diameter of a telescope is not the only factor to consider when building a telescope and locating an observatory.

Conclusion

How does the resolution of the telescope/binoculars compare to that of the naked eye?

CASE STUDY: The Keck Observatory

Observatories are generally located at high altitude on mountain ranges to minimise the distortion of images resulting from light passing through the atmosphere, and generally far from urban centres to escape light pollution.

The Keck Observatory, for example, is located at an altitude of 4100 m in Hawaii and consists of two 10-m optical telescopes. Even at this altitude, images of distant objects are blurred somewhat by the atmosphere. Engineers have developed a technology called adaptive optics, which eliminates the image distortions by measuring and then correcting for the atmospheric effects using a deformable mirror that changes shape 2000 times per second. As a result, the Keck telescopes are able to produce sharp images of celestial objects.

FIGURE 2.32 The Keck I and II optical telescopes in Hawaii are among the largest in the world.

FIGURE 2.33 The formulation of a planetary nebula captured by the Keck Observatory. A dying star is shedding its outer layers.
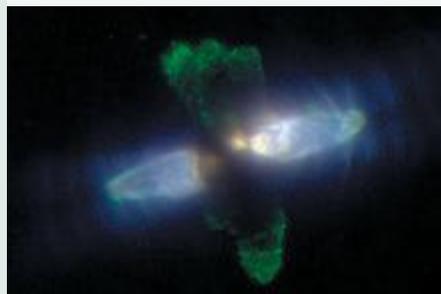
2.8.2 Radio telescopes

The biggest problem with optical telescopes is that they can only be used at night and observations cannot be made when the weather is cloudy. In 1931, it was discovered that stars emitted radio waves as well as light. Astronomers theorised that these radio waves could be used as an observation tool and, in 1937, the first radio telescope was built.

Radio telescopes are huge dishes that collect radio waves from deep in space and reflect them towards a central antenna. The waves from the antenna are then analysed by a computer, which produces an image that we can see.

Unlike the visible light that optical telescopes rely on, radio waves can travel through clouds and rain in Earth's atmosphere and can be detected in daylight as well as at night. Radio telescopes can also detect

FIGURE 2.34 The Five-hundred-metre Aperture Spherical Telescope (FAST) in China is the largest single radio telescope in the world.

signals from much further away than optical telescopes can. Today, radio telescopes are used to study giant clouds of dust and gas, as well as stars and galaxies. By studying the radio waves originating from these sources, astronomers can learn about their composition, structure and motion.

CASE STUDY: The Australia Telescope Compact Array

Images produced by individual radio telescopes are not very sharp. To solve this problem, signals from groups of telescopes pointed at the same object are combined to produce sharper images.

The Australia Telescope Compact Array in Narrabri, rural New South Wales, consists of six 22-m dishes used for radio astronomy. The dishes work together, which allows them to capture images with much finer detail, equivalent to that possible with a single radio telescope of much larger diameter.

2.8.3 Space telescopes

Visible light and radio waves are just two types of **electromagnetic radiation** (or EMR). There are many common types of radiation around us every day.

TABLE 2.3 Types of electromagnetic radiation and their uses

Type of EMR	Used in
Radio wave	Mobile phones, wi-fi, Bluetooth, television and radio transmission
Microwave	Microwave ovens
Infra-red	Remote controls, night-vision goggles, infra-red security sensors
Ultraviolet	3D resin printers, killing bacteria, phototherapy
X-ray	Imaging the human body, cancer treatment
Gamma ray	Food sterilisation, cancer treatment, medical imaging

Many celestial objects do not emit visible light or radio waves. They would be invisible if it were not for the development of telescopes that detect some of the other types of electromagnetic radiation.

Most of these radiation types are filtered out or absorbed by Earth's atmosphere, so the telescopes that use them are placed in orbit around the planet. The information gathered by these **space telescopes** is then transmitted back to Earth.

FIGURE 2.35 Space telescopes use different types of EM radiation to 'see' deep into the Universe.
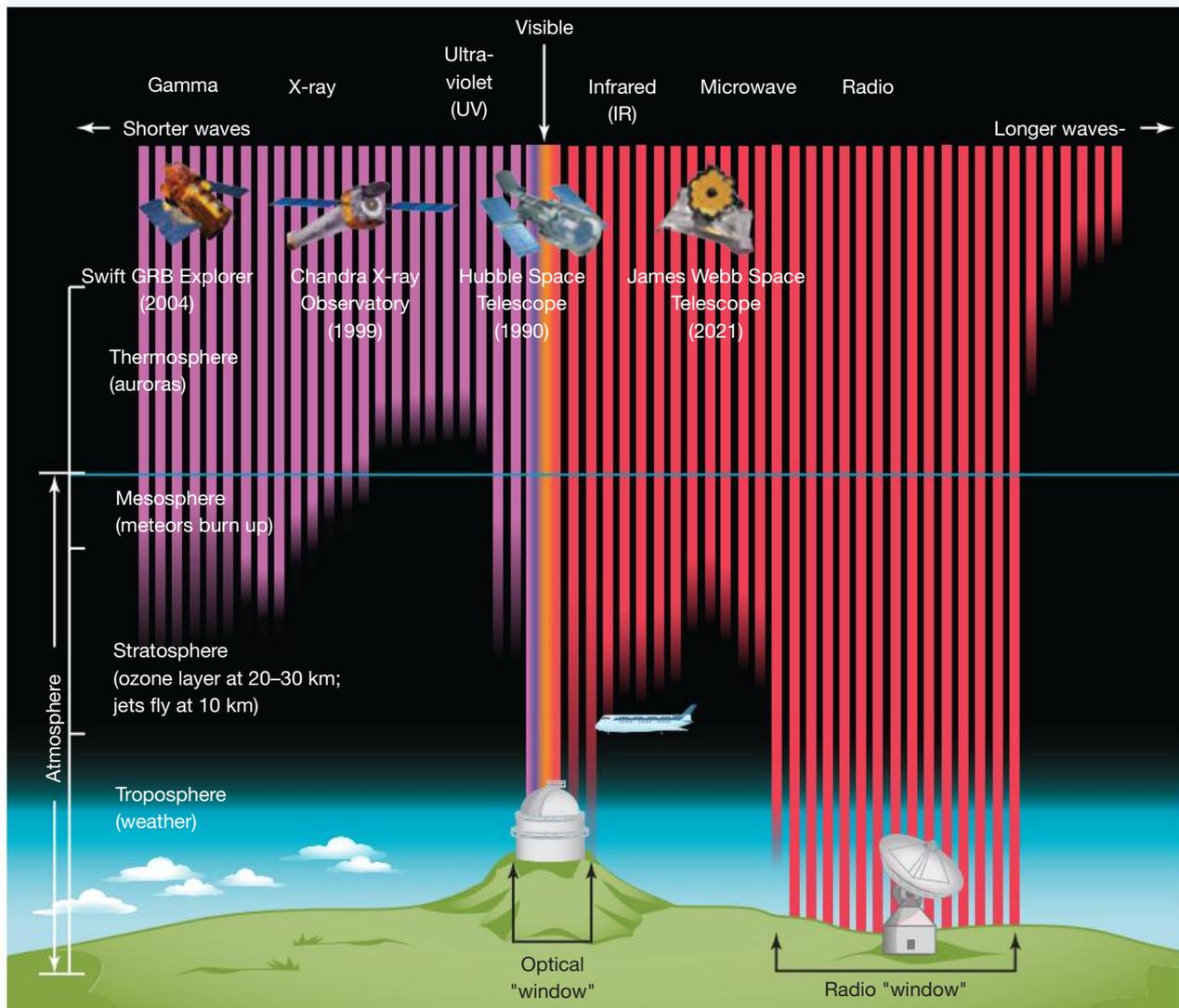
⊙ 2.8.4 Worlds beyond our solar system

With the use of ever-more advanced optical, radio and space telescopes, scientists can see further into the Universe than at any other time in history and learn the answers to many important questions. One of the big questions humans have asked for centuries is: Are there other worlds like ours in the Universe?

Scientists had theorised that **exoplanets** — planets that are not part of our solar system — could exist but had no evidence to support their theory. Then, in 1992, radio astronomers Aleksander Wolszczan and Dale Frail were using the Arecibo radio telescope when they detected three planets orbiting the remnants of a star in the constellation Virgo.

Since 1992, more than 5500 exoplanets have been detected, forming thousands of other solar systems. Some of these are like our own solar system, with both terrestrial and gas giant planets, and formed around stars that are like our Sun.

Space telescopes like the James Webb are now examining the gases in the atmospheres of these planets to learn whether they are, in fact, just like Earth.

WORKING SCIENTIFICALLY: Scientific communication

Australia contributes to space research and has made significant contributions to space exploration. But advancements in space technologies also benefit everyday life technologies on Earth.

Select one of the following areas of interest and create a podcast, video, poster or presentation to summarise Australia's contributions in that area and how it benefits people in everyday life.

Areas of interest:
- Earth observation
- Space debris monitoring
- Positioning, navigating and timing
- Communication technologies
- Robotics and automation
- Applied space medicine and life sciences
- Access to space

Recommended sources to consult:
- Australian Space Agency website
- CSIRO website (using the search box to look for space information)
- Australian Centre for Space Engineering Research website

WS **SC4-WS-08** Communicates scientific concepts and ideas using a range of communication forms

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2.8 Activities

learn on

2.8 Quick quiz **on**	2.8 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 5	3, 4, 6, 8	7, 9

Remember and understand

1. **MC** **Identify** which of the following were observed by Galileo through his telescope.
   A. Craters on the Moon
   B. Exoplanets
   C. Sunspots
   D. Alpha Centauri A and B
2. Complete the following sentence.
   The bigger the diameter of the telescope, the _____ its resolution.

3. **MS** Which of the following are true of radio telescopes? Select all that apply.
    A. They need to be placed in orbit.
    B. They are able to detect radio waves and X-rays.
    C. They detect radiation that is not affected by clouds.
    D. They are made up of dishes with a central antenna.
    E. They can only point in one direction.
    F. They can be used during the daytime as well as night.
    G. They can be used to detect exoplanets.
4. Complete the following sentence.
    The first exoplanet was detected by astronomers using the _____ in _____.

Apply and analyse

5. **Explain** why the location of the Sydney observatory, near the centre of the city, is not optimal for astronomical viewing. With this in mind, why would it have been built there?
6. Space agencies have launched telescopes in orbit around the Earth. **Explain** why orbiting telescopes such as the Hubble Space Telescope provide a significant advantage when viewing distant stars and galaxies.
7. Over time, optical telescopes have become much more sophisticated. **Explain** why is it important for telescopes other than optical telescopes to be built and used by astronomers.

Evaluate and create

8. Match each type of EM radiation with its common use.

a.	X-rays	**1.**	Communications
b.	Infrared	**2.**	Fast cooking
c.	Microwaves	**3.**	TV remote controls
d.	Radio waves	**4.**	Medical imaging

9. Create a poster or multimedia presentation to showcase the James Webb Space Telescope. The purpose of your presentation is to **describe** the history of the program and the key astronomical findings, and to **justify** the billions of dollars involved in building, launching and supporting the orbiting space telescope.

LESSON 2.9 Review

2.9.1 Topic summary

Our place in space

- **Our solar system**
  - A collection of rocks and gas
  - Orbiting the Sun
- **Our local star**
  - The Sun
  - Sunspots
  - Solar radiation
- **Earth in motion**
  - Day and night
  - Explaining the seasons
- **The Moon in motion**
  - Studying the Moon
  - Phases of the Moon
  - Ocean tides
  - Spring and neap tides
- **Lunar and solar eclipses**
  - Lunar eclipses
  - Solar eclipses
- **Cultural Knowledges of astronomy**
  - The Dreaming Road
  - The phases of the Moon
  - Predicting seasonal changes
- **Eyes on the skies**
  - Optical telescopes
  - Radio telescopes
  - Space telescopes
  - Worlds beyond our solar system

2.9.2 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	🟢	🟡	🔴
2.2	I can **compare** historical and current solar system models to show how models are modified or rejected due to new scientific evidence			
2.3	I can **identify** the main features of our Sun and explain the occurrence of sunspots and why solar radiation can be helpful or harmful.			
2.4	I can **explain** how seasons and the lengths of night and day are caused by the movement of Earth around the Sun and its rotation on its axis.			
2.5	I can **identify** characteristics of the Moon and explain why its appearance in the night sky changes over the course of a month.			
	I can **explain** how the Moon affects tides on Earth.			
2.6	I can **explain** how solar and lunar eclipses result from the relative positions of the Sun, Moon and Earth, and use physical and virtual simulations to model eclipses.			
2.7	I can **describe** how some Aboriginal and Torres Strait Islander Peoples predicted seasonal phenomena based on their observations of stars and phases of the Moon.			
	I can **explain** how some Aboriginal and Torres Strait Islander Peoples used stars to identify specific weather phenomena.			
	I can **investigate** the similarities between some Aboriginal and Torres Strait Islander Peoples' accounts and mainstream scientific explanations about the phases of the Moon and how the phases affect tides.			
2.8	I can **explain** how advances in telescope technology have increased our knowledge of our Universe.			

DEPTH STUDY IDEAS

- How do scientists look for exoplanets?
- Where did the Moon come from?
- How do scientists determine the composition of a planet or a moon, and their atmosphere if they have one?
- How do we know how old our solar system is?
- How were eclipses predicted in the past?
- What can the James Webb Space Telescope see?
- What has *Voyager 1* found since its launch in 1977?
- How does Australia contribute to space research?
- Does Australia have the potential to be used for orbital launch?

on Resources

on Post-test   Topic 2 Post-test

eWorkbook   Summary
Reflection

2.9 Activities

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4, 7, 10, 13, 16, 19, 22	2, 5, 8, 11, 14, 17, 20	3, 6, 9, 12, 15, 18, 21, 23, 24

Remember and understand

1. **MC** The rocky planets in the solar system are:
   - **A.** Venus, Earth, Mars, Pluto.
   - **B.** Earth, Mars, Uranus, Neptune.
   - **C.** Jupiter, Saturn, Earth, Uranus, Neptune.
   - **D.** Mercury, Venus, Earth, Mars.

2. **MC** In a model of the solar system, if a pea represents Earth, which object below would best represent the Sun?
   - **A.** A passionfruit pip
   - **B.** A golf ball
   - **C.** An apple
   - **D.** A basketball

3. Select the correct word to complete each of the following statements.
   - **a.** The Sun is composed of _____ and helium. Nuclear fusion reactions generate energy by fusing hydrogen atoms into helium.
   - **b.** _____ is the force that holds the planets in orbit around the Sun.
   - **c.** Kepler proved that the planets orbit the Sun in _____ orbits. In most cases the ellipse is nearly _____ in shape. The dwarf planet Pluto's orbit is very elliptical.
   - **d.** The Sun appears to move from east to west across the sky. This movement is in fact due to the Earth rotating west to east on its _____.
   - **e.** The Sun emits vast amounts of energy in the form of _____ and particles. Some radiation such as ultraviolet is very damaging to living things.

4. **MC** A day on Jupiter is about 10 hours long because:
   - **A.** it takes 10 hours to rotate on its axis.
   - **B.** it takes 10 hours to complete one orbit around the Sun.
   - **C.** it is closer to the Sun than Earth.
   - **D.** it takes 20 hours to rotate on its axis.

5. Complete the labels identifying important structures of the Sun.
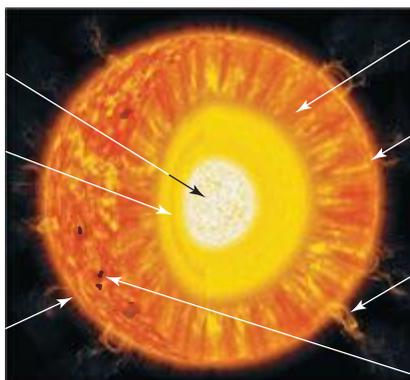
6. **MS** **Identify** which forms of solar radiation are needed by life on Earth. Select all that apply.
   A. Gamma rays
   B. X-rays
   C. Ultraviolet
   D. Visible light
   E. Infra-red
   F. Microwaves

Apply and analyse

7. The diagram shows Earth orbiting the Sun. At what positions does Australia experience summer and winter respectively?
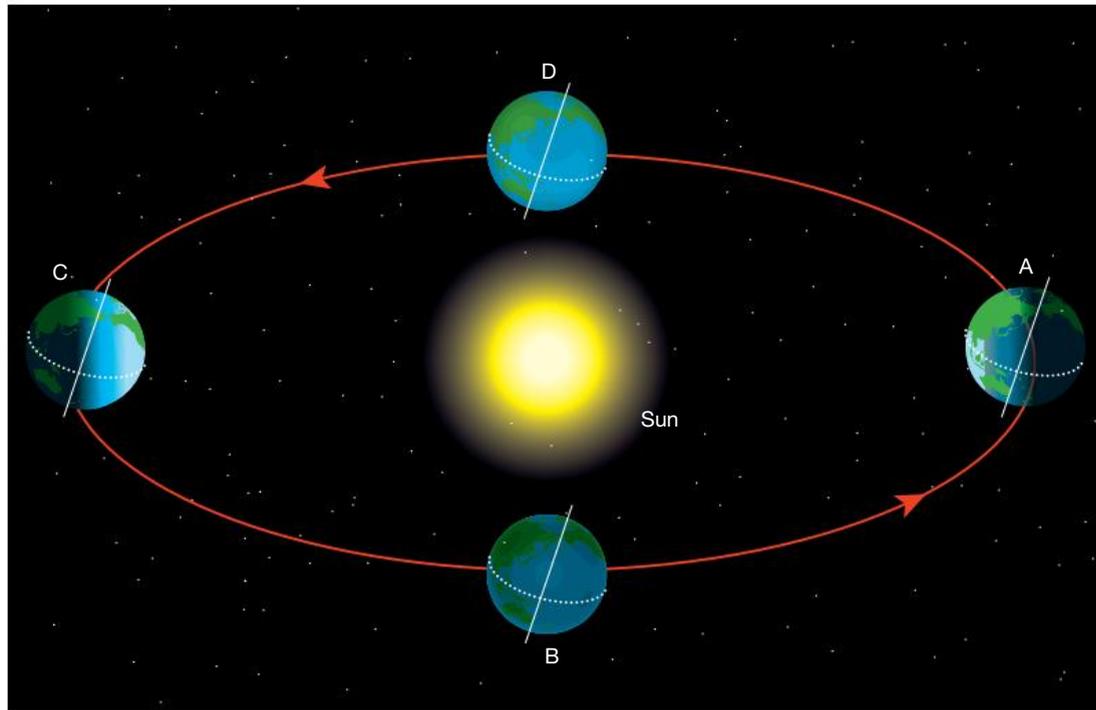
8. Calculate how many rotations of the Sun Earth has completed since you were born.
9. Refer to the following diagram to explain why Australia experiences summer from December to February.

Position of sun
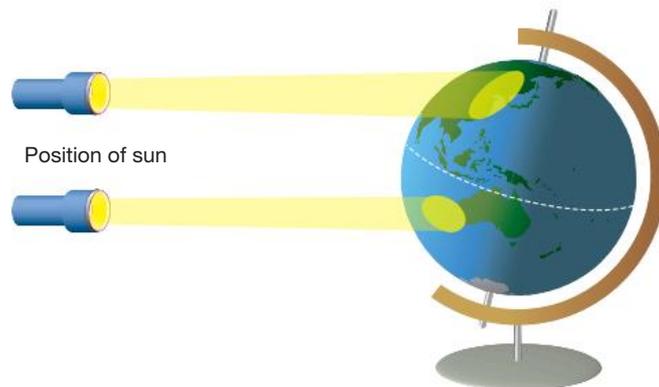
10. A long exposure image of the night sky produces a photograph like this. **Explain** why.

11. The diagram shows the Moon in eight different positions during an orbit around Earth.
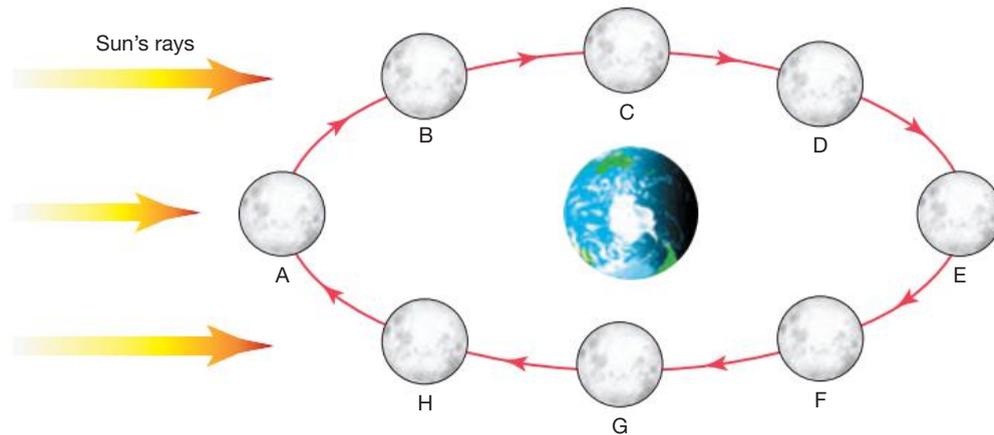
a. Which phase of the Moon would be seen from Earth when the Moon is in position E?
b. Which phase of the Moon would be seen from Earth when the Moon is in position G?

12. Complete the following sentences.
   a. The gravitational pull of the Moon on the water on Earth's surface causes the oceans facing it to bulge outwards, resulting in a _____tide.
   b. The tidal bulge on the side of Earth facing the Moon is _____ than that facing the Sun.
   c. The Moon takes approximately _____ days to complete a single orbit.

Evaluate and create

13. How many times does the Moon rotate around its own axis while completing a single orbit of Earth?

14. The table below shows high and low tide heights at Bondi beach over a 24-hour period of time.

Time	Height (m)
2.30 am	0.37
9.05 am	2.05
3.52 pm	0.10
9.53 pm	1.37

    a. How many hours (correct to one decimal place) are there between two consecutive high tides?

    b. How many hours (correct to one decimal place) are there between two consecutive low tides?

15. **Explain** why it is not possible to see a new moon during the day.

16. The table below shows the high and low tide heights for Sydney Harbour over a 24-hour period of time.

Time	Height (m)
5.09 am	0.37
11.16 am	1.41
4.56 pm	0.59
11.14 pm	1.71
5.51 am	0.44

    a. Calculate the approximate time between high tides.

    b. Explain what causes the tides and why the tides alternate between high and low.

17. In a lunar eclipse, the Moon is temporarily not clearly visible to observers on Earth. Draw an illustration to **explain** a lunar eclipse. Include the Sun, Earth and Moon in your diagram.

18. When the *Apollo 14* mission travelled to the Moon in 1971, astronaut Alan Shepard took along a golf ball. He used a rock-collecting tool as a golf club and reported that the ball he hit travelled 'miles and miles'.

    a. Using your knowledge of the Moon's surface and conditions, **explain** why the golf ball travelled so far.

    b. Why would Alan Shepard have needed life-support equipment while playing golf on the Moon?

    c. Why are the footprints of Alan Shepard and the 11 other astronauts who have walked on the Moon still present today?

19. **Identify** which of these photographs shows an eclipse of the Sun and which shows an eclipse of the Moon.

Eclipse 1   Eclipse 2
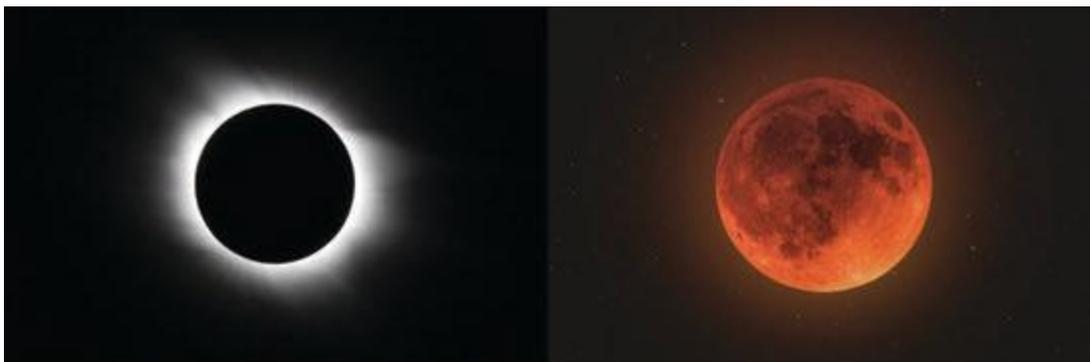
20. **Identify** which of the following illustrations demonstrates a lunar eclipse and which shows a solar eclipse.

a.

b.
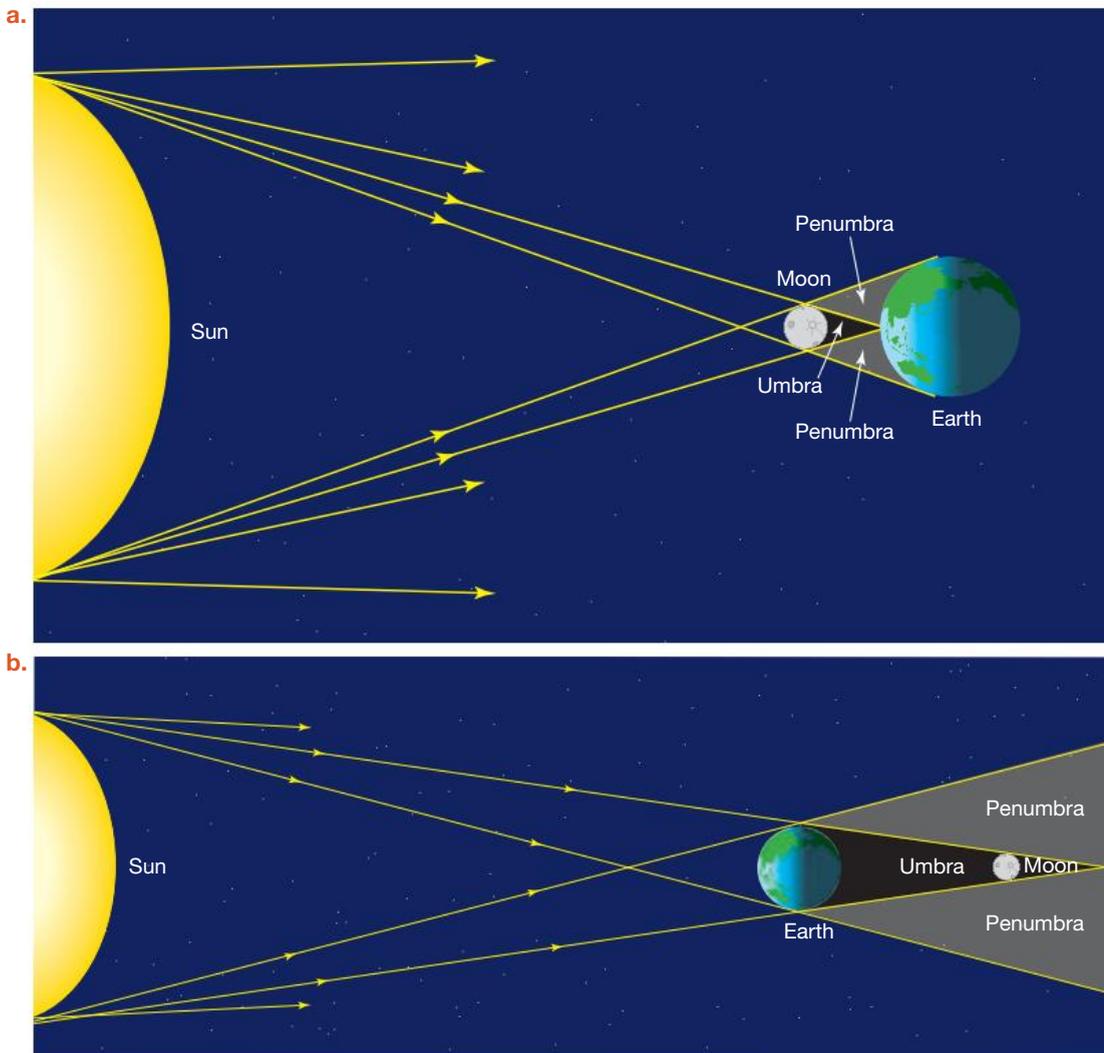
21. **MC** During a solar eclipse:
    A. the Moon is blocked out by the Sun.
    B. the Sun is blocked out by Earth.
    C. the Moon is blocked out by Earth.
    D. the Sun is blocked out by the Moon.
22. Telescopes use electromagnetic radiation. **Identify** an example of each of the following.
    a. An X-ray telescope
    b. An ultraviolet telescope
    c. A radio telescope based in Australia
23. Exoplanets, or planets beyond the solar system, are generally too small to be seen by direct observation. **Describe** how these planets are discovered.
24. **Explain** why only optical telescopes and radio telescopes can be located on the ground.

To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

3 Forces in action

LESSON SEQUENCE

LESSON 3.1 Overview

3.1.1 Why learn this?

In 2012, Felix Baumgartner, a parachutist from Austria, broke the record for the highest ever freefall from 39 km above Earth. He fell from a balloon for five and a half minutes, reaching a top speed of over 1000 km/h before opening his parachute to land.

Gravitational forces caused Baumgartner to reach such an incredible speed as he fell to Earth. Air resistance allowed his parachute to slow his rate of descent so he could land safely.

We feel forces like gravity every day. Gravitational forces keep objects grounded to Earth. Gravity also keeps satellites in orbit — without them, the phone and communication services we use would not exist. Gravitational forces also cause the Moon to orbit Earth and the planets to orbit the Sun.

Friction forces stop us from sliding as we take a step but they can also get in the way. Electrostatic and magnetic forces are harder to see but many devices and technologies use these. We will see these forces in action throughout our lives.

FIGURE 3.1 Gravitational forces keep both satellites and the Moon in orbit around Earth.

FIGURE 3.2 Gravitational forces give a snowboarder speed, while friction helps control the descent.

ACTIVITY: Engaging with using energy

1. Work in small groups of three to four students.
   a. Using a large piece of paper, draw up a table with terms listed in the left column like the table below.
   b. Discuss each term and what you all think it might mean.
   c. In the right column of your table, write the possible meaning that your group proposes for each term. If your group finds a term difficult, you can write 'don't know', but don't be afraid to have an educated guess.
   d. Share your group's responses with the class.

Term	Possible meaning
Force	
Friction	
Magnet	
Magnetic field	
Mass	
Gravity	
Weight	
Acceleration	
Buoyancy	
Orbit	
Aerodynamic	

2. Identify the forces acting as you stretch a rubber band.
3. Why does Earth keep travelling around the Sun?
4. Explain how a seatbelt protects you in a car crash.

5. Is there gravity on the Moon? If so, is it the same as the gravity on Earth?
6. Is it easier to slide a heavy box over concrete or vinyl? Explain why.
7. Why are modern cars designed to be sleek and streamlined?
8. Give some examples of magnets used in household devices.
9. Are all metals magnetic? Elaborate.
10. Explain how heavy cargo ships can float on water.

learn on

on **Pre-test**	Topic 3 Pre-test	
eWorkbooks	Topic 3 eWorkbook	
	Student learning matrix	
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook	
Digital document	Key terms glossary	

LESSON 3.2 Direct and indirect forces

LEARNING INTENTION

In this lesson you will investigate direct and indirect forces and describe the relationship between force and energy.

3.2.1 Forces everywhere

A **force** is a push, a pull or a twist. A force can change the speed, direction or shape of an object. For example, when a tennis racquet hits a ball, it changes the ball's speed and direction. It can also briefly change the ball's shape.

FIGURE 3.3 Examples of forces

Friction force

Spring force

Buoyant force

Gravitational force

Drag (air resistance) force

Applied force

Electric force

Magnetic force

Contact force
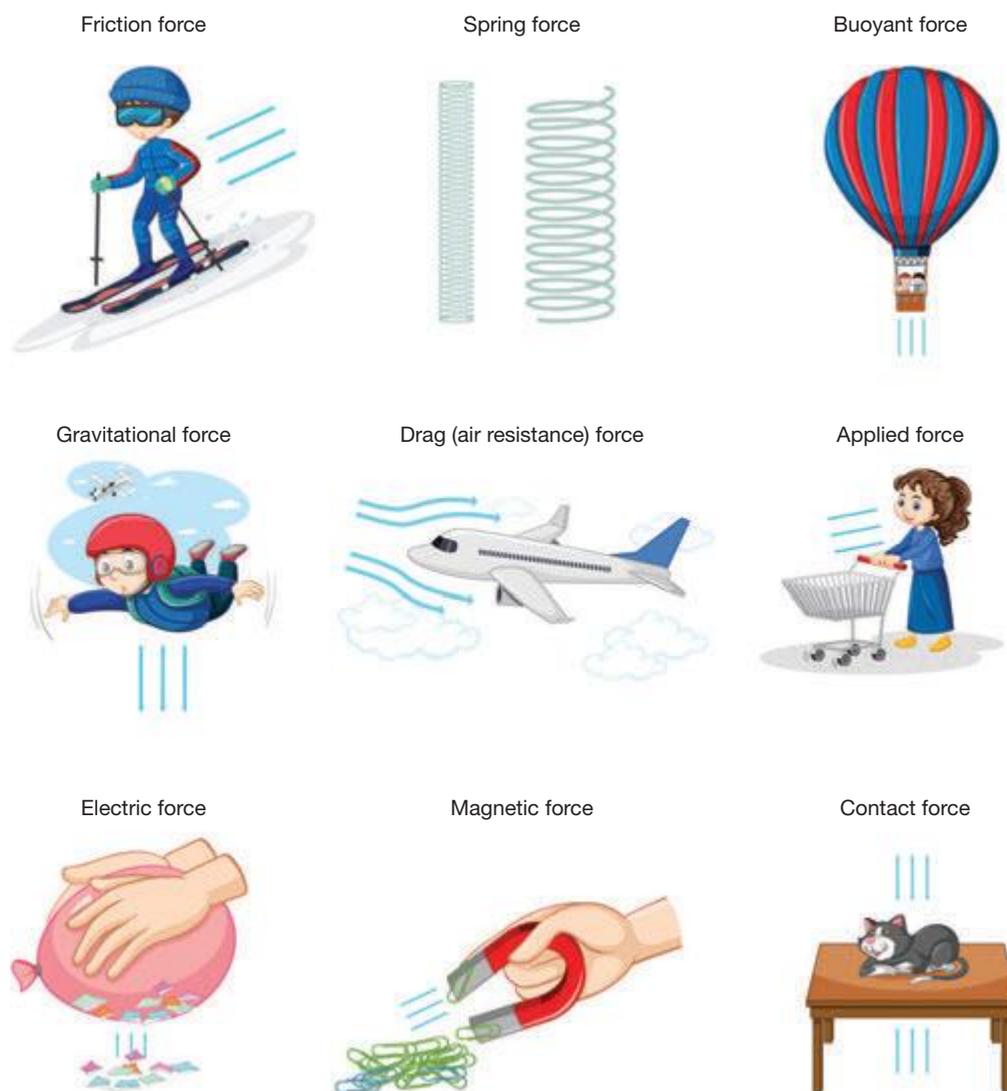
There are forces acting around us all the time and they can cause changes. Sometimes the effects are obvious and sometimes they are not. Right now, forces inside you are pumping blood around your body. When you type on a keyboard, you use force to press the keys. The many examples of forces in our daily lives can be classified as either a **direct force** or an **indirect force**.

FIGURE 3.4 A force can change the speed, direction or shape of an object. In this high-speed image, the force of impact between the racquet and ball changes their shapes briefly.

INVESTIGATION 3.1

What can a force do?

Aim

To observe changes that take place when forces are acting

Materials

- rubber band
- nylon or wool cloth
- coin
- tennis ball
- plasticine or Blu Tack
- plastic ruler or rod

Method

1. Copy the following table into your notebook.
2. Write down your observations — take notice of any changes in the motion or shape of each object and what force caused the change in the motion or shape.

What to do	Observations	
	Changes in motion or shape	What caused the change
Stretch a rubber band.		
Squash a lump of plasticine.		
Push down on the floor with one foot.		
Drop a tennis ball. Observe what happens: **a.** at the moment that you drop it **b.** as it falls **c.** as it hits the ground **d.** as it goes up again.		
Flick a coin with one finger so that it slides along the floor or a table. Observe what happens after the coin is flicked.		
Charge a plastic ruler or rod by rubbing it with a nylon or wool cloth. Then hold it close to a thin stream of tap water.		

Results

Record your observations in the table.

Discussion

1. When you squash a lump of plasticine/Blu Tack or stretch a rubber band, a change in shape is observed. Explain what is different about how these two materials respond after you stop applying your force.
2. Does the tennis ball change its shape when it hits the ground?
3. What would happen to a falling lump of plasticine or Blu Tack when it hit the ground? Would it bounce? Check your prediction.
4. In which two experiments were you able to cause an object to move without making direct contact with it?

Conclusion

Refer to your observations to describe the changes that can occur as a result of the direct and indirect forces that you investigated

3.2.2 Contact or non-contact?

Forces can act between two objects that are in contact with each other. These are called direct or **contact forces**. Familiar examples of direct forces include the force from your hand pulling on your shoelaces as you tie them, the twisting force of your hand on a bottle top as you unscrew it, and the force to squeeze toothpaste onto your toothbrush. Other examples of contact forces include friction and buoyancy.

Friction is a contact force between two surfaces that are sliding, or attempting to slide, over one another. For example, there is friction between the tyres of your bike and the ground when you pedal. Without friction, the tyres would just slip, and you would not move forward.

You cannot walk on water, but water does provide an upward force on you when you swim in it. This upward force is called buoyancy, and it is the force that enables you, and ships, to float.

FIGURE 3.5 You use contact forces when tying your laces, squeezing out toothpaste and unscrewing a bottle.

Forces can occur even between two objects that are not touching each other. These forces are called indirect or **non-contact forces**. Like all other forces, indirect forces can affect the motion of an object — they can get the object moving, slow it down or stop it altogether.

Gravity is an example of an indirect force. We can see the effects of the force of gravity pulling on an apple when it falls from a tree. The force of gravity acting on us is often called our weight. Gravitational forces also keep the Moon orbiting Earth and the planets in our solar system orbiting the Sun.

Magnetic forces are indirect forces as well. These forces act between two or more magnets, or between magnets and some metals, such as iron. **Magnets** have two ends or **poles**. When two magnets are brought close, they either **attract** (pull) or **repel** (push) each other, depending on the positions of their poles.

Electrostatic forces sometimes cause your hair to stand on end immediately after you pull off a jumper or after brushing your hair. When this happens, strands of hair repel each other without them making contact, so this is another example of an indirect force.

FIGURE 3.6 You may experience an electrostatic force when you brush your hair. Electrostatic forces are indirect forces.

FIGURE 3.7 When two north poles of a magnet repel each other, they apply indirect forces on one another.

3.2.3 Measuring forces

The standard unit for force is the **newton (N)**, which is named after Sir Isaac Newton (1643–1727), an English physicist famous for his discoveries about how forces affect motion. He was also the author of many scientific laws about light and astronomy.

A **spring balance** (or newton meter) is a device used to measure the magnitude (size) of forces. In it, an internal spring stretches as a force is applied to the spring balance, and we can read the force (in newtons) on the scale provided. Spring balances that contain stronger springs can measure larger forces. More sensitive spring balances have weaker springs and measure smaller forces.

FIGURE 3.8 A spring balance, also called a newton meter, is used to measure the size of a force.
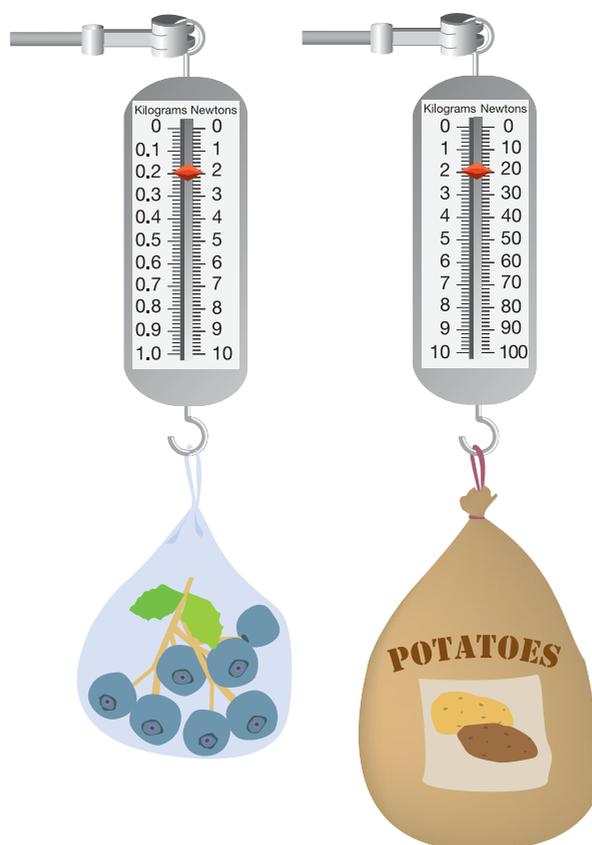
INVESTIGATION 3.2

Measuring forces

Aim

To select and use an appropriate spring balance to measure a range of forces

Materials

- spring balances ranging in capacity from 1 to 50 N
- 3 rubber bands of different thickness
- 3 masses from 100 g to 500 g, each with a ring attached

Method

1. Familiarise yourself with each of the spring balances. Examine the scale printed on each spring balance and the stiffness of the spring within.
2. For your spring balance to measure the size of a force accurately, each spring balance must read zero newtons when no force is applied. If this is not the case, ask your teacher how to 'zero' your spring balance. This means calibrating it to read zero at the start.
3. Select the thinnest rubber band and the spring balance that measures the smallest force.
4. Work in pairs. While one student holds an end of the rubber band, a second student attaches the spring balance to the other end and stretches the rubber band (but don't stretch it to its limit).
5. Measure the force needed to stretch the rubber band by reading the value on one of the spring balances. If the reading hits the end of the spring balance's scale, select one that has a greater capacity. Record your value in a suitable table.
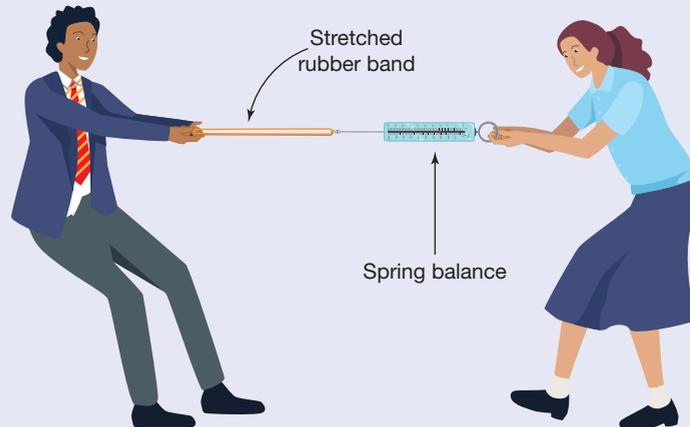6. Repeat steps 4 and 5 with the thicker rubber bands. You will need to select a different spring balance with a scale that suits the size of the new force.
7. Now measure size of the force needed to lift each of the masses, from smallest to largest, and record your results in a suitable table.

Stretched rubber band

Spring balance

Results

1. Design a suitable table and record the forces needed to stretch each of the rubber bands. Be sure to include the correct units of measurement.
2. Record the forces needed to lift each of the masses. Include the correct units of measurement.

Discussion

1. Compare the spring balances used in your investigation. Do the spring balances with the stiffer springs measure bigger forces or smaller ones?
2. What can happen if you select the incorrect spring balance to measure the size of a force?
3. A spring balance reads 1.0 N before it is used. Once a force is applied, it measures 12.5 N. What size was the actual force? Explain.

Conclusion

Explain how spring balances of different capacity differ and why it is important to select the most suitable spring balance to measure a force.

3.2.4 Forces and energy

Forces and energy are closely related. When you apply force to an object, you can change the amount of energy that object has. The type of energy that an object gains or loses, depends on the force applied.

For example, by applying a force to lift an object, you increase its **gravitational potential energy**. By applying a force to catch a basketball, you cause it to lose **kinetic energy**. When you apply a force to stretch an elastic object like a spring or rubber band, you increase its **elastic potential energy**. Each of these types of energy will be discussed in more detail later.

Objects that have more energy can generally apply more force on other things. For example, a stretched rubber band can pull objects with greater force. Objects that fall from a greater height will hit the ground with greater force and can cause more damage.

FIGURE 3.9 The force pulling the car up the roller coaster increases the car's gravitational potential energy.

FIGURE 3.10 By applying a force to stretch a spring, you are increasing the spring's elastic potential energy. A stretched spring will in turn apply more of a force on your fingers.

FIGURE 3.11 The force used to catch and stop a moving ball reduces its kinetic energy.

KEY IDEAS

Applying a force to an object can result in a change in the amount of energy that object has. Objects that have more energy can also apply a greater force on other objects around them.

EXTENSION: Work

Energy is defined as the ability to do work, so an object with more energy can do more work. Work is also done to increase the energy of an object. When you lift a box off the ground, you are doing work. This involves applying a force over the distance that you raise the box. In doing so, the box gains energy in the form of gravitational potential energy.

So, by applying a force on an object you can increase its ability to do work, like stretching the bow in a bow and arrow. When you apply a force to stretch the bow back a small distance, you are doing work to increase its elastic potential energy. Objects with more energy have the ability to do more work and apply a force. Releasing the bow causes it to apply a force on an arrow. In this action, the bow is doing work to shoot the arrow forward, increasing its kinetic energy.

In scientific terms, work can be defined as a force applied over a distance, mathematically,

$$\text{Work} = \text{force} \times \text{distance}$$

INVESTIGATION 3.3

The energy and force in crater formation

Aim

To investigate the relationship between energy and force when a crater is formed

Materials

- a plastic tub filled with wet sand
- 35 cm ruler
- tape measure
- bamboo skewer
- fine felt-tip marker or pen
- steel ball (approximately 15 mm diameter)

Method

1. Place the plastic tub on the ground in a suitable position so that the metal ball can be dropped into it from a height.
2. Check the surface of the sand is wet enough so that if you make a shallow hole with your finger, the sand stays in place.
3. Using a fine pen or felt-tip marker, mark each millimetre from one end of your bamboo skewer up to 30 mm.
4. Level the surface of the sand.
5. Use a ruler to position the metal ball 20 cm above the surface of the sand.
6. Drop the stationary ball and measure the depth of the crater made in the sand. Record the height from which the ball was dropped, and the depth of the crater in the sand using the bamboo skewer.
7. Repeat steps 4 to 6, increasing the height of the ball by 20 cm each time to a height of 1.8 m. Remember to record three trials for each height and average crater depth.

Results

1. Record all your data in a single table.
2. Construct a line graph to demonstrate the relationship between the drop height of the metal ball (on the horizontal axis) and the average depth of the crater made (on the vertical axis). Draw a smooth line of best fit that best shows any trend in your data.

Discussion

1. What type of energy does the metal ball possess as it is raised?
2. How does increasing the height of the metal ball affect the ball's energy?
3. What force creates the crater in the sand?
4. Refer to your graph to describe the trend between the height of the metal ball and the crater depth.

Conclusion

Refer to your findings to describe the relationship between the energy of the metal ball and the force it applies on the sand when it is dropped.

3.2 Activities

learn on

3.2 Quick quiz **on**	3.2 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4	2, 3, 6, 7	5, 8

Remember and understand

1. **Define** the term 'force'.
2. **Identify** the three possible results of a force acting on an object.
3. **Identify**:
   a. two direct (contact) forces
   b. two indirect (non-contact) forces.
4. **Identify** the force that:
   a. causes your hair to stand on end when you pull a jumper off
   b. causes dead leaves to drop to the ground in autumn.
5. **Explain** how a spring balance can be used to measure force.

Apply and analyse

6. **Compare** a spring balance that measures up to 10 N with one that measures up to 50 N.
7. Copy the following table into your workbook. Complete it by thinking of one or two everyday examples of forces that produce the effect in the first column. You can complete your table with diagrams or words.

Effect	Examples of forces in everyday life
Starting motion	
Stopping motion	
Speeding up motion	
Slowing down motion	
Changing the direction of motion	
Changing the shape of an object	
Having no visible effect	

Evaluate and create

8. Air resistance is the force that results as objects move through the air. Is air resistance a contact or a non-contact force? **Explain** your answer.

LESSON 3.3 Friction forces in everyday life

LEARNING INTENTION

In this lesson you will describe the role that friction plays in everyday life and conduct practical investigations to investigate friction forces.

3.3.1 What is friction?

Have you ever tried to walk on an icy path? It's difficult to start moving because you can't easily push off from the slippery surface. Once you're moving, it's then hard to stop. Walking along a concrete path is much easier. The rough concrete provides far more friction than slippery ice, allowing a better grip.
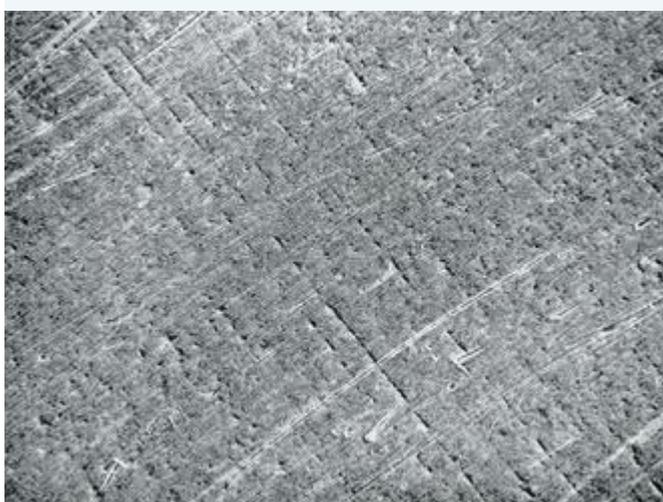
Friction is a force that opposes the movement of an object. It occurs between two surfaces that are in contact and sliding past each other. Objects travelling through air or water also experience friction.

Friction forces are particularly high if the surfaces in contact are rough. Small bumps on the surface of a rough object catch on bumps on the surface of the other object and slow down the movement.

FIGURE 3.12 A scanning electron microscope image of the surface of polished stainless steel. Even surfaces that seem smooth are actually rough and result in some friction.

Friction can act between any two materials in contact with each other. These two materials might be solids, as in the case of a car tyre and the road. Fluid friction, sometimes called drag, involves contact with a fluid or the air. Examples include the air drag on a fast-moving car or the fluid friction on a speedboat travelling through water.

The friction force between two surfaces, such as when you rub your hands together or sharpen a pencil, creates heat energy — remember energy and force are related.

KEY IDEAS

Friction is a force that opposes the movement of an object. Friction can act between any two materials in contact with each other. The surfaces might both be solids or, in the case of **fluid friction**, when a solid is travelling through water or through air.

Fluid friction

Any substance that is able to take up the shape of its container and can flow is called a **fluid**. Air and water are both fluids. Objects travelling through air and water experience fluid friction. Fluid friction in air is commonly called air drag or **air resistance**. The term 'drag' can also be applied to fluid friction in water. Air resistance on his parachute is what enabled Felix Baumgartner to decrease his speed quickly enough to land safely.

INVESTIGATION 3.4

The heat energy from friction

Aim

To observe the heat generated from the friction between two surfaces

Materials

- data logger
- temperature probe

Method

1. Work in groups of two or three.
2. Connect the temperature probe to the data logger.
3. Set the logger time to 15 seconds and the timing rate to 0.1 seconds (10 samples/second).
4. One student places the tip of the temperature probe in the centre of the two hands of another student who will be rubbing them together.
5. Start logging the temperature as the second student commences rubbing their hands together at a constant rate for at least 15 seconds.
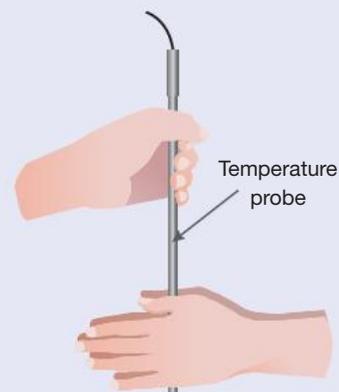
Temperature probe

Results

Record your results. You can either download and print the data table and line graph from the data logger or create a table yourself to record the temperature each second and plot your data as a line graph with a smooth curve of best fit.

Discussion

1. What evidence is there that friction generates heat energy?
2. Did the amount of heat energy created increase the longer the friction force acted? Refer to your graph when answering this question.
3. Why might you see someone rubbing their hands together on a cold winter's day?
4. Why do vehicles require car oil to reduce the friction between moving parts in a car engine?

Conclusion

Refer to your findings to explain how the friction between two surfaces affects the heat energy created when they are in contact.

CASE STUDY

Crickets use friction to make their familiar chirping sound. Generally, only male crickets do this. The sound is made by friction as they rub one wing across wrinkles on the underside of the other wing. It's a little like running your finger along the teeth of a comb.

FIGURE 3.13 Crickets produce their chirping sound using friction.

3.3.2 Friction — friend or foe?

Without friction, many of our daily activities would be almost impossible. We need the friction between our feet and the ground so that we can push off and start walking. It also means we can stop without sliding.

On a flat road, the friction between a tyre and the road is needed to start the car moving. Without it, the tyres would spin on the spot and the car wouldn't move. Tyres are designed with tread patterns to improve friction on the road.

ACTIVITY: PhET simulation — Friction

Access the **PhET simulation: Friction** interactivity in the Resources panel for a close up of how sliding one book over another causes the particles on the surface of each book to rub together and generate heat energy. What happens when you slide the book faster?

At times, friction can be a nuisance. Try sliding a heavy object across a rough surface. Before an object will move, you need to push or pull it with a force greater than the friction force.

Swimmers have to work hard to overcome the fluid drag of the water. In other sports, like motor racing, cars need to be specially designed to keep drag from the air as small as possible.

FIGURE 3.14 Aerodynamic testing can be done in a wind tunnel, or using computer modelling.

KEY IDEAS

This box on the left is easy to slide across the floor. Only a small force is needed to overcome the friction between the box and the floor as it is not heavy, and the floor is smooth.

The box on the right is much harder to push. A big force is needed to overcome the friction between the heavy box and the carpeted floor. The friction has increased because the bumps along the surfaces of the box and the floor are pressed together more tightly.

INVESTIGATION 3.5

Measuring the friction force

Aim

To compare the friction between different objects

Materials

- block of wood with hook attached
- range of masses (50–200 g)
- spring balance

Method

Part A: Comparing surfaces

1. Use a spring balance to pull a block of wood across your desktop. As long as you pull steadily, the reading on the spring balance will be equal to the force of friction on the moving block.
2. Record the friction force in a table (see Results section).
3. Repeat your measurement twice more on the desktop and calculate the average force of friction. Record all data in the table.
4. Repeat this procedure on several other surfaces of your choice. Surfaces that you might test are vinyl floor, carpet, doormat, concrete and bitumen. Record all data in the table.
5. Summarise your average results in a column graph.
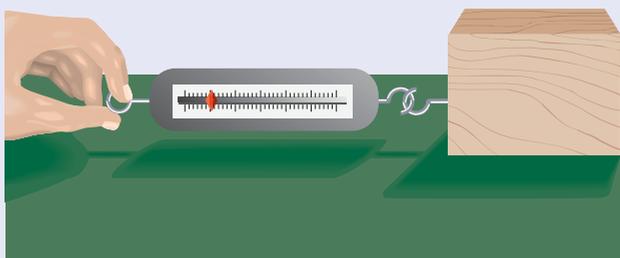
Part B: The effect of mass

Design and carry out an experiment to investigate the effect of mass of the object in contact with the ground on the size of the friction force. Record your results in a table and plot your data in a line graph to display any trends. Include a smooth line of best fit.

Results

Part A

Record all your data in a table like the one below. Display your average results in a column graph.

	Force of friction (newtons)			
	Trial			
Surface	1	2	3	Average

Part B

Record all your data in a table and plot your data in a line graph. Include a smooth line of best fit.

Discussion

1. List the surfaces in order, from greatest friction force to least.
2. What feature of a surface seems to determine the amount of friction?
3. For this investigation, identify:
   a. the independent variable
   b. the dependent variable
   c. two important control variables.
4. Why was it a good idea to repeat each measurement three times?
5. Do heavier objects experience more friction?

Conclusion

Refer to your findings to explain the factors that affect the amount of friction on a moving along a surface.

CASE STUDY: *Columbia*

The dangers of the high friction re-entry of spacecraft into the atmosphere were highlighted in 2003 when the space shuttle *Columbia* broke up 16 minutes before it was due to land. All seven crew members were killed. This tragedy is believed to have been caused by minor damage done to some of the ceramic tiles on the shuttle's surface during launch. This left a very small part of the surface unprotected from the high temperatures caused by friction. The resulting fire quickly reached *Columbia*'s fuel tanks, causing a huge explosion.

FIGURE 3.15 Damage to *Columbia*'s ceramic tiles was believed to have caused it to overheat and explode on re-entry in a tragic incident in 2003.

3.3.3 Reducing friction

Friction is useful if you want to get moving or if you want to stop. However, friction is a problem for moving parts in machines and other equipment. Wheels, like those on a skateboard, need to move freely around an **axle**. To achieve this, steel balls, called **ball bearings**, are inserted into the hub of the wheel. The bearings help the wheel roll around the axle, rather than slide over it. The rolling motion of the ball bearings helps to reduce friction — rolling objects experience less friction than sliding objects.

Lubricants, such as grease, can be applied to the ball bearings to reduce friction even further. The grease provides a slippery layer between the surfaces so that they move more easily.

Like rolling friction and sliding friction, fluid friction acts against the motion of objects. Fluid friction limits the speed of objects travelling through air and water. It increases the amount of fuel needed by cars, planes, motorised boats and submarines.

Cars, planes, watercraft and bicycles are **streamlined** to reduce fluid friction. The faster a vehicle needs to travel; the more important streamlining becomes. Some athletes even shave their bodies to streamline them.

Friction between joints in the human body must be minimised to reduce wear and tear. Your joints contain a lubricant called synovial fluid to help stop bones from scraping against each other.

FIGURE 3.16 Ball bearings help to reduce friction between the axle and the wheel hub of a skateboard.

Wheel

Axle

Wheel hub

Axle
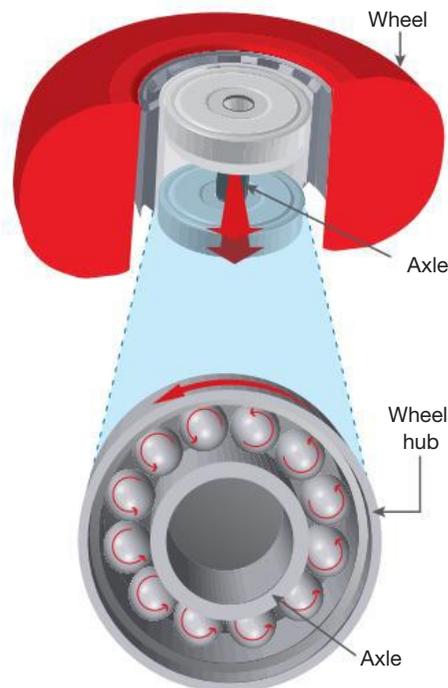
FIGURE 3.17 To reduce air drag, cyclists use equipment so they are as streamlined as possible.

FIGURE 3.18 Synovial fluid lubricates joints, like this one in the knee, and so reduces friction.

Muscle

Synovial cavity

Joint capsule

Synovial membrane

Tendon

Bone

Joint head

Articular cartilage

Socket
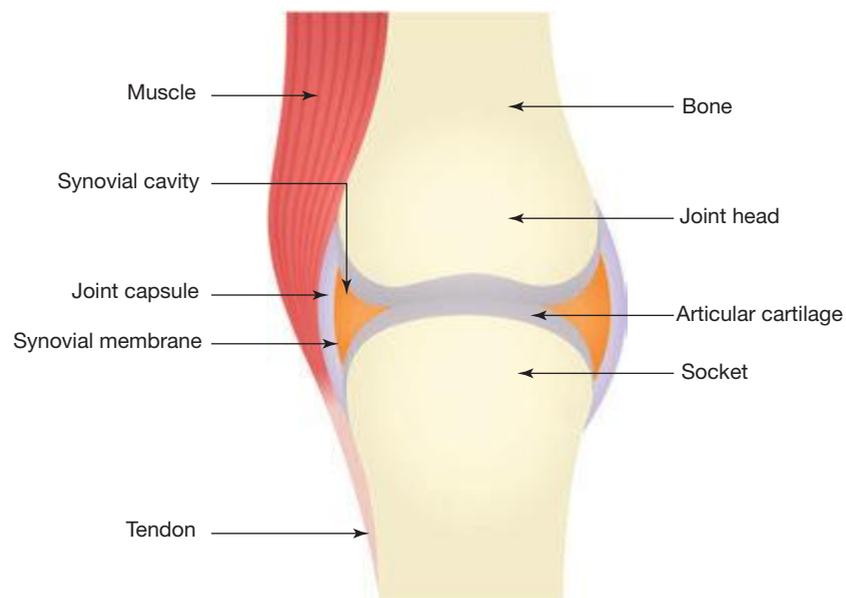
INVESTIGATION 3.6

Shoes and friction

Aim

To compare the friction of a variety of shoes

Materials

- a range of shoes
- spring balance
- electronic scales

Method

1. Design an experiment to compare the friction of a variety of shoes with a particular floor surface.
2. Collect a variety of shoes to test. Include different brands of school shoes and runners.
3. Identify the equipment you will need to measure the friction that exists between each shoe and a particular floor surface.
4. Collect information about each shoe to be tested, such as length, mass, sole material and tread.
5. Write up the method used in your investigation using a scientific report format.

Results

1. Record your results in a suitable table.
2. Construct a graph to display your results — think about what type of graph is most appropriate.

Discussion

1. Rank the shoes tested from having most friction to least friction.
2. Analyse the features of each type of shoe to explain why some shoes had more friction.
3. Identify the variables that you controlled in this experiment and the variables that you would have liked to control but could not.

Conclusion

Refer to your findings to compare the friction in your range of shoes and describe the features that contributed to the friction of the shoes.

3.3 Activities

learn on

3.3 Quick quiz on	**3.3 Exercise**

Learning pathways

■ **LEVEL 1**	■ **LEVEL 2**	■ **LEVEL 3**
1, 6	2, 3, 4, 7, 8	5, 9, 10

Remember and understand

1. **Define** the term 'friction'.
2. **Identify** the name of the friction force that acts on an object moving through the air.
3. **Explain** why friction is important when you walk.
4. **List** three ways in which friction can be reduced. Give an example of each method.
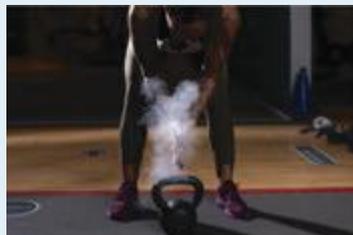5. What is fluid friction? List some situations in which it occurs.

Apply and analyse

6. Motorists are advised that they will waste fuel if their tyres are under-inflated. **Explain** why.
7. For each of the situations represented below, **state**:
   i. how the friction force is being helpful
   ii. what would happen if the friction force was absent.

(a)

(b)

(c)

8. For each of the situations represented below, **state**:
   i. how the friction force is being a nuisance
   ii. what could be done to reduce the effect of the force of friction

(a) (b) (c)

Evaluate and create

9. Olympic swimmers often wear smooth, tight-fitting suits so they are as streamlined as possible as they swim through the water. Some of them even shave their heads. Name one other sport in which athletes attempt to reduce friction and outline how they do so.

10. Match the different car tyres on the left with the weather and driving conditions.

A. Summer tyres Harder rubber compound and shallow tread provide optimal friction on dry roads but can lose grip in wet or cold conditions.	**1.** Dry and warm conditions.
B. Winter tyres Softer rubber and deep tread with sipes increase friction on snow and ice by gripping uneven surfaces and displacing snow.	**2.** Muddy or uneven terrain.
C. All-season tyres Balanced design offers moderate friction in most conditions but lacks specialised grip in extreme weather (snow or heat).	**3.** Rainy or wet conditions.
D. Wet-weather tyres Grooves and channels effectively reduce hydroplaning, maintaining high friction on slippery, water-covered roads.	**4.** Snowy, icy, or cold conditions.
E. Off-road tyres Aggressive tread patterns maximise friction on loose and uneven surfaces like mud, sand, or gravel, enhancing traction.	**5.** Dry, high-speed conditions.
F. Performance tyres Optimised for maximum friction at high speeds on dry roads, enhancing handling and stability in controlled environments.	**6.** Moderate year-round conditions.

LESSON 3.4 Analysing forces

LEARNING INTENTION

In this lesson you will use force diagrams to model balanced and unbalanced forces and analyse force diagrams to make predictions.

3.4.1 Representing forces

Force diagrams can be used to model situations where there are multiple forces acting. In these force diagrams, arrows are used to represent the forces. The direction of the arrow shows which way the force is acting, while the length of the arrow shows how large the force is. A long arrow represents a larger, stronger force than a short arrow.

Force arrows are **drawn to scale** to allow them to be compared and analysed. For example, if a force is applied to an object is three times greater than a second force on it should be drawn three times longer.

In force diagrams, the arrows that represent forces acting on an object should be drawn from the object's **centre of gravity**. All objects, including your body, have a centre of gravity. Picture a point in your body where your weight would be concentrated if your body was a single point. Your body's centre of gravity is about bellybutton height when you are standing.

Force diagrams can be used to model the horizontal forces involved in sliding a box along the ground. If the push force needed to slide the box along the ground is 80 N on rough concrete surface, but only 40 N on a smooth timber floor, then we represent the force needed on the concrete floor as an arrow, double the length of the arrow for the box on the timber floor but in the same direction.

In this scenario, friction is also involved. The friction force on the concrete surface is 50 N, which is five times greater than the 10 N friction for the smooth timber floor. The lengths of the arrows used to represent these forces are also drawn to scale.

3.4.2 Balanced and unbalanced forces

Forces act on us when we are moving and even when we are not. More than one force is acting on us at any given time — these forces can be **balanced** or **unbalanced**.

To determine if forces are balanced or unbalanced, we add all the forces acting on an object. If examining horizontal motion, then we only add the horizontal forces. If looking at motion vertically, we only focus on the vertical forces.

Forces are balanced if *the sum of all the forces is zero*. Forces are unbalanced if the sum of the forces is not zero.

When forces are *balanced, an object's motion will remain unchanged*. This means if the object is stationary, it will remain stationary. If the object is already moving, it will remain at the same speed and not slow down or speed up or change direction.

If forces are *unbalanced, the object's speed and/or direction will change*. This means if the object is stationary, it will start moving. If the object is already moving, it will speed up, slow down or change direction. It may even change both speed and direction.

FIGURE 3.19 Force diagrams.

Explain whether you expect the cyclist to speed up, slow down or travel at the same speed.

Explain whether you expect the dog to speed up, slow down or travel at the same speed.

100 N air drag

300 N cycling force

200 N walker's pulling force

100 N dog's pulling force

Explain whether you expect the high jumper to speed up, slow down or travel at the same speed horizontally and vertically.

700 N jumping force

500 N running force

100 N air drag

600 N air drag
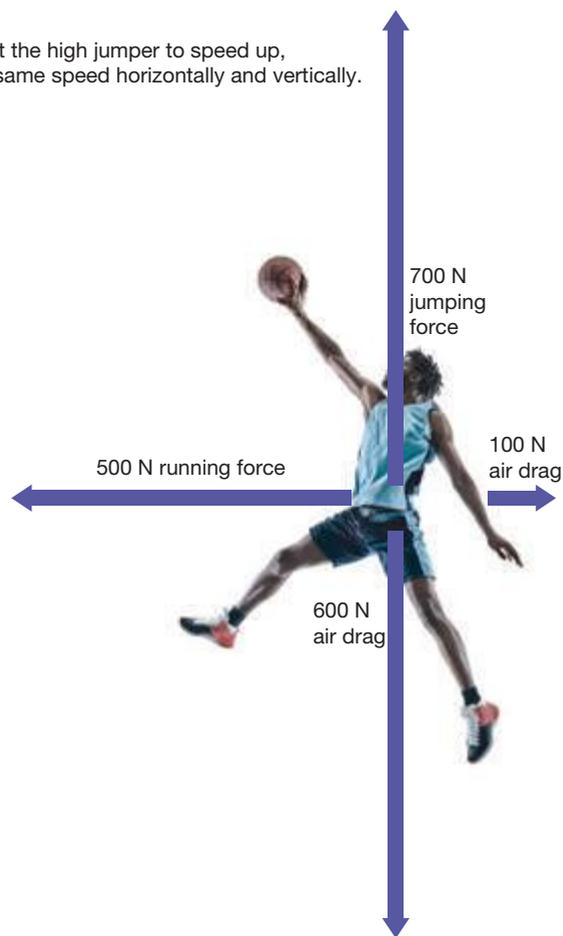
The arrows modelling the vertical forces acting on the kayaker in figure 3.20 are the same length. This shows that the forces are the same size. But these forces are acting in opposite directions. The force of gravity pulls down on the kayaker, while the buoyancy force of the water pushes up. The two forces are balanced so the kayaker does not move up or down.

FIGURE 3.20 Balanced vertical forces and unbalanced horizontal forces on a kayaker.
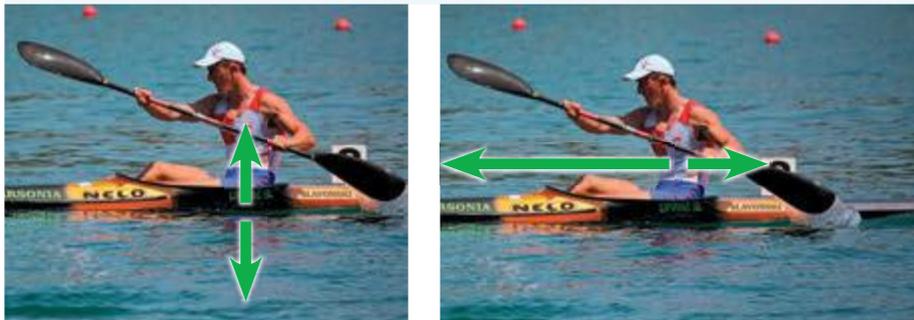
The arrows modelling the horizontal forces on the kayaker are not the same length. The forward force comes from the kayaker using a paddle to push forwards. The backward force is the **drag** from the water slowing the kayak down. These forces are unbalanced.

Unbalanced forces cause objects to speed up, slow down or change direction. The forward force is larger than the backward force, so we can predict that the kayaker and kayak will speed up in the forwards direction.

In the situation shown in figure 3.21, when modelling the forces on the cyclist and bike, both vertical and horizontal forces are involved. In this case the vertical forces are balanced but there are unbalanced horizontal forces. This means there is no change in motion vertically, but horizontally, the bike speeds up.

FIGURE 3.21 Modelling the forces on a cyclist and bike
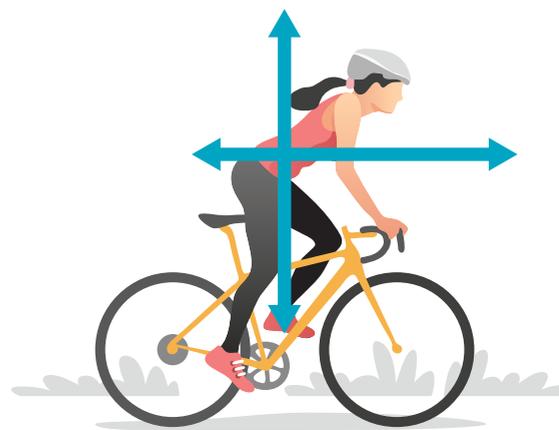
EXTENSION: The net force

The sum of the forces acting on an object is called the **net force**. When forces are balanced, the net force is zero. If the net force is not zero, the forces acting are unbalanced and the object's change in speed and/or direction will result from the size and direction of the net force.

FIGURE 3.22 These forces are unbalanced. Why? Which way is the seesaw moving?

ACTIVITY: PhET simulation — Balancing act

Access the **PhET simulation: Balancing act** interactivity in the Resources panel to observe how different masses can be used to balance the forces on a seesaw.

WORKING SCIENTIFICALLY: Identifying questions and planning an investigation

Asher's older siblings are scuba divers, and he has noticed that they have dive belts with weights on them. They explain that it is to counteract buoyancy and make it easier for them to stay underwater.

Asher is interested in how much additional weight is needed to sink an object that would otherwise float. His siblings explain that the size of the upward buoyancy force acting on a body partially or totally in water is equal to the difference between the mass of the submerged object and the mass of the volume of water displaced.

Identifying questions: Identify a testable question in relation to the volume of a floating object, such as a sealed container filled with air, and the additional mass it required to sink.

Planning an investigation: Plan an scientific investigation to test your question.

WS **SC4-WS-02** Identifies questions and makes predictions to guide scientific investigations

WS **SC4-WS-03** Plans safe and valid investigations

ACTIVITY: Balanced or unbalanced?

Explain whether you expect the person in figure 3.23 to speed up, slow down or travel at the same speed both horizontally and vertically.

FIGURE 3.23 A basketball player has several different forces acting on them when they jump to shoot the ball.
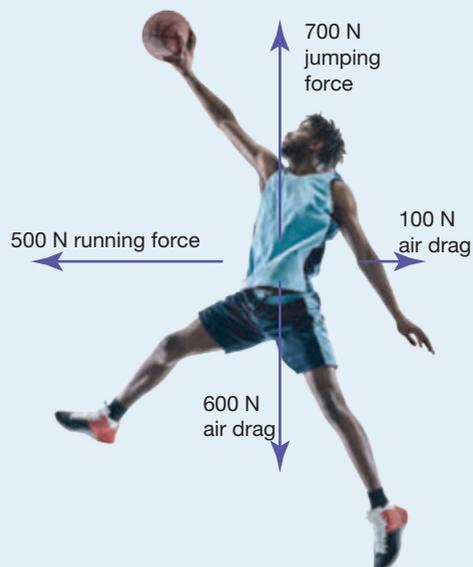
CASE STUDY: Safer cycling

Every year in Australia, around 1200 people die as a result of road crashes. Many of the deaths and injuries can be avoided.

Bicycle riders account for over one-third of the road crash injuries in people aged up to 16 years. The most serious injuries tend to be to the head and face. The wearing of bicycle helmets has greatly decreased the number of head injuries to cyclists.

A bicycle helmet has a layer of polystyrene foam at least one centimetre thick inside a shell of hard plastic. A cyclist's head falling to the road hits the ground at speeds of up to 20 kilometres per hour. Without a helmet, a sudden impact with the ground can cause serious head injuries. With a helmet, the impact force on the head is smaller as the plastic shell and polystyrene foam are crushed, and so the injuries are less severe.

FIGURE 3.24 A bicycle helmet is required by law in Australia.

FIGURE 3.25 The plastic shell and polystyrene foam of a helmet reduce the impact on the head in an accident.
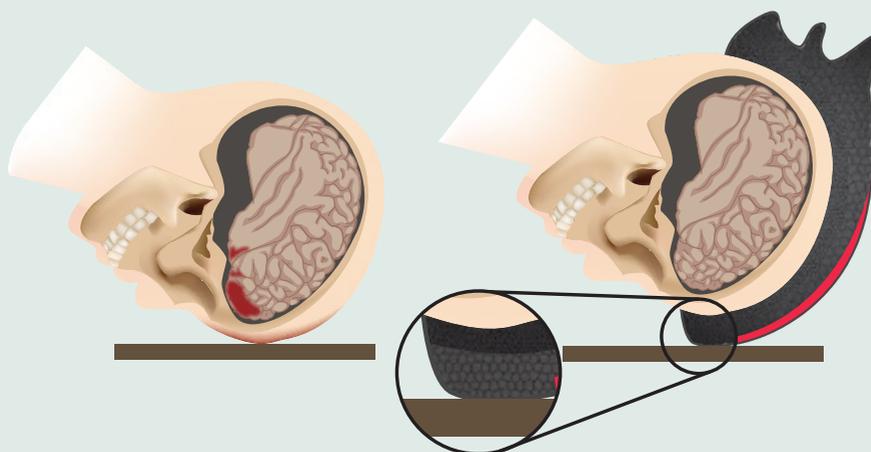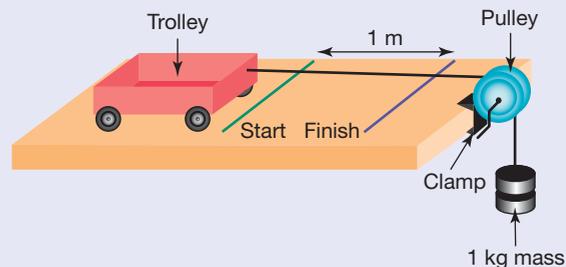
INVESTIGATION 3.7

Balanced and unbalanced forces

Aim

To model balanced and unbalanced forces

Materials

- a mass carrier and 50 g masses
- a 500 g or 1000 g mass
- string
- a motion car (trolley)
- flat surface, e.g. plank of wood
- a strip of high friction surface, e.g. carpet, corrugated cardboard or sandpaper
- a pulley and vertical clamp

Method

1. Clamp the pulley to the end of a flat surface such as a plank of wood or benchtop.
2. Place the motion car on the flat surface with the heavy mass placed on it securely.
3. Attach one end of a length of string securely to the mass carrier without any additional masses and run the string through the pulley.
4. Attach the other end of the string securely to the motion car. The string should be long enough to allow the suspended mass to reach the ground if the car just reaches the pulley.
5. Roll the car back to a position at the far end of the track.

You will be making observations and using force diagrams to model each of the following scenarios.

Scenario A: Small pulling force

Give the car a gentle nudge and observe whether the car speeds up, slows down, or travels at a constant speed **after** you have given it a nudge.

Scenario B: Medium pulling force

- Roll the car back to a position at the far end of the track.
- Add two 50 g masses to the mass carrier.
- Give the car a gentle nudge and observe whether the car speeds up, slows down, or travels at a constant speed **after** you have given it a nudge.

Scenario C: Large pulling force

- Roll the car back to a position at the far end of the track.
- Add another two 50 g masses to the mass carrier.
- Give the car a gentle nudge and observe whether the car speeds up, slows down, or travels at a constant speed **after** you have given it a nudge.

Scenario D: High friction surface

- Increase the friction along the track. This could be done by placing a strip of carpet, corrugated carboard or sandpaper on the track.
- Roll the car back to a position at the far end of the track.
- Give the car a gentle nudge and observe whether the car speeds up, slows down, or travels at a constant speed **after** you have given it a nudge.

Results

Record your observations for each of the four scenarios.

Discussion

1. Were the forces balanced in each scenario? How do you know?
2. For each of the four scenarios, represent all the horizontal forces on the car (using arrows) **after** you had given the car a nudge. Label the force represented by each arrow. While you did not measure the size of each force, the relative size of each of your arrows should indicate clearly whether the forces were balanced and, if not, which force was greater.

Conclusion

Refer to your findings to explain how force diagrams allow you to model the balanced or unbalanced forces in each of your scenarios and to explain whether an object will speed up, slow down or travel at a constant speed.

3.4 Activities

learn on

3.4 Quick quiz **on**	3.4 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2	3, 4, 5, 6, 7	8, 9

Remember and understand

1. When you flick a coin so that it slides across a table, it slows down.
   While your finger is still pushing the coin, there are four forces acting on the coin. What are they?
2. How many forces are acting on the coin after your finger stops pushing?
3. There are four forces acting on the person in the diagram.
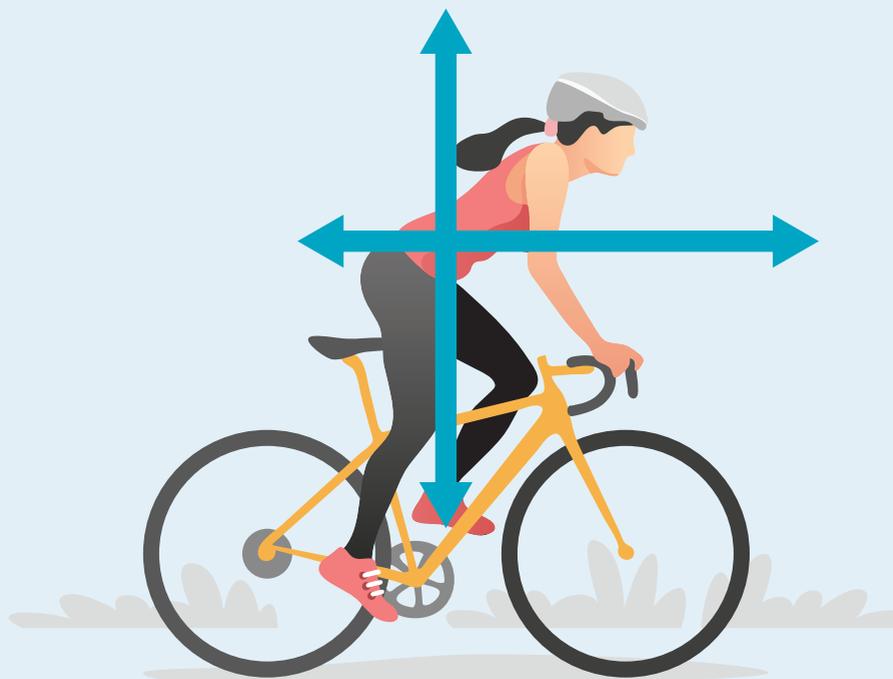
   Identify which forces are balanced.
4. **Identify** which forces are unbalanced.
5. Is the rider's speed increasing, decreasing or constant?

Apply and analyse

6. Draw force arrows to show the forces acting when the cyclist is slowing down.
7. 'A car is travelling in a straight line at a constant speed and so does not have any forces acting on it.' **Explain** why this statement is false.
8. A cricketer hits a ball in the air. Are there forces acting on the ball while it is in the air? **Explain** your answer.

Evaluate and create

9. Copy and complete the following table by thinking of an everyday example of a force for each of the effects of forces given. The first one has been done for you.

Effect	Examples in everyday life
a. Starting motion into the back of a friend on a swing	Pushing your hands
b. Stopping motion	
c. Speeding up motion	
d. Slowing down motion	
e. Changing the direction of motion	
f. Changing the shape of an object	
g. Having no visible effect	

LESSON 3.5 Gravitational forces and weight

LEARNING INTENTION

In this lesson you will describe the gravitational forces acting between objects and calculate weight forces.

3.5.1 Gravity everywhere

Gravity is the force that causes a ball that is thrown up into the air to fall back down to the ground. All objects are attracted to Earth due to this gravitational force. If you drop a stationary object, it will fall vertically to Earth's surface. Objects that are fired horizontally follow a curved path because, over the time it takes for them to hit the ground, they have travelled some distance horizontally.

FIGURE 3.26 All objects eventually fall to the ground due to gravity.
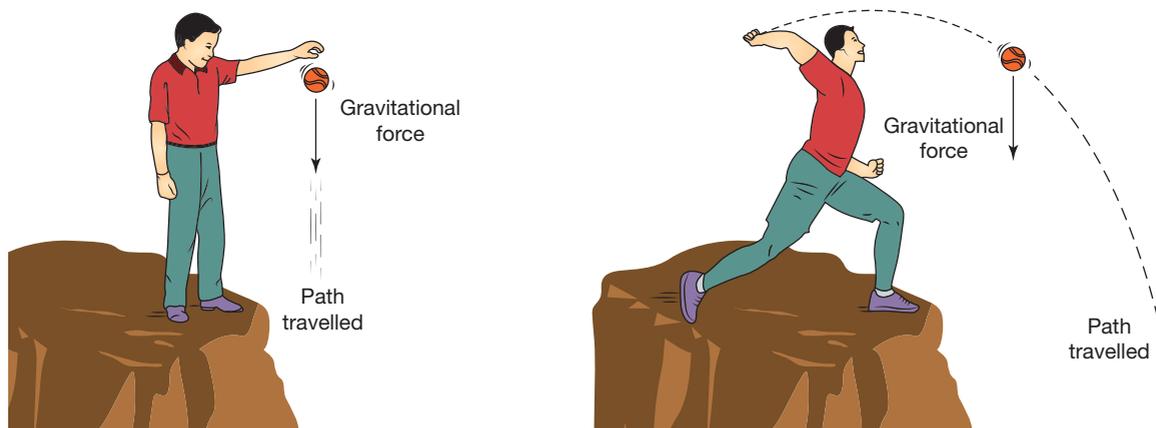
Gravitational forces are present throughout the Universe, holding the Moon in orbit around Earth, as well as Earth in orbit around the Sun. Gravity a force that acts between any pair of objects, whether they are in contact or not. It is therefore an example of an indirect force.

If it weren't for gravity, the Moon would fly past us. The gravitational attraction between Earth and the Moon keeps the Moon in orbit around Earth.

FIGURE 3.27 The Earth's gravitational force keeps the Moon in orbit around Earth and the Sun's gravitational force keeps Earth and the other celestial bodies in the solar system in orbit around the Sun.

No matter how large or small, all objects attract each other with a gravitational force. Gravity is actually a very, very small force. Even though all objects are attracted to each other, the effect is felt only when at least one of the objects is **massive** — as massive as a planet, moon or star. The bigger the mass of an object, the greater the gravitational force it pulls with.

The force of gravity between you and a wall is very small because both you and the wall have relatively small masses. You can't see the effect of gravity in this case. The force that attracts you to Earth and Earth to you is much bigger. You can see the effect of this force, especially if you fall! The gravitational force of Earth is directed towards the centre of Earth.

3.5.2 Weight and mass

You might be surprised to know that **mass** and **weight** are two different things. Mass measures how much matter an object contains. Regardless of where you are on Earth, the Moon or Mars, your mass does not change. Mass is usually measured in kilograms (kg), although other units such as tonnes and grams are often used.

Weight, on the other hand, is a measure of the size of the gravitational force pulling an object towards a massive object such as a planet, star or moon. Weight is a force so, like other forces, it is measured in newtons (N).

The weight of an object can be calculated if we know its mass and how quickly the object accelerates (speeds up) as it falls due to gravity using the following expression:

$$\text{Weight force} = \text{mass} \times \text{gravitational acceleration}$$

Using symbols for each variable: $F = mg$

where:
- F is the symbol for weight force, measured in newtons (N)
- m is the symbol for mass, measured in kilograms (kg)
- g is the symbol for acceleration due to gravity, measured in metres per second squared (m/s^2).
  On the surface of Earth, the acceleration due to gravity (g) is approximately 10 m/s^2.
  So, a student with a mass of 50 kg has a weight on Earth that can be calculated as follows:

$$F = mg$$
$$= 50 \text{ kg} \times 10 \text{ m/s}^2$$
$$= 500 \text{ N}$$

ACTIVITY: PhET simulation — Gravity Force Lab

Access the **PhET simulation: Gravity Force Lab** interactivity in the Resources panel for a close up of how gravitational forces relate to masses and distances between objects.

Like other forces, weight can be measured using a spring balance. The gravitational force on the object being measured pulls down on the spring and stretches it, moving the pointer over the scale to indicate its weight.

Wherever you go in the Universe your mass is always the same, but your weight depends on the size of the gravitational force acting on you. This gravitational force depends on your mass and:
- the mass of the planet, star or moon pulling on you. Your weight on Earth is greater than it would be on the Moon because Earth is so much larger than the Moon.
- how close you are to the object pulling on you. The weight of an astronaut, for example, decreases with increasing altitude.

KEY IDEAS

Mass measures how much matter an object contains and is usually measured in kilograms (kg).

Weight is a measure of the size of the gravitational force pulling an object towards the centre of a massive body such as Earth. It is measured in newtons (N) using $F = mg$, where m is the mass of the object in kg and g is the acceleration due to gravity at the object's location in m/s^2.

SAMPLE PROBLEM 1 An astronaut's mass

An astronaut on a Moon mission has a mass of 120 kg with his spacesuit. Calculate his mass and weight:
a. as he is about to launch from Earth
b. at an altitude of 400 km from Earth's surface where the acceleration due to gravity is 8.8 m/s^2
c. on the Moon where the acceleration due to gravity is 1.6 m/s^2.

THINK

The astronaut's mass does not change at each location as it is a measure of the amount of matter.
The astronaut's weight is calculated using $F = mg$.

a. At launch, on Earth's surface, the acceleration value is approximately 10 m/s^2.

b. At an altitude of 400 km, the acceleration value is 8.8 m/s^2.

c. On the moon, the acceleration due to gravity is 1.6 m/s^2.

WRITE

His mass in a, b and c is 120 kg.

$$F = mg$$
$$= 120 \text{ (kg)} \times 10 \text{ m/s}^2$$
$$= 1200 \text{ N}$$

$$F = mg$$
$$= 120 \text{ (kg)} \times 8.8 \text{ m/s}^2$$
$$= 1056 \text{ N}$$

$$F = mg$$
$$= 120 \text{ (kg)} \times 1.6 \text{ m/s}^2$$
$$= 192 \text{ N}$$

INVESTIGATION 3.8

Measuring weight

Aim

To investigate the effect of mass on weight

Materials

- 5.0 N spring balance
- mass carrier and 50 g slotted masses
- retort stand, bosshead and clamp

Method

1. Pull down on the hook of a 5.0 N spring balance until it reads 1.0 N. There are two forces acting on the hook. As long as the hook is not changing its motion, the forces are balanced. The tension force of the spring acting upwards is equal to the downward pull of your hand.
2. Pull the hook down until the spring balance reads 2.0 N. The downward pull has doubled.
3. Observe the effect of doubling the tension force on the distance that the spring has stretched.
4. Hang the spring balance from a clamp fixed to a retort stand and adjust the pointer so that it reads zero.
5. Attach a 50 g mass carrier to the hook of the spring balance and record its weight (in newtons) in a table, as shown in the Results section. Calculate and record the mass in kilograms by dividing the mass in grams by 1000.
6. Add 50 g masses, one at a time, until you have a total mass of 400 g. Each time, record the mass in kilograms and weight in newtons.
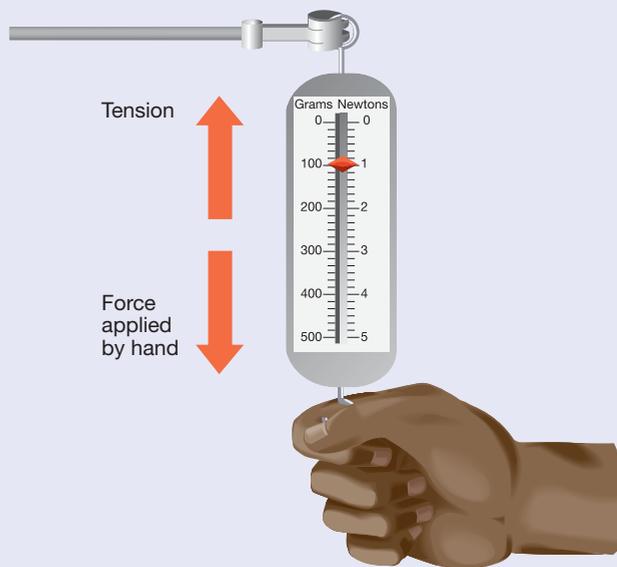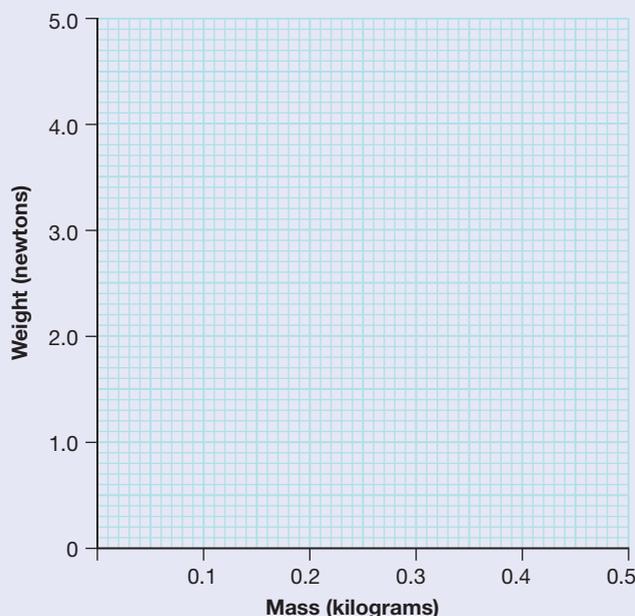
Results

1. Record all your results in a table like the one below.

Mass (g)	Mass (kg)	Weight (N)
50	0.05	
100	0.10	
150	0.15	

2. Use your results to construct a line graph using the axes below.

Discussion

1. When you doubled the tension force by pulling harder on the spring balance, what effect did this have on the distance that the spring stretched?
2. Did the spring increase its stretch by the same amount each time a 50 g mass was added?
3. How would your results be different if you had conducted this activity on Mars?
4. On your graph, draw a smooth line of best fit as close as possible to the points that you have plotted and continue your line to where you think it should be if you measured the weight of a mass of 500 g. This process is called *extrapolation*.
5. Is your line straight? Should it be straight?
6. What trend is revealed by your line graph as the mass suspended is increased?
7. What does your graph tell you should be the weight of a 500 g mass? Measure it and see how accurate your prediction is.
8. How could you predict the weight of an object if you knew its mass?

Conclusion

Refer to your findings to explain what the relationship is between the mass of an object and its weight. How can the weight of an object on Earth be calculated if we know its mass?

INVESTIGATION 3.9

The landing time of a parachute

Aim

To investigate the effect of one of the following variables on the landing time of a parachute
a. **Mass of the skydiver**
b. **Size (area) of the canopy**
c. **Shape of the canopy**

Materials

- plastic from freezer bags
- scissors
- large paperclips
- electronic scales
- plasticine
- stopwatch
- cotton or nylon thread
- metre ruler

Method

1. Use plastic from freezer bags to make a square canopy for the parachute. Cotton or nylon thread can be used to attach a model skydiver, which could be constructed using paperclips and plasticine.
2. Select a variable that you will investigate. This could be mass of the skydiver or the area of the canopy or the shape of the canopy.
3. Measure the variable that you are testing. For example, if you are varying the mass of the skydiver, use electronic scales to measure its mass. If testing the area of the canopy, measure the length of its sides and calculate the area. If varying the shape, a measurement may not be possible so record the shape used.
4. Keep all other variables constant except the factor that you are deliberately changing, so that your tests are fair. This is called **controlling variables**.
5. Release your parachute from a height of several metres and record the time taken to land.
6. Repeat your measurement of the landing time at least twice more and calculate an average. If your landing times vary considerably, you may need to repeat more often and exclude any results that reflect human error.
7. Investigate the variable you have chosen by changing the mass of the skydiver or the area of the canopy or the shape of the canopy. Make sure that you record the new skydiver mass or canopy area or canopy shape.
8. Repeat steps 5 to 8 for a range of skydiver masses or canopy areas or canopy shapes.

Results

1. Record the time taken to land for each trial and the average time taken in a table like the one below.

Measurements for variable tested	Time taken to land (s)			
	Trial 1	Trial 2	Trial 3	Average

2. If you have sufficient data, construct a graph to determine any trends in your results. If you investigated the mass of the skydiver or the parachute area, then a line graph would be appropriate as your data is 'continuous'. You will require at least 4 data points to demonstrate any trend. If you investigated the parachute area, your results are best displayed in a column graph as your data will be 'categorical'.

Discussion

1. What trend is evident in your findings? Can you explain the trend in your findings?
2. Analyse your results and comment on how your design could be improved.

Conclusion

Write a conclusion that explains the effect of one variable on the landing time of a parachute.

INVESTIGATION 3.10

### Motion due to gravity

Aim

To investigate the path taken by objects due to gravity

Materials

- tape measure or trundle wheel
- stopwatch
- equipment to fire a projectile forward, e.g. water rocket or projectile launcher
- ramp to launch a projectile at an angle, e.g. plank of wood

Method

1. Set your projectile launcher so that it can safely launch your projectile forward from an angle of approximately 20°.
2. Launch your projectile, being careful that other students are safely behind the launch position. If you can vary the speed at which your projectile is launched later, conduct this launch at a low speed.
3. Time how long it takes your projectile to land from the time it is launched.
4. Observe the path of the projectile and the height travelled by the projectile.
5. Measure the horizontal distance to the landing point from the launch position.
6. Try to maintain the same launch speed and angle while repeating steps 2 to 5 twice more. Calculate the average time of travel and distance travelled from your three trials.
7. If your equipment permits, increase the speed at which the projectile is launched and repeat steps 2 to 6.
8. Increase the launch speed further and repeat steps 2 to 6.
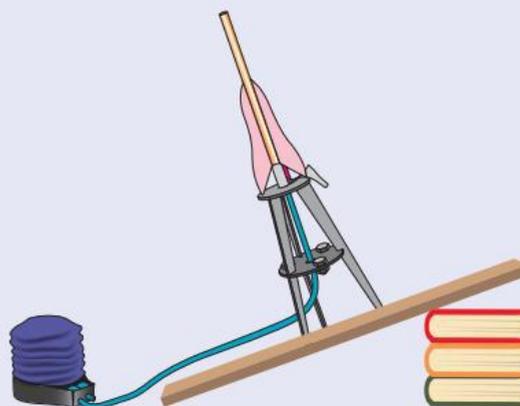
Results

1. Describe the shape of the path taken by the projectile each time.
2. Describe any changes observed to the height reached by the projectile as you increased the launch speed.
3. Construct a table to record the following data for each trial, including the average at each launch speed:
   - the time of travel
   - the distance travelled.

Discussion

1. Why did the projectile take the path observed? Refer to terms like gravitational force and acceleration.
2. Describe how the launch speed affects the projectile's time of travel, launch speed and height travelled.

Conclusion

Refer to your findings to explain what a projectile, launched upwards at an angle, takes and why it returns to the ground.

ACTIVITY: Gravitational fields

Use the **Gravitational fields** weblink in the Resources panel to observe the gravitational force between two massive planetary bodies. Investigate how the gravitational force between the bodies varies when you change the mass of each of the bodies and the distance between the two bodies. Describe your findings.

3.5.3 Balanced and unbalanced gravitational forces

Gravity is a force that is always acting on you. When you stand, this pull of gravity (also called weight) is balanced by the force of the ground pushing up. You may not notice this force, but after standing up a long time your muscles may be sore from supporting your weight. These balanced forces keep you stationary.

Unbalanced forces, however, cause objects to speed up, slow down or change direction. In bungee jumping, the two main forces acting on the jumper are the gravitational force pulling downwards and the bungee rope's elastic force pulling up. The staff managing the bungee jump select the right rope based on the jumper's size. Ropes have different thicknesses to suit the weight of each jumper.

FIGURE 3.28 Forces acting on a bungee jumper. The upward force increases as the rope stretches, eventually becoming greater than gravity, slowing the jumper to a stop. This causes the jumper to bounce upwards, reducing the elastic force of the rope. The jumper eventually stops when the elastic force of the rope is equal to the gravitational force.

Elastic force of the rope

Gravitational force (weight)
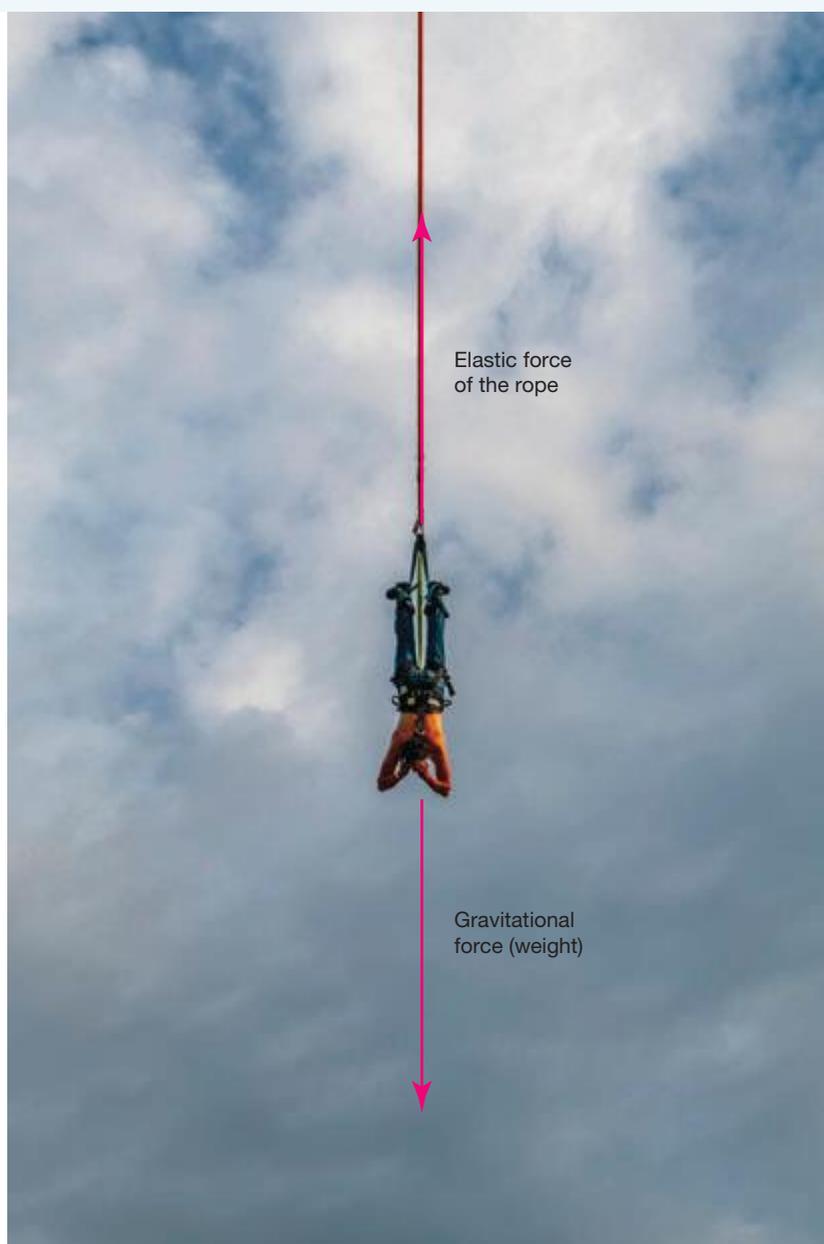
CASE STUDY: Forces involved in skydiving

There is something about falling through the air at 190 km/h that really gets the adrenalin pumping! Skydiving is an activity that is enjoyed by thousands of thrill seekers around the world and is an important part of military and rescue services.

1. Skydivers can jump from various heights, but most beginners jump from about 4 kilometres above the ground. When the plane is over the jump site, the skydiver leaps from the plane. Beginners are taught to release their parachute as soon as they are clear of the plane. More experienced divers freefall for some time before opening their parachute.

2. When skydivers jump from a plane, the Earth's pull of gravity causes them to fall with increasing speed towards the ground. Near the start of the jump, a diver does not fall very quickly. At this point in the jump, the diver does not experience much air resistance. But, as the diver's speed increases during the fall, so does the size of the air resistance pushing against them.

3. Skydivers can change the amount of air resistance pushing against them by moving their arms and legs and changing the position of their body. By lying flat, with their arms and legs out, divers increase the air resistance pushing against them. This position decreases their acceleration. With their legs straight up and their head down, a diver falls at a faster rate. This explains how one skydiver can catch up with another.

4. During a jump, a skydiver falls faster and faster. The air resistance pushing against a diver gets bigger and bigger as the speed increases. Eventually, the upward push of the air resistance and the downward pull of gravity are balanced. When this happens, the diver falls at a steady speed. This steady speed is called terminal velocity. The terminal velocity of a skydiver without a parachute is very fast. A diver could not land safely at this speed, so a parachute is needed.

5. When the parachute opens, a huge air-resistance force pushes against it. When the parachute first opens, the air resistance is larger than the gravity force pulling the skydiver down, so the diver slows down. The skydiver reaches a new, slower terminal velocity soon afer the parachute opens.

6. The skydiver lands safely at the drop zone.

3.5 Activities

learn on

| **3.5 Quick quiz** on | **3.5 Exercise** |

Learning pathways

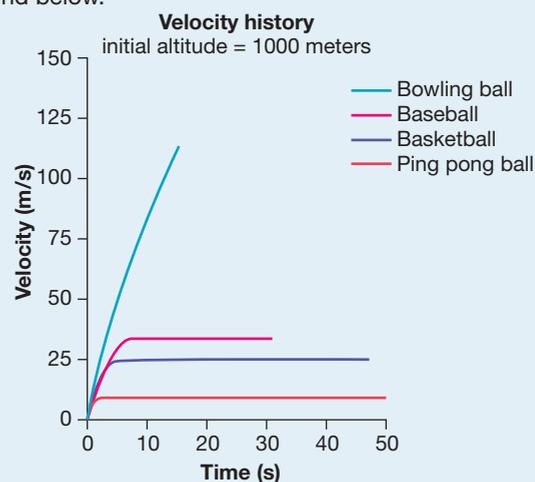| ■ **LEVEL 1**	■ **LEVEL 2**	■ **LEVEL 3**
1, 5, 8, 12	2, 4, 6, 9, 11	3, 7, 10, 13

Remember and understand

1. Describe the difference between mass and weight.
2. The force of gravity is not the same on all objects. On what property of each object does it depend?
3. If you were to land on Mars, what would change?
4. What is the weight on Earth of a person with a mass of 50 kilograms?
5. What is terminal speed?

Apply and analyse

6. If every object with mass pulls on other objects with a force of gravity, explain why you don't notice objects being attracted to you.
7. Answer the following
   a. On Earth, Belinda has a weight of 450 newtons. Calculate her mass.
   b. On the Moon, the gravity is around one-sixth that of Earth. What would you expect Belinda's weight to be on the Moon?
8. a. What three forces are acting on the bungee jumper on the opening page of this topic just before reaching the water?
   b. Which force is most likely to be the largest? Explain your answer.
9. When you drop a bowling ball and a feather from the same height in Earth's atmosphere, they reach the ground at different times.
   a. Explain why this is the case.
   b. If the bowling ball and feather were falling in a vacuum where there is no air resistance acting on them, which do you think will reach the ground first?
   c. Find out how the acceleration of a falling object is related to the force due to gravity acting on a falling object in a vacuum. Use your research to explain your answer to part **b**.

Evaluate and create

10. **SIS** Would a rubber band be as effective as a spring in a force measurer? Design an investigation that would allow you to find this out.
11. **SIS** A number of different balls were dropped from a height of 1000 m above the ground and their velocity recorded over time. A graph showing the results can be found below.
    a. Of the four balls, which reached its terminal velocity first?
    b. How long did it take the basketball to reach its terminal velocity?
    c. What was the approximate terminal velocity of the ping pong ball?
    d. Explain why some balls reached their terminal velocity faster than others.

Velocity history
initial altitude = 1000 meters

— Bowling ball
— Baseball
— Basketball
— Ping pong ball

12. Find out more about the contributions to science made by Isaac Newton. Write a brief report about his achievements other than his Law of Universal Gravitation.
13. Imagine that you are working in the first space laboratory on Mars. The pull of gravity is a little more than one-third of what it is on Earth. Write a diary entry or summary report for your very first working day in the laboratory. Your response should be an account of your day from 6 am when your alarm rings until 10 pm when you go to bed. Emphasise the effects of less gravity on daily activities.

LESSON 3.6 Forces and objects in orbit

LEARNING INTENTION

In this lesson you will use the concept of forces to describe the motion of objects in orbit.

3.6.1 Natural satellites

At night the Moon is clearly visible. Like the Sun, it rises in the east and sets in the west because the Earth rotates on its axis over a 24-hour period from east to west. The Moon's appearance changes over the course of a month. It passes through a series of **phases** from full Moon to new Moon and back again. This is because the amount of the Moon's surface bathed in sunlight changes as it orbits Earth.

FIGURE 3.29 Phases of the Moon
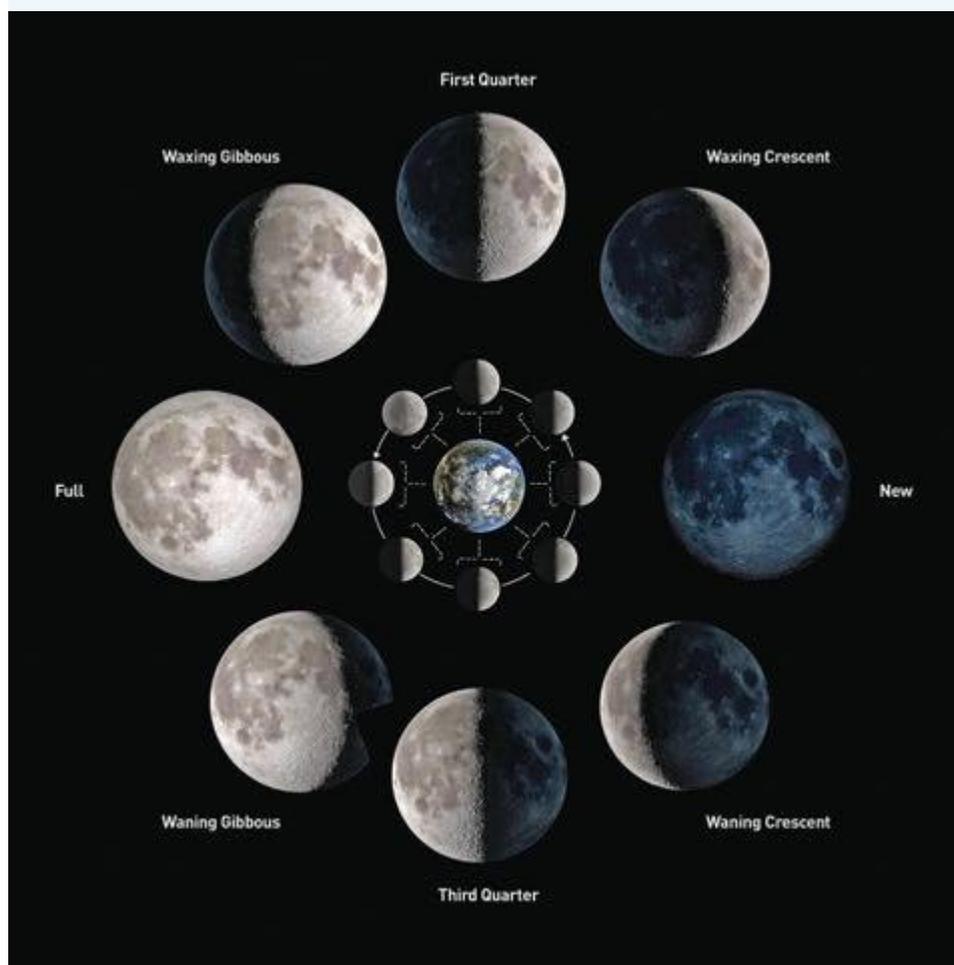
FIGURE 3.30 Earth and the Moon are both natural satellites. The Moon orbits Earth while Earth orbits the Sun.
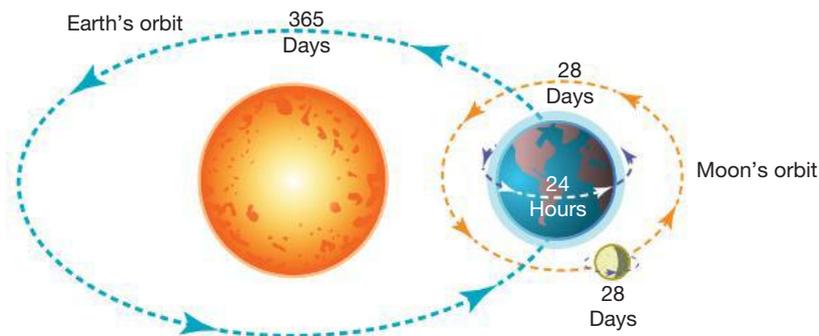
Both Earth and the Moon are examples of **satellites**. A satellite is an object that travels around another, generally larger body called the 'parent body' in a circular path called an **orbit**. Not all orbits are perfectly circular; some are slightly elliptical (oval). Earth completes one orbit of the Sun in 365.25 days while the Moon's orbit around Earth takes almost 28 days. Being naturally occurring objects, orbiting planets and moons are considered **natural satellites**.

Our calendar year consists of 365 days as it is based on the time it takes for Earth to orbit around the Sun. What about the remaining quarter day? Well, every four years an extra day is added to February to create a leap year of 366 days.

EXTENSION: Does the Moon rotate?

Although the appearance of the Moon changes as it passes through its phases, from Earth we view the same face of the Moon throughout the year. The far side of the moon is not visible from Earth. Some think this is because the Moon does not rotate (spin) as it orbits Earth. In fact, the Moon is spinning. It's just spinning at the same rate as its orbit and completes one revolution almost every 28 days. It's called 'synchronous rotation'.

Use the **How the Moon orbits Earth** weblink in the Resources panel to watch the video. Notice that the same side of the Moon is always facing Earth because the Moon completes one full rotation over the same time that it completes an orbit of Earth.

3.6.2 Artificial satellites

The first artificial (man-made) satellite to orbit the Earth, called *Sputnik 1*, was launched in 1957. Since then, thousands of artificial satellites have been launched into orbit. Many of those are communication satellites, relaying phone, radio and television signals between continents continuously.

FIGURE 3.31 A communication satellite in orbit around Earth.

FIGURE 3.32 The International Space Station (ISS) was launched in 1998 and orbits Earth at an altitude of approximately 400 km. At this altitude, the ISS completes an orbit every 93 minutes. It can carry up to seven crew who conduct experiments in a range of scientific fields.

3.6.3 Forces on satellites

Satellites in orbit travel in a circular path. This means that they are continually changing direction to maintain their distance from the body they are travelling around. Remember that a force, if unbalanced, will result in a change in motion, like a change in direction.

The force causing a satellite to remain in orbit is the **gravitational force**. In the case of a satellite orbiting around Earth, the gravitational attraction to Earth causes the satellite to continually change direction rather than fly off in the direction it was travelling. If the satellite is being pulled to Earth by gravity, why isn't it travelling down to Earth? It is because the satellite has sufficient speed to stay in orbit.

FIGURE 3.33 Satellites are attracted to Earth by a gravitational force but remain in orbit because of their speed.
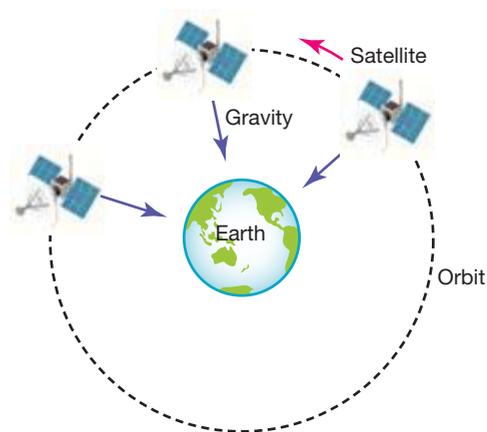
KEY IDEAS

A gravitational force keeps a satellite in orbit around a parent body. The gravitational force is directed towards the centre of the parent body. The speed of the satellite keeps it in a stable orbit, preventing it from spiralling inwards.

INVESTIGATION 3.11

Modelling the forces in orbit

Aim

To investigate the forces acting on an object in orbit

Materials

- 1.5 m length of nylon fishing line
- glass tube or empty biro case (about 15 cm long)
- rubber stopper with a hole in it
- mass carrier and 50 g slotted masses

Method

1. Tie the rubber stopper firmly to the end of the fishing line.
2. Thread the other end of the fishing line through the tube and attach it firmly to the mass carrier.
3. **Move to an area of the playground where you are several metres away from all other students to avoid risk of injury.**
4. Add a mass to the mass carrier and, while holding the tube well above your head, spin the stopper around in a circle so that it orbits at a constant radius from the tube, as shown below. **The hanging masses should not be moving up or down**. Record the radius of the orbit.
5. Now add another mass to the mass carrier and adjust the speed of the orbiting stopper to maintain the same orbiting radius.
6. Observe what happens if you slow down the speed of the orbiting stopper.

← hanger and masses
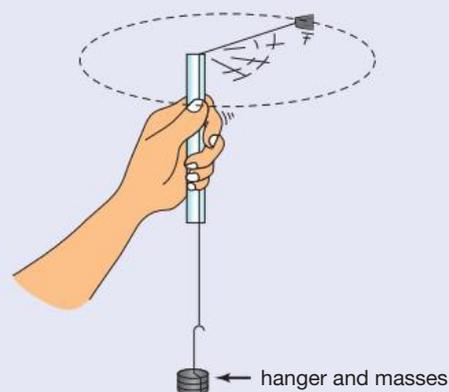
Results

1. What force causes the rubber stopper to stay in orbit?
2. When an extra mass was added to the mass carrier, how did you need to adjust the speed of the orbit to maintain the radius of the orbit?
3. What happened when you allowed the speed of the orbit to slow down?

Discussion

1. In this investigation, you modelled the force keeping a satellite in orbit. In this model:
   a. what did the rubber stopper represent?
   b. what did the force along the fishing line represent?
2. Label the diagram below with the direction of the force along the fishing line and the direction of travel of the stopper at each point in its orbit.
3. What did adding an extra mass to the mass carrier model? How did the speed of the rubber stopper need to change to maintain a stable orbit?
4. Explain what happened when you allowed the speed of the rubber stopper to slow down.
5. What would happen to the rubber stopper if the fishing line broke? Would it travel to the centre of the circle? Explain.
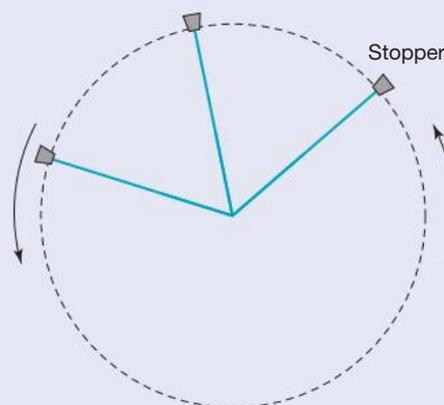
Stopper

Conclusion

Refer to your findings to explain what force acts on a satellite in orbit and what would happen to that satellite if the force suddenly stopped acting.

Scientific models

Scientists have developed a model of the solar system. They use this model to explain gravitational forces and the movement of celestial bodies.

Identify data and observations used by scientists to develop this model.

3.6 Activities

learn**on**

3.6 Quick quiz **on**	3.6 Exercise

Learning pathways

■ LEVEL 1 1, 2, 4	■ LEVEL 2 3, 6, 7, 8	■ LEVEL 3 5, 9, 10

Remember and understand

1. **Identify** the force that keeps satellites in orbit.
2. Why are the Moon and planets considered 'natural' satellites?
3. **Explain** why we view the phases of the Moon over the course of a month.
4. What bodies do each of the following orbit?
   a. The Moon
   b. Earth
5. In a single diagram, illustrate how both the Moon and Earth are natural satellites. In your diagram, show the Moon in position for a full Moon.
6. **Explain** why every fourth year is a leap year.
7. Why doesn't an orbiting object fall into the central body it orbits?
8. A student whirls a tennis ball attached to a piece of string around her head in a horizontal circle.
   a. **Explain** in terms of forces why the tennis ball travels in a circle.
   b. What would happen to the ball if the string broke?

Apply and analyse

9. **Explain** why a satellite in a low Earth orbit would travel at a faster speed than a satellite in a higher altitude geostationary orbit.

Evaluate and create

10. Refer to the data in the table below, showing key features of the planets in our solar system.

Planet	Period of orbit	Period of rotation	Gravitational force	Average surface temperature (°C)	Number of satellites
Terrestrial planets					
Mercury	88 days	59 days	0.38	−180 to 420	0
Venus	225 days	243 days	0.91	450	0
Earth	1 year	1 day	1.00	22	1
Mars	687 days	24.5 hours	0.38	−120 to −30	2
Gas giants					
Jupiter	12 years	10 hours	2.9	−140	At least 62
Saturn	29 years	11 hours	1.3	−170	At least 33
Uranus	84 years	17 hours	0.93	−210	At least 27
Neptune	165 years	16 hours	1.2	−220	At least 13

a. In Earth time, how long is a year on:
   i. Venus
   ii. Saturn?
b. In Earth time, how long is a day on:
   i. Mercury
   ii. Uranus?
c. Does the time taken for a planet to orbit the Sun depend on the distance from the Sun? **Explain your answer**.

LESSON 3.7 Electrostatic forces

LEARNING INTENTION

In this lesson you will describe the electrostatic forces exerted between objects.

3.7.1 Inside atoms

You might have felt static electricity when taking off a jumper. It can make your hair stand up on end or create little sparks that tingle. To understand static electricity, you need to know about **atoms** and the smaller subatomic particles they are made of.

The idea that all matter is made up of atoms originated in ancient Greece around 2500 years ago. Experiments done in the 1800s and 1900s provided evidence for the existence of subatomic particles that today we call electrons, protons and neutrons.

Scientists' understanding of the structure of atoms has helped them to explain how objects can acquire an electric **charge**. Benjamin Franklin, an American scientist in the 1700s, was the first person to use the term 'charge'. He also named the two charges: positive and negative. Like the poles of a magnet, they are opposite to one another.

FIGURE 3.34 Benjamin Franklin discovered the electrical nature of lightning.

3.7.2 Positive or negative charges

At the centre of each atom is a heavy **nucleus**. Surrounding the nucleus is a lot of empty space and tiny particles called **electrons**. Electrons are constantly moving around the nucleus. Each electron carries a **negative electric charge**.

Inside the nucleus are two different types of particles. The **protons** inside the nucleus are much heavier than electrons. Each proton carries a **positive electric charge**. The **neutrons** inside the nucleus are similar to protons but carry no electric charge. The positive electric charge of a proton exactly balances the negative charge of an electron. Atoms usually contain an equal number of electrons and protons.

Materials can be 'charged' and as a result any material that has more protons than electrons is said to be **positively charged**. Any material that has more electrons than protons is said to be **negatively charged**.

Any material that has equal numbers of electrons and protons is said to be neutral. The term 'uncharged' is also used to describe neutral materials.

FIGURE 3.35 A neutral atom contains an equal number of protons and electrons. (Some of the neutrons protons are hidden in this diagram of a carbon atom.) The number of neutrons is not always the same as the number of protons.
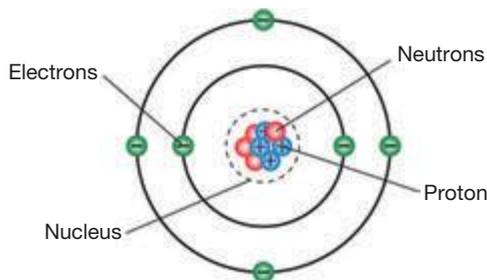
EXTENSION: The nucleus of an atom

The central part of the atom is called the nucleus. The nucleus is very small compared with the overall size of the atom. To give you an idea of the size of the nucleus compared with the whole atom, imagine this: If an atom was as big as the Sydney Cricket Ground, the nucleus would be the size of a marble placed at its centre.

3.7.3 Charge

Objects usually become charged by the addition or removal of electrons. This charge is called an **electrostatic charge** because, once an object gains an electric charge, it remains 'static' or stationary on that object. Only in conductors (mainly metals) do charges move through the object, creating a 'current' of charge rather than a static charge.

There are two ways that an object can gain an electrostatic charge: by friction or by contact with another object that is already charged.

By friction

Rubbing a neutral material against another can add or remove electrons. When you rub a plastic ruler with wool, for example, electrons from atoms on the surface of the neutral wool are forced onto the neutral plastic ruler. The plastic ruler, having gained negative electrons, becomes negatively charged. At the same time, the wool, having lost electrons, becomes positively charged.

By contact with a charged object

If a neutral material is touched by a charged object, electrons can be transferred from atoms on the surfaces of the two objects. When the charged object is removed, the previously neutral material has gained or lost electrons and so becomes charged itself. The student touching the dome in figure 3.36 becomes charged by contact and loses electrons to the dome. The student's hair stands on end, as the positively charged strands repel one another.

Electrons are the easiest particles to add to or remove from atoms, because they are not held tightly in the nucleus as protons are.

FIGURE 3.36 The Van de Graaff generator was first built in 1929. A static charge builds up on the dome. If a student touches the dome, their hair can stand on end because the strands of hair all carry like charge.

KEY IDEAS

Objects gain an electrostatic charge when electrons are gained or lost from it, often by friction with other objects.

INVESTIGATION 3.12

Electrostatic forces

Aim

**To investigate forces from electrostatic charge**

Materials

- two balloons
- light thread
- woollen cloth
- metre ruler

Method

1. Suspend one balloon from the metre ruler with light thread, as shown in the diagram.
2. Rub the balloon with a woollen cloth.
3. Remove the woollen cloth and then place it close to, but not touching, the part of the balloon that was rubbed. Observe any movement of the balloon.
4. Suspend a second balloon from the metre ruler so that it is close to, but not touching, the first balloon.
5. Rub each of the balloons on the surfaces that are facing each other with a woollen cloth.
6. Remove the cloth and position the balloons so that they are as close together as possible without touching each other. Observe any movement of the balloons.

Metre ruler

1 m

Light thread
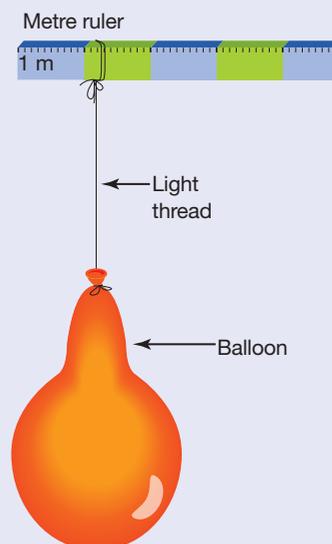
Balloon

Results

1. Describe the movement of the single balloon when placed near the woollen cloth after being rubbed by the cloth.
2. Describe the movement of the two balloons after each had been rubbed by the cloth.

Discussion

1. Explain what happened when the cloth was brought near the charged balloon.
2. Does the balloon have the same charge as the woollen cloth after it is rubbed? Explain.
3. Describe the movement of the two charged balloons when brought near each other. Do the balloons have like or unlike electric charges? Explain.

Conclusion

Refer to your findings to explain how electrostatic charges are produced and what force they exert between objects with like charge.

INVESTIGATION 3.13

The Van de Graaff generator

Aim

To investigate electrostatic charge

CAUTION: Your teacher will carry out this activity. Do not touch the charged dome of a Van de Graaff generator unless instructed to by your teacher. Always use an earthed rod to discharge. Carry out the demonstration while standing on a plastic tray.

Materials

- Van de Graaff generator
- several strands of wool
- plastic tray

Method

1. Turn the Van de Graaff generator on and let it charge up. Observe how the charge is generated by a rotating rubber band within the device.
2. Bring an earthed metal rod near it and observe the discharge between the metal dome and the earthed rod.
3. Turn the generator off and discharge it using the earthed metal rod.
4. Tape several strands of wool onto the dome. Make sure they are spread out over the surface of the dome. Turn the generator on and let it charge up once more.
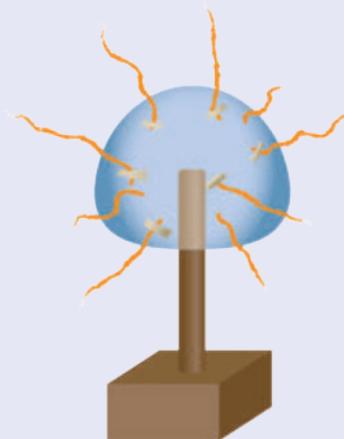
Results

1. What do you observe occurring between the earthed rod and the metal dome when the machine is turned on?
2. What happens to the wool when the metal dome is charged?

Discussion

1. Explain your observations. Use words like charging and discharging in your explanation.
2. Explain why this happens in terms of the charges on the dome and on the strands of wool.
3. The wool forms a pattern around the dome. Explain why this pattern forms.

Conclusion

Refer to your findings to explain how an electrostatic charge is created by a Van de Graaff generator and how it can be discharged. What effects can the forces from electrostatic charges produce?

EXTENSION: The Van de Graaff generator

The **static electricity** that builds up on objects when charged can leak slowly away to the air around them. When a large electric charge moves from one charged object to another object, a spark may be seen discharging between the two objects. A Van de Graaff generator can be used to demonstrate this.

A Van de Graaff generator has a large rubber belt held tightly between two plastic rollers. When the motor is turned on, the belt rotates. As the moving belt rubs over the lower roller, a charge is transferred from the roller to the rubber belt by friction. The charge on the rubber belt is then transferred to the metal dome via a metal comb. This leaves the dome with a built-up charge. Bringing a metal object, such as an earthing rod, near the dome allows electrons to flow to neutralise the charge on the dome, producing a spark.

FIGURE 3.37 In a Van de Graaff generator, charge is transferred from the rubber belt to the metal dome. In this Van de Graaff generator, a positive charge builds up on the dome. A spark discharge can be produced if an earthing rod is brought near the metal dome.
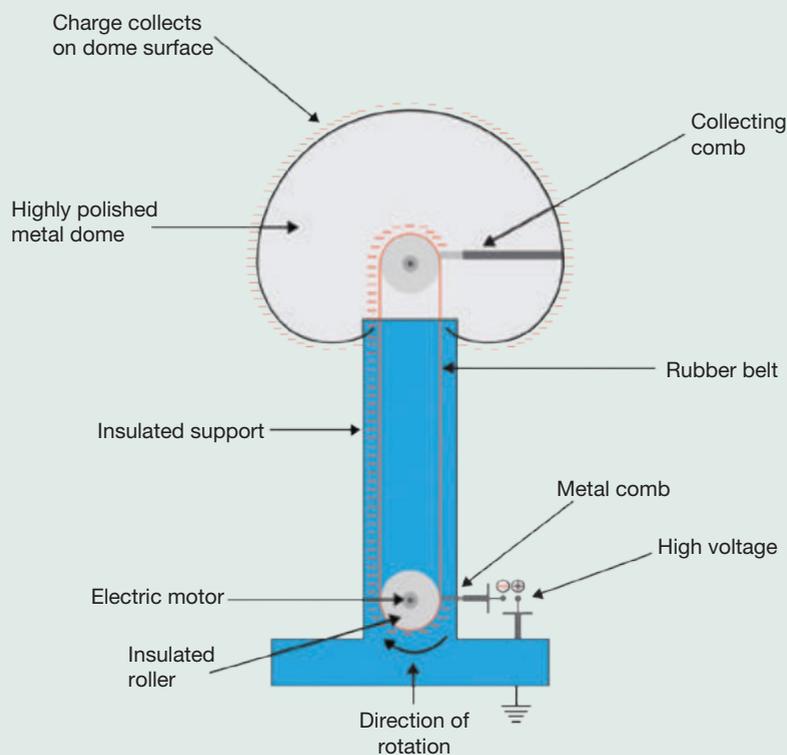
EXTENSION: When lightning strikes

The particles of water and ice inside clouds are constantly moving against each other. Their movement causes charge to build up in the cloud. Some parts of the cloud become more negative, while other parts become more positive.

The charges keep building up. Eventually, there is so much charge built up in part of the cloud that it quickly discharges to another cloud or to the ground below. The result is the spectacular spark we call **lightning**.

FIGURE 3.38 Lightning, a rapid discharge of electricity, happens when there is a build-up of charges.
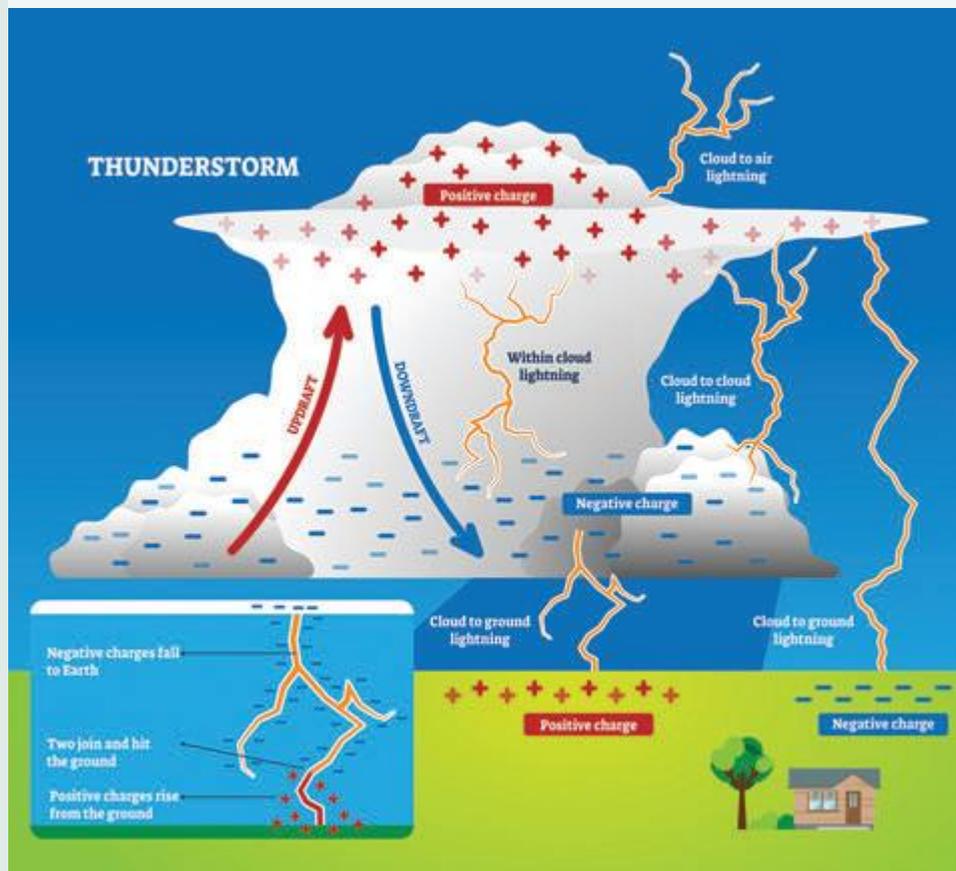
If a bolt of lightning strikes a building, it can cause a huge amount of damage. Lightning takes the easiest path to the ground, so **lightning rods** are mounted on top of tall buildings. It is more likely that lightning will strike the rod, keeping the rest of the building safe.

Although lightning is spectacular to watch, it can also be very dangerous. It is unsafe to be outside during an electrical storm so take shelter inside a building or in a car. Never take shelter under trees, as they are often struck by lightning.

3.7.4 The electric field

A charged object can attract or repel other charged objects near it. Like charges repel one another, while oppositely charged objects attract one another.

These forces of attraction and repulsion do not rely on contact between the two charged objects, just as two magnets do not need to be touching to exert a force on each other.

In the same way that magnetic fields are used to explain how magnetic forces can exist without contact, electrostatic forces can be explained by electric fields. The area around charged objects carries an **electric field**. The electric field lines are closest together near the charged object where the force is strongest.

FIGURE 3.39 The electric fields around a positive and a negative charge. The field lines show the direction of the force that would be applied to a small positive charge if it were placed in the field.
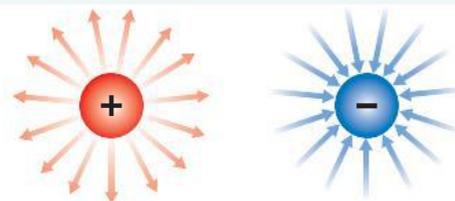

Charged and neutral objects

Neutral objects can also be attracted to charged objects. A charged plastic pen attracts a neutral stream of water. A charged comb will make dry hair stand up. Figure 3.40a shows how a negatively charged plastic pen can pick up a small, neutral piece of paper.

Only a few charges have been labelled in figure 3.40a. In reality, there would be billions of them. The labelled charges are there to show whether an object is neutral or charged, and how the charge is distributed in the object.

When the negatively charged pen is close to the paper, electrons are repelled from the top surface of the paper, leaving the surface with a positive charge. Note that the whole piece of paper is still neutral. If there is enough charge and the pen is close enough to the paper, the force of attraction is great enough to pull the paper up. Once the paper is touching the pen, some of the negative charges move across and arranges itself so that it is evenly spread out.

FIGURE 3.40 Neutral objects can be attracted to charged objects, such as **a.** paper and **b.** water.

a.

Negatively charged pen

Top surface of paper attracted to pen

Neutral paper

Some electrons transfer to the paper

b.
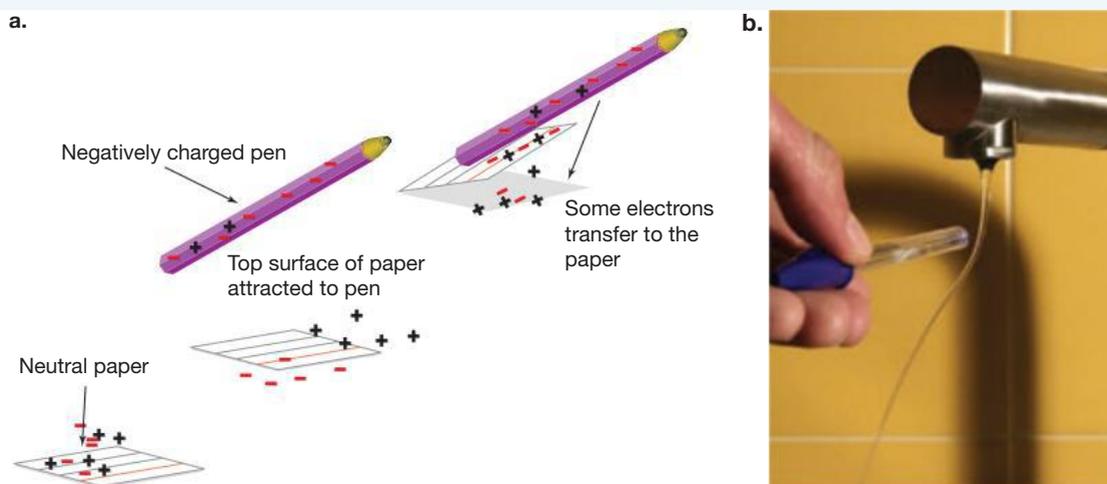
ACTIVITY: PhET simulation — Charges and fields

Access the **PhET simulation: Charges and fields** interactivity in the Resources panel to observe variables affecting the strength and direction of the electric field generated by charges.

INVESTIGATION 3.14

Defying gravity

Aim

To investigate the forces resulting from electrostatic charges

Materials

- plastic ballpoint or felt-tip pen
- woollen, cotton or nylon cloth
- balloon

Method

1. Rub a plastic pen with a piece of cloth, then hold it near a thin stream of water from a tap.
2. Describe what happens to the water.
3. Rub an inflated balloon with the woollen cloth and place it against a wall.
4. Does the balloon stick to the wall?
5. If the balloon does not stick to the wall, try rubbing it with a different type of cloth.

Results

Record your observations.

Discussion

1. Explain the behaviour of the water and balloon in your own words.
2. Explain the effect of the cloth on the balloon.

Conclusion

Refer to your findings to explain how electrostatic forces can be produced and describe what they are able to do.

3.7 Activities

learn**on**

3.7 Quick quiz **on**	3.7 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 4, 6, 8	2, 5, 9, 12	3, 7, 10, 11

Remember and understand

1. Write down the type of electrical charge of the following particles:
   a. a proton
   b. a neutron
   c. an electron.
2. State how an object containing protons and electrons may be neutral (or uncharged).
3. When you rub a plastic ruler with a woollen cloth, the plastic ruler becomes negatively charged.
   a. Describe what happens to the atoms in the cloth and ruler to cause this change.
   b. Complete the following sentence. As the ruler becomes negatively charged, the cloth becomes
   _____ charged because it has more _____ than electrons.
4. Complete each of the following sentences by using the words 'attract' or 'repel'.
   a. Two positively charged objects would be expected to _____ each other.
   b. Two negatively charged objects would be expected to _____ each other.
   c. A positively charged object would be expected to _____ a negatively charged object.

Apply and analyse

5. Explain, with the aid of a diagram, how it is possible for a neutral object to be attracted to a charged object. ▶

6. Two balloons are hanging on threads next to each other, but not touching. They begin to move away from each other. If one of the balloons is positively charged, **identify** the charge of the other balloon.
7. If you placed a charged pen near a whole A4 sheet of paper, would you expect the paper to rise and stick to the pen? Give a reason for your answer.
8. Draw a labelled diagram to show how a neutral stream of water from a tap is attracted to a charged plastic pen. Use the symbols + and – to represent positive and negative charge.

Evaluate and create

9. Investigate why you are less likely to get an electric shock after walking on carpet in humid weather than in dry weather.
10. **a.** As planes move through the air, they build up large amounts of static electricity. How does this happen?
    b. Before refuelling, a wire is used to connect the plane to the ground. Why is this important?
11. Devise a model (this may be diagrammatic) to represent positive and negative charges, to show how objects become positively and negatively charged. Use your model to demonstrate:
    a. whether a neutral object contains any electric charge
    b. what must happen to make an object:
        i. negatively charged
        ii. positively charged
12. Have you ever heard a crackling sound when you remove your clothes at night? What causes it?

LESSON 3.8 Magnetic forces

LEARNING INTENTION

In this lesson you will predict how magnets attract or repel each other based on their polarity and observe and map the magnetic fields of magnets.

3.8.1 Magnets

Magnets can attract some metals without touching them, so magnetic forces are a type of indirect or non-contact force. Magnets only attract materials containing the metals iron, nickel or cobalt. Steel is a metal **alloy** and is made of a mixture of metals. If steel contains iron, cobalt or nickel, it will also be attracted to a magnet.

FIGURE 3.41 Magnets that might be found at home.

Magnets that retain their magnetism when removed from other magnets are called **permanent magnets**. **Temporary magnets** on the other hand only behave as magnets when in contact with a permanent magnet. Once they are no longer in contact with a permanent magnet, they stop acting as magnets.

FIGURE 3.42 Paperclips in contact with a permanent magnet can pick up other paperclips and so act as temporary magnets.
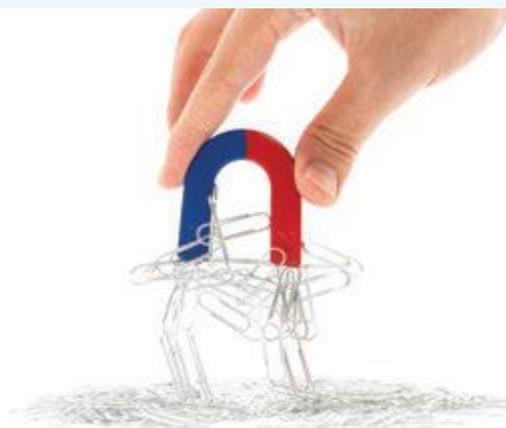
INVESTIGATION 3.15

Magnetic materials

Aim

To investigate whether materials are attracted to magnets

Materials

- bar magnet
- selection of materials to be tested: e.g. pencil, paper, plastic straw, coins, iron nail, stainless steel spoon, aluminium foil, paperclip, copper wire

Method

Place a bar magnet close to a range of materials to find out which ones are attracted to it. Test as many of the following items as possible: pencil, paper, plastic straw, coins, iron nail, stainless steel spoon, aluminium foil, paperclip, copper wire.

Results

Record your observations in a table like the one below.

Attracted	Not attracted

Discussion

1. Which materials were attracted to the magnet?
2. Were all the metals attracted to magnets?
3. Of the materials that were attracted to the magnet, which one was attracted most strongly? Why do you think this was so?

Conclusion

Based on your findings, identify what types of materials are attracted to magnets.

3.8.2 Magnetic poles

The pulling force of a magnet is strongest at its ends, or poles. All magnets have a north pole and a south pole.

Even when a magnet is broken in half, each half still has a north pole and a south pole. If you could keep breaking a magnet in half over and over again, each half would always have both a north pole and a south pole.

FIGURE 3.43 North pole and south pole of a bar magnet.

North pole
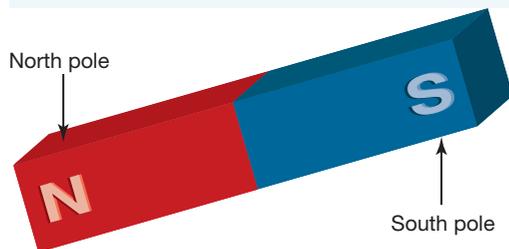
South pole

**FIGURE 3.44** Magnets always have a north and south pole, even if broken in half.
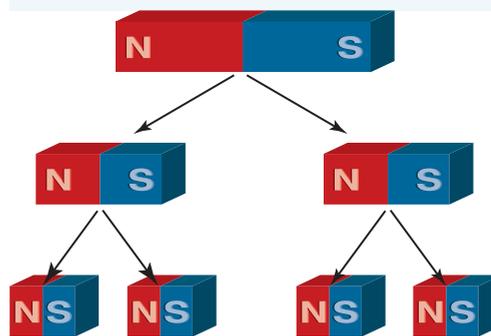
Opposites attract

When the north poles of two magnets are brought close together, the magnets push each other away (or repel each other). This same **repulsion** force is felt between two south poles.

When the north pole of a magnet comes close to the south pole of another magnet, the opposite happens. They attract one another with a pulling force.

FIGURE 3.45 Like poles repel and unlike poles attract.

Like poles repel.

Unlike poles attract.
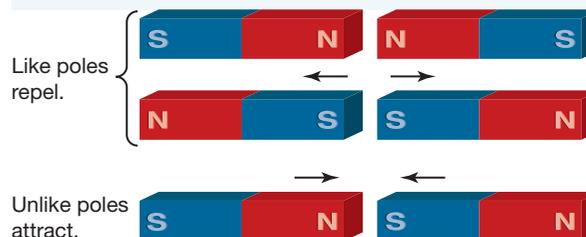
INVESTIGATION 3.16

Poles apart

Aim

To investigate whether poles attract or repel

Materials

- 2 bar magnets

Method

1. Take two bar magnets and identify the north and south pole of each.
2. Position the magnets near each other in each of the arrangements shown below.
3. Record whether the magnets attract or repel each other in each case.

a.

N S

b.

N N

c.

S S

d.

S N

Results

Draw a table like the one shown below to record whether you observed the magnetic poles attract or repel each other.

Arrangement	Magnetic poles brought together		Attraction or repulsion?
a.	N	S	
b.	N	N	
c.	S	S	
d.	S	N	

Discussion

1. Describe what happens when:
   a. opposite poles are brought together
   b. like poles are brought together.
2. Were the forces observed direct or indirect forces? How do you know?
3. If you were able to break the magnets in half, would you have observed similar results? Explain your response.

Conclusion

Refer to your findings to describe whether magnetic poles attract or repel when brought near one another.

3.8.3 Magnetic fields

The metallic objects attracted to a magnet lie within the magnet's **magnetic field**. The magnetic field is the area around a magnet where a magnetic force acts.

Although magnetic fields are invisible, we can visualise what they look like by sprinkling iron filings around a magnet. The iron filings line up along the magnetic field lines.

FIGURE 3.46 Iron filings sprinkled around bar magnets demonstrate the magnetic field.


KEY IDEAS

A magnetic field is the area around a magnet where magnetic forces act.

The magnetic field can be illustrated as shown in figure 3.47. The field lines are closest where the magnetic force is strongest and further apart where the force is weakest.

Magnetic field lines always point a way from a north pole and towards a south pole around a magnet. The direction of the magnetic field lines can be determined by placing a compass in the magnetic field and observing the direction of the north pole of the compass.

FIGURE 3.47 The magnetic field around a bar magnet.
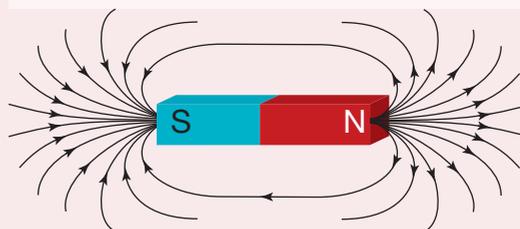
3.8.4 Earth's magnetic field

If you hang a magnet from its middle, it always lines up with the north and south poles of Earth. Earth, like the Sun and some planets, has its own magnetic field. It is very much like the magnetic field of a bar magnet. Scientists have proposed a number of different theories to explain what causes Earth's magnetic field. One popular theory is that, as Earth spins, the movement of molten iron in Earth's outer core creates electric currents in the core that generate the magnetic field.

The Earth's geographic poles do not line up exactly with the magnetic poles. The magnetic North and South Poles are located nearly 1000 km from the geographic North and South poles.

FIGURE 3.48 Earth's magnetic field
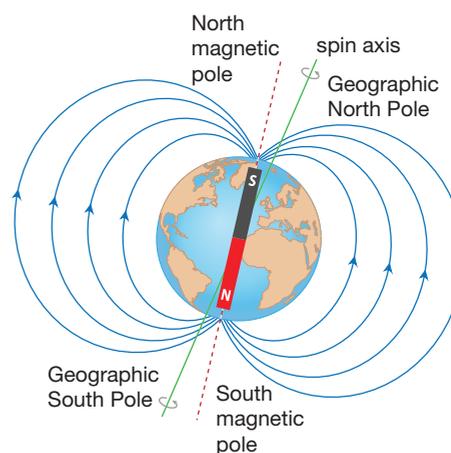
EXTENSION: Which way is north?

A compass is a simple tool for letting us know where north is. The compass needle moves freely around a pivot until it points north. It is pushed and pulled by magnetic forces so that it lines up with Earth's magnetic field, just like a hanging magnet. In fact, a compass needle is a magnet.

The tip of the needle that points or 'seeks' north is the north pole of the magnet. The north pole of a compass actually gets its name from the term 'north-seeking pole' because it lines up or 'seeks' the magnetic north pole of Earth. For the north pole of a magnet to point to Earth's north pole, this pole of Earth must really be acting like the south pole of a magnet — remember that opposites attract!

FIGURE 3.49 A compass consists of a magnetised needle that can pivot to align itself with magnetic north.

ACTIVITY: PhET simulation — Magnet and compass

Access the **PhET simulation: Magnet and compass** interactivity in the Resources panel to observe the direction of the magnetic field around a magnet.

INVESTIGATION 3.17

Mapping the magnetic field

Aim

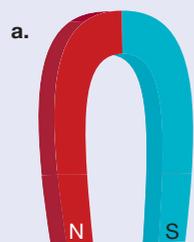**To map the magnetic field around magnets**

Materials

- horseshoe magnet
- iron filings within a sprinkling container
- transparent plastic A4 sheet
- sheet of A4 paper
- 2 bar magnets
- 2 notebooks
- small compass

Method

1. Place a bar magnet in the centre of a sheet of white paper.
2. Predict the magnetic field around the bar magnet and illustrate it. Be sure to include the direction of the field lines.
3. Test your prediction using a compass. Move the compass around the sides of the bar magnet; the north pointing end indicates the direction of the field lines.
4. Predict the direction of the field lines through the centre of the bar magnet and test that prediction as well.
5. Place a notebook on either side of the bar magnet to support a transparent plastic A4 sheet placed over the magnet and sheet of paper.

Iron filings in salt shaker

Plastic sheet

Book

Magnet
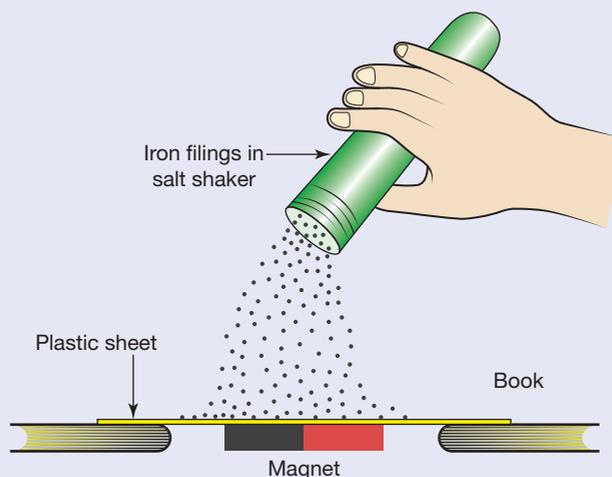
6. Carefully sprinkle iron filings over the transparency, gently tapping it to spread the filings out. Take care not to let iron filings get under the plastic sheet.
7. Draw a diagram of the pattern made by the iron filings. Label the north pole and south pole of your magnet on the diagram. The pattern in your diagram is a map of the magnetic field around the bar magnet.
8. Use the iron filings to investigate the magnetic fields around a horseshoe magnet and the pairs of magnets shown below.

a.

N   S

b.

S   N   S   N

c.

S   N   N   S

d.

N   S   S   N

Results

1. Draw diagrams to show your predicted magnetic field around and through the bar magnet.
2. Draw diagrams to show the magnetic fields in the three arrangements illustrated above. Include arrows on the field lines to demonstrate the direction of the magnetic field.

Discussion

1. Did your predictions match the results obtained from the compass?
2. What pattern of field lines formed between two:
   a. opposite poles
   b. like poles?
3. Compare the orientation of field lines in the horseshoe magnet to the bar magnets.
4. Do the magnetic field lines ever seem to cross over?
5. How is the model we have for magnetic fields useful in explaining the forces between magnets?

Conclusion

Summarise your findings in this investigation.

3.8.5 Magnetic metals

The metals iron, nickel, cobalt and the alloys containing them are among the few metals that are attracted to magnets.

Scientists have developed a model or visual representation to explain what causes these metals to be magnetic. In their model, the metals are thought to be made up of small components called **domains**, which behave like mini magnets. Each of these domains or mini magnets has a north pole and a south pole.

As well as being affected by magnets, iron, nickel and cobalt can also be made into magnets. When the domains inside the metals face the same direction, the metal acts as a magnet.

A needle or nail containing one of these metals can be magnetised by stroking it with a bar magnet in the same direction many times. The domains in the needle are lined up only temporarily and eventually they go back to their original directions. Such objects are called temporary magnets.

FIGURE 3.50 a. If the domains inside magnetic materials are facing different directions, the pushes and pulls of the 'mini-magnets' are cancelled out. It results in the material not behaving like a magnet. b. If the domains are lined up facing the same direction, the material has an overall north pole and an overall south pole. The material will behave like a magnet.
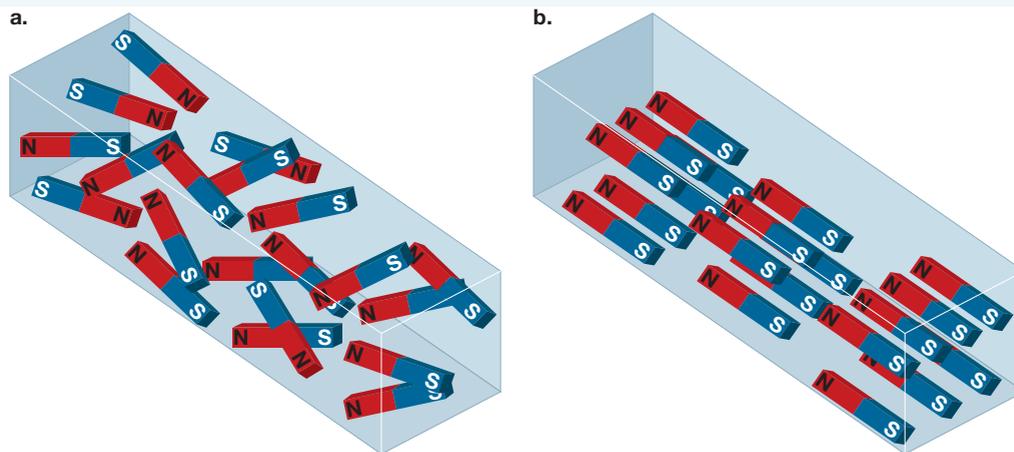
Bar and horseshoe magnets are permanent magnets. They do not lose their magnetism easily, except by being dropped or by being heated to very high temperatures.

## INVESTIGATION 3.18

Making your own compass

Aim

To make a compass using an iron nail

Materials

- large iron nail (about 50 mm long)
- strong bar magnet
- paperclips or small nails
- container of water
- compass
- styrofoam cup, wax paper or cork

Method

1. Take a large iron nail and stroke it with a strong permanent magnet. After each stroke, lift the magnet high above the nail before commencing the next one. You need to make sure that each stroke is in the same direction and made with the same end of the magnet.
2. After a total of 40 strokes, test your new magnet by trying to attract paperclips or small nails.
3. Compare the strength of your magnet with that of others in your class.
4. Use your magnet to make a compass like the one shown below. You will need a container of water and a float. The bottom of a styrofoam cup, or a cork will make a good float.
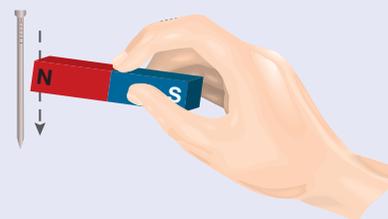
5. Try dropping your 'homemade' magnet on the floor several times. Test it to see if it still works.

Results

1. Were you able to make the iron nail into a magnet?
2. Did the iron nail in your homemade compass point in the same direction as the real compass? In which direction did it point?
3. Did your 'homemade' magnet lose any magnetism after dropping it several times on the ground?

Discussion

1. Was the magnet permanent or temporary? How do you know?
2. Which end of your magnet is the north pole? How do you know?
3. Explain, in terms of domains:
    a. how stroking a nail could make this nail act like a magnet
    b. why dropping your nail magnet several times weakens its strength as a magnet.

Conclusion

Refer to your findings to explain how a metal, like iron can be made into a magnet and then used to create a compass.

3.8 Activities

learn on

3.8 Quick quiz on	**3.8 Exercise**

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 3	2, 6	4, 5, 7

Remember and understand

1. MS **Identify** which of the following statements are correct. Select all that apply.
   A. Permanent magnets never lose their magnetism.
   B. All metals are strongly attracted to magnets.
   C. Iron, steel and nickel are attracted to magnets.
   D. Iron is the only substance attracted to magnets.
2. What is the difference between a permanent magnet and a temporary magnet?
3. How should two bar magnets be placed on a table so that they repel each other?
4. **Describe** a magnetic field.

Apply and analyse

5. **a.** The magnetic North Pole of Earth can be considered as one pole of a bar magnet. Is it acting as the south pole or the north pole of a magnet?
   b. **Explain** your answer.
6. **Explain** which way the coloured end of a compass would point if you were in a plane flying directly above Earth's magnetic north pole?

Evaluate and create

7. Design and carry out an experiment to measure the strength of different magnets. Write a clear method for your experiment and outline your expected results.

LESSON 3.9 Electromagnets

LEARNING INTENTION

In this lesson you will construct electromagnets, compare their strength, and test the effect of distance on the action of a magnet. You will also describe examples of magnetism in familiar contexts.

3.9.1 Switched-on magnets

A magnet's pulling force can be very useful, but sometimes it gets in the way. An **electromagnet** is a magnet that can be turned on and off with the flick of a switch.

An electromagnet is made up of a coil of wire wrapped around an iron core. When an electric current travels through the coil, it creates a magnetic field, which is made stronger by the iron core. When the current is switched off, the iron core is no longer magnetised.

Electromagnets are used in many machines and appliances. Figure 3.51 shows one such use. The electromagnet is attached to a giant crane. The electric current is turned off while the electromagnet is lowered into a position over the load of scrap metal to be lifted. When the current is switched on, the iron or steel in the scrap metal is attracted to the electromagnet and lifted into a container. When the electric current is switched off, the metal falls from the crane's electromagnet. However, if the metal was not mostly iron or steel, the electromagnet would be of little or no use.

FIGURE 3.51 The electromagnet attached to the crane attracts iron and steel objects when the electric current is switched on.

**ACTIVITY: PhET simulation — Magnets and electromagnets**

Access the **PhET simulation: Magnets and electromagnets** interactivity in the Resources panel to observe the direction of the magnetic field around an electromagnet and relate the magnetic field strength to the distance from the magnet.

KEY IDEAS

An electromagnet consists of a coil of wire supplied with an electric current. An iron core placed in the coil strengthens the electromagnet's magnetic field.

The magnetic field around an electromagnet resembles the field around a permanent magnet. Switching the direction of the electric current through the coil of an electromagnet will cause the magnetic poles to swap.

FIGURE 3.52 The magnetic field around an electromagnet
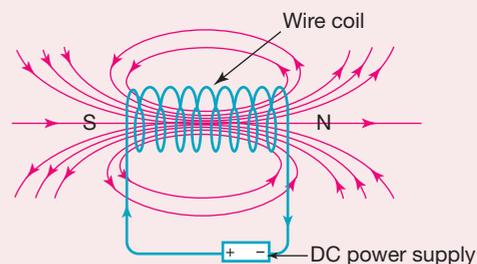
ACTIVITY: Mapping the magnetic field around an electromagnet

Put a small compass in the tray of a matchbox. Wind about a metre of insulated wire around the matchbox as shown. Connect one of the leads to the terminal of a battery or DC power source. Briefly touch the other end to the other terminal. Observe what happens. Then try swapping the leads to the opposite terminals of the battery or power supply.

Magnetic compass   Matchbox tray   Battery
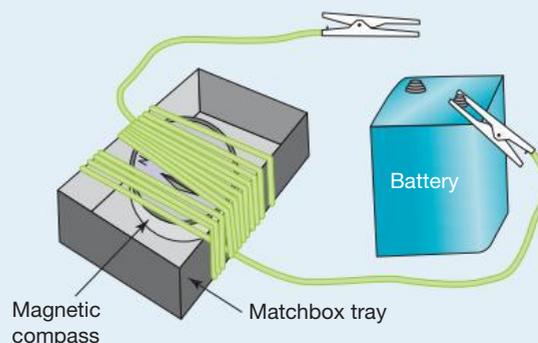
INVESTIGATION 3.19

### Making electromagnets

Aim

To investigate what affects the strength of an electromagnet

Materials

- DC power supply
- 2 insulated wire leads: one short, the other 1.5 m long
- large iron nail
- electric switch
- small paperclips
- a magnetic compass

Method

1. Set up the circuit shown below.
2. Wind the long wire neatly around the nail 15 times.
3. Set the power supply to 2 volts and close the switch. Test the nail to see if it will pick up any paperclips.

Power supply
Insulated copper wire
Switch (open)
Nail
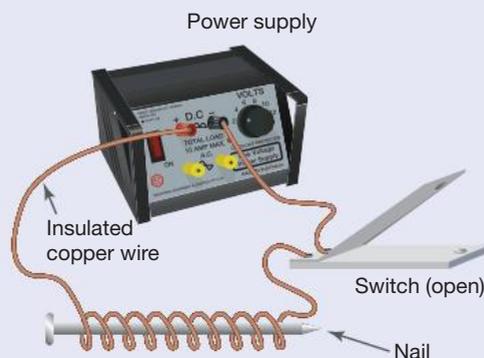
4. Use a compass to map the magnetic field around the electromagnet. Don't forget to show the direction of the field lines.
5. Wind five more turns of wire around the nail.
6. How many paperclips does the electromagnet pick up now?
7. Keep winding the wire onto the nail. Record the number of paperclips picked up for 25 and 30 turns of wire.
8. Raise the voltage to 4 volts. Repeat steps 2 to 7.

Results

1. Illustrate the magnetic field around the electromagnet. Don't forget to show the direction of the field lines.
2. Record your data in a table like the one below.

Voltage of power supply (V)	Number of turns of wire	Number of paperclips picked up
2	15	
2	20	
2	25	
2	30	
4	15	
4	20	
4	25	
4	30	

Discussion

1. How does the magnetic field of the electromagnet compare with that of a permanent magnet?
2. Determine the north and south pole of your electromagnet and label them in your diagram of the magnetic field.
3. What effect does increasing the number of turns of wire have? Refer to your results.
4. What effect does increasing the voltage supply have? Refer to your results.
5. What factors affect the strength of your electromagnet? Refer to your results.

Conclusion

Summarise your findings to describe the variables that affect the strength of an electromagnet.

DATA SCIENCE 1: Data science in context

Collecting, using and analysing datasets

Scientists have developed a model for the magnetic field to explain how magnets attract and repel each other.

Is the strength of a magnetic force likely to be affected by the distance from a magnet? What do you predict?

Design an investigation to test the effect of distance on the action of an electromagnet. You will be looking at how the distance of an electromagnet from another magnet affects the force of attraction.

You will need to select and set up equipment that allows you to collect quantitative data. When you vary the distance of a magnet to another magnet or metal weight, you will measure the effect on the force of attraction.

WORKING SCIENTIFICALLY: Investigating magnetic force and distance

Magnets are used in everyday life, from fridge magnets to powering electric motors. This investigation involves exploring how the strength of a magnetic force varies with distance. Your data will be collected accurately and clearly presented so that trends can be identified and conclusions drawn.

Aim

To investigate the effect of distance on the action of an electromagnet

▶

Materials

Select from the following:
- Retort stand and clamp
- String
- Sticky tape
- Long, low-tension spring
- Metre ruler
- Electromagnet (consisting of a solenoid with an iron core)
- DC power supply
- 2 wire leads with banana plugs
- Sticky tape
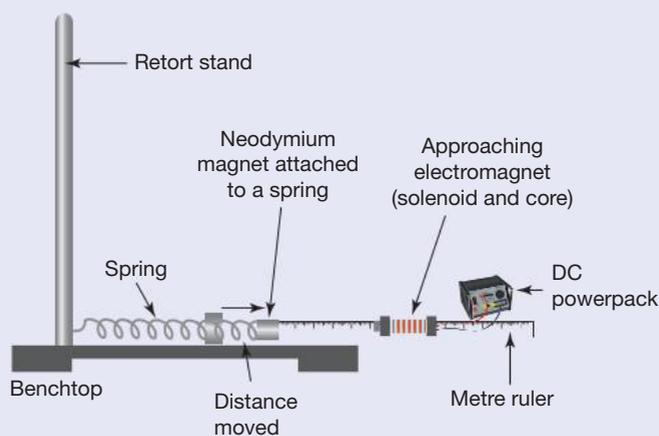- Neodymium magnet (strong permanent magnet)

N.B. A solenoid makes an effective electromagnet. It is a coil with several hundred turns of insulated copper wire wound around a cylindrical iron core.
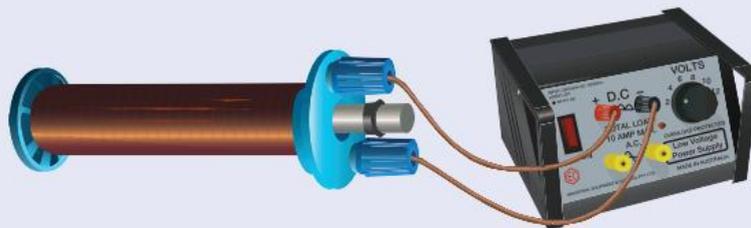
Method

1. You could trial one of the following options to test the effect of a magnet's distance.
   a. Moving a suspended magnet
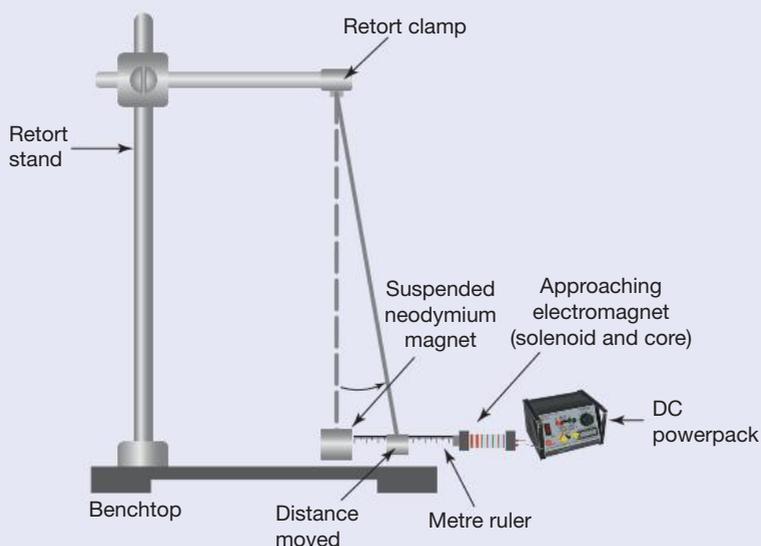
   b. Moving a magnet attached to a spring

2. Create an electromagnet by:
   a. placing an iron core within the solenoid
   b. connecting the solenoid to a DC power supply switched to 2V.

3. Check that the end of the electromagnet facing the magnet produces a force of attraction. If it creates a force of repulsion, you will need to change swap the leads to the opposite terminals on the power pack. Increase the voltage supplied if you need to increase the force produced.

Data

4. You will vary the distance of the approaching electromagnet (your independent variable) and measure the distance that the suspended/attached magnet moves (your dependent variable) as an indication of the force of attraction.
5. If the iron core is dislodged, sticky tape it in place.
6. Repeat your experiment for a total of three trials and calculate an average.

Results

Data collection

- Perform multiple trials to ensure reliability.

Communicating findings and processing data:

- Construct a table to record your results.
- Use the recorded data to calculate averages for each trial.
- Plot your data as a line graph and include a smooth line of best fit. The independent variable is plotted on the horizontal axis and dependent variable on the vertical axis.

Discussion

Data analysis

1. Examine your graph to Identify relationships or trends in the data- how does the strength of the magnetic force change with distance. Use tour knowledge of forces and magnetic fields to explain your findings.
2. How does representing your data in a graph or table make it easier to identify trends or relationships?
3. Compare your trends with that obtained by other groups. Were their results consistent with yours? This is also a way to check the reliability of your findings.
4. Identify any anomalies or unexpected results? If so, what could explain them?

Conclusion

Summarise the findings of your investigation, providing evidence from the data to support your conclusion.

Code:

**WS** **SC4-WS-05** - Uses a variety of ways to process and represent data.

WS **SC4-WS-06** - Uses data to identify trends, patterns and relationships, and draw conclusions
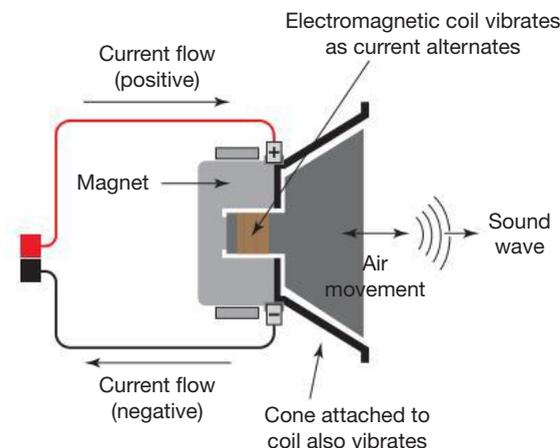
3.9.2 Using electromagnets

Electromagnets are used in many devices. Microphones and speakers, including those in smartphones, contain both permanent magnets and electromagnets.

The voice or music we hear through a mobile phone is produced by a speaker. The sound is generated when electricity passes through a coil of wire, causing it to become an electromagnet. The current travelling through the electromagnet is alternating (AC), meaning that it changes direction rapidly, causing the electromagnet to be attracted and repelled by a ring-shaped permanent magnet around it. This makes the diaphragm of the speaker vibrate, which produces the sound.

FIGURE 3.53 Cross-section through a speaker

Diaphragm

Electromagnet
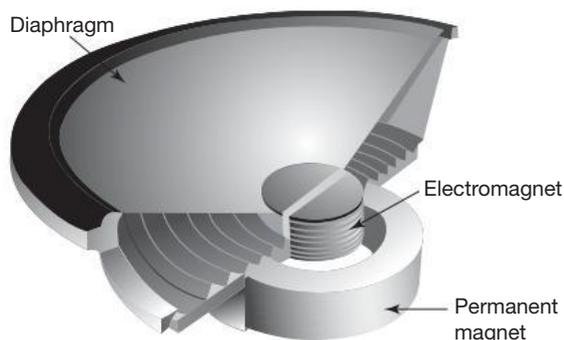
Permanent magnet

FIGURE 3.54 Sound is produced from a speaker when an electromagnet vibrates due to alternating attraction and repulsion forces between it and a permanent magnet.

Electromagnetic coil vibrates as current alternates

Current flow (positive)

Magnet

Sound wave

Air movement

Current flow (negative)

Cone attached to coil also vibrates

Some doorbells rely on an electromagnet to produce a ringing or buzzing sound. When switched on by the push of a button, an electric current passes through the electromagnet producing a magnetic field. This pulls the metal clapper towards the gong and produces a ringing sound.

Many new technologies also rely on electromagnets. Magnetic resonance imaging (MRI) is a medical scanning technique that uses strong electromagnets to produce detailed images of the body. MRI scans enable doctors to diagnose and treat patients accurately. To undergo a scan, the patient reclines on a table and is moved into the doughnut-shaped opening of the MRI machine, which contains the electromagnets.

Some trains in Europe and China use a technology in which electromagnets elevate the train to reduce friction, allowing them to travel at incredibly high speeds. They are called 'maglev' trains — a name derived from the words MAGnetic LEVitation.

Maglev trains reach speeds of over 500 km/h and don't even need a normal engine to run! They use pushing forces between electromagnets, both on the track and on the train, to levitate the train. Electromagnets also propel the train along the track: magnets ahead of the train pull it forwards, while magnets behind push it.

FIGURE 3.55 Structure of a doorbell

electromagnet

metal clapper
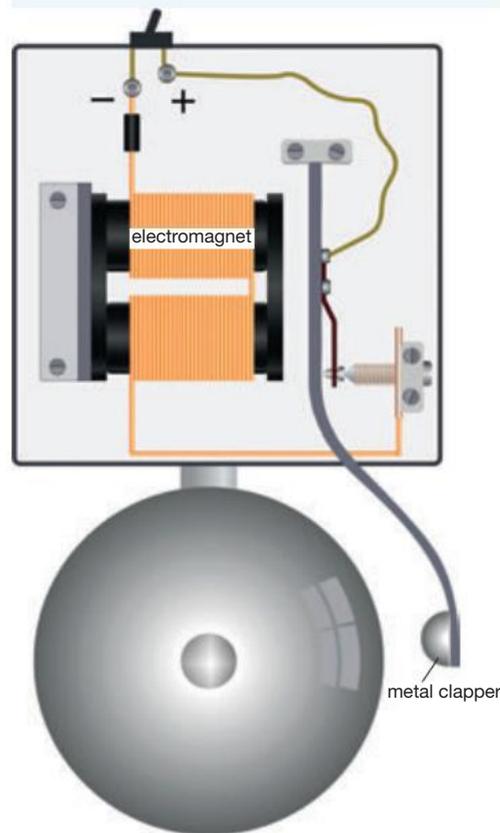
FIGURE 3.56 MRI scans involve powerful electromagnets to produce detailed images of internal structures of the body.

FIGURE 3.57 The maglev train
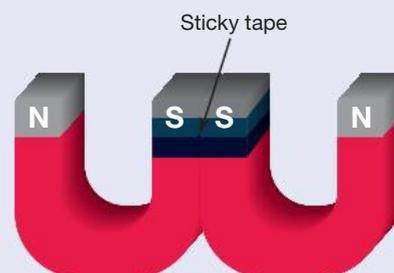
INVESTIGATION 3.20

Build a loudspeaker

Aim

To model a loudspeaker

Materials

- AC power supply
- 1 metre of insulated copper wire
- two wire leads with alligator clips
- cardboard
- two horseshoe magnets
- sticky tape

Method

1. Tape together the like poles of two horseshoe magnets side by side so that they form a W shape.

Sticky tape

N   S   S   N

2. Cut out a circle of cardboard. Cut a wedge out of the circle and bring the cut edges together to make a shallow cone. Tape the edges together so that the cone will keep its shape.

45°
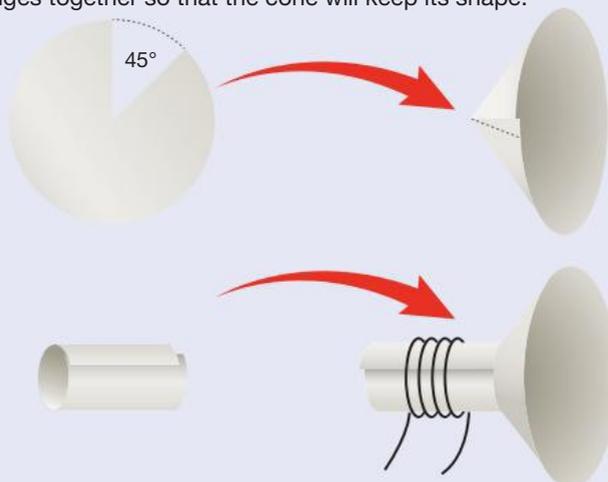
3. Cut a strip of the cardboard approximately 5 cm by 20 cm. Roll the strip up to make a tube about 3 cm diameter, or just large enough to slip over the two taped poles of the horseshoe magnets. Tape the cardboard tube so that it keeps its shape.
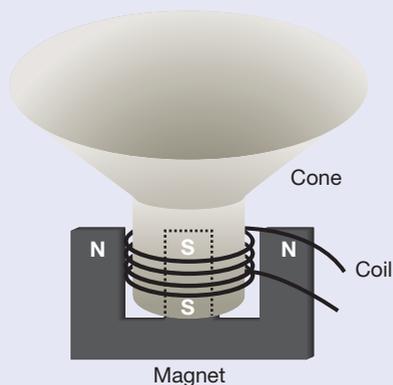4. Place the tube on the point of the cone and fix it there with several strips of tape.
5. Wind the copper wire around the tube and tape it in place.
6. Position the loudspeaker over the central poles of the horseshoe magnet.
7. Connect the coil to a low-voltage AC supply and observe what happens.

Results

Record your observations.

Discussion

1. Copy the illustration of the model loudspeaker above. Label the permanent magnet and the electromagnet.
2. Explain why the cone moves.
3. How might a loudspeaker produce different tones or pitches of sound?

Conclusion

How did you model the features of a loudspeaker in this investigation?

3.9 Activities

learn on

3.9 Quick quiz **on**	3.9 Exercise

Learning pathways

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1	2, 3	4, 5

Remember and understand

1. **a. Describe** what an electromagnet is and **explain** how it works.
   b. What is the advantage of an electromagnet over a permanent magnet?

Apply and analyse

2. **Explain** why a maglev train is able to travel so fast.
3. Which of the following devices commonly use permanent magnets and electromagnets? Select all that apply.
   a. Electric motors
   b. Speakers
   c. MRI machines
   d. Refrigerators (door seals)
   e. Generators
   f. Compass

Evaluate and create

4. Arianna made her own electromagnet to find out how the number of windings around a nail affected the number of paperclips that the nail could pick up. She used the circuit shown in Investigation 3.19 with the power supply s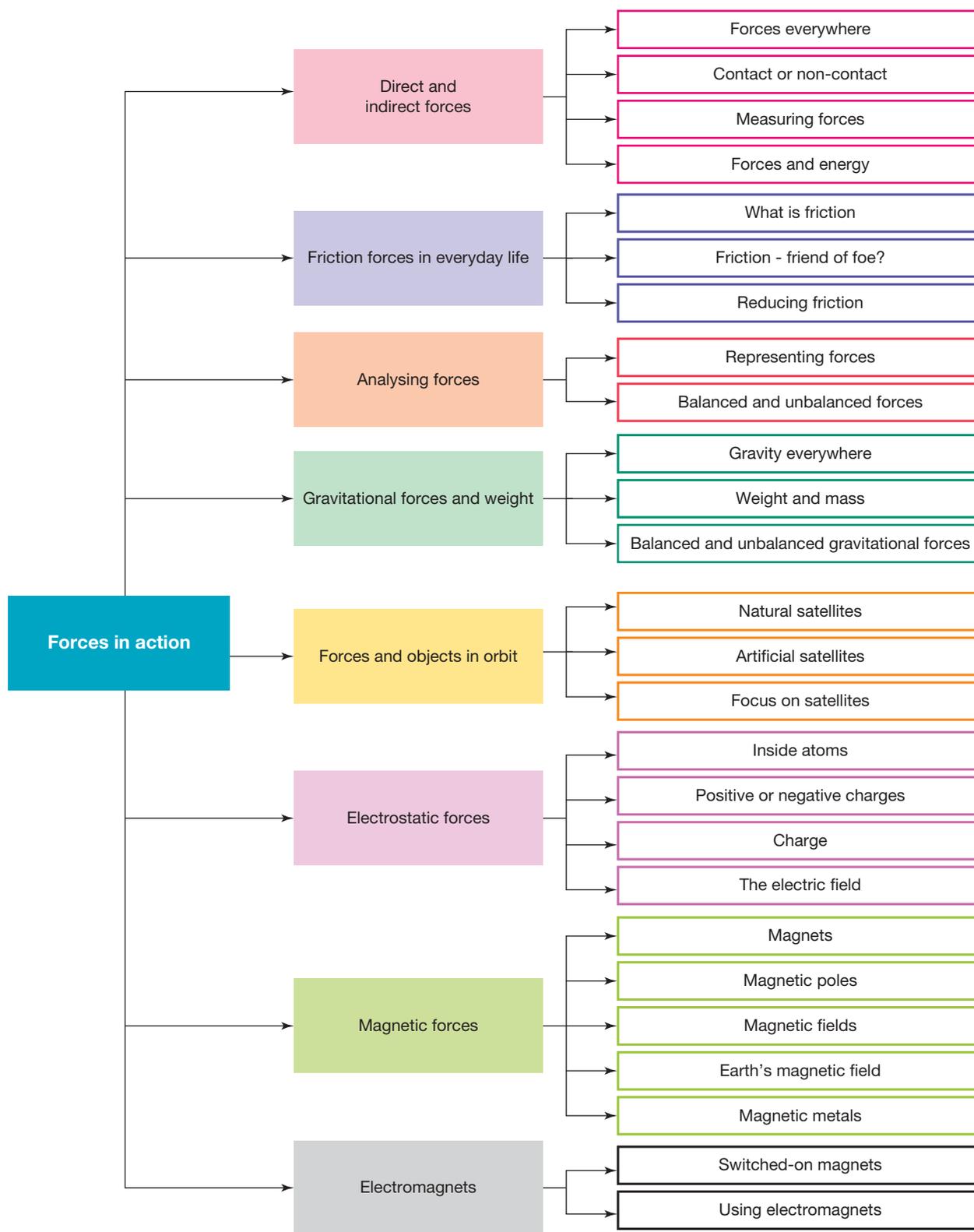et to 2 volts. Arianna then repeated her measurements with the power supply set to 4 volts and then to 6 volts. She recorded her observations in a table and then constructed the graph shown here.
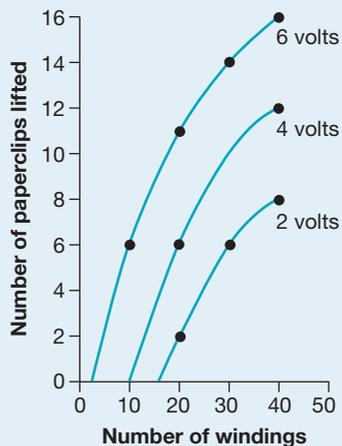
   a. How many paperclips did Arianna lift with 20 windings and the power supply set to 6 volts?
   b. Arianna lifted 12 paperclips when the power supply was set to 4 volts. How many windings were there around the nail?
   c. How many paperclips could Arianna expect to lift with 50 windings around the nail and the power supply set to 2 volts?
   d. Suggest a way that Arianna would be able to improve the reliability of her results.

5. **Design** a device that uses an electromagnet to make a noise when you close a switch or push a button. Explain how your device works.

LESSON 3.10 Review

3.10.1 Topic summary

Forces in action

Direct and indirect forces
- Forces everywhere
- Contact or non-contact
- Measuring forces
- Forces and energy

Friction forces in everyday life
- What is friction
- Friction - friend of foe?
- Reducing friction

Analysing forces
- Representing forces
- Balanced and unbalanced forces

Gravitational forces and weight
- Gravity everywhere
- Weight and mass
- Balanced and unbalanced gravitational forces

Forces and objects in orbit
- Natural satellites
- Artificial satellites
- Focus on satellites

Electrostatic forces
- Inside atoms
- Positive or negative charges
- Charge
- The electric field

Magnetic forces
- Magnets
- Magnetic poles
- Magnetic fields
- Earth's magnetic field
- Magnetic metals

Electromagnets
- Switched-on magnets
- Using electromagnets

3.10.2 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	🟢	🟡	🔴
3.2	I can investigate direct and indirect forces.			
	I can describe the relationship between force and energy.			
3.3	I can describe the role that friction plays in everyday life.			
	I can conduct practical investigations to explore friction forces.			
3.4	I can use force diagrams to model balanced and unbalanced forces.			
	I can analyse force diagrams to make predictions.			
3.5	I can describe the gravitational forces exerted between objects.			
	I can calculate weight forces.			
3.6	I can use the concept of forces to describe the motion of objects in orbit.			
3.7	I can describe the electrostatic forces exerted between objects.			
3.8	I can predict how magnets attract or repel each other based on their polarity.			
	I can observe and map the magnetic fields of magnets.			
3.9	I can construct electromagnets and compare their strength.			
	I can test the effect of distance on the action of a magnet.			
	I can describe examples of magnetism in familiar contexts.			

DEPTH STUDY IDEAS

- How have magnetic domains in oceanic rocks shown evidence of continental drift?
- What methods based on friction forces do Aboriginal and Torres Strait Islander Peoples use to make fire?
- Animals, such as tuna, cheetahs and peregrine falcons, have had millions of years to evolve aerodynamic shapes and behaviours limiting air resistance when moving. How have humans used animals as inspiration when developing technologies to limit drag?
- How is Earth's magnetic field protecting Earth from cosmic radiation?
- What are the advantages and disadvantages of maglev trains compared to other forms of public transport?
- Which types of rocks in Australia make good grinding stones?
- In the space industry, how do scientists use the gravitational slingshot manoeuvre?

on Resources

on **Post-test**   Topic 3 Post-test

eWorkbooks Summary
                Reflection

3.10 Activities

learn on

Remember and understand

1. **Identify** the forces not labelled in each of the images.

   a.

   b.

   c.
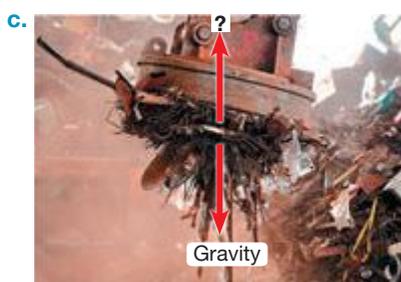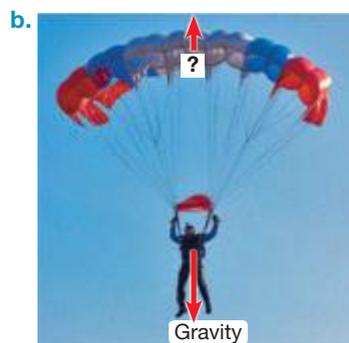
2. Match the force to the effect it creates.

Pushes you up when you are swimming underwater	surface tension
Causes all objects with mass to attract each other	magnetic force
Acts on an object when it moves across the surface of another object	buoyancy
Resists the motion of all objects on the surface of water, but not on objects below the surface	friction
Pushes up on objects on the surface of water, but not on objects below the surface	gravity
Can lift a paperclip from a desktop	air resistance

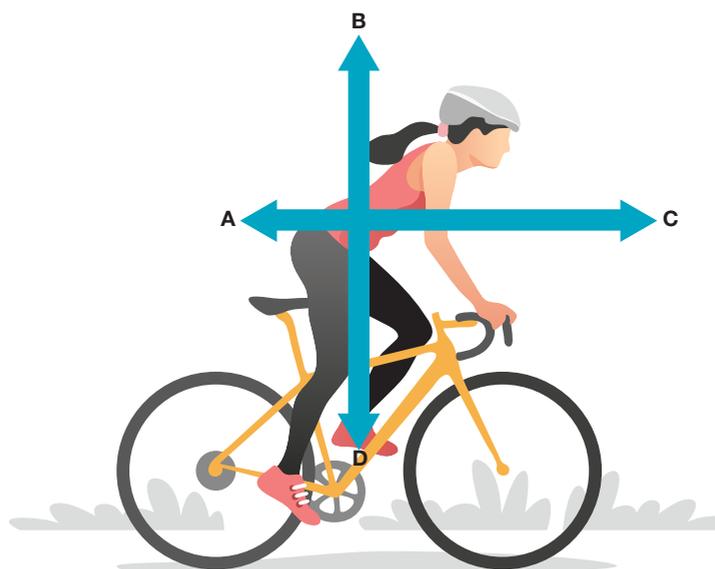3. Select the correct units for the following measurements: m, kg, km, N
   a. mass
   b. weight
   c. force

4. Complete the following sentence:
   Like charges _____ and unlike charges _____.

5. The arrows in the following diagram represent four of the forces acting on a cyclist riding on a smooth, flat surface.

a. Which two forces are balanced?
b. Which arrow could represent air resistance?
c. Is the cyclist speeding up, slowing down or travelling at a steady speed? **Explain** your answer.
6. Redraw this diagram, adding arrows to represent the forces acting on the book
a. while it is at rest on the desk.
b. while it is falling towards the floor.
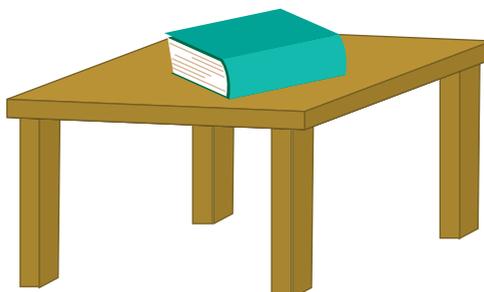
7. **MC** The compass needle is not shown in the diagram. If the needle was included in the diagram, in which direction would it point?
A. North
B. South
C. East
D. West

8. Fill in the blanks:
In a circular doorknob, the _____ is the wheel and the _____ is the axle.

9. a. Copy the following diagrams and label the fulcrum, load and effort on each of the levers. The first diagram has the load (blue arrows) and effort (pink arrows) labelled.

i.

ii.

iii.

iv.

**b.** For each diagram, identify what type of level it is.

Apply and analyse

10. Explain why streamlining an object reduces fluid friction.

11. Electricians use screwdrivers and long-nosed pliers with handles that are coated with plastic. Suggest a reason for this.

12. When you rub your shoes on some types of carpet, your body becomes negatively charged. Explain what will happen to the extra negative charge on your body if you:
  a. stand still for a few minutes
  b. touch a metal door handle immediately after rubbing your shoes on the carpet
  c. place the palm of your hand near a negatively charged balloon hanging from a thread
  d. place the palm of your hand near a positively charged balloon hanging from a thread.

13. Use a labelled diagram to explain how a positively charged balloon can be attracted to an uncharged plaster wall.

14. Explain why the pull of gravity is less on the Moon than it is on Earth.

15. When a package of emergency supplies is first dropped from a plane, it gains speed rapidly. Why does the package eventually stop gaining speed before reaching the ground, even without the use of a parachute?
  a. It reaches terminal speed
  b. Because of gravity
  c. The effect of air resistance is greater than that of gravity
  d. The package gets caught in the wind

16. Explain how lubricants, such as grease and oil, reduce the production of heat in the moving parts of car engines and other mechanical devices.

17. Imagine that you wanted to drive a screw into a length of wood.
If you had a choice of using a thin handle or thick handle screwdriver, which one would you use? State a reason for your choice.

18. In cricket, the arm acts as a lever when the ball is bowled.
  a What class of lever is the arm acting as?
  b. Is the arm acting as a speed multiplier or a force multiplier? Explain your answer.

c. Which part of the body acts as the fulcrum?
    i. The elbow
    ii. The muscle
    iii. The shoulder
    iv. The hand

19. A ramp makes it easier to push or pull objects upwards. What is the 'penalty' for making the task easier?
    a. Objects must be moved further.
    b. It takes more energy.
    c. Objects must be moved in the opposite direction.
    d. The load is increased.

20. Why is a system of two single pulleys better than one single pulley for lifting very heavy loads?

21. Which of the following are ways in which racing cyclists reduce the effect of air resistance on their motion?
    a. Using an aerodynamic helmet
    b. Wearing tight-fitting, streamlined clothing
    c. Wearing loose clothing
    d. Positioning their body to become more streamlined
    e. Use tyres with more grip
    f. Shaving body hair

Evaluate and create

22. Scuba divers wear very heavy belts when they are diving. What difficulty would be caused if a heavy belt wasn't used? Use the terms buoyancy, gravity and net force in your answer.

23. Identify some investigations that sports scientists could undertake to improve performance in each of the following sports:
    a. tennis
    b. golf
    c. cricket.

24. Describe how your body would move if you were a passenger in a car that stopped very suddenly, and you were not wearing a properly fitted seatbelt.

25. Explain how the thick layer of polystyrene foam or similar material inside the outer shell of a helmet reduces the likelihood of severe head injuries in an accident.

26. Answer the following.
    a. Determine the size and direction of the net force acting on the object shown in the diagram.

200 N
air resistance

800 N
gravity
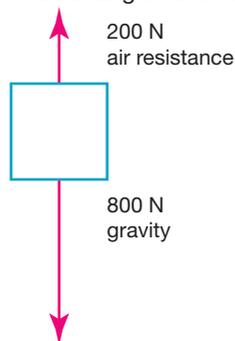
    b. If the object is moving downwards, what will happen to its speed?
    c. If the object is moving upwards, what will happen to its speed?

27. Explain why door handles are placed as far away from the hinges as possible.

28. Pulleys are important in the functioning of rollercoasters. Explain what the purpose of pulleys in rollercoasters is, and describe in what part of the ride they are most important.

29. A student uses a pencil and ruler to model a first-class lever. It is tested by lifting 20-cent coins placed at one end of the ruler.
    a. Draw a diagram to show how a pencil and ruler can be set up to model a first-class lever. Label the fulcrum, effort and load.
    b. What is the mechanical advantage of the lever when it uses four coins to lift 12 coins?
    c. If the 12 coins are placed six centimetres from the fulcrum, how far should the four coins be from the fulcrum to lift the larger pile of coins?

30. A plank is 3.6 metres long. It is being used as a lever to lift a 40 kilogram box. This represents a load of 400 newtons.

    a. If the fulcrum were placed in the centre of the plank, what downward effort would the man on the right of the diagram need to apply to raise the box?

    b. If the man wants to push down on the end of the plank with an effort of only 200 newtons:

        i. how far along the plank should the fulcrum be?

        ii. what would the mechanical advantage of the lever be?

    c. How could the mechanical advantage of the lever could be increased?

    d. Is the plank being used as a speed multiplier or a force multiplier? Explain your answer.

    e. Suggest a different way of using the plank as a simple machine to get the box into the truck.

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