Summary Guides

Science 7

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Geethanjali Michalik and Pat O’Shea assert the moral right to be identified as the authors of this work.

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Please be aware this book contains images of Aboriginal and Torres Strait Islander people who may be deceased.

Contents

Introduction

The *Summary Guides – Science* series has been written by practising educators who are passionate about creating user-friendly, accessible guides for science.

The explanations and exercises in these guides develop core science knowledge and skills for personal, work and civic life, and provide the base knowledge to understand science comprehensively. Science will be part of your daily life no matter what you choose to do as an adult – understanding it will help you think critically and make sense of the world.

This book summarises key concepts clearly. It includes real-world examples, step-by-step explanations and exercises for you to complete. The best way to use this book is to make a habit of it, regularly working through the material and questions, and comparing your answers with those provided. Whether you commit to a daily, weekly or fortnightly routine, consistent practice is the key to your success.

Gee and Pat

About the authors

Geethanjali Michalik is a dedicated educator with a strong background in science education and a passion for empowering learners through meaningful and accessible learning experiences. With experience in developing science programs in Australia and Singapore, Geethanjali has led teams in delivering high-quality, inquiry-based science education aligned with the Australian Curriculum.

In addition to her leadership in science education, Geethanjali is the founder of a girls' program dedicated to inspiring confidence, leadership and a passion for science, technology, engineering and mathematics (STEM) in young women. Through this initiative, she continues to advocate for inclusive and empowering learning environments. Her goal remains consistent: to create engaging, equitable and impactful learning opportunities that ignite a lifelong love of science.

Pat O'Shea is a passionate teacher with a long history of involvement in science education generally and chemistry teaching in particular. This involvement includes:

- roles with the VCAA developing resources for the VCE chemistry course
- being an author or co-author of many textbooks and trial exams
- maintaining a website that distributes free resources for chemistry teachers
- many years of presentations with STAV (Science Teachers Association of Victoria).

Pat's emphasis has always been on investigative learning, where students are encouraged to develop their passion for science through hands-on experimentation.

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Curriculum correlation

While this book has been written to follow the Australian curriculum: Science, its content also covers specific state curricula. Go to the Insight Publications website for curriculum correlation charts.

Chapter 1 – Biology

1.1 What is biology?

Biology is a branch of science that studies living things. A biologist is a scientist who studies biology. Biologists try to understand the natural world and everything that lives in it including plants, animals, fungi, bacteria, viruses, algae and **protozoa**.

Key term

protozoa	tiny organisms made up of one cell; the word means 'first animals'

By the end of this chapter, you will be able to:

- investigate classification systems used in biology; you will also look at ways that Aboriginal and Torres Strait Islander peoples classify living things, and how they differ from contemporary science
- consider the reasons for classifying, such as identification and communication
- classify a variety of organisms based on their similarities and differences
- consider how biological classifications have changed over time
- use hierarchical systems such as kingdom, phylum, class, order, family, genus and species
- apply scientific conventions to name species.

1.2 Classification

Classifying organisms

Scientists **classify** things to help study and understand them. In biology, classifying **organisms** helps scientists:

- organise living things into groups and understand all living things on Earth
- study living things more easily by finding patterns
- understand how organisms relate to each other and how they evolved
- communicate clearly about living things using a common language and system.

Key terms

classify	group together things that have something in common
organism	a living thing

Activity 1.2.1

1. **a.** Classify the following things into any groups of your choice.

Frogs	Cakes
Phones	Shoes
Forks	Chickens
Ducks	Pigs
Tapirs	Lizards

   b. How did you classify them?

1.3 Categorisation

Categorising organisms

When classifying organisms, we group them by their similar **characteristics** such as their physical appearance, how they reproduce or their behaviours. The names of these groups are called **categories**.

For example, living things with scales and that breathe under water are categorised (grouped) as fish.

Key terms

characteristics	a noticeable feature of someone or something
category	the name of a group used to classify things with similar features (e.g. shape, animal, living, non-living)

Advanced tools that can use DNA analysis have transformed classification, allowing us to understand some surprising relationships. For example, even though whales are aquatic, they are more closely related to hippos than to fish.

Another example is sharks and dolphins. They look similar due to evolution but belong to entirely different groups. Sharks are fish, whereas dolphins are mammals.

Activity 1.3.1

1. List the categories (names of the groups) you used in Activity 1.2.1 to classify the list of things.
2. Would you change the categories you used in Activity 1.2.1 based on their characteristics?

1.4 Dichotomous keys

A dichotomous key is a scientific tool used to identify things based on their characteristics ('di' means 'two'). It is presented as a flow chart or a set of 'yes' or 'no' questions. It allows biologists to identify organisms by narrowing down the options.

Using a dichotomous key

There are two kinds of dichotomous keys: branched and linked. We can use a branched dichotomous key to classify something as living or non-living.

1. Does it grow and develop over time?

   Yes → Go to step 2.

   No. It is non-living.
2. Does it reproduce or have the ability to produce offspring?

   Yes. Go to step 3.

   No. It is non-living.
3. Does it respond to stimuli (e.g. light, sound, touch)?

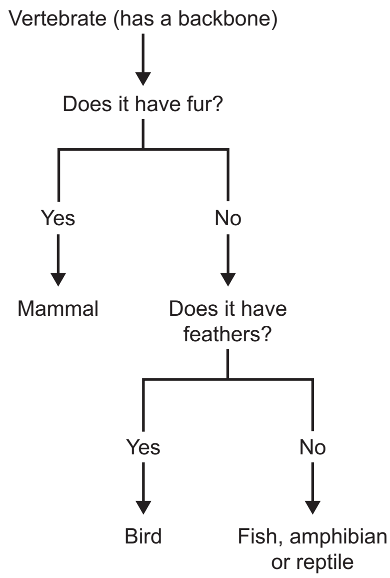
   Yes. Go to step 4.

   No. It is non-living.
4. Does it require energy (e.g. food, sunlight) to survive?

   Yes. It is living.

   No. It is non-living.

We might use a branched dichotomous key to work out what kind of animal something is.



Activity 1.4.1

Following is a dichotomous key for identifying different objects. Use the key to classify the objects listed in the table. The first one has been done for you.

Object	Living	Non-living
e.g. torch		✓
Tree		
Rock		
Butterfly		

Dichotomous key:

1. Does the object grow and develop?

   Yes. Go to step 2.

   No. It is non-living.

2. Does the object have the ability to reproduce?

   Yes. Go to step 3.

   No. It is non-living.

3. Does the object use energy to survive?

   Yes. It is living.

   No. It is non-living.

Activity 1.4.2

Could you create a dichotomous key for the items you classified in Activity 1.2.1? What are the characteristics you could ask about?

1.5 First Nations' perspectives on classification

Aboriginal and Torres Strait Islander peoples use a system of classification connected to their culture, traditions and relationship with Country.

Things are classified according to their uses, cultural significance and role in the environment. Classifying this way has helped First Nations peoples survive and thrive by understanding what resources are available where and when. For example:

- some plants are grouped as sources of foods, medicine or tools
- animals may be classified according to their behaviour, spiritual significance or seasonal availability.

In Yolŋu culture of Arnhem Land, all animals and plants are classified into one of two groups: Dhuwa and Yirritja. For example:

- certain fish are considered Dhuwa, while others are Yirritja
- humans are also classified into Dhuwa or Yirritja depending on how they interact with their environment and one another.

1.6 The Linnaean classification system

Imagine you're a scientist who just discovered a glowing mushroom in a rainforest. How would you know what it is or what it is called? By using classification! The mushroom's colour and shape can help you figure out its kingdom, phylum and species.

Fun fact

Some mushrooms are bioluminescent. This means they glow in the dark. This glow attracts insects that can help the mushrooms spread their spores.

Carl Linnaeas (1707– 1778) was a Swedish scientist who developed a system to organise and name all living things. His system categorises organisms into groups that are then organised into levels. It starts with the broadest group 'kingdom' and finishes with the most specific group 'species'. To remember the order of the groups, you can use the mnemonic '**K**ing **P**hilip **c**an **o**nly **f**ind **g**reen **s**ocks'.

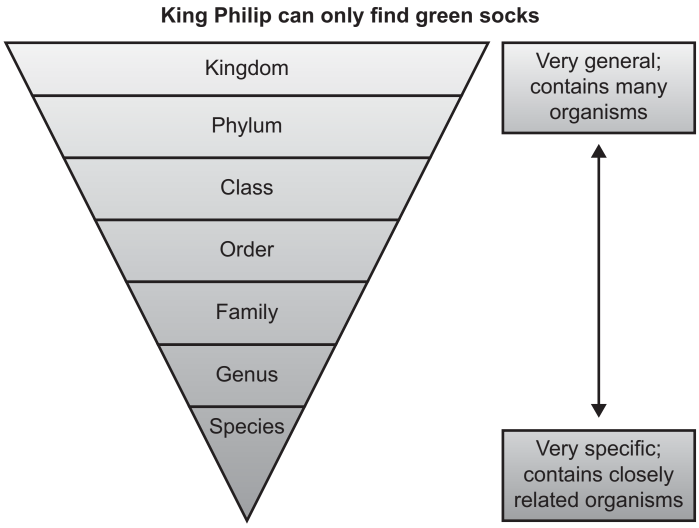


Figure 1.1: A Linnaean classification system chart

Scientists worldwide use the Latin language to name organisms so that they can all understand characteristics of the species, no matter what language they speak.

The species tells us what kind of organism it is. For example, *Canis familiaris* is the scientific name for domesticated dogs. The first part, *Canis*, is the genus, and the second part, *familiaris*, is the species. *Canis* is the Latin word for 'dog'; *familiaris* is Latin for 'of a household' (scientific names are written in italics). This naming system is called binomial nomenclature, which means 'two names'.

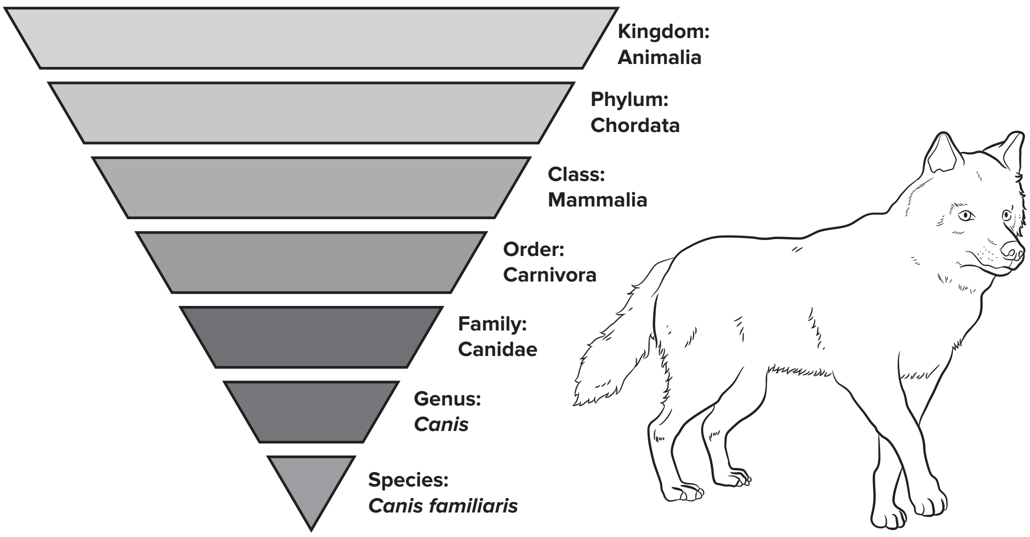
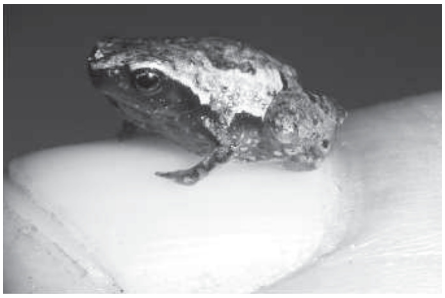


Figure 1.2: A Linnaean classification system chart for dogs; note that the genus starts with a capital letter, *Canis*, while the species name is lowercase, *familiaris*.

Using Linnaean classification to discover new species

When a new species is discovered, scientists study its characteristics and use the Linnaean system to identify and describe it. In this way, the scientists can determine how the new species fits into existing groups.

For example, in 2019 scientists discovered a new species of tiny frog in Madagascar. Using the Linnaean system, they determined that the frog belonged to the genus *Mini.* They chose the species name *mum* to describe its extremely small size. They analysed its physical traits (e.g. its body shape and colours) and compared these with similar frogs to place it within the correct family and genus.



Kingdom: Animalia
Phylum: Chordata
Class: Amphibia
Order: Anura
Family: Microhylidae
Subfamily: Cophylinae
Genus: *Mini*
Species: *Mini mum*

Figure 1.3: The Linnaean classification system for the Madagascan frog *Mini mum*

Fun fact

The scientific name for a polar bear is *Ursus maritimus*, which means 'sea bear' because they spend so much time swimming.

Another example of how useful the Linnaean classification system is can be found in medicine. If a new species of bacterium is found to be causing a disease and it has similar characteristics to a known bacterium, doctors can use this information to treat it quickly (e.g. with antibiotics).

1.7 Food chains and webs

Ecosystems

Earth is made up of living things, such as plants, animals and microorganisms, and non-living things, such as water, soil and sunlight. An ecosystem is a community of living things interacting with each other and with the non-living things in their environment. Everything in an ecosystem is connected, and each part plays a role in keeping the system balanced. For example, plants provide food and oxygen, animals help spread seeds, and fungi act as decomposers to break down dead plants and animals to return nutrients to the soil.

If one part of the ecosystem changes, it can affect everything else. For example, if a type of plant disappears, the animals that rely on it for food might also struggle to survive.

What happens if you forget to water a plant at home? Now imagine what happens if a whole forest loses its water source. Small actions, like saving water or planting trees, can make a big difference!

Ecosystems in Dreaming stories

In many First Nations Dreaming stories, ecosystems are explained through the relationships between living things and the land. One example is the story of the Rainbow Serpent.

In the story, the Rainbow Serpent is a powerful being that created the rivers, mountains and waterholes as it moved across the land. These waterholes became vital parts of the ecosystem, providing a source of water for plants, animals and people. The story also teaches that the land and its resources must be respected and cared for to keep the balance of life.

Activity 1.7.1

Make separate lists of the living things and non-living things in your backyard or local park (ecosystem).

Food chains

A food chain shows how energy moves through all the organisms in a habitat. It starts with the Sun as the main energy source. Plants use the sunlight to make food through a process called photosynthesis. That is why they are called **producers**. Animals are called **consumers** because they eat the plants or animals to get energy. For example:

Sun → leaves → caterpillar → bird → fox

The direction of the arrows in the food chain shows the flow of energy from one organism to another. This simple chain helps us understand how each organism gets energy.

Key terms

producer	an organism that creates its own food, such as plants undergoing photosynthesis
consumer	an organism that obtains energy by eating other organisms

Key fact

Photosynthesis is the process plants use to make their own food. In leaves, a green substance called chlorophyll traps the energy from sunlight. Plants use this energy as well as water from the soil and carbon dioxide in the air, to produce food (sugar) and oxygen.

The process can be written as:

Sunlight + water + carbon dioxide → sugar + oxygen

Activity 1.7.2

From your list of living things in your backyard or local park for Activity 1.7.1, create two examples of food chains describing the flow of energy.

Food webs

In real life, food chains overlap and connect to form food webs. A food web shows all the energy relationships in an ecosystem. These relationships are how animals, plants and other organisms depend on one another.

For example, in a pond ecosystem, we can observe the following food chains:

- Sun → algae → tadpoles
- Sun → algae → small fish → larger fish → birds

We can combine these to create the food web shown in Figure 1.4.

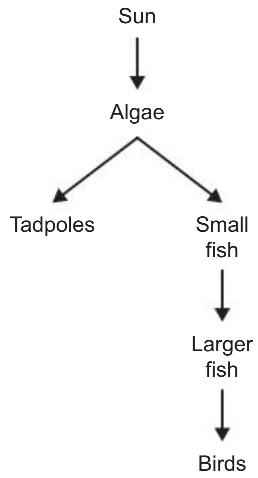


Figure 1.4: A food web for a pond ecosystem

Food webs can show all the complex interactions in an ecosystem better than a single food chain.

Activity 1.7.3

On a piece of paper, draw a food web with the food chains you created in Activity 1.7.2.

Positions in a food chain

Every organism has a specific role or position in a food chain. These positions are known as trophic levels. We have already looked at producers (plants) and consumers (animals).

- Producers are the base of the food chain because they produce energy from sunlight (e.g. plants and algae).
- Primary consumers are animals that eat producers (e.g. insects).
- Secondary and tertiary consumers are predators that eat other animals (e.g. foxes and eagles).

Pollinators and decomposers also have important roles in a food chain:

- Pollinators are animals that help plants produce by transferring pollen (e.g. bees).
- Decomposers are organisms that break down plants and animals, which returns nutrients to the soil (e.g. fungi, bacteria and worms).

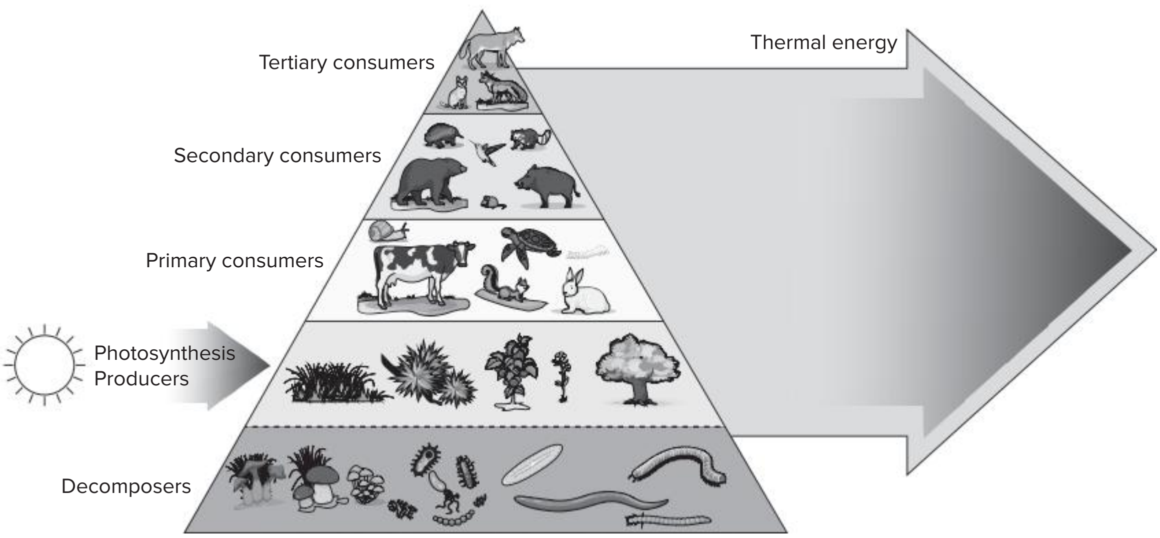


Figure 1.5: Trophic levels of organisms in a food chain

Fun fact

The largest food web is the ocean's, connecting plankton (producers) all the way to whales (consumers).

Activity 1.7.4 Create your own ecosystem

Imagine you're building a new planet. What animals, plants and microorganisms would you include? Think about how they would work together. Outline who your producers, consumers and decomposers will be and what characteristics they would have. Would you add bees for pollination? What about worms to keep the soil healthy? Draw your planet and explain your choices.

1.8 Impacts of changes in the environment on food chains and webs

Ecosystems are complex and delicate. They rely on a balance of all living **(biotic)** and non-living **(abiotic)** factors. Even small changes can have big impacts on food chains and food webs.

- Seasonal changes: In winter, fewer plants grow and some animals hibernate or migrate. This reduces the available energy sources.
- Destruction of habitat: When forests are cleared, animals lose their homes and food sources. For example, if trees are removed, herbivores like koalas might starve, which can then affect predators like dingoes.
- Introduction of a species: When a new species is brought into an ecosystem, it can upset the balance. For example, the introduction of cane toads in Australia harmed native predators and disrupted food webs.
- Abiotic factors: Changes in non-living factors (e.g. temperature, water availability and pollution) can affect plants and animals. For example, a drought can reduce water supplies, harming all organisms in the food web.

Key terms

abiotic	non-living; a non-living condition or thing in an ecosystem
biotic	living; a living thing in an ecosystem

Activity 1.8.1

List three examples of abiotic factors and three examples of biotic factors in your backyard or local park.

For example, a food chain in a coral reef would consist of the following.

- *Producer*: algae
- *Primary consumer*: parrotfish
- *Secondary consumer*: moray eel
- *Tertiary consumer*: reef shark

If there are changes in any of the above organisms, we can see great impacts on the food chain and the ecosystem. For instance, if parrotfish populations decline because of overfishing, algae may overgrow, damaging coral reefs.

Activity 1.8.2

What other impacts can you think of if there is a decline in parrotfish populations? What other organisms are affected?

Impacts on food webs in Australia

Example 1: Destruction of habitat

When forests are cleared for agriculture or housing, this has a big impact on food chains in Australia. For example, the loss of eucalyptus forests has reduced food for koalas (primary consumers) and habitat for other species such as possums. With fewer koalas, predators such as dingoes may struggle to find enough food, disrupting the food web.

Example 2: Introduction of cane toads

Cane toads (Figure 1.6) were introduced into Australia in 1935 to control pests in sugarcane fields. However, the toads became an invasive species. Native predators such as snakes, goannas and birds that tried to eat the toads were poisoned, causing their populations to decline. This disrupted local food webs, affecting both predators and the animals these predators typically controlled, such as rodents and insects.

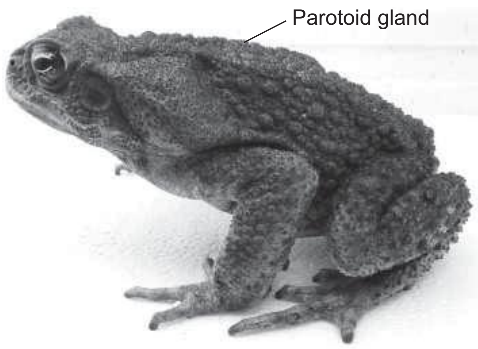


Figure 1.6: Cane toads produce a poison called bufotoxin in their parotoid gland. Cane toad eggs are also poisonous to fish.

Example 3: Seasonal changes and bushfires

Bushfires, especially in dry seasons, can destroy habitats and food sources. For example, after a fire, wallabies (herbivores) might struggle to find plants to eat, which in turn affects predators such as dingoes. However, some plants, such as banksias, are adapted to fire and release seeds afterwards, helping ecosystems recover.

First Nations land management

First Nations peoples have an incredible understanding of ecosystems and how they function. They recognise that all living things are interconnected and rely on one another for survival. This understanding is reflected in practices such as:

- observing animal behaviour and plant growth to predict seasonal changes
- protecting breeding areas and ensuring that only the resources needed are taken.

One of the most well-known examples of First Nations land management is firestick farming. This involves carefully planned, low-intensity fires to:

- clear dead vegetation, reducing the risk of destructive wildfires
- encourage new plant growth, which attracts animals such as kangaroos and emus
- protect important habitats and biodiversity.

This sustainable approach ensures ecosystems remain healthy and productive over time.

First Nations cultural burning on Quandamooka Country

If cultural burning was a person, one might describe her as patient, slow-moving, calm and quiet. A cultural burn will snake slowly through a site, missing some patches. This creates a burn mosaic.

The fire is not too hot and does not burn high into the tree canopy.

Use of fire in the landscape varied across Australia, between different First Nations groups. Uses for fire can include: fuel and hazard reduction, regeneration of habitat, generation of and management of particular sources of food, fibre and medicines, facilitation of access and movement, protection of cultural and natural assets, or healing Country's spirit.

Quandamooka people have the oldest published archaeological occupation site on the east coast of Australia. Their use of fire is a deliberate and integral part of caring for Country. That includes burning and prevention of burning.

As leaders and practitioners of cultural burns on Minjerribah, the Quandamooka people wanted to establish standard practices for wildlife management during burning – specifically, whether thermal imaging drones could establish where koalas and other animals are present in areas to be burnt. This could inform actions to reduce risk.

Extract from *The Conversation* https://theconversation.com/cultural-burning-is-safer-for-koalas-and-better-for-people-too-200997,

Positive effects of human activity

When people make sustainable choices, they can help ecosystems thrive. The following are some examples of positive actions.

- Revegetation projects: Planting native trees and shrubs can restore habitats and support local wildlife.
- Clean-up programs: Removing litter from waterways and parks helps protect plants and animals.
- Wildlife corridors: Building pathways for animals to safely move between habitats reduces the risk of accidents and allows species to spread out.

Negative effects of human activity

Some human actions can harm ecosystems.

- Deforestation: Clearing land for farming or construction destroys habitats and disrupts food webs.
- Pollution: Chemicals, plastics and other waste harm animals and plants and can poison waterways.
- Overfishing: Taking too many fish from the ocean disrupts marine food chains and can lead to population collapse.

Balancing human needs and ecosystem health

To ensure ecosystems remain sustainable, we need to balance human activity with environmental care. This involves:

- reducing waste and pollution
- protecting natural areas from destruction
- learning from First Nations knowledge to manage land in a way that supports all living things.

If we combine scientific approaches with traditional ecological knowledge, we will be able to understand and care for the ecosystems better. This will ensure that future generations continue to benefit from a healthy, balanced environment.

Look it up

People in cities all over the world build ‘bee hotels’ to support pollinator populations. Conduct some research online to learn how to make your own bee hotel.

End-of-chapter summary

- Classification systems help organise the diversity of organisms by grouping them according to their similarities and differences, using hierarchical levels such as kingdom, genus and species.
- Tools such as dichotomous keys and the Linnaean system enable scientists to identify and name species, helping us to understand evolutionary relationships and ecosystem roles.
- First Nations peoples have long used classification systems based on ecological roles and cultural significance. They integrate sustainable practices such as firestick farming and seasonal resource management.
- Food chains and webs illustrate energy flow and interconnected relationships in ecosystems, highlighting the impacts of environmental changes, such as habitat destruction and invasive species.
- Combining modern science with traditional knowledge enhances our ability to sustain ecosystems and balance human activity with environmental health.

Revision questions

1. What is the primary purpose of classifying organisms?

A. To identify their habitats

B. To organise and understand biodiversity

C. To increase the number of species

D. To reduce competition among organisms

2. Which level of the Linnaean classification system is the most specific?

A. Class

B. Order

C. Genus

D. Species

3. What is the role of decomposers in a food chain?

A. They produce energy from sunlight.

B. They break down dead organisms and recycle nutrients.

C. They are primary consumers.

D. They hunt and eat other animals.

4. Which of the following is an example of an abiotic factor affecting a food web?

A. Introduction of a new predator

B. Seasonal migration of birds

C. Changes in temperature or rainfall

D. Overpopulation of herbivores

5. In First Nations classification systems, how are organisms primarily grouped?

A. Based on physical traits

B. Based on their role in the ecosystem and cultural significance

C. Using Latin binomial nomenclature

D. By their geographical location

6. Explain why Latin is used in scientific names of organisms.

7. Describe one way firestick farming benefits ecosystems.

8. What is a dichotomous key, and how is it used in classification?

9. Use the dichotomous key to classify the following animals, based on their given characteristics.

Animal 1: Has feathers

Animal 2: Does not have feathers; has smooth, moist skin

Animal 3: Does not have feathers; has scales and fins

Dichotomous key:

1. Does the animal have feathers?

Yes → It is a bird.

No → Go to step 2.

2. Does the animal have smooth, moist skin?

Yes → It is an amphibian.

No → Go to step 3.

3. Does the animal have scales and fins?

   Yes → It is a fish.

   No → It is a reptile.

10. Create a simple food chain for a forest ecosystem, starting with the Sun. Label each organism as a producer, primary consumer or secondary consumer.
11. Analyse the impact of habitat destruction on a food web. Use an example to illustrate your answer.
12. Use the following organisms to construct a food web: grass, kangaroo, snake, eagle, grasshopper, lizard.
13. Describe how the introduction of an invasive species, such as cane toads in Australia, can disrupt food webs.

Chapter 2 – Earth and space

2.1 What is Earth and space science?

Earth and space science is a branch of science that studies Earth's systems. It studies geology, weather and the oceans as well as the universe beyond, including planets, stars and galaxies.

Studying Earth and space science is crucial for understanding and protecting our planet, preparing for natural disasters, managing resources and exploring the universe. It equips us to tackle global challenges and inspires us to learn more about Earth and beyond.

By the end of this chapter, you will be able to:

- explain how Earth's tilt and position relative to the Sun creates the seasons and the cyclic patterns of lunar phases and eclipses of the Sun and Moon
- understand how gravity and positions of the Moon and the Sun affect Earth's oceans and tides
- describe First Nations peoples' knowledges of the phases of the Moon and the connection between the lunar cycle and ocean tides, and different First Nations calendars.

2.2 Predictable phenomena on Earth

The Sun is the only star in our solar system. A star is a hot giant ball of gas that produces its own light and heat. The solar system is part of our galaxy, the Milky Way. A galaxy can contain billions of stars! Earth, the Moon and the Sun are part of a great system that is responsible for creating natural events such as seasons, tides, lunar phases and eclipses.

By understanding how Earth, the Moon and the Sun interact, we can learn more about how they influence life on Earth.

Our solar system

The solar system is like a giant, intriguing neighbourhood in space, with the Sun at the centre and a range of 'residents' orbiting around it. These residents include **planets**, moons, **asteroids**, **comets** and even **dwarf planets**.

Key terms

planet	a large, round, naturally occurring object orbiting a star
asteroid	a large space rock that orbits the Sun
comet	a small icy dirtball that orbits the Sun
dwarf planet	an object that resembles a planet but is much smaller; it orbits the sun, but it is not large enough to clear its path of debris

At the heart of our solar system is the Sun, which provides the energy needed for life on Earth. It's over one million times larger than Earth and acts as a giant magnet, pulling everything in the solar system into orbit with its strong gravitational force.

Key fact

An orbit is the path of an object around another repeatedly. Earth travels a set path around the Sun once a year. Therefore, Earth orbits the Sun.

Planets move around the Sun in elliptical (oval-shaped) paths, while moons orbit their planets. Gravity and motion work together to create this beautiful cosmic dance.

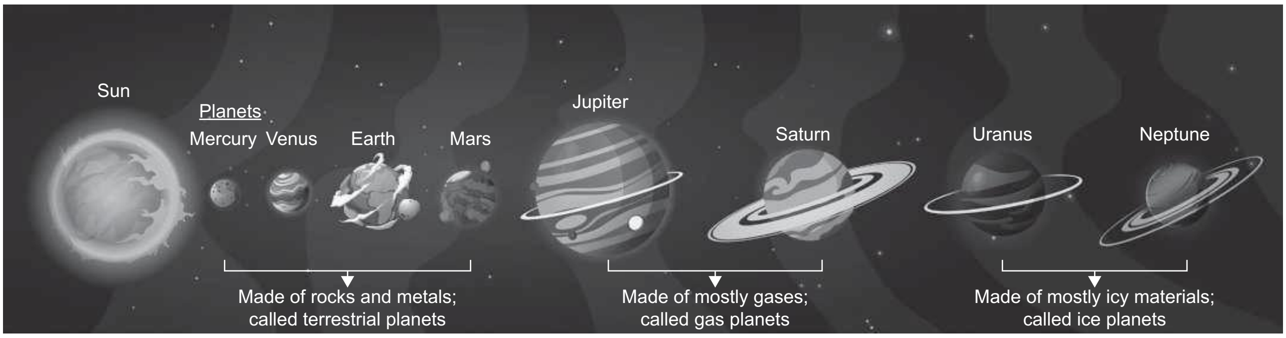


Figure 2.1: An impression of our solar system

Fun fact

The Sun is so big that about 1.3 million Earths could fit inside it!

2.3 Earth

Earth is like a ball that is slightly flattened at its two poles – the top and bottom. It is tilted at an angle of 23.5°.

Earth is also divided into two halves (hemispheres) by the equator, which is like a border line that runs around the outer middle of Earth. The two hemispheres are the northern (top) and southern (bottom) hemispheres (Figure 2.2).

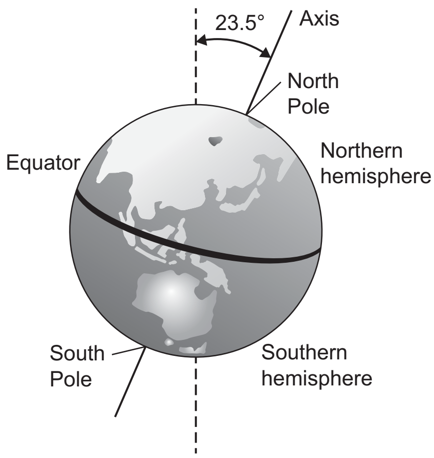


Figure 2.2: Earth and its hemispheres

Fun fact

The tilt of Earth's axis is stabilised by the gravitational pull of the Moon. Without the Moon, Earth's tilt might wobble chaotically, drastically altering the climate!

Activity 2.3.1

Create a model of Earth's orbit using a lamp (the Sun) and a globe. Tilt the globe and move it around the lamp to visualise how sunlight hits different regions during the year.

Rotation causes day and night

We can see the Sun rise in the east and set in the west. It may seem that the Sun moves, but it is actually Earth that rotates.

Earth spins or turns on an axis, which you can think of as a pole running through Earth from the North Pole to the South Pole. It takes 24 hours for a full rotation – 1 day (Figure 2.3).

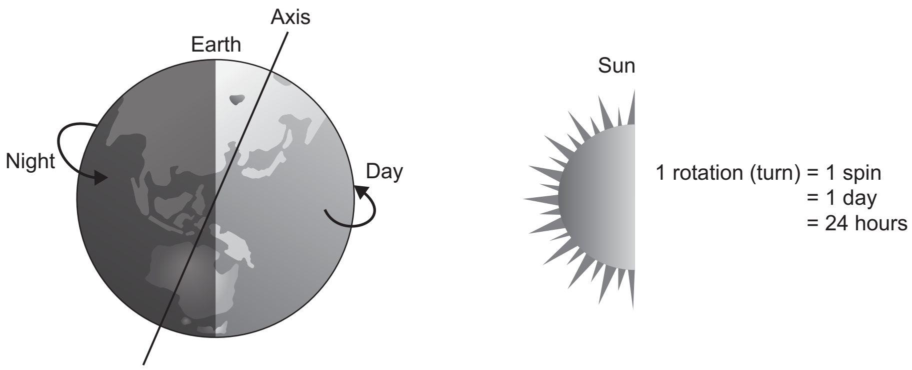


Figure 2.3: Earth's rotation

Revolution causes the seasons

Earth completes a revolution around the Sun tilted on its axis at an angle of 23.5˚. One revolution takes 365.25 days. The extra quarter day is why there are leap years. Every 4 years, there is a leap year, which has 366 days to account for the extra quarter day each year.

The 23.5˚ tilt is what causes uneven warming and produces the seasons. Earth spins on its axis like a ball, while also orbiting the Sun. The tilt means different parts of Earth receive different amounts of sunlight throughout the year.

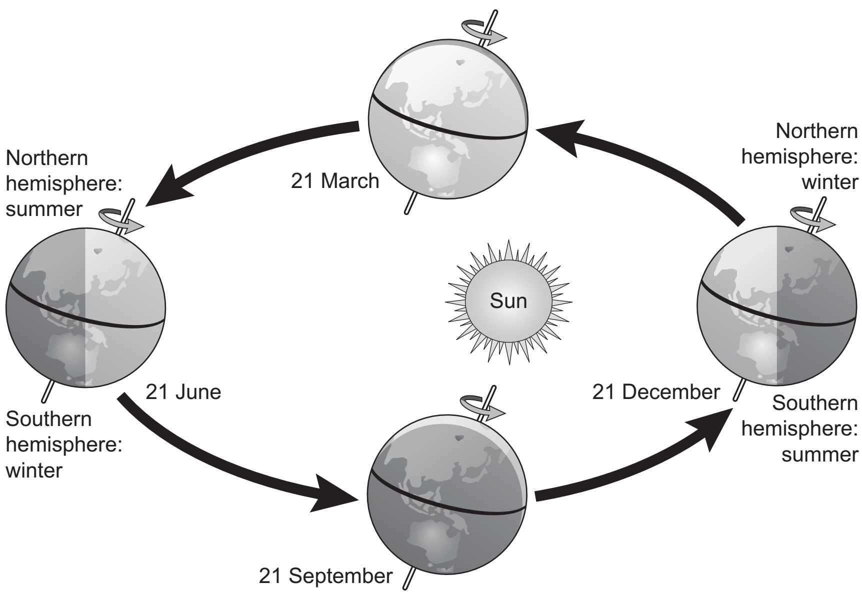


Figure 2.4: Earth's revolution and seasons

- **Summer:** When the part of Earth (hemisphere) you live on is tilted towards the Sun, it receives more direct sunlight. This makes the days longer and warmer, which gives us summer.
- **Winter:** When the part of Earth (hemisphere) you live on is tilted away from the Sun, it receives less direct sunlight, and the days are shorter. This gives us winter.
- **Spring and autumn:** These two seasons occur when neither hemisphere is tilted away or towards the Sun. Therefore, the sunlight is more evenly distributed, resulting in milder weather.

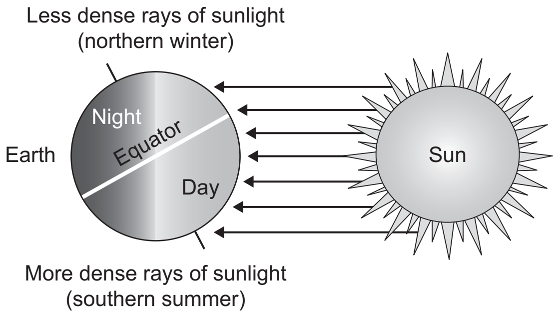
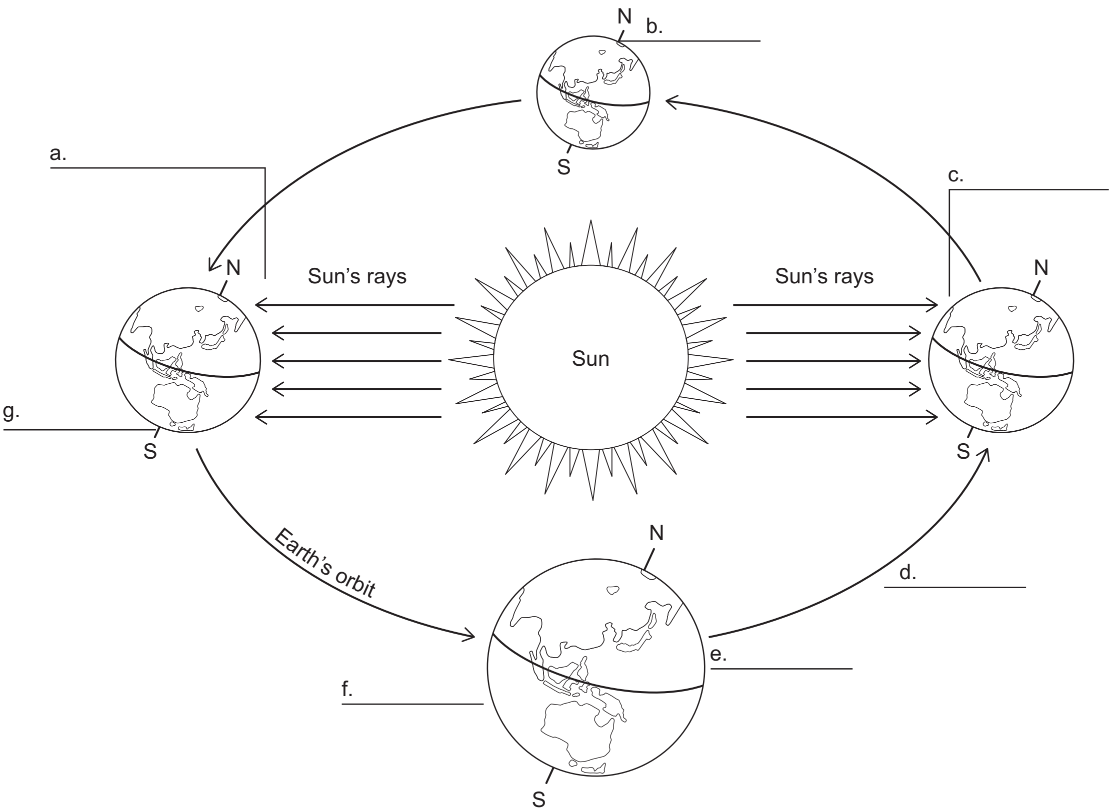


Figure 2.5: Earth's seasons

Activity 2.3.2

Add these labels to the following diagram.

Northern hemisphere	Winter
Southern hemisphere	North Pole
Summer	South Pole
Revolution	



Understanding the seasons

In December, Australia (southern hemisphere) is tilted towards the Sun. The Sun's rays are stronger and the days are longer and warmer, which gives us summer. In June, when Earth has revolved to the other side of the Sun, Australia (southern hemisphere) is now tilted away from the Sun, and experiences winter. The Sun's rays are now weaker, and the days are shorter and colder.

This cycle repeats every year, creating seasonal changes. The northern hemisphere encounters the opposite season because of the Earth's tilt. For example, in Europe it is winter in December and summer in June.

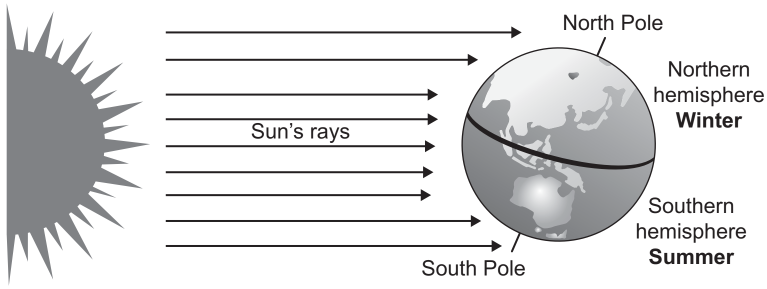


Figure 2.6: Earth's seasons in December: the southern hemisphere experiences summer and the northern hemisphere experiences winter.

2.4 The Moon

Phases of the Moon

Just as Earth orbits the Sun, the Moon orbits Earth. The Moon doesn't produce its own light – it reflects sunlight. The reflection changes through eight phases as Earth orbits the Sun, and the Moon orbits Earth.

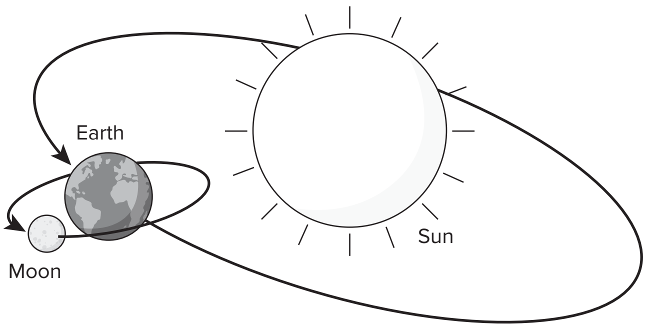


Figure 2.7: Earth and the Moon's orbits

As the Moon orbits Earth, the amount of sunlight it reflects that is visible to us creates the different lunar phases. This cycle, which is called the lunar month, takes approximately 29.5 days.

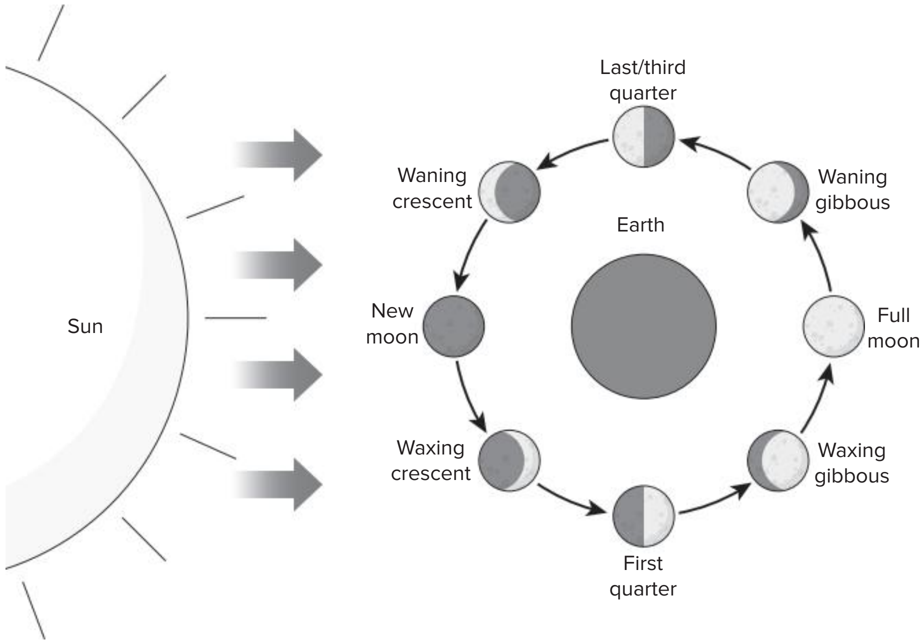


Figure 2.8: Moon's lunar phases

New moon happens when the Moon is between Earth and the Sun. The lit side is away from us.

Full moon happens when Earth is between the Sun and the Moon. We can see the entire lit side of the Moon.

First quarter and **last quarter**, also known as the 'third quarter', happen when we only see half of the lit side of the Moon.

Some other ways to describe the phases of the Moon are:

- waxing – the Moon appears to be getting bigger as more of the lit side is facing us
- waning – the Moon appears to be getting smaller as less of the lit side is facing us
- gibbous – more than half of the Moon is illuminated but it is not a full moon
- crescent – less than half of the Moon is illuminated. It is visible as a slim arc-shaped sliver.

Activity 2.4.1

Use the following table to record the shape of the Moon each day for 30 days. Try to label them using the descriptions on the previous page.

Date:	Date:	Date:	Date:	Date:	Date:
Date:	Date:	Date:	Date:	Date:	Date:
Date:	Date:	Date:	Date:	Date:	Date:
Date:	Date:	Date:	Date:	Date:	Date:
Date:	Date:	Date:	Date:	Date:	Date:

Eclipses

Eclipses happen when Earth, the Moon and the Sun are in perfect alignments.

Solar eclipses happen when the Moon passes between Earth and the Sun, blocking the Sun and creating a shadow on Earth.

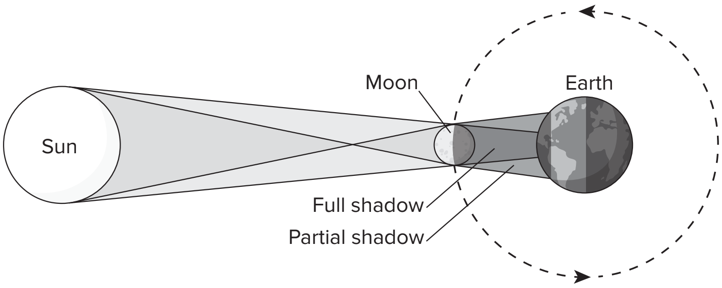


Figure 2.9: A solar eclipse

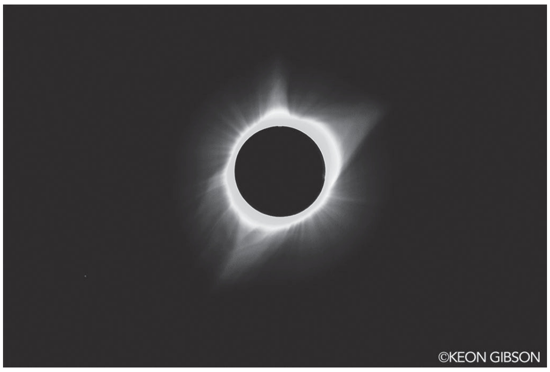


Figure 2.10: The total phase of the 21 August 2017 total solar eclipse as seen from Casper, Wyoming, USA. Credit: NASA's Goddard Space Flight Center, © Keon Gibson.

Lunar eclipses happen when Earth passes between the Sun and the Moon. Earth blocks sunlight from reaching the Moon filtering out the blue light and leaving only red light. Earth's atmosphere interferes with the sunlight, which makes the Moon appear a reddish colour. This is why it is sometimes called a 'blood moon'.

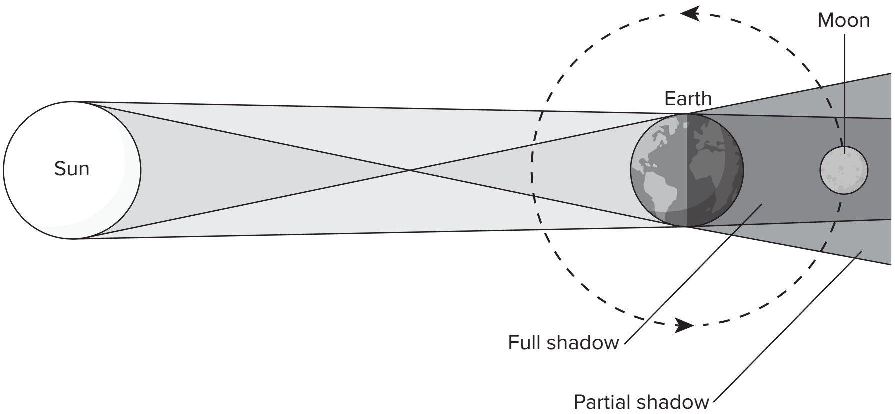


Figure 2.11: A lunar eclipse

Figure 2.12: A lunar eclipse. Image credit: NASA's Scientific Visualization Studio.

2.5 Ocean tides

Earth, the Moon and the Sun have gravity. The gravitational pull between each of these celestial bodies affects ocean tides.

Tides are the rise and fall of oceans that are caused by the changing gravitational pull of the Sun and the Moon as the Moon and Earth move through space.

High tide

On the side of Earth that is facing the Moon, the Moon's gravity pulls the water towards it, creating a tidal force. The tidal force causes Earth – and its water – to bulge out on the side closest to the moon and the side farthest from the moon. These bulges of water are high tides.

The highest tides occur when the Sun, Earth and the Moon align during full and new moons because of their combined gravitational forces. These are called spring tides.

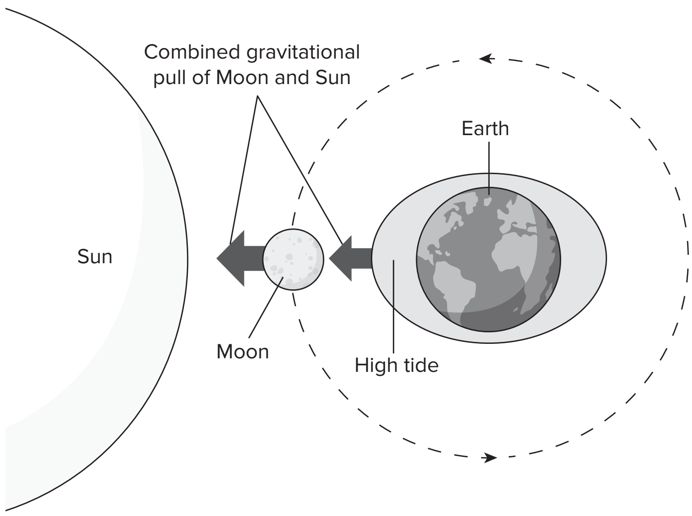


Figure 2.13: A spring tide

> **Fun fact**
>
> The Bay of Fundy in Canada has the highest tidal range in the world, with water levels rising and falling by up to 16 metres!

Low tide

Low tides occur between the high tides. The lowest tides happen when the Sun and Moon form a right angle, during the first and last quarters. The gravitational pulls are not combined, and much lower tides called neap tides occur.

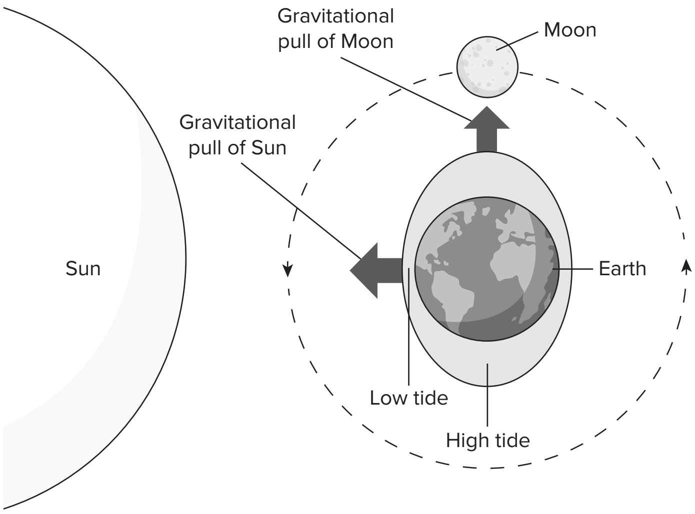


Figure 2.14: A neap tide

The changes in tides support and bring nutrients to diverse marine ecosystems. For example, in the Great Barrier Reef, low tides expose the sea bed, which allows crabs and shellfish to feed. High tides allow nutrients to flow into different coastal areas, supporting different ecosystems.

Scientists study tidal cycles to better understand how to support marine life. For example, they can schedule the best times to release hatchlings or plant coral.

2.6 First Nations' understanding of Earth, the Sun and the Moon

Before European settlement, Aboriginal and Torres Strait Islander peoples had an advanced understanding of the stars and planets and their movements. They could identify every star visible to the naked eye and understood the shifting patterns of stars, the motion of planets and the yearly changes in the night sky. This deep knowledge was crucial for predicting seasonal events and mastering navigation.

Unlike many other cultures, First Nations' astronomy often incorporated not just the brightness and arrangement of stars but also the dark shapes within the Milky Way and the colours of stars.

For example, in the story of the 'Emu in the Sky', the shape of the emu is not created by star constellations but by dark spaces within the Milky Way. The emu's head is formed near the Coalsack Nebula and its body stretches along a part of the Milky Way formed by dark dust clouds. The position of the emu in the night sky provided information about seasonal changes and events, such as when emus lay eggs.

Figure 2.15: The Emu in the Sky constellation

This perspective on the cosmos continues to hold cultural and practical significance today. In modern times, First Nations peoples, including scientists and educators, are continuing to share and promote their knowledge of the stars and the universe.

One notable example is Kirsten Banks, a Wiradjuri astrophysicist and science communicator. Kirsten is a passionate advocate for First Nations astronomy who was first inspired by the story 'Emu in the Sky' as a child. She uses her platform to educate people about the connection between First Nations cultures and the stars. Through her work, Kirsten highlights how First Nations peoples use the night sky to guide their lives and understand the world around them.

For tens of thousands of years, Aboriginal and Torres Strait Islanders have observed the Moon, its phases and the tides to guide their daily lives. Their deep understanding of these cycles reflects their strong connection to the environment. On the Island of Mer in eastern Torres Strait, the Melanesian Meriam People understood that when there was a neap tide at quarter moon (the 'Werir Meg', or Hungry Tide) this was the best time to fish. During the Werir Meg, the seafloor was clear and open so it was easier to see and catch fish.

Activity 2.6.1

Research a First Nations lunar calendar and compare it to the calendar on your computer (which is known as the Gregorian calendar). Discuss how these calendars may or may not reflect an understanding of the environment.

Dr Kirsten Banks on dark comets

Dr Kirsten Banks, along with Drs Rebecca Allen and Sara Webb, all astronomers at Swinburne University, recently discussed a new scientific discovery: the dark comet. Below is an extract of their article from *The Conversation* website.

What is a dark comet? A quick guide to the 'new' kids in the solar system

In 2017, NASA discovered and later confirmed the first interstellar object to enter our solar system.

It wasn't aliens. But artist impressions of the object (called 'Oumuamua, the Hawaiian word for "scout") do resemble an alien spaceship out of a sci-fi novel. This strange depiction is because astronomers don't quite know how to classify the interstellar visitor.

Its speed and path around the Sun don't match a typical asteroid, but it also has no bright tail or nucleus (icy core) we normally associate with comets. However, 'Oumuamua has erratic motions that are consistent with gas escaping from its surface. This dark comet has had astronomers scratching their heads ever since.

Flash forward to today [December 2024], and more of these mysterious objects have been discovered, with another ten announced just last week. While their nature and origins remain elusive, astronomers recently confirmed dark comets fall into two main categories: smaller objects that reside in our inner Solar System, and larger objects (100 m or more) that remain beyond the orbit of Jupiter.

In fact, 3200 Phaethon – the parent body of the famous Geminid meteor shower – may be one of these objects.

How do dark comets differ from normal comets?

Comets, often described as the Solar System's "dirty snowballs", are icy bodies made of rock, dust and ices. These relics of the early Solar System are critical to unlocking key mysteries around our planet's formation, the origins of Earth's water, and even the ingredients for life.

Astronomers are able to study comets as they make their close approach to our Sun. Their brilliant tails form as sunlight vaporises their icy surfaces. But not all comets put on such a dazzling display.

The newly discovered dark comets challenge our typical understanding of these celestial wanderers.

Dark comets are more elusive than their bright siblings. They lack the glowing tails and instead resemble asteroids, appearing as a faint point of light against the vast darkness of space.

However, their orbits set them apart. Like bright comets, dark comets follow elongated, elliptical paths that bring them close to the Sun before sweeping back out to the farthest reaches of the Solar System.

They go beyond Pluto, some even making it out to the Oort Cloud, a vast bubble of tiny objects at the fringe of our Solar System. Their speed and paths are what allow astronomers to determine their origins.

Extract from *The Conversation* https://theconversation.com/what-is-a-dark-comet-a-quick-guide-to-the-new-kids-in-the-solar-system-245763, CC BY 4.0.

Figure 2.16: This artist's impression shows the first interstellar asteroid, 'Oumuamua. Observations from the European Southern Observatory's Very Large Telescope in Chile and other observatories around the world show that this unique object was travelling through space for millions of years before its chance encounter with our star system. It seems to be a dark red, highly elongated metallic or rocky object, about 400 metres long, and is unlike anything normally found in the Solar System.

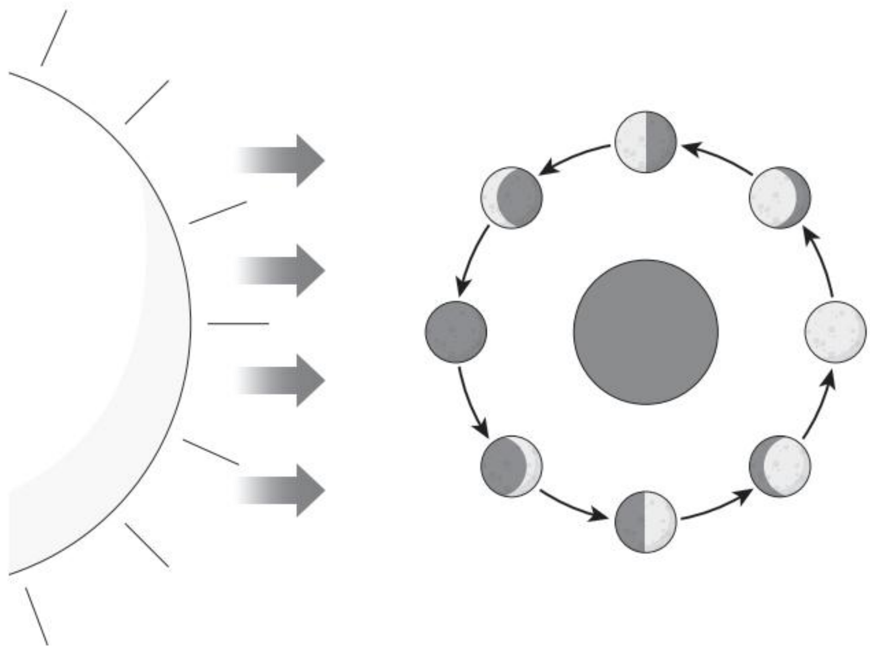
Credit: European Southern Observatory/M. Kornmesser. Image licensed under Creative Commons, CC BY 4.0.

End-of-chapter summary

- Earth's tilt and its orbit around the Sun create the seasons. Different sunlight intensity and day lengths are experienced during summer, winter, spring and autumn.
- The Moon's phases, from new to full, result from its position relative to Earth and the Sun. Solar and lunar eclipses occur during specific alignments.
- Tides are driven by the Moon and Sun's gravitational pull, with spring and neap tides depending on their alignment.
- First Nations Australians have long used lunar cycles to understand tides and guide sustainable practices, integrating this knowledge into cultural calendars. Combining First Nations wisdom with modern science enriches our understanding of Earth, the Sun and the Moon.

Revision questions

1. What causes the seasons on Earth?
   - **A.** The distance between Earth and the Sun
   - **B.** Earth's tilt on its axis
   - **C.** The speed of Earth's rotation
   - **D.** The Moon's gravitational pull
2. Which phase of the Moon occurs when the Moon is between Earth and the Sun?
   - **A.** New moon
   - **B.** Full moon
   - **C.** First quarter
   - **D.** Last quarter
3. What is the main cause of tides on Earth?
   - **A.** The Sun's heat
   - **B.** Earth's rotation
   - **C.** Ocean currents
   - **D.** The Moon's gravitational pull
4. What happens during a spring tide?
   - **A.** Tides are lower than usual.
   - **B.** Tides are higher than usual.
   - **C.** The Moon is in its last quarter.
   - **D.** Earth's tilt is greatest.
5. Explain why the southern hemisphere experiences summer in December.
6. Label the diagram for the different phases of the Moon.



7. What are the two main forces that create tides on Earth?

8. Describe the difference between a solar eclipse and a lunar eclipse.

9. How do First Nations peoples use the lunar cycle in their daily lives? Provide one example.

10. Why are spring tides higher than neap tides?

11. Imagine you are on a trip to Canada in July.

  a. Which season is it in Canada, and why?

  b. Which season is it in Australia at the same time?

12. You see a waxing crescent Moon in the night sky. Predict the next two phases of the Moon and describe what they will look like.

13. The Yolŋu People use the Moon and tides for sustainable fishing. How might this knowledge help modern scientists manage fisheries?

14. Draw a diagram showing the positions of the Sun, Earth and the Moon during a lunar eclipse. Label your diagram and explain why the Moon appears reddish during this event.

Chapter 3 – Physics

3.1 What is physics?

Physics is a branch of science that studies matter, energy, motion and force. People who work in physics are called physicists.

There are many branches of physics, including optics, sound, light, electricity, astronomy and motion. Physics studies the smallest particles (e.g. atoms) as well as stars, planets and the universe.

Think about it

1. What is a force?
2. Is friction important?
3. Why does Earth keep travelling around the Sun?

By the end of this chapter, you will be able to:

- describe the impact of a force on a moving object
- represent forces with force arrow diagrams
- determine the net force on an object and use a force measurer
- explain how machines harness our knowledge of forces
- describe the role of gravity in the orbits of planets and moons
- describe examples of machines used by First Nations peoples.

3.2 Forces

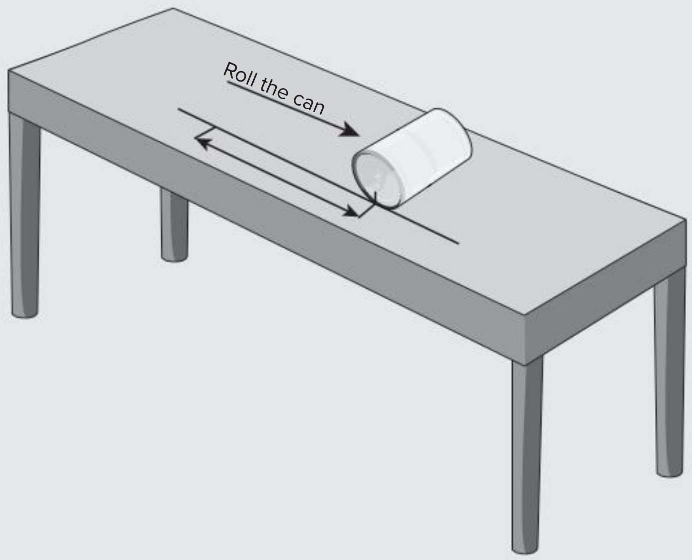
A **force** is a push, pull or twist that changes an object's motion, speed or direction. A force is an action that can make something move or change its shape.

Key term

force	a push, pull or twist that changes the motion of an object

Think about it

Consider a soft-drink can lying on its side on a bench.



How many ways could you make the can roll on the bench without directly touching the can? (Think laterally – there are many possibilities!)

For each way, identify the force as a push or pull, and a contact force or non-contact force.

How many ways could you think of? For example, you could:

- blow through a straw onto the can
- wave your jumper rapidly on one side of the can
- throw an object at the can
- tilt the bench
- half-fill a balloon and direct the mouth of the balloon to blow on the can
- rub an inflated balloon on your jumper to create static electricity and hold it near the can
- put a nail in the can and hold a magnet near the can to attract it
- squirt the can with a jet of water.

In the previous exercise, you applied a force to the can and caused it to roll – you changed its motion. The attraction to the balloon, the magnet and the jet of water are all examples of forces.

You are applying forces all the time. You apply a force when you:

- stand up
- lift your pen to write and direct the pen over the page
- close your laptop
- walk to your locker
- undo the combination lock.

All these actions involve changing the motion of objects.

Contact or non-contact

Forces can be described as **contact forces** or **non-contact forces**, depending on whether the force contacts the object or not. A push is usually a contact force, whereas the electrostatic attraction of a balloon to a soft-drink can is a non-contact force.

It can sometimes be challenging to determine whether a force is a contact or non-contact force. Using a magnet and a piece of iron in the can will result in a contact force if you drag the can along the bench with the magnet touching the can. But it will be a non-contact force if you carefully keep a gap between the magnet and the can.

Blowing on the can through a straw is still a contact force even though the straw does not touch the can. You are blowing a stream of air particles at the can and these particles contact the can when they collide with it.

Activity 3.2.1

1. What is the difference between contact forces and non-contact forces?
2. Are the following examples contact forces or non-contact forces?
   a. Using a magnet to move a can
   b. Blowing on a can through a straw
3. List two other examples of non-contact forces (unrelated to this example of the soft-drink can).

Key fact

A non-contact force acts on an object without touching it.

What forces can do

The table includes five examples of a force being applied to an object. Picture each activity (or try it!). Complete the table by adding what you expect to see in the second column and a reason for the change in the third column.

Task	Expected change	Reason for the change
1. Drop a large piece of plasticine or Blu Tack onto the floor.		
2. Drop a ping-pong ball.	As it falls: When it hits the floor:	

Task	Expected change	Reason for the change
3. Push a small block of wood along a bench.		
4. Hold a coin on its side and flick the coin.		
5. Stretch an elastic band.		

Look it up: Forces in slow motion

One way to view the fascinating effects of forces is to watch slow-motion videos of common activities. You will see aspects of the force in action that are not evident at normal speed. Two examples from the Slow Mo Guys are the videos Rubber Band Versus Watermelon and Balloon Bullet Time.

Search ‘slow motion forces in action’ to find examples of your own.

Types of forces

You will learn about different types of forces throughout high school. Some of these forces include the following.

- Applied force: Any push or pull force exerted on an object.
- Tension: A pulling or stretching force.
- Magnetism: A force exerted on some metals.
- Gravity: An attractive force between objects that have mass.
- Friction: A force that resists motion.
- Elastic: A force that occurs when a springy object is squashed or stretched.

3.3 Representing forces

In diagrams, forces are usually represented as arrows that point in the direction the force is acting. The length of the arrow indicates the size of the force. The unit of force is the newton (N), which is named after renowned English mathematician and physicist Sir Isaac Newton.

Figure 3.1 is a simplified force diagram of a ball being pushed along a bench.

How is force A different from force B?

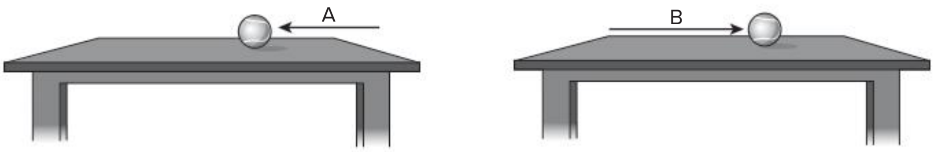


Figure 3.1: A force diagram of a ball being pushed along a bench.

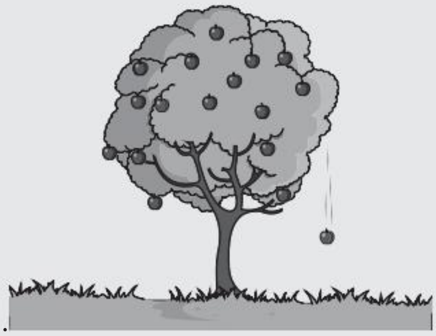
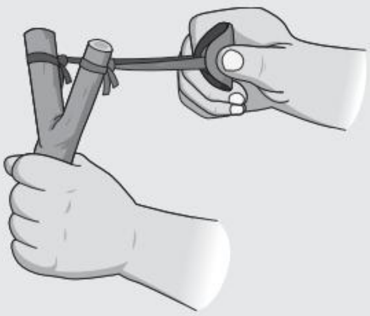
Key fact

Forces can be represented by arrows. The arrows show the size (magnitude) and direction of the force.

Think about it

The following table lists come common types of forces. Complete the table by adding an arrow to each diagram, describing what is happening and stating whether the force is contact or non-contact.

Force	Example (use an arrow to draw the force)	What happens?	Contact or non-contact force
Magnetic force			
Electrostatic			
Buoyancy	 Hold a ping-pong ball under water. Let the ball go.		

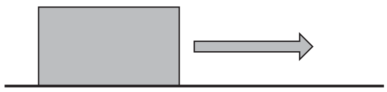
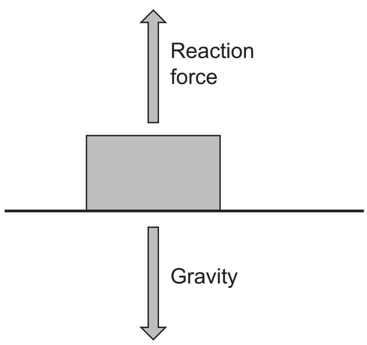
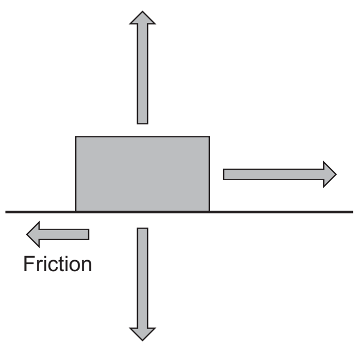
Force	Example (use an arrow to draw the force)	What happens?	Contact or non-contact force
Gravitational			
Pushing force			
Air resistance			
Friction			
Elastic (spring) force			

> **Key facts**
>
> **Balanced versus unbalanced forces**
>
> Balanced is when forces are equal and act in opposite directions on an object.
>
> Unbalanced is when forces are acting in opposite directions but are not equal in magnitude.

Force diagrams

Table 3.1 can help you understand the concepts of **net force** and **balanced forces**. A block is being pushed along a bench. A moving block often experiences **friction**, which is a force generated by the surface of the block passing over the surface of the bench. Friction is a force that opposes (acts against) motion.

Table 3.1: Interpreting force diagrams

Force diagram	Explanation
	There is a net force acting to the right, so the block moves to the right.
	These forces are equal and opposite. The net force is zero, so the block remains stationary. The forces are balanced.
	The force to the right is greater than the force to the left, so the net force is to the right. The block moves right. The forces are unbalanced.
	Forces can be added; the net force on this block is 10 – 5 = 5 N to the right.
	A block sitting on a bench also experiences gravity and a reaction force. Gravity acts on the block to push it down, but the bench pushes back with an equal reaction force, so the block does not move up or down.
	This block is sliding to the right. The rubbing of the block produces friction. Friction acts in the opposite direction to the movement of the block. Friction opposes motion.

Key term

net force	the overall force on an object

Key facts

- An object that has balanced forces acting on it is not necessarily stationary; it could be moving at constant speed.
- When forces are unbalanced, the motion of the object will change.
- When forces are balanced, the motion of the object will remain constant.

Gravity is the force of attraction between any two masses. There is a force of gravity between yourself and each student in the class. It is a very small force because your masses are small. Large masses, like the Sun and Earth, have high forces of gravity.

Figure 3.2 shows the forces acting on a cyclist. A propulsion force acts in the forwards direction; air resistance opposes this in the backwards direction. Gravity acts down on the cyclist and the reaction force opposes gravity. Similarly, we can consider the forces acting on an aeroplane. Gravity acts down, lift from the wings acts up, thrust acts to push the aeroplane forwards and air resistance (or drag) opposes thrust.

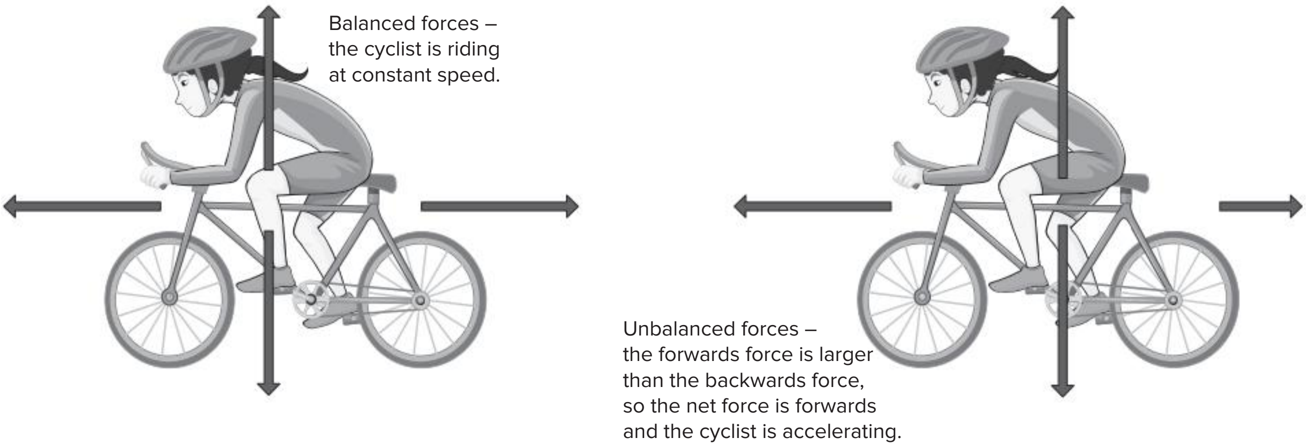
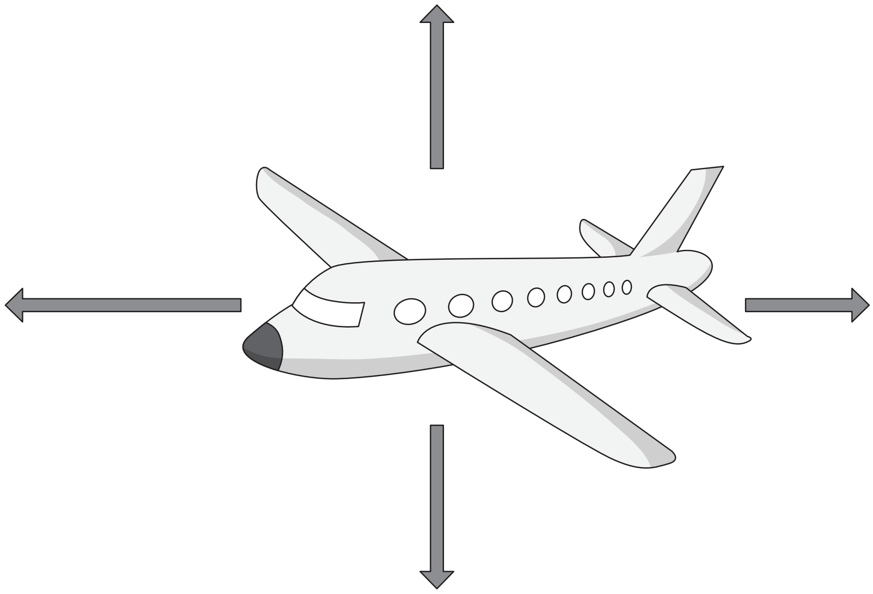


Figure 3.2: The effect of balanced and unbalanced forces on a cyclist

Activity 3.3.1

1. Explain what a force can do.
2. Give two examples of non-contact forces.
3. Identify the type of force when:
   a. a boat floats on water
   b. steel cans are separated for recycling
   c. a ball slows down on a pool table
   d. you stand on scales to measure your weight
   e. you get a little electric shock after walking across carpet.
4. The motor on a small boat is supplying a force of 5 N north but the boat is moving south. Use the concept of net force to explain this.

5. This diagram shows the forces acting on an aeroplane.



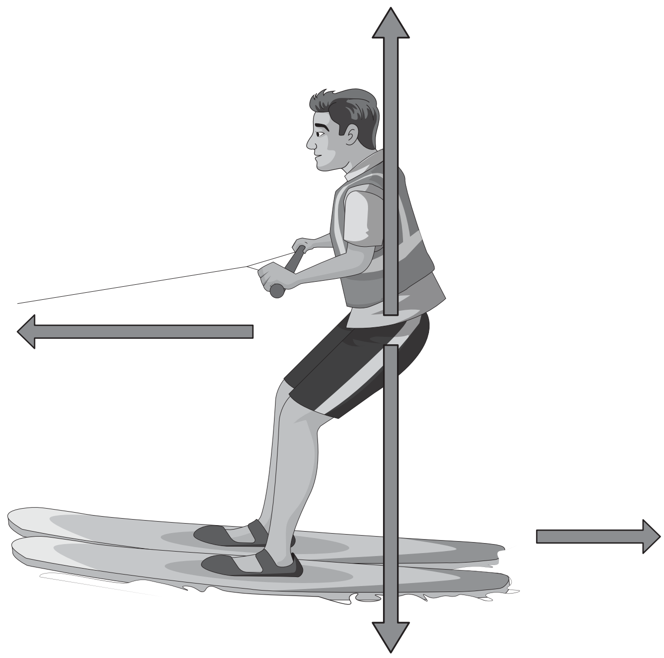
a. Explain what each force shown is due to.

b. Is the aeroplane travelling at constant speed? Explain your answer.

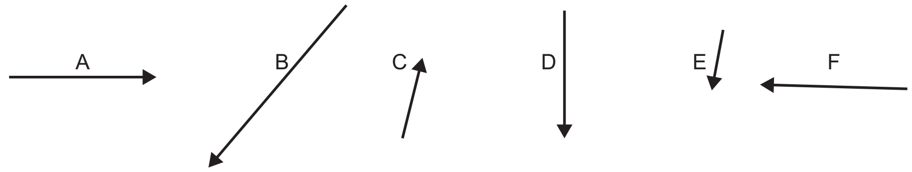
c. Is the aeroplane travelling at constant altitude?

6. List three forces you have applied at home before leaving for school (e.g. turning a door handle to open a door).

7. Explain each of the forces on the water skier.



8. Refer to forces A to F.



a. Which is the largest force?

b. Which two forces have the same magnitude?

c. Which two forces are in the opposite direction?

3.4 Measuring force

When you use kitchen scales, you are measuring a force. The scale measures how much force is pushing down on it. That force is the item's weight. The scales have a spring. The greater the weight, the more the spring is compressed. The weight depends on the item's mass and the strength of the gravitational field.

Key fact: variables

For any investigation, we need to identify the variables.

- The independent variable is the thing we are testing – what we change in the investigation.
- The dependent variable is the thing we measure. This will give us results from our investigation.
- Controlled variables are the things we keep the same.

For example, imagine we want to investigate whether the size of a paper plane affects how far it can travel. The independent variable would be the different sizes of paper planes. The dependent variable would be the distance each plane travelled. Some controlled variables would be the type of paper used, the throwing location and the way the plane was folded. We would have to keep these the same.

See Chapter 5, page 101 for more information on variables.

Investigation: Measuring force using an elastic band

Some students wanted to measure forces experienced by an elastic band. They used the following method.

Aim

To measure the forces experienced by an elastic band.

Method

1. An elastic band was placed on the clamp of a retort stand.
2. A 50 g mass was added to the elastic band (Figure 3.3). The band stretched and the students used a ruler to measure how far it stretched.

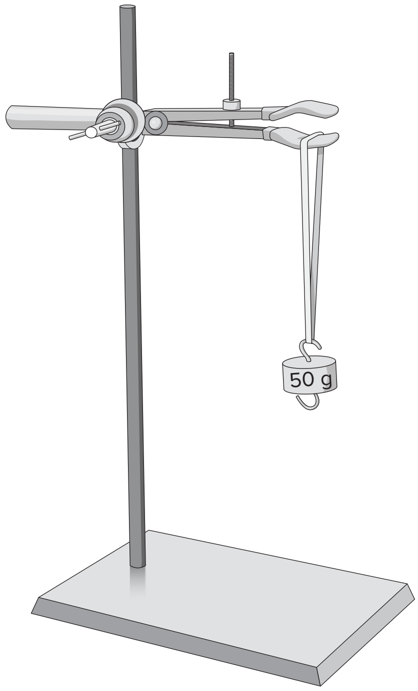


Figure 3.3: The students' experimental set-up

3. The students added more weights one at a time and measured the extra extension each time.
4. The students drew a diagram of the experiment (Figure 3.4).

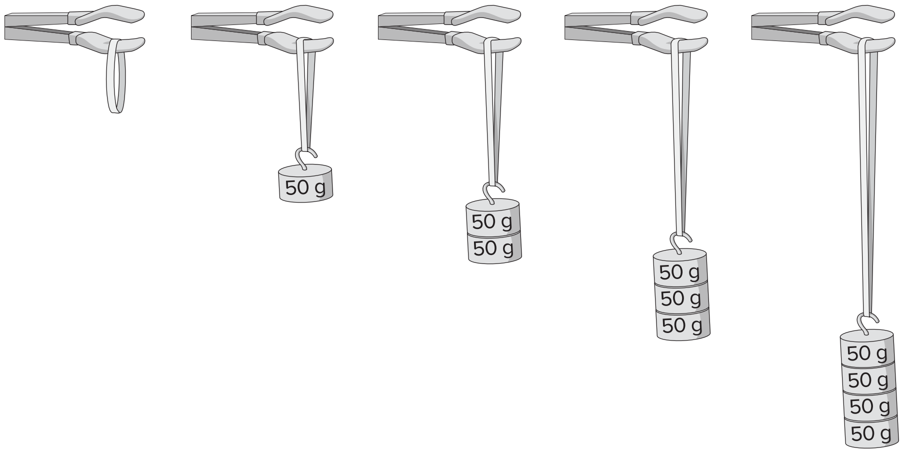


Figure 3.4: Adding more weight to the elastic band

Variables

Identify the variables in the students' investigation.

Independent variable: ______________________________

Dependent variable: ______________________________

Controlled variables (list 1–2): ______________________________

Results

1. Use a ruler to measure how far the elastic band extends after each addition and make a table of your results like the one shown here. Each mass is 50 g. When you measure extension, do not include the length of the band with zero weights on it.

Table 3.2: Results table for investigation

Number of weights	Mass (g)	Extension (cm)
0	0	0
1	50	
2	100	
3	150	
4	200	

2. Use your table to draw a line graph of extension versus mass (see pages 104–105 for guidance on creating a graph). Remember the independent variable goes on the *x*-axis (horizontal line) and the dependent variable goes on the *y*-axis (vertical line).
3. What conclusions or trends can be observed from the graph?
4. Draw arrows on Figure 3.4 to indicate the forces present when a weight is hanging on the elastic band.

Extension: How scales work

An object that is at rest either has no force acting on it or the sum of all the forces acting on it (the net force) is zero.

An elastic band with a weight hanging from it has two forces acting on it but they are equal and opposite, so they cancel each other. The net force is zero.

When the weight is doubled, the force due to gravity doubles but the extra stretching of the elastic band doubles the elastic force. This is shown in Figure 3.5.

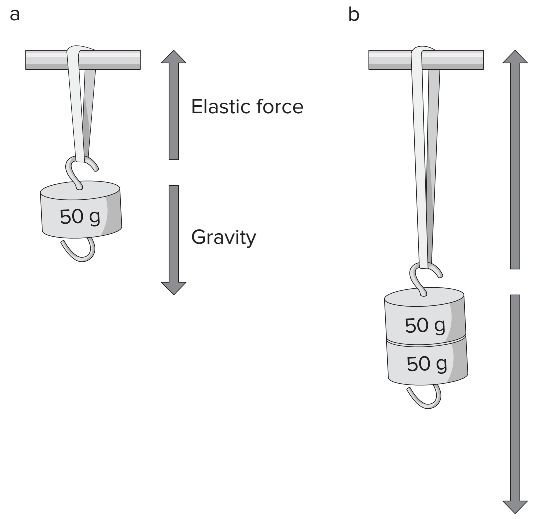


Figure 3.5: In both diagrams, the forces are balanced. In diagram b, the mass is doubled; therefore, the force of gravity is doubled, and the elastic force is doubled.

Scales use springs in the same way – they measure mass by how far gravity on the mass pushes the spring down (Figure 3.6).

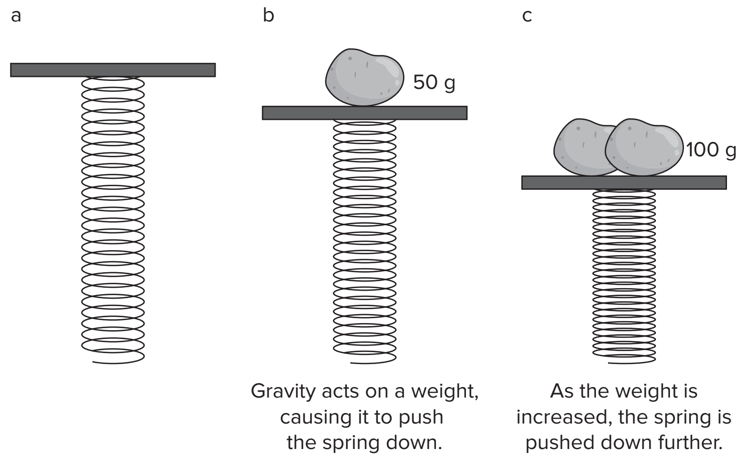


Figure 3.6: Compression of a spring by adding weight. In all three scenarios, the forces are balanced. In spring c, the mass is double that on spring b; therefore, the force of gravity is doubled, and the elastic force is doubled.

Your school might have a **force measurer**, or spring balance, as shown in Figure 3.7. The device has a scale (in newtons, N) that the manufacturer has tested that can be used to read the weight of an object.

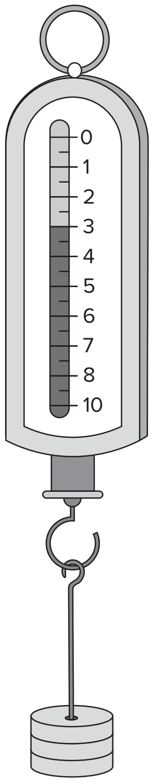


Figure 3.7: A force measurer

Fun fact

Sports scientists measure force with sensor-enabled fitness equipment to analyse athletes' movements and help them improve their technique.

3.5 Friction

Friction is a contact force that opposes motion. It is present when two surfaces move past each other. Friction depends on the surface and the mass of the object.

Think about it

Slide an object along the bench. Why does it slow down?

Suggest ways in which you can change the rate at which the sliding object slows down.

Try your ideas out. What conclusion can you draw?

Investigation: Measuring friction

Some students wanted to compare the amount of friction of different surfaces. They performed the following investigation.

Aim

To compare the amount of friction of different surfaces.

Method

1. Strips of six different materials were stretched out on a bench.
2. A force measurer was used to pull a wooden block along each surface.

   The higher the friction, the higher the reading on the force measurer.

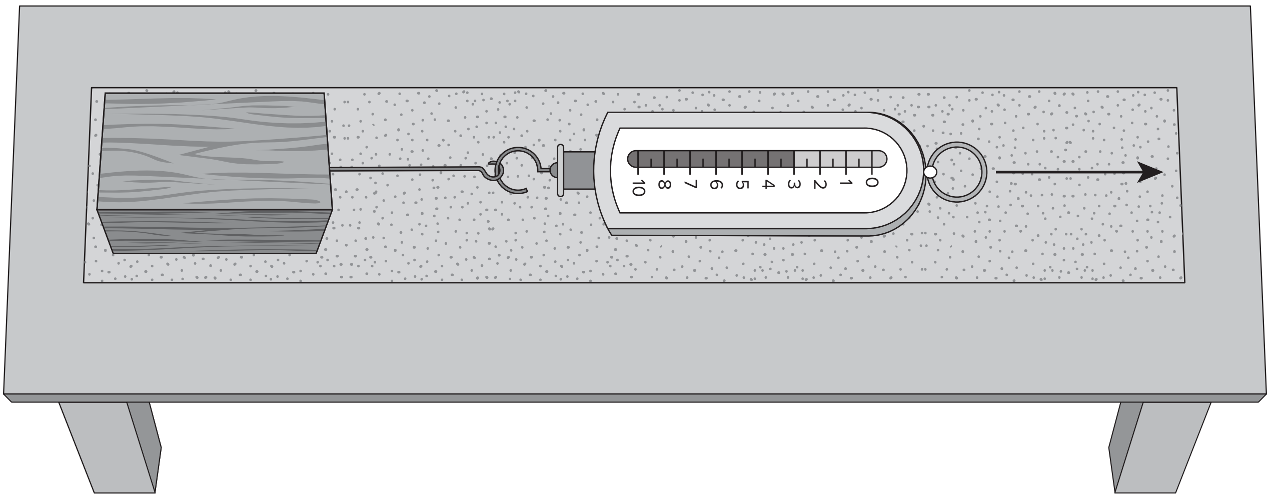


Figure 3.8: The technique for pulling a block along a strip of sandpaper

3. Each material was tested three times. The block was pulled at the same speed each time and the measurements were recorded in Table 3.2.
4. In the second column of Table 3.2, the students predicted the ranking of the surfaces (least to most friction).

Results

1. Calculate the average result for each type of surface and record this in Table 3.2. See page 105 for the steps in calculating an average.

Table 3.3: Results

Surface	Ranking prediction	Force (N)			
		Trial 1	Trial 2	Trial 3	Average
Bench	1	23	28	25	
Cotton	4	74	78	82	
Sandpaper	5	55	53	51	
Glass	2	18	16	18	
Aluminium	3	36	40	38	

2. Did the results support the students' predicted rankings (from least amount of friction to greatest)?
3. What was the purpose of students performing three trials for each surface?
4. Explain why sandpaper has a high level of friction.

Key fact

There are two special types of friction: air resistance and water resistance. Air resistance is when objects move through the air, and obviously, water resistance is when objects move through water.

Understanding friction

Friction is easy to understand if you look at a microscopic view of a surface – what looks like a smooth surface is more likely to contain pits and bumps. The rougher the surface, the higher the friction. The heavier the object, the more the surfaces are pushed together. Friction can wear away surfaces (Figure 3.9).

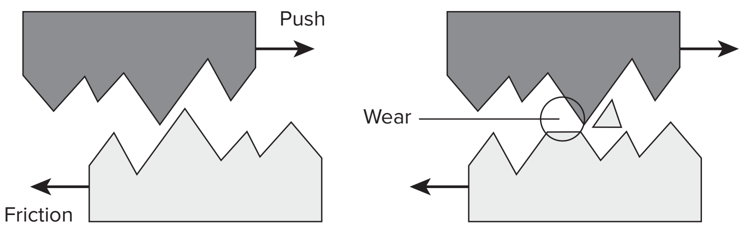


Figure 3.9: The effect of friction on a surface

Friction has significant effects on daily tasks.

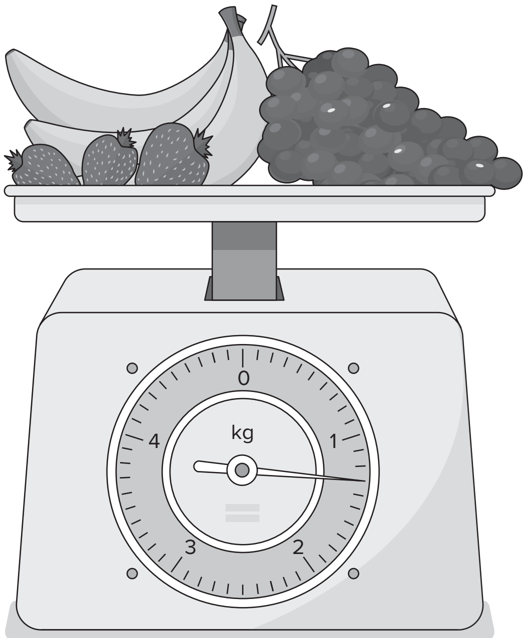
- We need friction to walk – grip between our shoes and the footpath stops us slipping over and provides forward thrust.
- We need friction between our hands and an object to pick the object up.

- Moving parts in cars rub on each other. Heat is released.
- Friction stops everything sliding off an uneven bench!

Friction between an object and the air passing over it is referred to as air resistance. It can be difficult to run fast into a strong wind – you have to force your way through the air particles. Cars are shaped aerodynamically to minimise air resistance, and parachutes are designed to harness air resistance.

Activity 3.5.1

1. The diagram shows fruit sitting on a spring balance.



   a. Identify the two forces present.

   b. Are the forces balanced?

   c. Explain how the spring balance works.

2. Do all elastic bands behave the same when you hang weights from them? Explain your answer.

3. A tub of margarine slides along a bench.

   a. What force makes the margarine tub slow down?

   b. Explain how the force causes the tub to slow.

4. For each scenario, explain whether you want friction to be high or low.

   a. A slide at the park

   b. The sole of your shoe

   c. A car tyre on a road

   d. The handle of a doorknob

   e. A skating rink

3.6 Gravity

One of science's most famous experiments was by Italian scientist Galileo Galilei in 1590. To investigate the question of whether heavier or lighter objects fall faster, Galileo dropped objects off the famous Tower of Pisa. It was generally thought that the heavier item would fall faster.

Think about it

If a ping-pong ball and a tennis ball are dropped from the same height at the same time, which will hit the ground first?

Galileo's surprising proposition was that both objects would fall at the same rate and hit the ground at the same time.

Figure 3.10: Galileo showed that objects of different mass fall at the same rate.

The force acting on objects that are dropped is gravity. The force of gravity is stronger on a heavier object, but the heavier the object is, the harder it is to accelerate. Therefore, the two effects cancel each other. Doubling the mass doubles the force of gravity, but it is twice as hard to move.

When an object falls, it has to push through the air. The air particles resist this – this is air resistance. If you drop a feather and an apple from the same height, the apple will hit the ground first because air resistance slows the feather. Without air resistance, they would fall at the same rate.

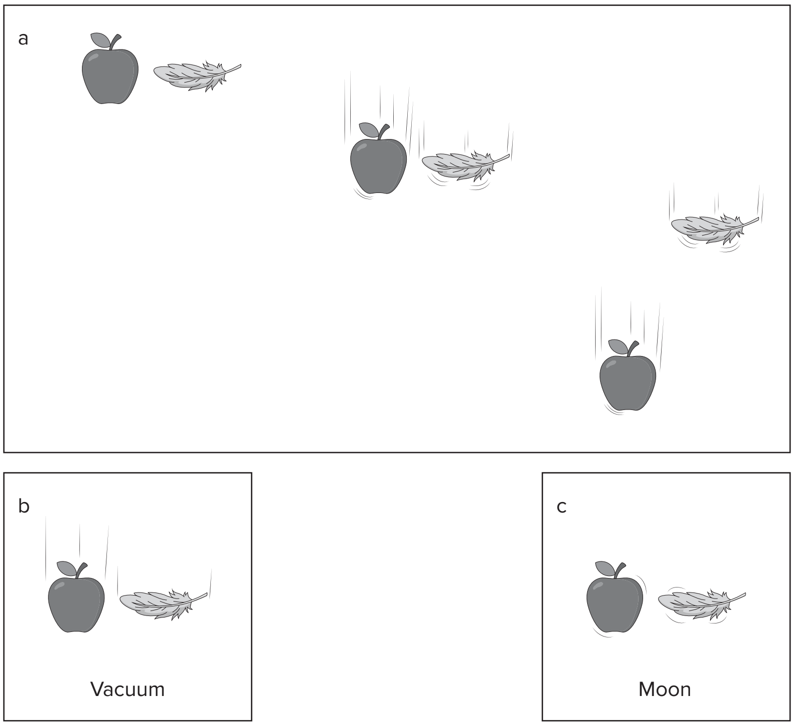


Figure 3.11: (a) An apple and a feather are dropped at the same time from the same height. Initially, they fall at the same rate, until the feather reaches terminal velocity. The apple reaches the ground first. **(b)** In a vacuum, they fall at the same rate. **(c)** On the Moon, where there is no air, they would fall more slowly but at the same rate as each other.

Extension: Terminal velocity

The faster an object moves, the greater air resistance becomes. As objects fall, their speed increases but it becomes harder for the object to push through the air. The force of air resistance eventually equals the force of gravity and the object falls at a constant speed, its **terminal velocity** (Figure 3.12).

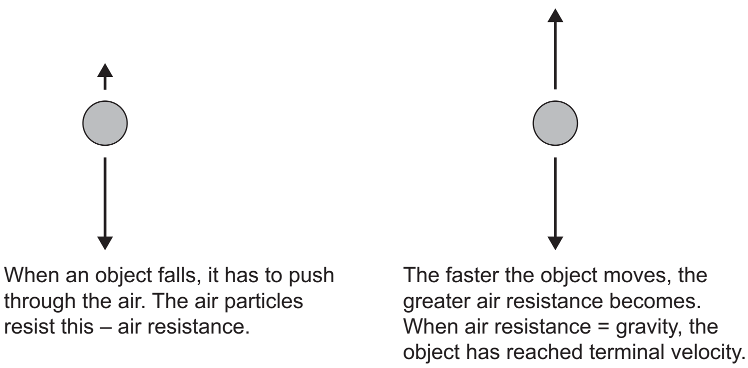


Figure 3.12: Terminal velocity is reached when air resistance = gravity.

The high air resistance of a feather and its low mass means it reaches terminal velocity quickly and it has a relatively low terminal velocity.

Key facts

- Objects fall because they are attracted to Earth. This is gravity.
- Gravity holds the Moon in orbit around Earth.
- Gravity holds Earth (and the Moon) in orbit around the Sun.
- In a vacuum, all objects fall at the same rate.
- In reality, air resistance affects the rate at which objects fall, and eventually the object with the lowest air resistance falls faster.

In Year 7, you do not need to know the formula for determining the force of gravity, but it is shown below for your reference.

$$F = \frac{Gm_1m_2}{d^2}$$

where m_1 and m_2 are the masses and d is distance between them. (F stands for the gravitational force, while G is the gravitational constant.)

Note that gravity depends on the size of the two masses involved and how far apart they are.

- The bigger the masses, the stronger the force.
- The further apart the masses, the lower the force.

Recall that gravity is a force that causes objects to attract. If you jump from a plane, the gravity of Earth attracts you to the centre of Earth.

Objects anywhere on Earth are attracted to Earth's centre.

Gravity keeps planets and moons in their orbits.

Figure 3.13: Gravity affects objects on Earth and in space.

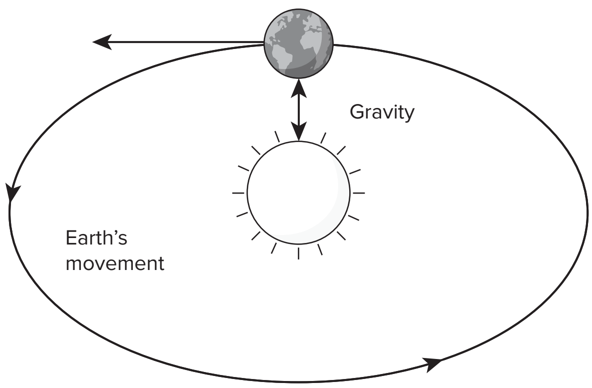


Figure 3.14: Earth moves very rapidly through space. The force of gravity between Earth and the Sun holds Earth in an elliptical orbit around the Sun and prevents it from moving away. The orbit is a balance between the planet's motion and the pull of gravity.

When you sit on a chair, you can feel the chair pushing on you – the chair is resisting gravity. On the Moon, the force of gravity on you would be less than on Earth because the mass of the Moon is only around one-sixth of the mass of Earth.

The bigger the object is, the greater the strength of its gravitational field. A gravitational field refers to the area surrounding an object where another object experiences a force of gravity. That's why the Earth's gravitational field is stronger than the Moon's.

Mass and weight

Generally, in everyday language, the terms '**mass**' and '**weight**' are used interchangeably. However, in science they mean different things (Table 3.4).

Table 3.4: The difference between mass and weight

Mass	Weight
Mass is the amount of matter in an object.	Weight is a measure of the force of gravity on an object.
Mass is the same everywhere.	Weight differs depending on the force of gravity. In space, you might have zero weight (weightlessness).
Mass is measured in grams (g) or kilograms (kg).	Weight is measured in newtons (N).
Mass does not have a direction.	Weight has a direction.
Mass is measured on an ordinary balance.	Weight is measured on a spring balance.

Weight differs on Earth and in space. On Earth, gravity is why we have weight and why we can only jump a certain height. Gravity is why the Moon orbits Earth and Earth orbits the Sun. In outer space, you would experience weightlessness. Objects don't 'fall' in outer space – water droplets hover as spheres.

The heavier an object is, the greater the pull of gravity. An astronaut can jump higher on the Moon than they can on Earth because the Moon has a lower mass and exerts a lower force of attraction on the astronaut than Earth does. In outer space there is no gravity, so the astronaut is weightless (Figure 3.15).

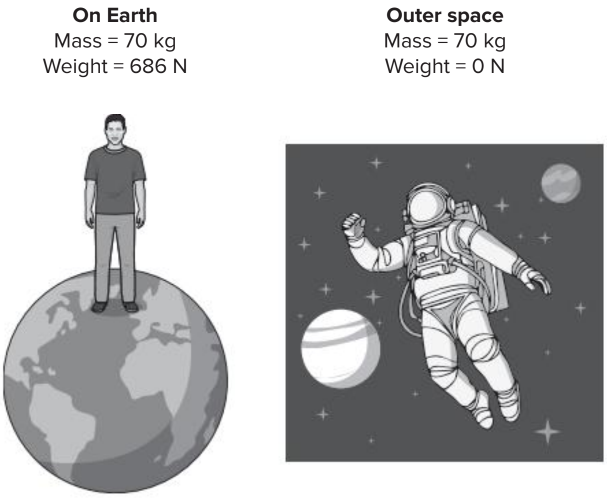


Figure 3.15: A person weighs more on Earth than in outer space.

Key terms

mass	the amount of matter in an object
weight	the size of the force of gravity on an object

The weight of an object can be calculated at any location using:

Weight (N) = mass (kg) × gravitational field strength (N/kg)

or

$w = m \times g$

(g is 9.8 N/kg on Earth)

For example, if you want to know the weight on the Earth's surface of something that has 20 kg mass, then you do the following calculation:

w = 20 kg × 9.8 N/kg

w = 196 N

3.7 Magnets

A magnet is an object that produces its own magnetic field. A magnet has two distinct poles, north (N) and south (S) (Figure 3.16). Magnetism is a basic force of nature that works over a distance.

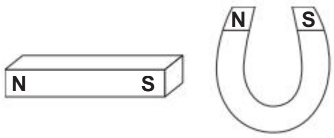


Figure 3.16: Magnets have north and south poles.

Magnets attract objects made of iron (and also some cobalt and nickel samples). If you place a nail or paperclip near a magnet, the force of attraction between the two is obvious (Figure 3.17).

Figure 3.17: Magnets attract objects made of iron, such as paperclips.

Magnets produce a **magnetic field** around them. Magnetic fields are depicted as lines around the magnet. Figure 3.18 shows how small nails near the magnet will line up.

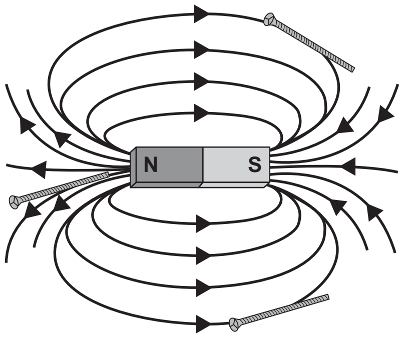
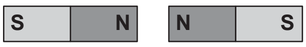


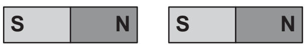
Figure 3.18: The lines in the diagram show the direction of the magnet's force near it. Nails or pins will line up in the direction of the field.

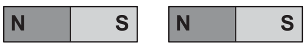
Magnets can be attracted to or repelled by each other. Opposite poles attract and like poles repel.

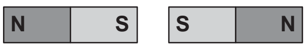
Activity 3.7.1

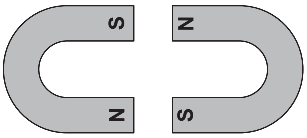
1. Use arrows to show whether the magnets will attract or repel.

   a. 

   b. 

   c. 

   d. 

   e. 

2. What is the 'rule' for deciding if magnets will attract or repel?

Key facts

- Most magnets have two poles.
- Like poles repel; unlike poles attract.

Extension: Magnetism

The earliest records of the use of magnets are from about the first century BCE, in Greek and Chinese writings. It was known that certain rocks, called lodestones, were able to attract iron objects. The Chinese were the first to use a form of magnetic compass to determine direction, while the Greeks were purported to have used magnets in warfare. Generally, lodestone was a curiosity rather than a useful material. It is only in recent times that several important uses have emerged for magnets, such as:

- storage of computer data
- magnetic strips on credit cards
- hard disks of computers

- fridge door seals
- music speakers
- maglev (magnetic levitation) trains
- medical imaging equipment.

Magnetic materials are made up of thousands of tiny magnets, called **domains**. In its natural state, a material's domains are randomly aligned, and the material is not magnetic. However, if a magnetic field is applied to the material, the domains line up in the same direction and the object becomes magnetic. It will remain magnetic as long as the domains remain aligned (Figure 3.19).

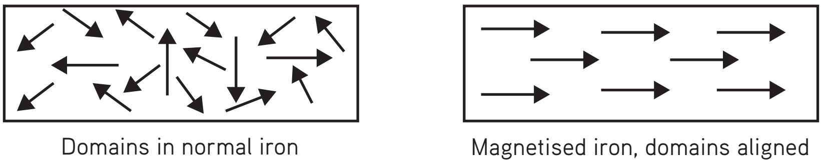


Figure 3.19: The alignment of domains determines whether an object is magnetic.

Investigation: Strength of a magnetic field

Some students wanted to see how the strength of a magnetic field changes with distance. They used the following method.

Aim

To investigate how a magnetic field changes with distance.

Method

1. A magnet was placed on a balance.
2. A second magnet was clamped to a retort stand so that the north pole of the top magnet was directly above the north pole of the lower magnet (Figure 3.20).

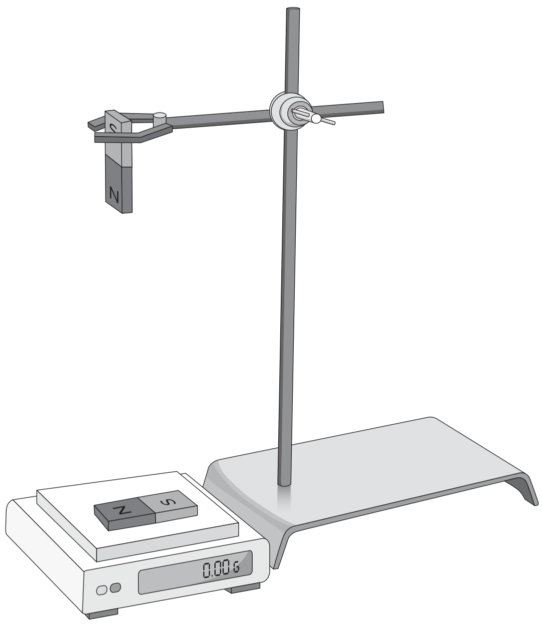


Figure 3.20: The experimental set-up

3. The top magnet was lowered in stages, and the students recorded the reading on the balance each time.
4. The experiment was stopped when the magnets were about 0.5 cm apart.

Prediction

What do you think would happen as the magnet was lowered in the retort stand?

Results

Table 3.5: Typical data

Distance (cm)	20	15	10	8	6	5	4	3	2	1	0.5
Balance reading (g)	0.0	0.1	0.3	0.6	1.2	2.8	4.6	7.5	12.0	31.0	48.0

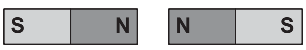
1. Draw a graph of these results, with distance on the horizontal axis and balance reading on the vertical axis. Look at the largest measurements to decide what numbers to put on the scale. (See pages 104 and 105 for guidance on drawing a graph.)
2. Identify the independent variable and the dependent variable.
3. What conclusions can you draw from the graph?

Activity 3.7.2

1. Circle the items in the list below that are likely to be magnetic.

   $1 coin, ice-cream container, plate, nail, fridge door, aluminium pie dish
2. How can you predict if something is a magnet (not whether it is attracted to a magnet)?
3. Give four examples of magnets being used in society.
4. How many poles do magnets have?
5. Predict where you would find the poles for each of the following.
   - **a.** Button magnet
   - **b.** Horseshoe magnet
   - **c.** Bar magnet
   - **d.** Fridge magnet
6. Explain why you should not carry a magnet in your pocket. You may need to do some research to answer this question.
7. Draw lines to represent the magnetic field around the magnet below.

8. For each example below, write in whether there is an attraction or repulsion present.

   a. 

   b. 

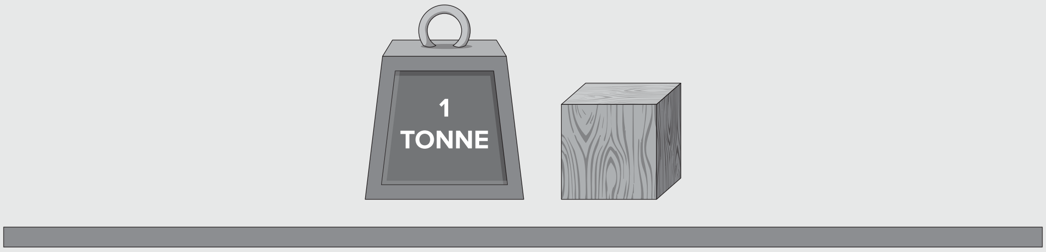
9. You are lost in the bush and need to head east to be saved. You have a bar magnet. Research how you might use this magnet, and other knowledge, to determine which direction is east.
10. Do some research to find one unusual use for magnets and outline what you found out.

3.8 Machines

A simple machine is a device that is used to modify motion and the magnitude of a force in order to perform work. Machines use leverage, also known as mechanical advantage, to increase force. Simple machines include inclined planes, levers, wedges, wheels and axles, pulleys and screws.

Think about it

Imagine you are supplied with a heavy weight, a plank and a block of wood.



How could you use the plank and block of wood to lift the weight? In your notebook, sketch the set-up you would use to make this task as easy as possible.

Consider the following simple machines.

1. Use a screwdriver to prise open the lid of a can. Does the length of the screwdriver make a difference? Notice how the lip of the can is the **pivot** for your screwdriver.

Key term

pivot	a fixed point where something can turn or balance

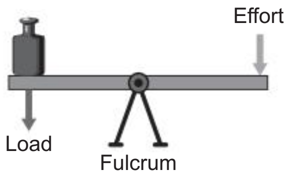
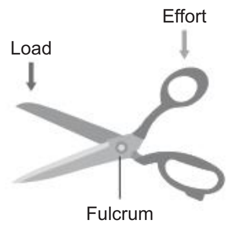
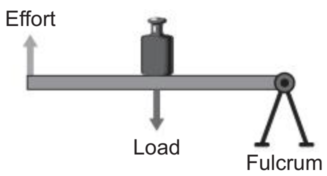
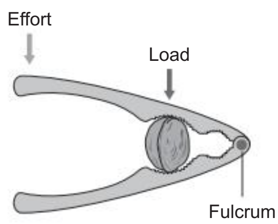
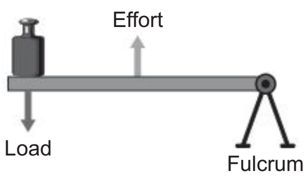
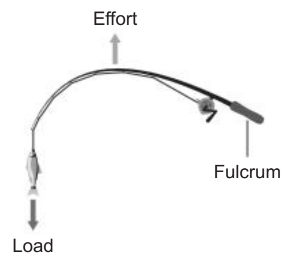
Figure 3.21: Using a screwdriver to open the lid of can

2. Use a range of screwdrivers to turn screws into a piece of soft timber. What conclusions can you draw about how easy it is to turn different screws?
3. Use a nutcracker but change the position of the nut. Which position of the nut maximises the effort you put in?
4. Use scissors to cut pieces of plastic. Change how far the plastic is from the pivot point of the scissors. Which position of the plastic maximises the effort you put in?

Levers

A lever is a simple machine that consists of a bar that rotates around a fixed point, called the fulcrum. There are three types of levers: first class, second class and third class. The type of lever is determined by the positions of the **fulcrum**, **load** and **effort** (Table 3.6).

Table 3.6: Types of levers

Lever type	Example
First class The fulcrum is between the load and the effort. 	Scissors You apply effort to the handles, and this places pressure (load) on any object within the blades. The blades pivot on the fulcrum. 
Second class The load and effort/force are on the same side of the fulcrum. 	Nutcracker 
Third class The effort is between the load and the fulcrum. 	Fishing rod 

Key terms

fulcrum	pivot point of device, usually a screw or rivet
load	how hard the tool pushes on an item it is applied to
effort	how hard you push or squeeze

Inclined plane

One of the most common simple machines is the inclined plane.

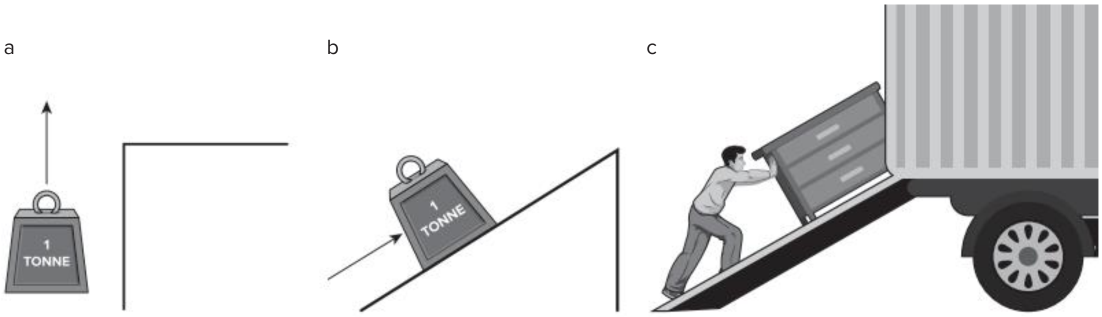


Figure 3.22: (a) Lifting a weight straight up is difficult; **(b)** sliding it up a ramp (inclined plane) is easier. **(c)** Removalists use ramps to load heavy furniture into their truck.

Figure 3.22 shows the use of an inclined plane (ramp) to lift a weight. The longer the ramp, the easier it is to move the weight but the further you have to push it.

Table 3.7 shows some other examples of inclined planes.

Table 3.7: Some common inclined planes

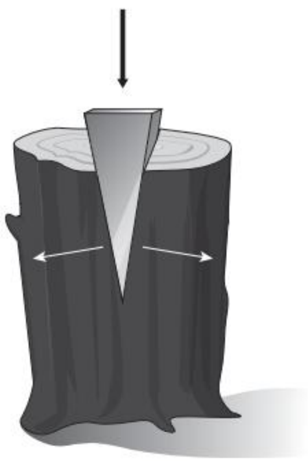
Inclined plane	
Wedge 	A wedge has two inclined surfaces that make it easier to split logs. When a wedge is pushed in one direction, it creates a force in a sideways direction. The narrower the wedge, the easier it is to insert but the further you have to push it for it to work. Chisels and axes are types of wedges.
Screw 	Screws are inclined planes wrapped around a cylinder. A screw functions like a wedge in a rotational motion to tighten or lift objects. It is easier to turn a screw than a flat piece of metal. The wider the diameter of the screw, the harder it is to turn. The tighter the spiral, the easier it is to turn.

Table 3.7: Continued

Inclined plane	
Winding road 	A winding road up a slope is an inclined plane with a very gentle slope. It acts like a ramp and makes it easier for trucks carrying heavy loads than a straight steep road. However, the journey takes a lot longer.

Extension: Mechanical advantage

Simple machines, such as levers and inclined planes, make work easier because they offer a **mechanical advantage**. Mechanical advantage is how much easier a machine makes it to lift or move something, by allowing you to use less force to move a bigger weight. A simple machine can multiply an input force.

Consider a 50 g weight hanging from the left side of a balance beam (Figure 3.23a). The mass required to balance this 50 g is also 50 g, if it is placed the same distance from the fulcrum (Figure 3.23b).

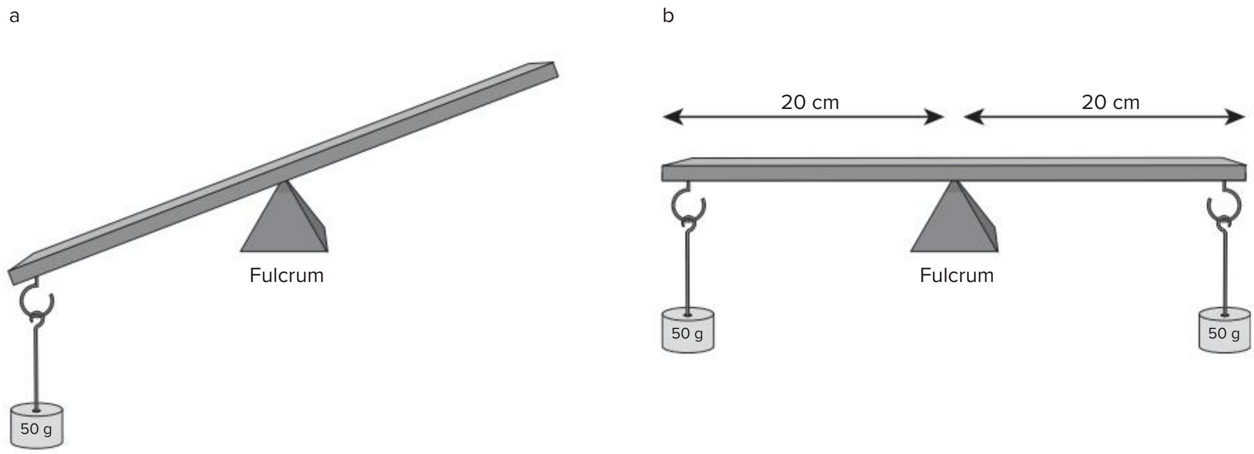


Figure 3.23: (a) This beam is unbalanced. **(b)** This beam has been balanced by placing a weight of equal mass the same distance from the fulcrum.

The mechanical advantage of a machine is the ratio of the load to the effort:

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

So for the scenario in Figure 3.23b, the mechanical advantage is:

$$\text{Mechanical advantage} = \frac{50\text{ g}}{50\text{ g}} = 1$$

If the load equals the effort, the mechanical advantage is 1. A mechanical advantage of 1 means that the output force is equal to the input force, which is no advantage to the user.

To achieve a higher mechanical advantage, we can increase the load relative to the effort. Table 3.8 demonstrates the effect on the mechanical advantage when the load is increased relative to the effort.

Table 3.8: Calculating mechanical advantage

Load (g)	**Effort (g)**	Mechanical advantage = $\frac{\text{load}}{\text{effort}}$
100	50	$= \frac{100}{50} = 2$
150	50	$= \frac{150}{50} = 3$
200	50	$= \frac{200}{50} = 4$

The mechanical advantage of a machine can also be calculated by dividing the distance of the fulcrum to the effort by the distance of the fulcrum to the load:

$$\text{Mechanical advantage} = \frac{\text{distance of fulcrum to effort}}{\text{distance of fulcrum to load}}$$

So we can also achieve a higher mechanical advantage by increasing the distance of the fulcrum to the effort or decreasing the distance of the fulcrum to the load.

If you need to lift very heavy masses, you need to ensure you have a large mechanical advantage. Garden tools often have longer handles than blades. This is to ensure there is a mechanical advantage. It is also relevant how far into the blades you place the branch you are chopping.

Pulleys

Pulleys are another common tool. A pulley is a grooved wheel that a cord passes around. It acts to change the direction of a force applied to the cord and is used to raise heavy objects (Figure 3.24). The mechanical advantage of a pulley system depends on the number of ropes supporting the movable load. So the more ropes involved, the greater the mechanical advantage. A single pulley has a mechanical advantage of 1 (Figure 3.24a), which means the input and output forces are equal, so no advantage. Adding more pulleys increases the mechanical advantage proportionally (Figure 3.24b), which does help.

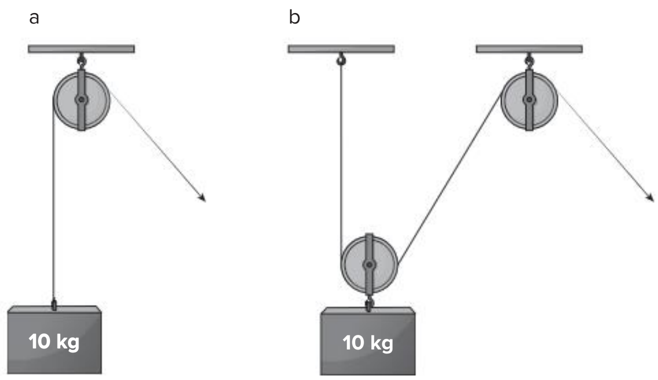


Figure 3.24: Changing the mechanical advantage of pulleys: **(a)** mechanical advantage of 1 (no advantage); **(b)** two pulleys – a mechanical advantage of 2.

For some more complicated pulley systems, it is the number of sections of movable rope that determines the mechanical advantage. Note that you don't count the section of rope where you apply the effort to lift the load. In Figure 3.25, there are four supporting ropes that can move, so the force required is only one-quarter of what is needed if no pulleys are used.

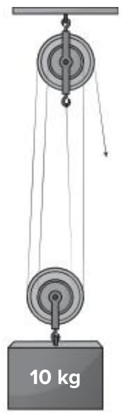


Figure 3.25: This pulley arrangement has a mechanical advantage of 4.

Science as a human endeavour: First Nations peoples' use of forces

There are many examples of First Nations' understanding of forces.

- Stone axes and tool fragments have been dated to over 46 000 years old. This is the world's earliest evidence of axes with handles. The source of many of the stone tools was the Mount William stone axe quarry near Lancefield in central Victoria. Stone fragments from this mine were traded to all parts of Australia. The quarry was still a very active trading centre when European settlers arrived in the region. Many of the stone items were formed into wedge shapes.

Figure 3.26: These First Nations stone tools are wedge shaped.

- Boomerangs are perhaps the first example of the use of an aerofoil. As Figure 3.27 shows, an aerofoil has a rounded top that causes an area of low pressure above the surface, leading to the uplift of the boomerang or aeroplane.

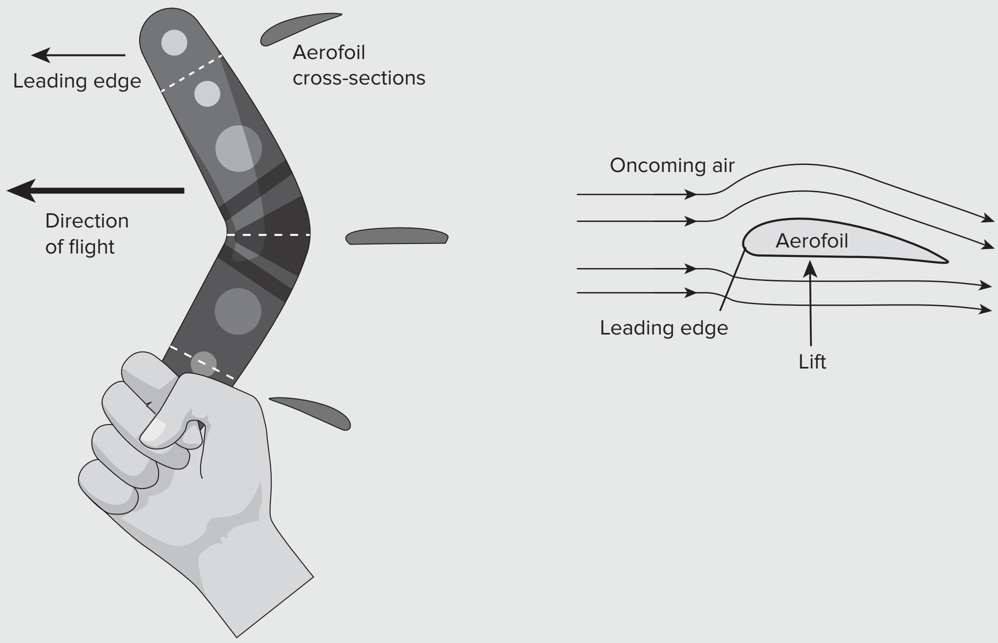


Figure 3.27: The essential aerofoil shape of a boomerang causes uplift.

- David Unaipon (who is featured on the $50 note) was a renowned inventor and a respected teacher and lecturer. One of his most successful designs was for a rotating shearing clipper that greatly reduced the time required to shear a sheep. He also drew a design for a flying device, based on motorised boomerang-shaped propellors. A team from the University of New South Wales recently built his 1914 design and flew a small prototype.
- A woomera is a spear launcher. It is a hand-held device that effectively extends the length of the thrower's arm, enabling a spear to be released with greater speed (Figure 3.28).

Figure 3.28: This man is using a woomera to throw a spear.

End-of-chapter summary

- A force is a push, pull or twist on an object. It causes a change in the motion of an object.
- Types of forces include buoyancy, elastic, electrostatic, magnetic, gravity and friction.
- Forces can be represented by arrows that have a magnitude and direction. Forces can be added to obtain a net force.
- A force measurer (spring balance) contains a spring that can be used to measure the size of a force.
- Friction is the force generated when surfaces slide over each other. The rougher the surface, the greater the effect of friction.
- Gravity is a force of attraction between two bodies due to their mass. The larger the mass, the stronger the force of gravity. Earth's gravity pulls objects towards its centre. Gravity keeps planets in fixed orbits around the Sun.
- Magnets have two poles and are made from iron or compounds containing nickel or cobalt. Magnets are surrounded by a magnetic field.
- All objects would fall at the same rate if there was no air resistance.
- The speed of a falling object increases until its air resistance equals the force of gravity. From that point, it travels at a constant speed referred to as the terminal velocity.
- Mass is the amount of matter in an object.
- Weight is the force of gravity on an object.
- Levers are simple machines designed to make tasks easier. Many common tools can be classified as first-class, second-class or third-class levers.
- Machines usually offer the user a mechanical advantage, a measure of how much the applied force (effort) is amplified.
- Inclined planes and pulleys are common machines that offer a mechanical advantage.

Revision questions

1. Determine the net force on each of the following.

a.

b.

2. A skydiver jumps from a plane.

a. Show the forces on the skydiver before he opens his parachute.

b. Show the forces on the skydiver just after he opens his parachute.

c. Show the forces on the skydiver after the parachute has been open for a while.

3. The Moon orbits Earth. Its mass is approximately one-sixth the mass of Earth.

a. Why does the Moon remain in orbit?

b. If you weigh 60 kg on Earth, what is your weight on the Moon?

c. If you drop an apple and a bowling ball on the Moon, which will reach the ground first?

4. For each type of force listed, state whether the force is contact or non-contact and give one example of where this force is useful.

Force	Contact/non-contact	Example
Buoyancy		
Magnetism		
Gravity		
Electrostatic		

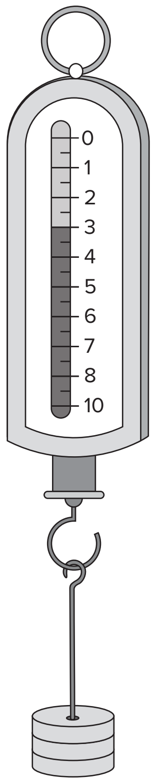
5. I drop several items off the roof of the building. Which will hit the ground first, if any, out of each of the following pairs of items?

a. Golf ball and tennis ball

b. Car and car tyre

c. Pencil and paper

6. The diagram shows a force measurer holding three weights.



a. Draw the forces acting on the weights.

b. Are the forces balanced?

c. What will seven weights read on the scale?

d. Are these contact forces?

7. 

   a. Will these magnets attract or repel?

   b. Can these magnets be used to retrieve coins from a drain?

8. A block slides along a bench.

   a. Why is friction greater when the mass of the block increases?

   b. Which direction will friction operate in?

   c. State one way you can reduce friction.

9. a. Label the load, effort and fulcrum on these garden shears.

   b. Challenge question: Refer to the tool to explain what a mechanical advantage is.

Chapter 4 – Chemistry

4.1 What is chemistry?

Chemistry is a branch of science that studies **matter** – its properties, how it changes and the energy involved in these changes. It explains how substances interact, combine and transform into new substances.

Chemistry helps us understand what matter is made of and how it behaves. It explains how materials are produced and helps us to develop new materials and substances such as medicines to improve our lives. We see chemistry in action every day when we cook food, wash dishes, use sunscreen, shed tears when we cut onions, drink coffee and eat!

Key term

matter	anything that has mass and takes up space

Fun fact

Chemistry is regarded as the central science because it connects physics, biology and Earth and space science.

By the end of this chapter, you will be able to:

- explain the different arrangements of particles in solids, liquids and gases
- explain how the state of a substance depends on its energy and the strength of forces between particles
- distinguish between a compound and a mixture
- distinguish between homogeneous and heterogeneous mixtures
- describe materials in terms of their properties
- apply a range of techniques to separate the components of a mixture.

Think about it

These questions will get you thinking about what things are made of – their ‘chemical composition’.

1. What is matter?
2. What is a chemical reaction?
3. How are nails made?
4. List six substances in the room you are in.

4.2 The particle model

Substances

The Visy plant in the Melbourne suburb of Spotswood is a glass and bottle manufacturer. Visy makes glass by heating a mix of sand, recycled glass, limestone (calcium carbonate) and soda ash (sodium carbonate).

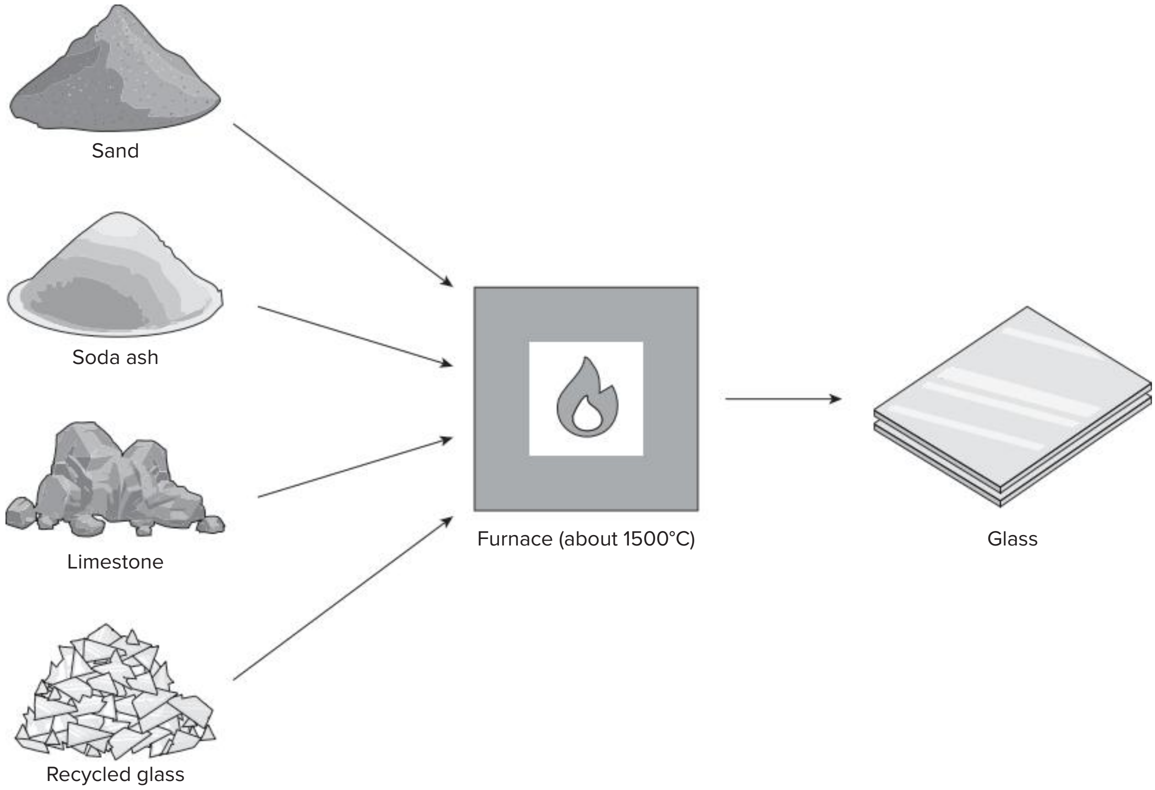


Figure 4.1: The manufacture of glass is a chemical reaction.

Glass and sand are examples of **substances**. Cheese, apples, oxygen and water are other examples of the millions of substances on Earth. One of the main goals of a chemist is to change substances into more useful substances. Substances can be changed in **chemical reactions** (Figure 4.2).

Figure 4.2: Some examples of industrial chemical reactions

One of the goals of chemists is to produce useful materials.

> **Think about it**
>
> What changes (or reactions) occur in the following industries? (What do these factories use and what do they make?)
>
> ? → Dairy processing → ?
>
> ? → Paper factory → ?

To understand how to react and change substances, we need to know what they are made from. Scientists use the **particle theory** to describe substances and the changes they undergo. According to particle theory, all substances contain a basic building block – a particle. Particles are too small to see but they have a size and a mass.

Substances are made from **matter** and matter contains particles. Chemistry is the branch of science that studies matter, and how it changes in reactions.

> **Key fact**
>
> Chemists explain and describe the behaviour of substances using particle theory. All matter is made from particles.

4.3 States of matter

Close your eyes.

- Can you feel your teeth by running your tongue along them?
- Can you feel the saliva moving in your mouth?
- Can you feel air moving through your nose?

These questions highlight the three common states of matter: solid, liquid and gas.

Solid

A solid is a state of matter with a defined shape and volume. In a solid, atoms, ions and molecules pack tightly together and may form crystals. Examples of solids are rocks, ice, diamond and wood.

Liquid

A liquid is a state of matter with a defined volume, but no defined shape. In other words, liquids take the shape of their container. Liquid particles have more energy than particles in a solid, so they are further apart and less organised (more randomly arranged). Examples of liquids are water, juice and vegetable oil.

Gas

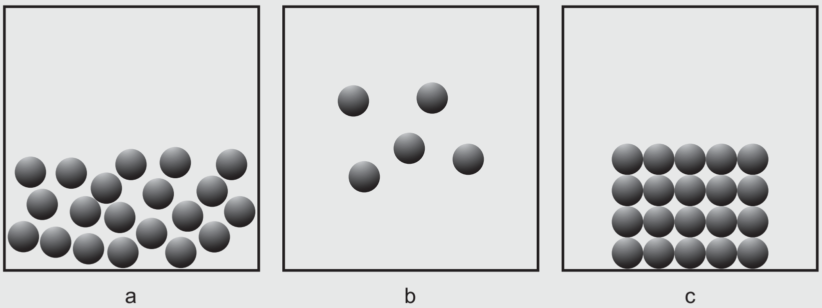
A gas is a state of matter that lacks a defined volume and shape. Like a liquid, a gas takes the shape of its container. Unlike a liquid, a gas easily expands and contracts to fill the entire volume of the container. Gas particles have more energy than particles in solids or liquids. They tend to be further apart and move more randomly than in a liquid. Examples of gases are air, water vapour and helium.

Think about it

1. In the table below, list common examples of each state of matter. The first one has been done for you. In the second row, draw how the particles are arranged in that category. In the third row, describe the features of that state.

	Solid	Liquid	Gas
Examples	*Copper*	*Oil*	*Nitrogen*
Particle arrangement			
Features of this state			

2. The following models of a solid, a liquid and a gas are not labelled. Identify the state of matter for each model. Describe the motion of a particle in each diagram.



Force versus energy

The state a substance is in depends on:

- how strongly attracted the particles are to each other
- how much energy the particles have.

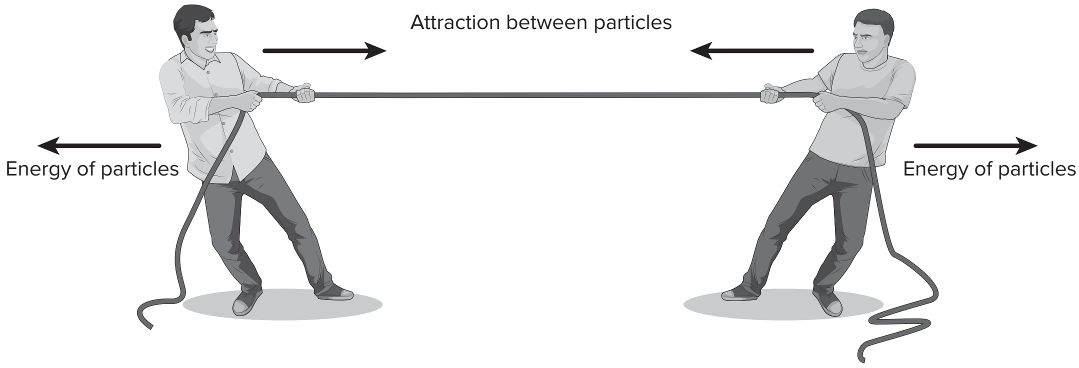


Figure 4.3: The state of a substance depends on attraction between particles and how much energy the particles have.

Particles in solids and liquids are closely packed because they attract each other. The particles are moving but they cannot move apart because of the forces of attraction. The more you heat a solid or liquid, the faster the particles move and the more likely they are to break free from each other and form a gas.

At 20˚C, gold is a solid, water is a liquid and oxygen is a gas. We can rank the forces of attraction in these three items: the particles in gold have the strongest forces of attraction between them while the particles in oxygen gas have the weakest.

- In solids and liquids, the forces of attraction can resist the energy of the particles.
- In gases, the energy of the particles has overcome the forces of attraction.

As you heat a substance, the energy of the particles increases. The **melting point** of a substance is a measure of how strong the forces between the particles are in that substance (Table 4.1).

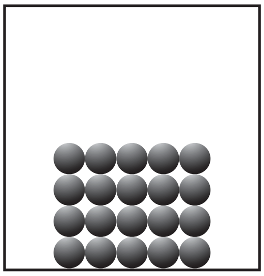
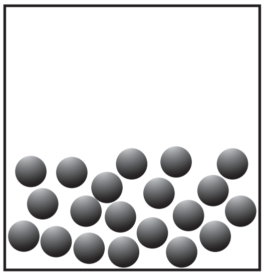
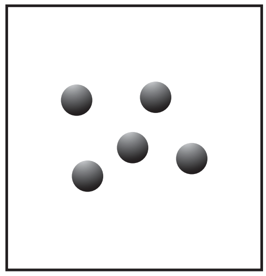
Key term

melting point	the temperature at which a substance melts

Table 4.1: Melting points of a range of substances

Substance	Melting point (˚C)
Oxygen	–218
Olive oil	–6
Water	0
Lead	328
Tungsten	3422

Table 4.2: States of matter summary

Solid	Liquid	Gas
		
Fixed shape	Takes shape of container	Fills whole of container
Particles vibrate	Particles move close together	Particles move rapidly far apart
Strong forces between particles	Strong forces between particles	No forces between particles
Cannot be compressed	Cannot be compressed	Can be easily compressed

Activity 4.3.1

Consider the melting point values in Table 4.1 to answer the following questions.

1. What conclusions can you draw about how melting points vary?

2. Cooks use butter or oil for many recipes.

- **a.** What advantages does the use of butter have over oil? (How might a cook find butter easier to work with?)
- **b.** What advantages does oil have over butter?

3. Consider a lead block at 20˚C.

- **a.** How do the particles in lead move? What state of matter is lead observed to be at 20˚C?
- **b.** How does the motion of the lead particles change if it is heated from room temperature to 80˚C?
- **c.** Why does tungsten have a higher melting point than lead when they are both metals?
- **d.** What is happening in the lead sample when it melts at 328˚C?

Extension: Gases

We cannot see many gases, so they can be ignored or poorly understood.

Can we assume they have similar properties? Do they react? Are they dangerous?

Many gases play important roles in society.

- Oxygen gas (O_2): Ambulances and hospitals stock supplies of oxygen gas to treat patients with breathing problems or suffering from smoke inhalation (Figure 4.4).

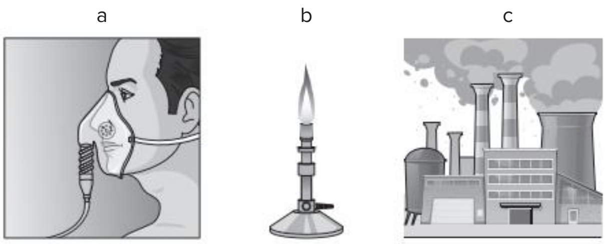


Figure 4.4: (a) Oxygen masks aid breathing. **(b)** Bunsen flames are hotter or cooler depending on the oxygen level. **(c)** Burning requires oxygen.

- Natural gas (methane) (CH_4): Many houses in Australia use natural gas for cooking and heating. The gas reacts with oxygen in the air, releasing energy.
- Carbon dioxide (CO_2): Plants require carbon dioxide for photosynthesis. The emission of CO_2 from industry is also a problem that is causing climate change.
- Nitrogen dioxide (NO_2): Nitrogen in the air reacts with oxygen in car engines to produce NO_2, which is released in the car exhaust. It is a brownish-coloured gas that is often evident in large cities as air pollution.

Activity 4.3.2

1. Research a gas of your choice. Try to answer the following questions.
   - What is its formula?
   - Where is it found or how is it made?
   - What are its properties?
   - Is it harmful to humans?
   - What is it used for?
2. Search the internet to answer the following questions.
   - Does laughing gas really make you laugh?
   - Is it dangerous to breathe in helium?
   - Is krypton green as in Superman movies?
   - How do neon signs work?

4.4 Changing states of matter

The phase a substance is in – solid, liquid or gas – is referred to as its **state**. Candle wax is a solid. When we heat it, it can turn to a thick runny liquid – this is a **state change**. The particles behave differently when the state changes. Figure 4.5 summarises the scientific terms for state changes and shows how the particles are arranged in each phase.

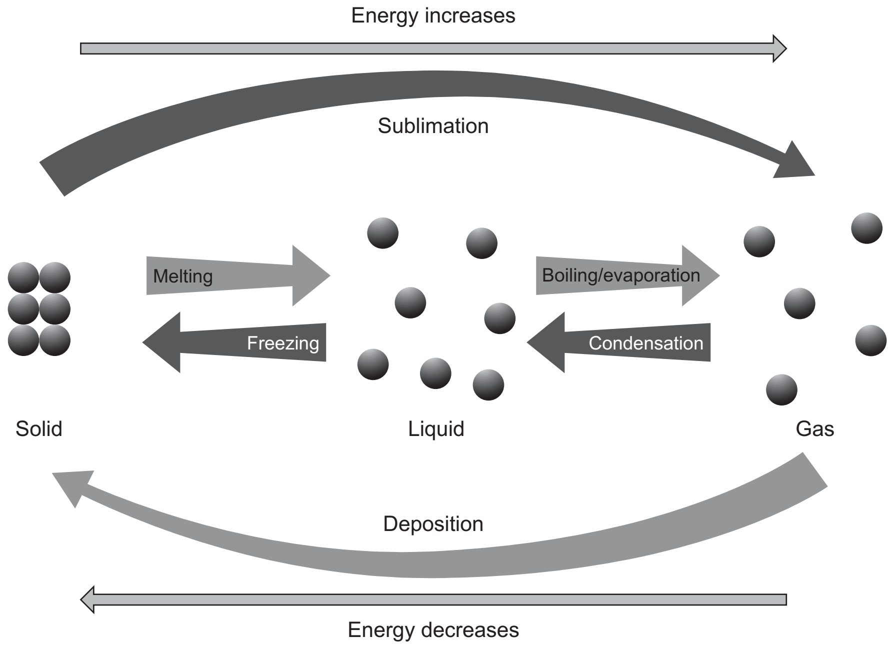


Figure 4.5 Changes of state

Key terms

state	a state of matter, e.g. solid, liquid or gas; sometimes called a phase
change of state	when matter changes from one state to another; also called a phase change

Think about it

The following figure shows a knob of butter in a frying pan. The solid butter turns into a runny yellow liquid as the heat from the stovetop comes through the frying pan.

1. When butter melts, it is undergoing a state change from solid to liquid. Can you think of six other common changes of state (e.g. water boiling in a kettle)?
2. What words are used to describe changes of state?
3. Name one substance that you can normally see as a solid, as a liquid or as a gas.
4. Oxygen is a gas. Can it be a solid?
5. Not many substances undergo sublimation. What is sublimation?

Activity 4.4.1

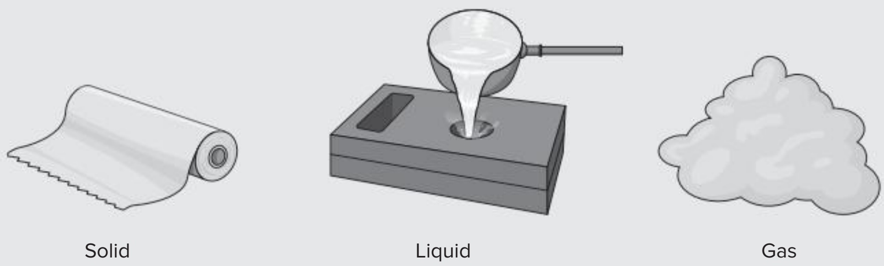
1. a. How do you know it takes energy to change water from a liquid to a gas?
   b. When does the energy of particles in a liquid overcome the attractive forces?
2. Identify the phase change when you:
   a. sweat
   b. put jelly in the fridge to set
   c. have trouble seeing in the mirror after a shower
   d. dip a strawberry in a chocolate fondue fountain.

Fun fact

Aluminium is normally a solid, water a liquid and oxygen a gas. However, each of these substances can be in any of the three states – solid, liquid or gas. It depends on temperature and the forces in the substance.

Use your imagination

Aluminium can be a solid, liquid or gas depending on the temperature. The figure shows a sample of aluminium and what happens to it if we keep heating it to higher and higher temperatures. Imagine you are an aluminium particle in the roll of aluminium foil. Write a story about what happens around you as the temperature rises.



Heating curve for water

Several ice cubes are added to a beaker and a thermometer is placed in the beaker. The beaker is placed on a hotplate. The hotplate is turned on and the temperature of the contents of the beaker is recorded every minute. The temperature readings are shown on the graph in Figure 4.6.

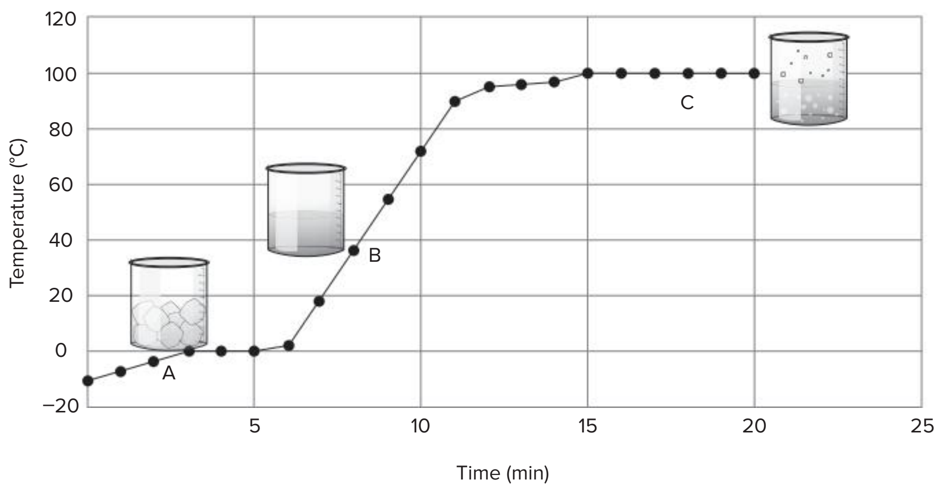


Figure 4.6: A graph of the temperature of water in a beaker as it is heated

Activity 4.4.2

Refer to the graph in Figure 4.6 to answer these questions.

1. Describe what you would observe between:
   a. 0 and 6 minutes
   b. 6 and 15 minutes
   c. 15 and 20 minutes.
2. Explain what is happening at about:
   a. time A
   b. time B
   c. time C.
3. At what temperature is this sample of water boiling?
4. Why is the water not rising above 98°C?

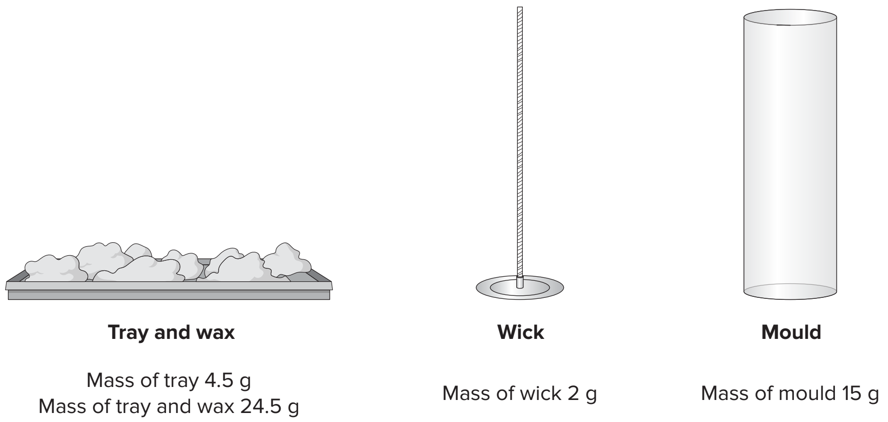
Think about it

The melting point and boiling point of water are often listed as 0°C and 100°C. However, these values depend on the purity of the water. The more impurities in the water, the further the values will be from these stated values. Sea water does not freeze until temperatures of about –10°C, fortunately for the fish!

Boiling point also depends on air pressure. Water boils at temperatures as low as 90°C on Mount Everest, where the air pressure is lower.

Activity 4.4.3

A student studying particle theory is making a candle. The student weighs a tray for the wax, some wax pieces, a wick and a mould for the candle.

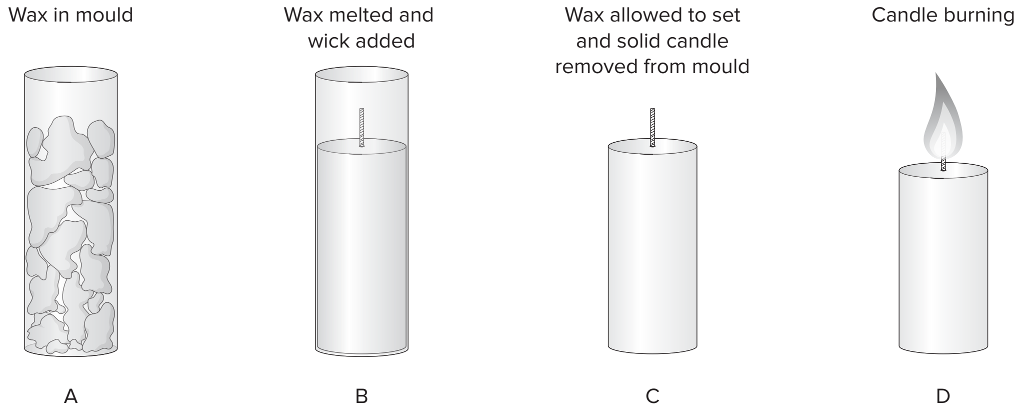


Materials for making a candle

The student then:

- adds the wax to the mould
- heats the wax to a liquid and sits the wick in the wax
- lets the candle wax set
- lights the candle and allows it to burn.

The stages of this process are marked with letters A–D in the figure below.



The steps for making a candle

1. What is the name for the change that occurs to the wax when it is heated (A to B)?
2. How are the particles arranged differently in B than in A?
3. What is the name for the change that occurs to the wax when it is allowed to set (B to C)?
4. a. Use the masses provided in the figure on the previous page to calculate the mass of wax used.
   b. What do you expect the mass of the candle, mould and wick to be in B?
   c. What do you expect the mass of the candle and wick to be in C?
   d. Does the mass of the wax change when it melts? Use particle theory to explain your answer.
   e. Do you expect the mass of the candle to be the same as the mass of the wax pieces and wick?
5. Does the mass change when the candle burns? Justify your answer by referring to particle theory.
6. Refer to the particles of wax to explain how melting and burning are different.
7. A beaker is now placed upside down and over the burning candle. Describe what happens and why it happens.

4.5 Diffusion

You can use your understanding of particle movement to understand the process of diffusion. Figure 4.7 shows a coloured gas moving through air until it is evenly spread through both containers. This is **diffusion**. Diffusion leads to the gases being evenly spread through the container.

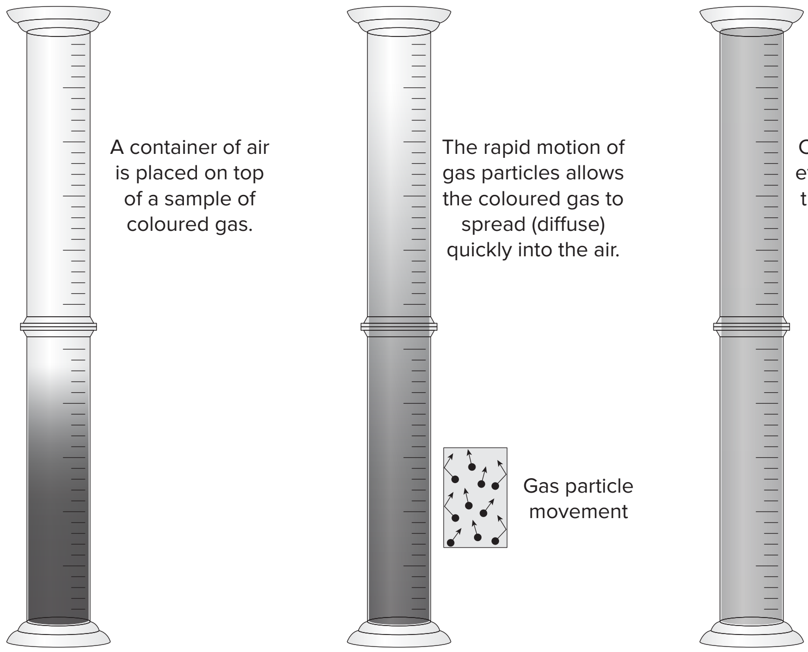


Figure 4.7: Diffusion

Key term

diffusion	the movement of particles from an area of high concentration to an area of lower concentration; the spread of particles from one substance through another

Diffusion is evident when a strong perfume is opened in a corner of a room. The fragrance will be detected throughout the room soon after. The rate of diffusion depends on the temperature in the room. Diffusion is faster at higher temperatures because the particles are moving faster.

Diffusion can also be seen in liquids, but it is a slower process because the movement of particles is slower in a liquid. Figure 4.8a shows some drops of ink being added to a beaker of water and then the gradual movement of the ink throughout the liquid.

The ink spreads because of the random movement of the water particles carrying the ink to different parts of the container. Figure 4.8b represents the particle movement.

a

b

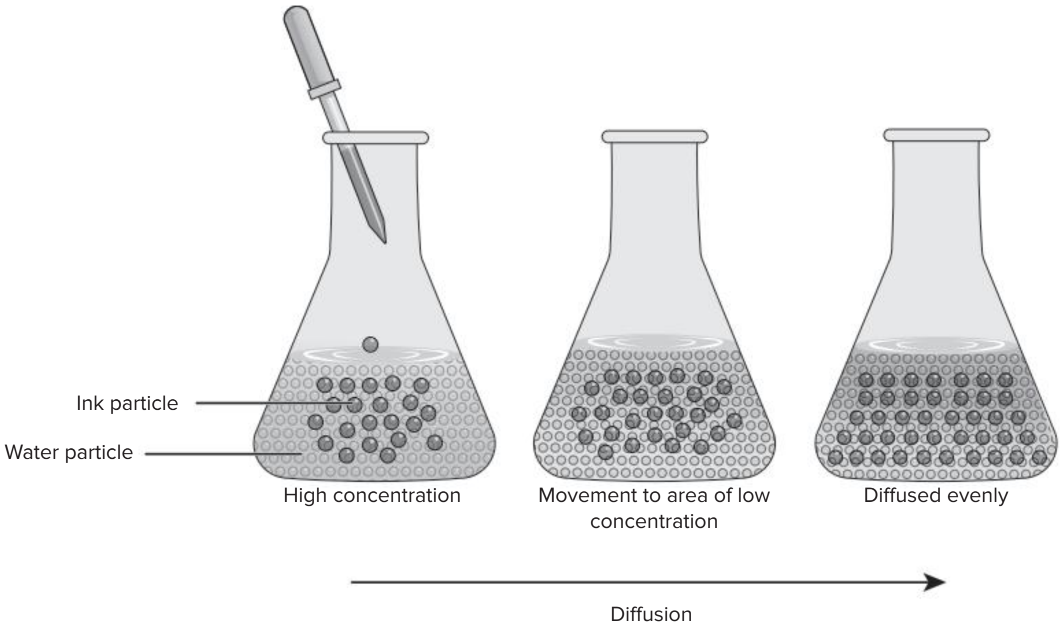


Figure 4.8: (a) The ink is diffusing through the water. **(b)** During diffusion, the ink particles move from an area of high concentration to an area of low concentration.

Activity 4.5.1

1. Explain what 'diffusion' means.

2. A vanilla-scented candle is lit on a shelf on one side of a classroom.

- **a.** Will all students in the class detect the vanilla odour at the same time?
- **b.** Use particle theory to explain how the vanilla odour is moving.

4.6 Properties

We are always making choices about what material to use for a particular task.

- We don't use aluminium foil for a shopping basket – it has low strength.
- We don't use glass for a hammer – it is brittle.
- We don't use plastic for electrical wires – it does not conduct.

Notice how we use '**properties**' to explain these choices, properties such as strength, density and electrical conductivity. Scientists and engineers rely heavily on properties when comparing suitability of materials.

Table 4.3: Examples of properties of substances

Property	Description
Melting point	The temperature at which a solid turns to a liquid
Electrical conductivity	Whether an electric current can pass through a substance
Malleability	Whether the material shatters when struck
Transparency	Whether light can pass through a substance
Density	The amount of mass in a given volume
Durability	The expected time a substance will remain useful
Hardness	How hard it is to push a sharp point into a substance
Tensile strength	Whether the material stretches easily
Flammability	Whether the object burns in a flame
Magnetism	Whether the object is attracted to a magnet

We compare and describe materials in terms of their properties.

If something is a **plastic**, it is likely that it has a low density, has a relatively low melting point, does not conduct electricity, but is durable.

Activity 4.6.1

1. What properties do you associate with:
   a. metals?
   b. glass?
2. Some properties sound as though they refer to the same thing, but there is a difference.
   Explain the difference between:
   a. melting point and flammability
   b. hardness and strength
   c. electrical conductivity and thermal conductivity.
3. What is the most important property to consider when choosing a material for a:
   a. car windscreen?
   b. frying pan?
   c. mobile phone screen?

4. Choose between the two identified materials for each application by considering each material's properties.

a. Iron or plastic for a poker used to stir a fire

b. Nylon or woven celery fibres for a rope

c. Copper or string for electrical wiring in a house

5. Complete the table by choosing from the following items: nail, leather belt, plastic comb, test tube, salt, icy-pole stick. (Not all items will go in the table.)

Which item(s) can you see through?	
Which item do you think is the densest?	
Which item will melt first in a hot pan?	
Which item(s) are magnetic?	
Which item(s) conduct electricity?	
Which item(s) can dissolve in water?	

Density

Density refers to the amount of matter in a given volume.

A formula for calculating density is:

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$d = \frac{m}{V} \text{ or } m = d \times V \text{ or } V = \frac{m}{d}$$

where d = density (in g/cm^3 or g/mL)

V = volume (in cm^3 or mL)

m = mass (g)

Example 1

Calculate the density of ethanol if a mass of 100 g has a volume of 126 mL.

$d = \frac{m}{V}$

$= \frac{100}{126}$

$= 0.79$ g/mL

Example 2

Calculate the density of a lead cube of side length 2 cm and mass 91 g.

First, calculate the volume of the cube using the formula:

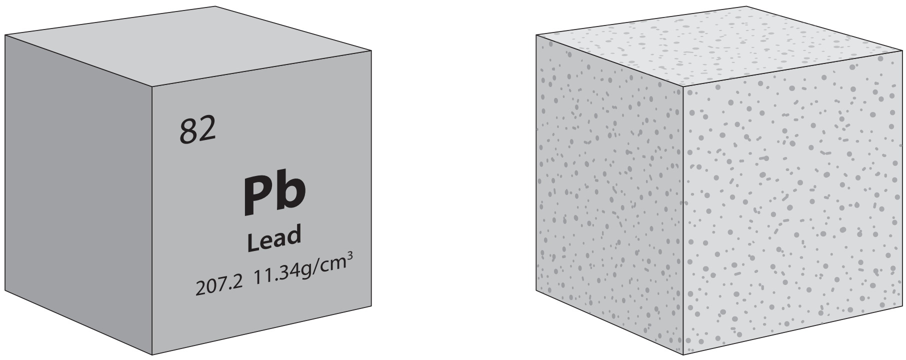
$V = l^3 = 2^3 = 8\ \text{cm}^3$

$$d = \frac{m}{V}$$

$$= \frac{91}{8}$$

$$= 11.4\ \text{g/cm}^3$$

Activity 4.6.2



The lead cube and the foam cube are equal sizes but the densities of the two cubes are very different.

1. How could you tell that the density of each cube in the figure above is different?
2. Explain what density is.
3. Why is density not the same thing as mass?
4. How could you calculate the density of each cube?
5. How are the particles in the two cubes likely to be different, or arranged differently?
6. **a.** Give an example of where high density can be an advantage in a material.

   b. Give an example of where low density can be an advantage in a material.

Activity 4.6.3

Use the equation for density to complete the table.

Item	Density (g/cm^3)	Mass (g)	Volume (cm^3)
Nail		20	3.8
Water		0.85	0.87
Gold	15.5		7.6
Oil	0.88	28.4	
Plastic	0.76		0.068

Floating

The density of olive oil is 0.92 g/mL and the density of water is 1.0 g/mL. Therefore, olive oil has a lower density than water and will float on top of water.

In general, a less dense object floats on a more dense liquid and a more dense object sinks when dropped into water.

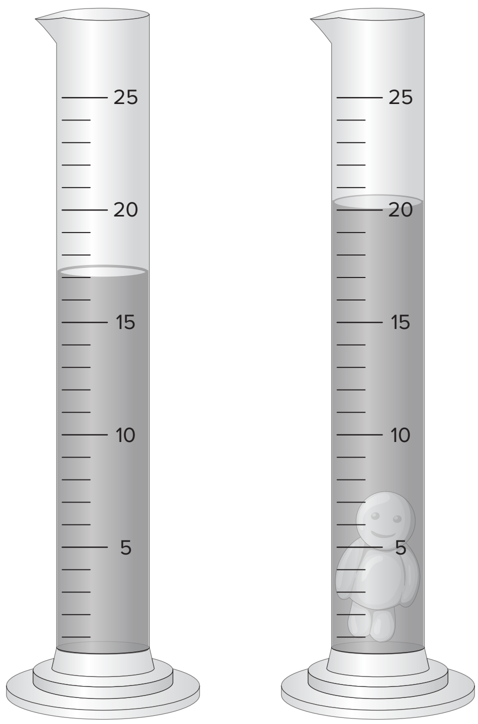
Swimming in the Dead Sea

It is easier to float in the Dead Sea in the Middle East than it is in a swimming pool. This is because the Dead Sea is one of the saltiest bodies of water in the world. The density of the salty water is far greater than that of normal lakes and rivers.

Density of a jelly lolly

To calculate the density of an irregular-shaped object, you need to calculate its volume. But its irregular shape makes this difficult. Instead, the displacement of water can be used.

Activity 4.6.4 – extension



Calculating the volume of an irregular-shaped object

1. Use the figure above to calculate the density of the lolly, given that its mass is 2.8 g.
2. If you were to use this same container to try to find the volume of a small nail, the change in volume would be too low and hard to read on the scale. Suggest a change in the method that will enable you to obtain a more accurate estimate of the volume of the nail.

4.7 Mixtures

So far, we have discussed substances in their pure state, where there is only one type of particle – **pure substances**. However, many substances are **mixtures** that contain two or more different types of particles (Table 4.4).

Key terms

pure substance	a substance that is only made up of one type of thing; for example, a gold bar
mixture	a combination of substances that can be physically separated; for example, a salad

Table 4.4: Some examples of mixtures

Mixture	Description
Sea water	Water with salt in it
Milk	Contains water, fats, proteins and sugars
Cereal	Might contain grains, fruits and nuts
Soap powder	Contains a range of cleaning agents and whiteners
Clothes	Can be a blend of materials such as polyester and cotton

Pure substance versus mixture

A chocolate chip cookie is a mixture. You can grind a cookie up and separate pieces of chocolate, nut or oats from it.

Raspberry jam is a mixture. You can extract seeds and pieces of fruit from the jam and boil off water from it.

Aluminium foil is a pure substance. You cannot extract anything other than aluminium from it.

Table 4.5: A comparison of a compound and a mixture

Compound: table salt	Mixture: sea water
Every small crystal has the same shape. Every crystal is sodium chloride. Each crystal has the same properties. It cannot be separated into different parts.	Water, salt, sand and microplastics are present. It can be separated into water and salt. Sea water in different parts of the ocean might be different.

Activity 4.7.1

Classify each of the following items as pure substance or mixture. In the third column, comment on what substances any mixture might contain.

Substance	Pure or mixture?	Comments
Pond water		
Sugar		
Orange juice		
Iron nail		
Salad dressing		

Extension questions

1. Research the composition of soil. List five substances that might be found in soil.
2. Is air a mixture or a compound? Research this topic and summarise your conclusion. Justify your answer.

4.8 Solutions

Sometimes it is obvious if something is a mixture, but sometimes it is not. Soil is an obvious mixture, but air and sea water are not. Scientists call these two types of mixtures:

- **homogeneous**: the mixture has a consistent appearance (e.g. air and red cordial)
- **heterogeneous**: different components are easily visible (e.g. muesli and pond water).

A **solution** is an important type of homogeneous mixture. Seawater is a solution. It is water that has salt (sodium chloride) spread out in it (**dissolved**). Figure 4.9 shows a solution being formed. A **solute** (e.g. sugar) is added to a **solvent** (e.g. water). A solution is formed.

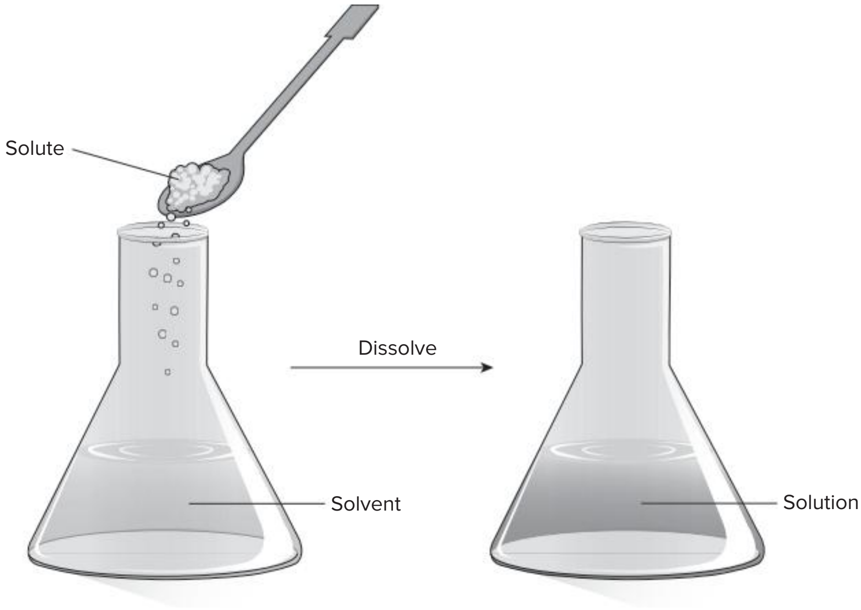


Figure 4.9: Formation of a solution

Key terms

solute	a substance dissolved in a solvent to form a solution
solvent	a substance that dissolves another substance to form a solution

You will be familiar with many solutions, such as soft drink and vinegar. Here are some other facts about solutions.

- Not all clear liquids are solutions. Pure substances can be clear liquids too. For example, ethanol, acetone and benzene are clear liquids that scientists use in the laboratory.
- Water is not always the solvent. For example, a cough medicine might be made up of a medicine dissolved in ethanol.
- Not all solids dissolve in water.
- The amount of solute dissolved in a given volume is referred to as the **concentration** of the solution.

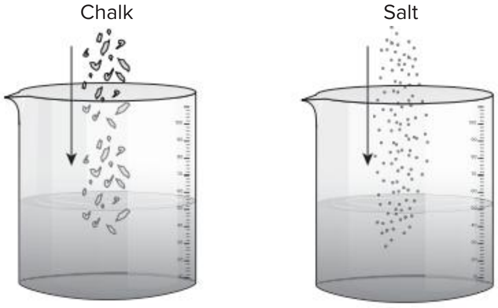
It is very easy to test the solubility of a solid in water – just add a sample and stir. Salt and sugar are soluble in water, but chalk and sand are not.

Activity 4.8.1

1. List three examples of solutions.
2. **a.** Explain what concentration means.
   b. Give two examples where concentration is important (e.g. cordial).
3. **a.** A black marker for a whiteboard contains alcohol. Identify the solvent, solute and solution in the marker.
   b. Identify the solvent, solute and solution in a cup of coffee.

4. Some solids are soluble in water (e.g. salt); some are not (**insoluble**) (e.g. chalk).

   a. Clumps of chalk and salt contain either chalk or salt particles, as shown below. When the clumps are stirred in water, the chalk particles behave differently from the salt particles. Show this different behaviour on the diagram.



Chalk and salt behave differently in water.

   b. List five solids that are soluble in water and five that are not.

Separation

It can be useful to separate mixtures into their components. Scientists may do this to remove impurities or to create useful products. For example, they may filter water to make it safer to drink or separate milk to get cream and skim milk. An understanding of properties is very useful in designing methods to separate mixtures.

4.9 Separation strategies

Investigation: Designing procedures to separate some mixtures

Your task is to design procedures that could be used to separate some mixtures.

1. Four mixtures are listed in the table below. Propose a method for separating each mixture.

   The best separation is one that gives you a pure sample of each part of the mixture.

2. Fill in the table with details of how you propose to separate these mixtures. For example, you might propose to use a magnet to separate sawdust and copper. Your method might suggest running a magnet over the outside of the container to attract the copper out. (This may or may not work – it is a proposed method only.) You would then write in the third column that you are using a difference in magnetism between copper and sawdust.

Mixture	Proposed method	Difference in properties you are targeting
Sawdust and copper		
Copper and iron		

Mixture	Proposed method	Difference in properties you are targeting
Olive oil and water		
Salt and chalk		

3. The observations and results of one group are shown in Table 4.6.

Table 4.6: The observations of mixtures and results of one group

Mixture	Method	What happened	Possible modifications
Sawdust and copper	Added mixture to water.	Copper sank; some sawdust floated, some sank.	Different strategy – place mixture on bench and blow a hair dryer near it.
	Burnt a sample.	Sawdust formed messy black soot.	
Copper and iron	Magnet poked into the mixture.	Iron sticks to the magnet but it is hard to get the small pieces off the magnet.	Run the magnet over the outside of the container rather than put it inside the container.
Olive oil and water	Added to a test tube and poured the oil off.	It is hard to only pour off the oil.	Use a small dropper to suck the oil layer off.
Salt and chalk	Mixture was stirred in water. Water was filtered to collect one component.	A white powder was caught in the filter paper. It could be dried. Not sure where the other component was.	Add the water that passed through the filter to a beaker and boil it away.

Results

1. Sawdust and copper
   - **a.** When separating sawdust and copper, identify two reasons why burning the sawdust is not a good idea.
   - **b.** The hair dryer method suggested can work well. Explain how you would set up this separation.

2. Copper and iron

a. What conclusion can you draw about metals and whether they are magnetic?

b. How could you change the method to stop the iron pieces sticking to the magnet?

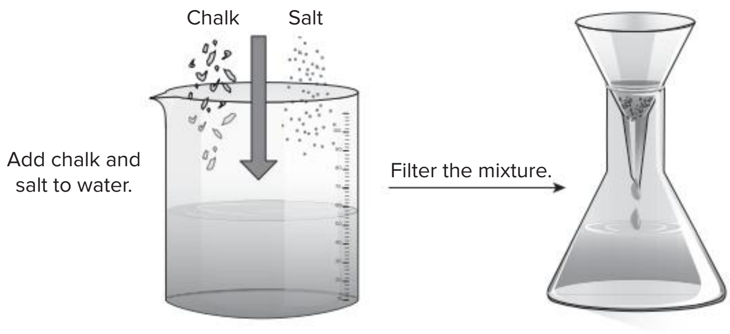
3. Oil and water

What are some other examples of liquids that do not mix in water?

4. Salt and chalk

a. Chalk and salt behave differently when stirred into water. Draw how the particles behave in the water. Explain your diagram.

b. The mixture in the beaker is filtered. Use the letters S and C to show where the particles of each will be after filtering.



Separation techniques

Evaporation

To separate a solution by evaporation, the solution is heated so that the water evaporates, leaving the solid particles. This is how salt lakes such as Lake Eyre in outback Australia form. Salt is refined in this way from sea water.

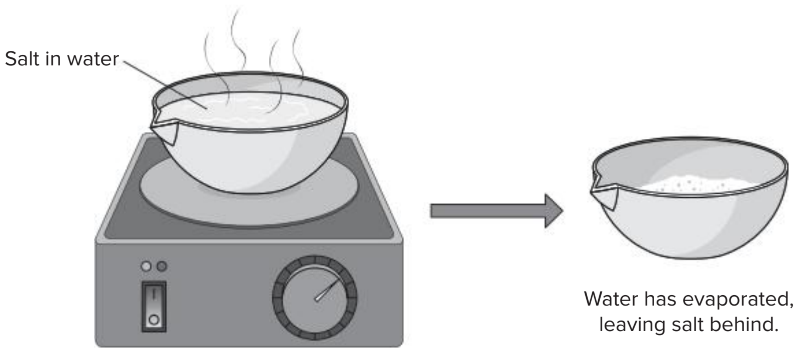


Figure 4.10: Evaporating off the water leaves behind salt.

Decantation

Oil and water do not mix. The oil has a lower density than water, so it sits on the top. The oil and water form two layers. The oil on top can be poured off, or ‘decanted’.

This can also be done with a separating funnel (Figure 4.11). When the tap is opened the heavier liquid drains from the bottom of the funnel.

Decantation is also used to pour liquid from a sample of liquid with sediment in the bottom.

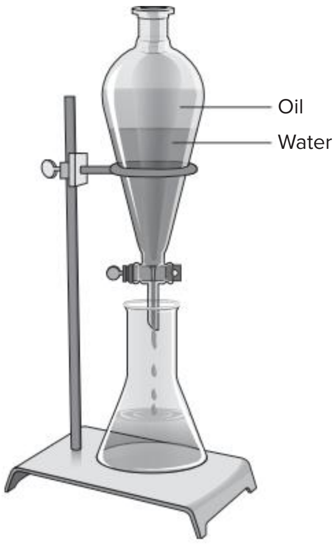


Figure 4.11: Separating oil and water with a separating funnel. The denser water drains out first, leaving the oil in the funnel.

Crystallisation

In Figure 4.12, the beaker on the left contains a concentrated solution of copper sulfate. It is blue in colour. A small seed crystal of copper sulfate can be dangled in the solution. Over the following days, the crystal ‘grows’. A large crystal of pure copper sulfate can be obtained from an impure solution.

Many pills and tablets are formed in this way.

Figure 4.12: Separating a solute from a solvent by crystallisation

Distillation

An alcohol solution is a mixture of ethanol and water. Ethanol and water have different boiling points, so they can be separated by distillation. Ethanol boils off first (at 79°C), leaving water, which has a boiling point of 100°C.

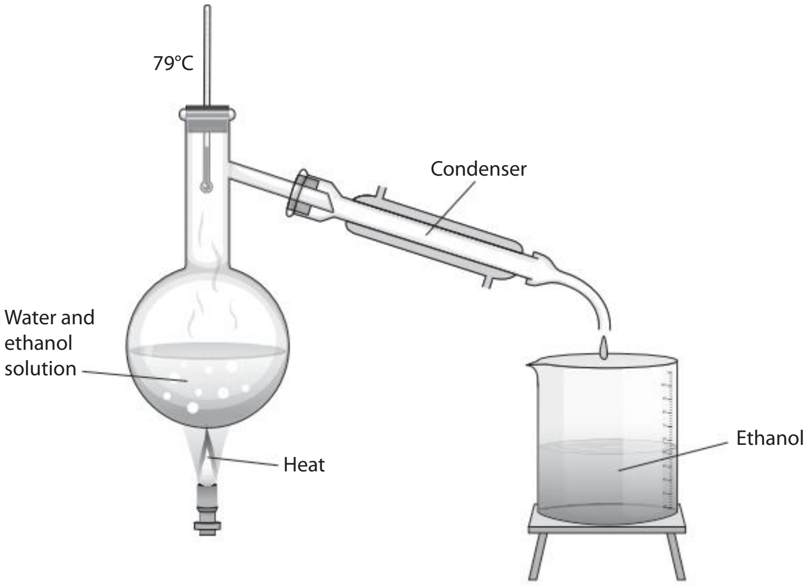


Figure 4.13: An alcohol solution being separated by distillation

As the ethanol boils, it converts to a gas, which rises out of the flask. When it goes through the condenser, which is cooled by water, it forms a liquid, which drips into the beaker. The water remains behind.

Whisky, brandy and other alcoholic drinks are made this way. They are often referred to as 'spirits' because they turn to a gas during distillation.

Chromatography

Chromatography separates mixtures by how fast each component moves up the paper, which depends on how soluble each component is in the solvent.

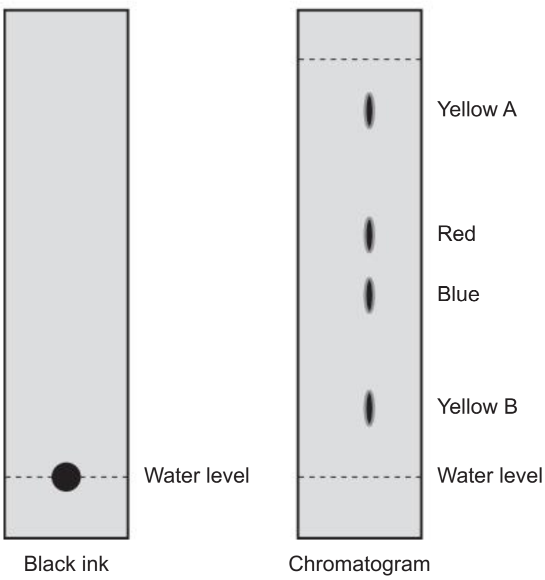


Figure 4.14: Separating black ink by paper chromatography

Figure 4.14 shows a spot of black food dye on a strip of absorbent paper. The paper is placed in a beaker with a small amount of water in the bottom. After about 10 minutes, four different coloured spots can be seen at different points on the paper. This shows that the black food dye is a mixture of four dyes – red, blue and two yellow dyes.

Yellow dye A is the most soluble in water – it moves the furthest. Yellow dye B is the least soluble – it does not move very far.

Centrifugation

The device shown in Figure 4.15 is a centrifuge. Samples are placed in test tubes and spun at high speeds. The heavy items are flung to the bottom of the test tube, enabling them to be separated from the lighter items.

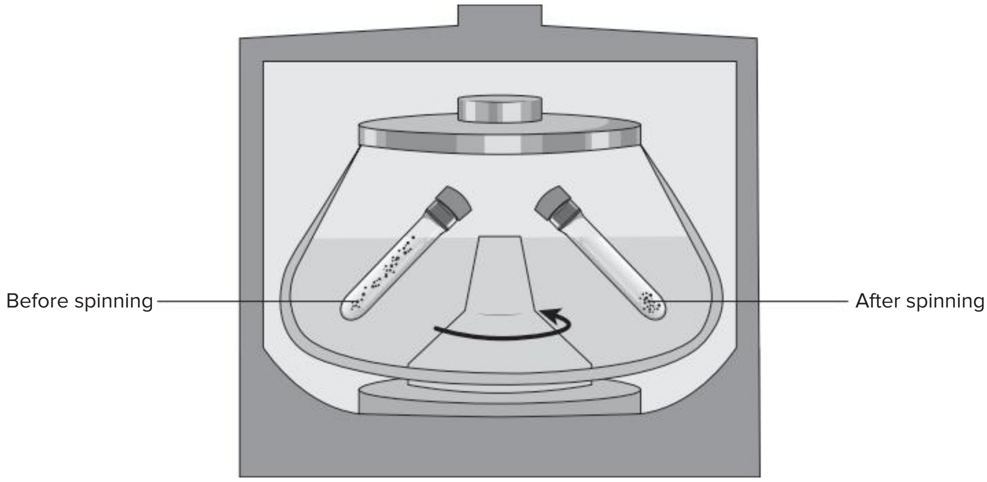


Figure 4.15: A centrifuge: before spinning, the particles are evenly spread; after spinning, the heavier particles are at the bottom of the test tube.

Milk and blood are often centrifuged to extract useful components. Milk separates into cream and whey, and blood separates into plasma and red blood cells.

First Nations separation techniques

There are many examples of separation techniques used by First Nations peoples, including the following.

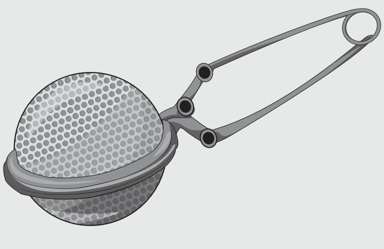
- Cycad (*Macrozamia*) seeds can be a source of flour for baking, but they also contain hallucinogenic impurities. First Nations peoples learnt to crush the seeds and then leave them in a creek for several days, until the toxic compounds wash out, leaving the useful flour behind. The toxins are water soluble, but the flour is not. The use of dilly bags makes this a form of filtering.
- Winnowing refers to the process of throwing crushed grain into the air. The wind blows the lighter chaff away while the heavier seeds fall directly back to the ground where they can be collected. First Nations peoples have used flour from acacia and grass seeds for baking for thousands of years.

- Yandying works in a similar way to gold panning. A mixture of seeds, soil and twigs is shaken in a dish called a yandy or coolamon (it has many other names, depending on the language group). The heavier particles (the seeds) accumulate at the base of the yandy where they can be collected. Collecting seeds often involves two stages of yandying: first, to separate the seeds from their pods, and second, to separate the baked seeds from ash after the seeds are roasted.

Figure 4.16: Yandying

Think about it

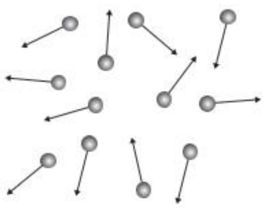
The following table shows some devices used for separation in the home and kitchen. Answer the questions in the table to help identify the devices.

Item	Use	Questions
	Cake makers! What does this device do?	What property of materials does this device target?
	What is this used to separate?	How do coffee devices do similar things?

Item	Use	Questions
	The contents in the top of the jug are separate from the bottom. What is this jug used for?	Carry out some research to find out how the cartridge works.
	Where do you see these labels? Which numbers do you see the most?	How do you think your local council separates the items in recycling bins?

Activity 4.9.1

The following table lists the terms that are fundamental to particle theory. Explain what each term means, including a diagram if possible. Use the description of gas as an example.

Solid	Liquid	Gas	Mixture
		 Expands to take up whole container Fast particles Low density No forces between particles	

Melting/freezing	Boiling/condensing	Diffusion	Solution
Density	Electrical conductivity	Element	Compound

4.10 Exploring the lab

In science in general, and chemistry in particular, you will conduct investigations in the laboratory. It is important that you are familiar with investigation equipment and how to use it.

Common laboratory equipment

Figure 4.17: Some of the equipment you may need to use in the lab

Activity 4.10.1

Choose five items from Figure 4.17: research them online, and explain how they are used in an investigation.

The Bunsen burner

A Bunsen burner is used to heat material in the laboratory. It is a specialised piece of equipment that you should use with care. Figure 4.18 shows its features.

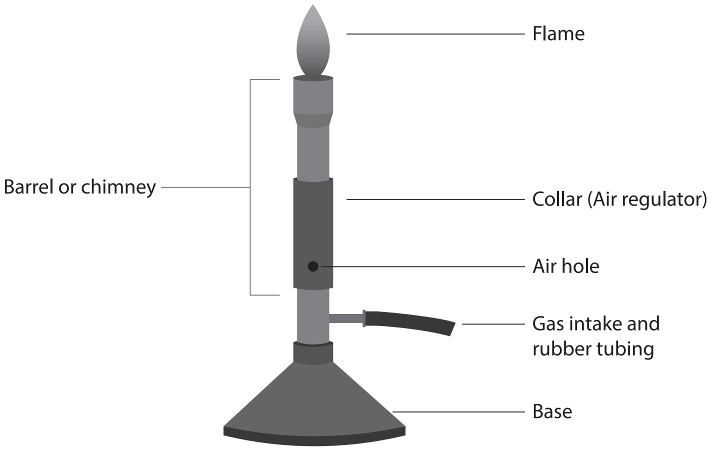


Figure 4.18: The Bunsen burner and its parts, labelled

A Bunsen burner uses two types of flame:

- an orange flame, called the safety flame, that burns at around 300˚C
- a blue flame, known as the heating flame, which is much hotter and more dangerous, burning at around 1500˚C.

Lighting a Bunsen burner

It is vital you learn to set up and use a Bunsen burner safely. If you do not, you could be severely burned or create a dangerous gas leak.

Before you start, follow safety procedures: put on a lab coat and safety glasses, tie up loose hair and make sure you know where the fire extinguisher and fire blanket are in your lab. (Safety is discussed further in the next section.)

1. Check the burner – inspect the rubber tubing for holes or cracks. Ensure the area around the Bunsen burner is clear of flammable materials (including notebooks!).
2. Place the Bunsen burner on a heat-proof mat and connect the gas hose to the gas tap.
3. Turn the collar so the air hole is closed.
4. Light the burner, preferably using a lighter with an extended nozzle. Hold it close to the top of the burner, just above the air intake. Have the lighter burning first, then turn on the gas supply and the flame should ignite. If it doesn't, turn off the gas supply and wait a few seconds before trying again.
5. Once your burner is lit, turn off your lighter or put out your match.
6. Adjust the air intake to control the size and temperature of the flame. When you are not using the Bunsen burner, close the collar to use a safety flame.

Remember, never leave a Bunsen burner unattended, even on the safety flame. The Bunsen burner is metal and can get hot. When you are finished, turn off the gas supply and let it cool down completely before storing it away. Do not handle it while it is still hot.

Safety in the laboratory

When studying science, you could be asked to conduct investigations using hazardous materials including chemicals and fire. There are specific laboratory rules to follow to keep yourself and others safe. Use the acronym PIECE to remember these rules.

P	Protective equipment: Wear safety glasses, gloves and a lab coat to protect you from hazardous substances.
I	Instructions: Listen to and read all instructions carefully before you begin.
E	Equipment: Inspect your equipment to make sure you have the correct items and that it is intact and working properly.
C	Consumption: Never bring or consume food or drink in the laboratory as it could become contaminated.
E	Energy: Manage your energy – walk sensibly and hold equipment securely while moving around the lab.

Reading volume measurements

When you read volume measurements, you need to understand that liquids can curve and could potentially distort your results. Using specific equipment and taking measurements at eye level will help you read your results accurately.

You will usually use beakers and measuring cylinders to measure volume. When you need to be precise, always use the smallest measuring cylinder available that can measure the required amount. For example, if you need to measure 7.0 mL of something, use a 10 mL measuring cylinder to obtain the most accurate result.

Observing the meniscus

A liquid does not form a flat surface in a small container because **surface tension** makes it curve slightly. This curve is called the **meniscus**. To account for this curve, you should always measure volume at eye level.

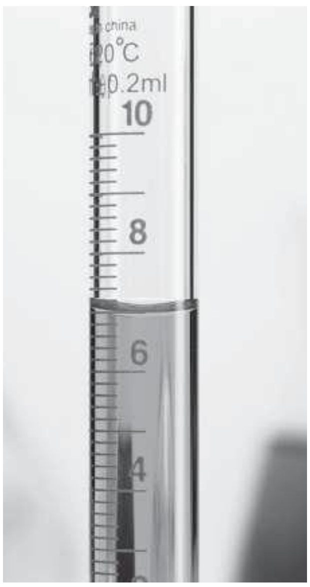


Figure 4.19: A measuring cylinder showing a curved meniscus

Key terms

surface tension	where the molecules of a liquid are more attracted towards one another at the surface of a liquid than to the air above it
meniscus	the curve seen at the top of a liquid in response to its container

In addition to accounting for the meniscus, you can also have issues reading measurements if you are not aware of **parallax error**. If you do not take the reading at eye level, your perspective could distort the results. Figure 4.20 shows how a parallax error can happen.

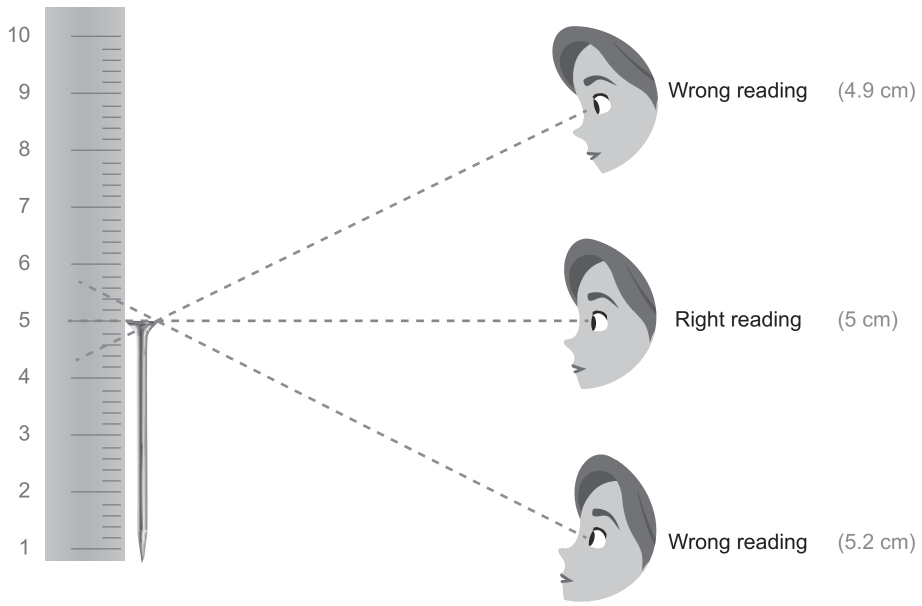


Figure 4.20: Taking the measurement while looking from above gives a reading of 4.9 cm. The measurement taken while looking from below looks like 5.2 cm. The correct reading of 5 cm is taken from eye level.

Key term

parallax error	the seeming shift in something's position when it is viewed from different angles

End-of-chapter summary

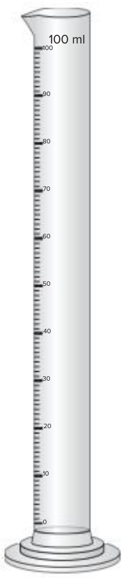
- Chemists use particle theory to describe the behaviour and properties of substances.
- All matter consists of particles.
- Substances can be solids, liquids or gases, depending on the temperature.
- In solids and liquids, the attractive forces between particles are strong enough to hold the particles close together. In gases, the energy of the particles is high enough to overcome the attractive forces between particles.
- 'Condensation', 'freezing', 'melting' and 'boiling' are terms used to describe changes in state.
- Substances can be compared or described in terms of their properties.
- Melting point, density, hardness and electrical conductivity are common properties.

- Substances can be pure or mixtures.
- In a homogenous mixture, the individual components cannot be discerned (e.g. sea water).
- In a heterogeneous mixture, more than one component can be seen (e.g. soil).
- A solution is a homogeneous mixture, in which one substance (solute) is dissolved in another (solvent).
- Useful separation techniques include decantation, chromatography, distillation, winnowing, centrifuging, yandying and filtration.

Revision questions

1. Name the process occurring when:
   - **a.** gold bars are poured at a smelter
   - **b.** tea from a tea bag spreads through a cup of hot water
   - **c.** crushed oranges are poured through a sieve
   - **d.** water vapour forms on a shower mirror
   - **e.** you push the handle of a bicycle pump in while blocking the hose with your finger
   - **f.** you boil muddy water to catch the steam for drinking water
   - **g.** a teaspoon of sugar is stirred into water
   - **h.** crushed grain is thrown in the air to remove the seed shell.
2. Identify the following pieces of equipment.

a.



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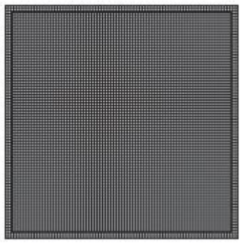
b.

____

c.



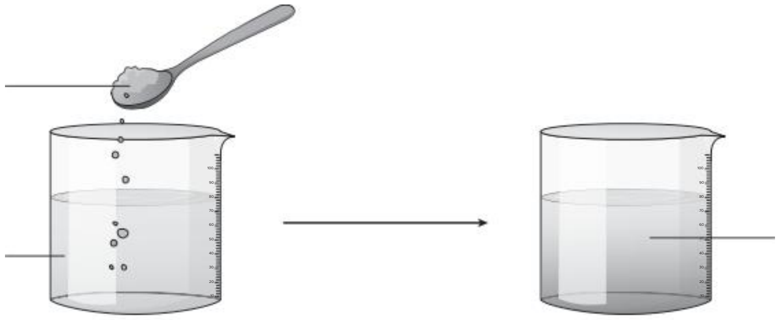
____

d.

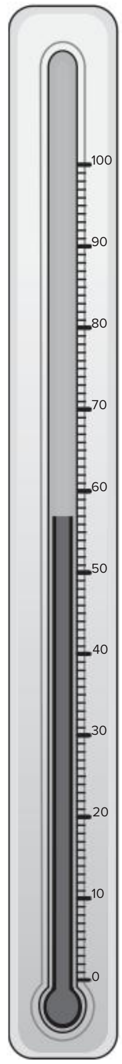
____

3. A chopped onion is placed on the barbecue in an underground carpark. Use this situation to explain what gas diffusion is and what patrons in the carpark might notice.

4. Label the following components of a mixture using the terms 'solution', 'solute' and 'solvent'.



5. Read the temperature on the thermometer.



6. List two examples of:

a. homogeneous mixtures

b. heterogeneous mixtures.

7. The water in a saucepan reaches boiling point and bubbles can be seen leaving the liquid.

a. Explain how the particles in the water are behaving differently from the particles in steam.

b. Why does the water boil?

c. Do the forces of attraction between the water particles change as the water gets hotter?

8. Do particles in a solid move? Explain your answer.

9. You squeeze an orange into a glass, then fill the glass with water.

a. How does the colour of the orange juice change after the water is added?

b. How does the taste change?

10. You add a tablet of antacid to a glass of water and stir it.

a. Identify the solute, solvent and solution.

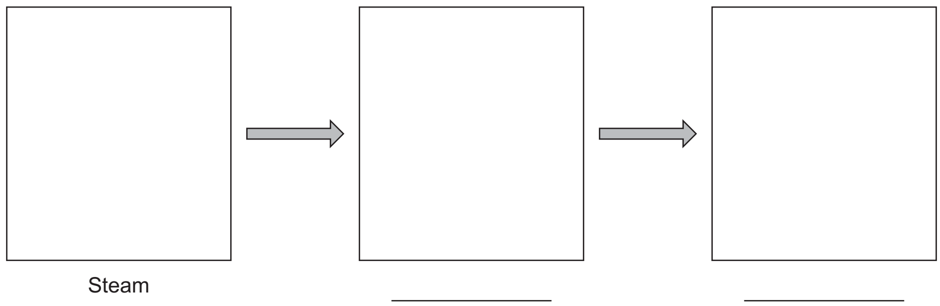
b. Compare adding the antacid to water with adding a piece of chalk to water. Explain why these two actions will produce very different results.

11. A cube of silver with a side length of 5 cm has a mass of 468 g. Calculate the density of the silver.

12. A teacher adds small nails, a tablespoon of sand and a tablespoon of sugar to a jar. He then shakes the jar to mix the particles.

Outline how you might separate this mixture back into its original components without destroying any of the components.

13. A student holds an upturned jar over the spout of a boiling kettle. She captures some steam in the jar. She then quickly puts a lid on the jar and places it in the freezer of a fridge. Over the next few hours, the steam undergoes two major changes.



a. In the first box, draw how the particles are arranged in steam.

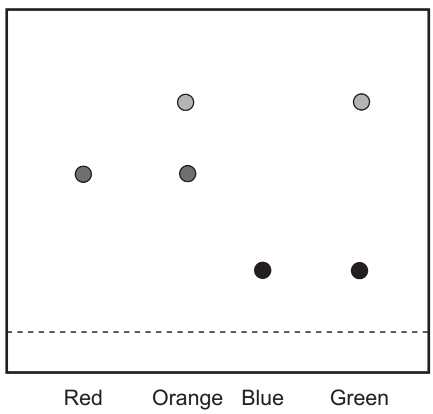
b. In the other two boxes, draw how the particles are arranged when the steam changes to different states in the freezer. Write the names of these states under each box.

c. Above the arrows, write the scientific name for the changes occurring at each stage.

14. The following chromatogram is of four different coloured lollies – red, orange, blue and green. A spot of colour from each lolly was placed on the dashed line.

a. Why do the spots move at different speeds?

b. What conclusions can you draw from the chromatogram?



Chapter 5 – Science inquiry skills

5.1 Conducting an investigation

Scientists conduct investigations to test their ideas about the world. All the facts you have read in this book have been investigated – even the ones about space!

We can be scientists too. We may have an idea that something is true, but if we want to be sure about it, we need to test our guess – the **hypothesis** – and gather evidence to prove our idea is correct.

For example, a friend tells you that a long, narrow paper plane will fly further than a short, wide paper plane. You are not sure if they are correct. The best way to find out is to conduct an investigation to determine whether the claim is true.

Key term

hypothesis	an educated guess or idea about something that has not yet been proven

5.2 Asking and framing your question

The first part of any investigation is deciding what we want to find out. Scientists ask questions about the world around them to try to understand the universe. We need to ask a specific question about what we want to find out. In addition, we need to frame the question so that we can investigate it. This initial framework involves defining our aim and stating our hypothesis.

Aim

The aim is the end goal for your investigation. In the paper plane example, some aims could be to make a paper plane that flies the highest, stays up the longest or does the most loops. Your aim is to find the design that will enable the paper plane to fly the furthest distance.

Start an aim with 'To' and follow with words such as 'investigate', 'observe', 'determine' or 'measure'. For example, Aim: To investigate how the design of a paper plane affects the distance it can fly.

Hypothesis

The next step is to write your hypothesis. The hypothesis should be an **educated guess** about the result of your investigation. It should be based on knowledge you already have about the subject. So your hypothesis might be that a long, narrow paper plane would fly further than a short, wide paper plane. This is based on the design of regular aeroplanes you have seen.

You would not say your hypothesis is that your paper plane will fly to the Moon! That is not an educated guess, as we know from experience throwing paper planes that it is not likely to happen.

Write your hypothesis as an 'If, then' statement. For example, 'If a paper plane is long and narrow, then it will fly further'. Your hypothesis could be wrong – and this is okay. What matters is that you can test it. Putting everything together gives us the following.

- Aim: To investigate how the design of a paper plane affects the distance it can fly.
- Hypothesis: If a paper plane is long and narrow, then it will fly further than one that is short and wide.

5.3 Planning your investigation

The next step is to plan your investigation. This means you need to think about how you will conduct your investigation to get the best evidence, what equipment you might need and how you will conduct the investigation safely and ethically.

To ensure you get the best evidence, you need to identify your variables.

Variables

There are three types of variables: the independent variable, the dependent variable and the controlled variables.

- The **independent variable** (IV) is the thing we test – the thing we change in the investigation.
- The **dependent variable** (DV) is the thing we measure. This will give us results from our investigation.
- **Controlled variables** are the things we keep the same. There can be lots of these!

> **Remember it!**
>
> The independent variable is just that – Miss Independent! It gets to **change**.
>
> The dependent variable **depends** on its buddy. It will only change if Miss Independent changes. Then you get to **measure** it.

For example, imagine you want to investigate whether the design of a paper plane affects how far it can travel. For any investigation, you can find the variables by going back to your hypothesis: If a paper plane is long and narrow, then it will fly further than one that is short and wide.

- The independent variable would be the different designs of paper planes. You **change** this.
- The dependent variable would be how far each plane travels. You **measure** this.
- Some controlled variables would be the type of paper used, the throwing location and the person throwing the plane. Keep these the same.

Going back to our hypothesis, the 'If, then' statement helps us identify our variables.

If a paper plane is *long and narrow* (IV), then it will *fly further* (DV).

Materials

Next, consider what equipment you might need – your materials. In the case of a paper plane investigation, the equipment needed should be straightforward, but other investigations are far more complex and require specialised scientific equipment.

The materials list would be:

- sheets of paper (A4 size)
- tape measure (at least 4 m long)
- chalk or tape to create a throwing line
- notebook and pen/pencil for recording results
- a large, open area, such as a hallway or playground, without wind or obstacles.

Determining the method

Now you can decide on the procedure – the **method** – you will follow for the investigation. First, choose the two designs for the planes.

Long and narrow design – Plane A

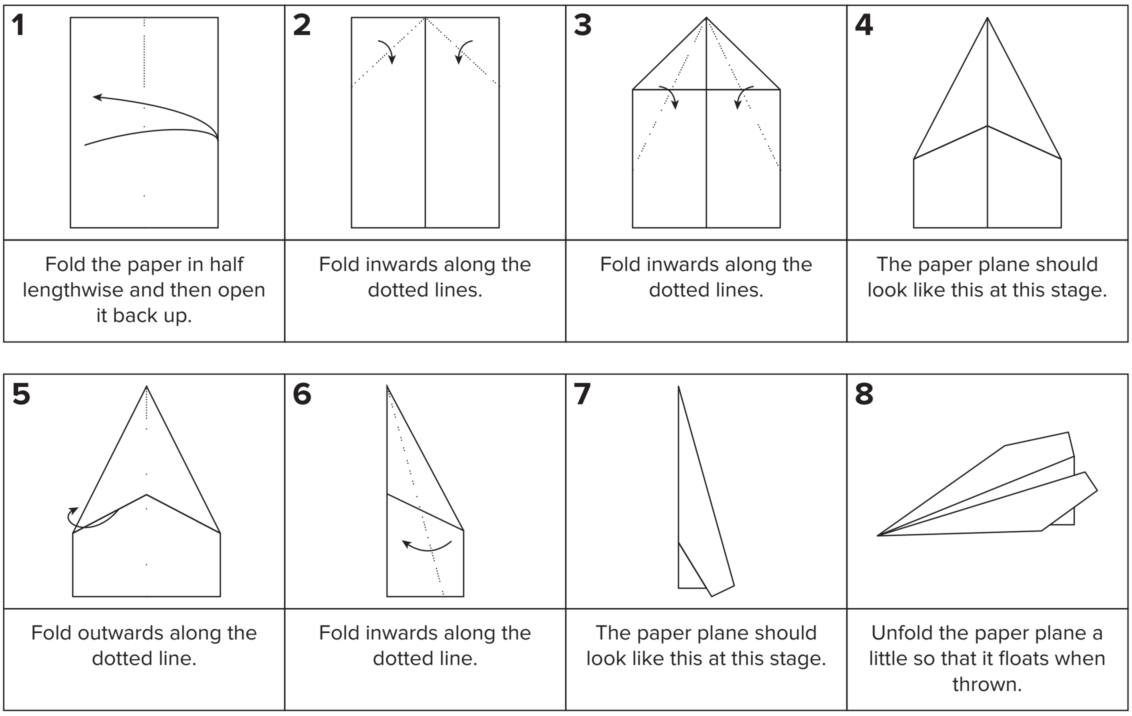


Figure 5.1: Follow the steps to make Plane A.

Wide and short design – Plane B

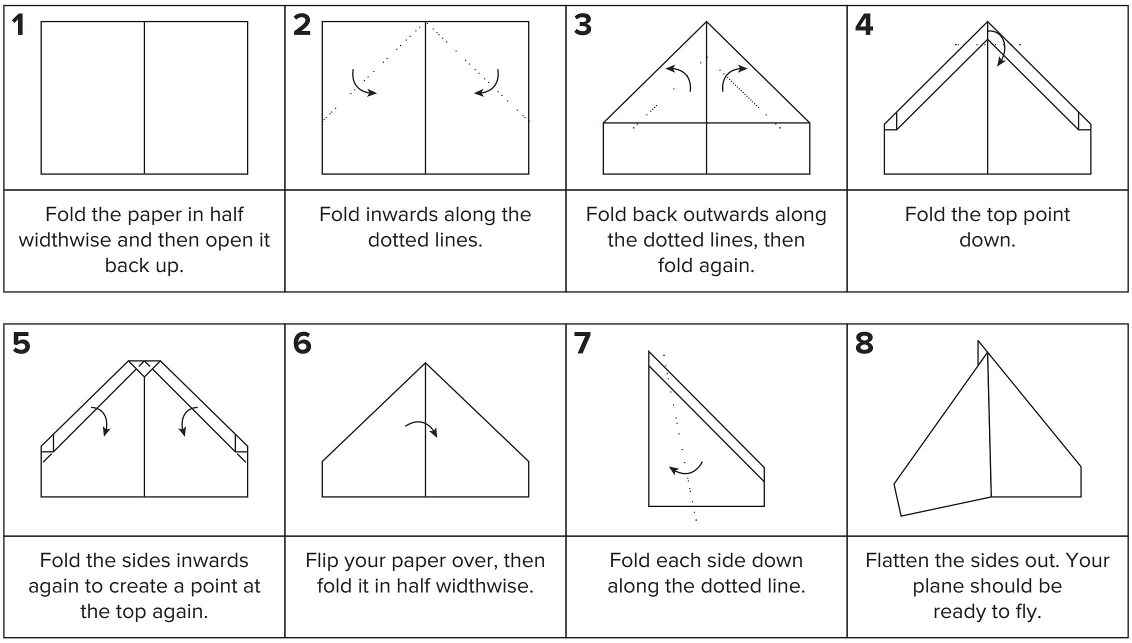


Figure 5.2: Follow the steps to make Plane B.

Then you can make the two planes.

Next, decide how to measure the flight distance. You will need to mark a throwing line and use a tape measure to measure from that line to the plane once it lands. You will also need to find a location protected from the wind so that it doesn't affect the results.

You can now write your method. Make each step clear and concise to help you achieve your aim.

Method

1. Fold a sheet of A4 paper, into the long and narrow design (Plane A, Figure 5.1).
2. Fold a second sheet of A4 paper, into the short and wide design (Plane B, Figure 5.2).
3. In a hall or other large, sheltered space, mark a throwing line at one end with chalk or tape.
4. Throw Plane A and measure the distance it travels. Record this in your notebook.
5. Throw Plane B and measure the distance it travels. Record this in your notebook.
6. Repeat steps 4 and 5 two more times. (Make sure the same person throws the planes, and they use the same throwing technique every time.)

5.4 Risk assessment

Being safe is crucial when you perform investigations, and in the science laboratory in general. The safety part of science is not exciting – you just need to accept that it is one of the most important factors in any investigation. You must work to minimise hazards, identify materials that could be dangerous and wear safety equipment.

Safety tips

Most of these tips are common sense things you already know, but a reminder never hurts!

- Wear safety goggles to protect your eyes.
- Tie back long hair to avoid it getting caught in anything. Avoid dangling jewellery.
- Wear close-toed shoes to protect your feet.
- If you are using hazardous material, find and follow the safety information for that material.
- Take care with anything hot or heated, such as Bunsen burners, or substances and equipment heated in an investigation.
- Never run in the science lab.
- And finally, follow all instructions from your teacher.

Extension

Make your own lab safety poster highlighting a rule not already on this list. Make sure your poster says why the rule is important.

The paper plane investigation is very safe. The only precaution you need to take is ensure no one is standing where the planes are being thrown. (And try to avoid getting a paper cut when folding!)

Ethics

Another thing to consider is whether an investigation is **ethical**. This is particularly important when performing investigations involving animals or people. We must balance the need to find an answer to our question with what is best for the participants and the researchers. For example, while it may not be illegal to investigate ways to make high-school students cry, it certainly wouldn't be ethical, particularly if the students didn't know that was the aim of your investigation.

Key term

ethical	following principles to guide you in doing what is morally right

Luckily, there are no ethical concerns for the paper plane investigation.

5.5 Displaying your results

Once you have conducted your investigation, it is time to display your results. Each measurement you have taken is one point of data. You can put these points in a table, called a results table.

Results table

Table 5.1 shows the distance of each plane throw in centimetres. It is important to include the unit of measurement (centimetres) in case someone else wants to compare or **replicate** your results.

Key term

replicate	reproduce by repeating a process or procedure

Table 5.1: Results table for throw distance of paper planes

Plane design	Throw distance (cm)		
	Throw 1	Throw 2	Throw 3
Plane A (long, narrow)	269	358	333
Plane B (short, wide)	273	255	285

You should throw your paper planes multiple times to make the results more accurate. If you threw the plane once, a freak gust of wind or a trip-up when throwing might distort the data. It is better to perform the test a few times and then take an average of your results.

Graphing

Another way to display your results is as a graph. This can make your results easier to interpret, particularly if they are complex. Some people understand numbers better if they are shown visually.

The most common graphs used in science are column (bar) graphs and line graphs. A couple of examples are shown in Figures 5.3 and 5.4. Figure 5.3 shows a bar graph created using the results of our investigation. The graph is annotated to show you the important features.

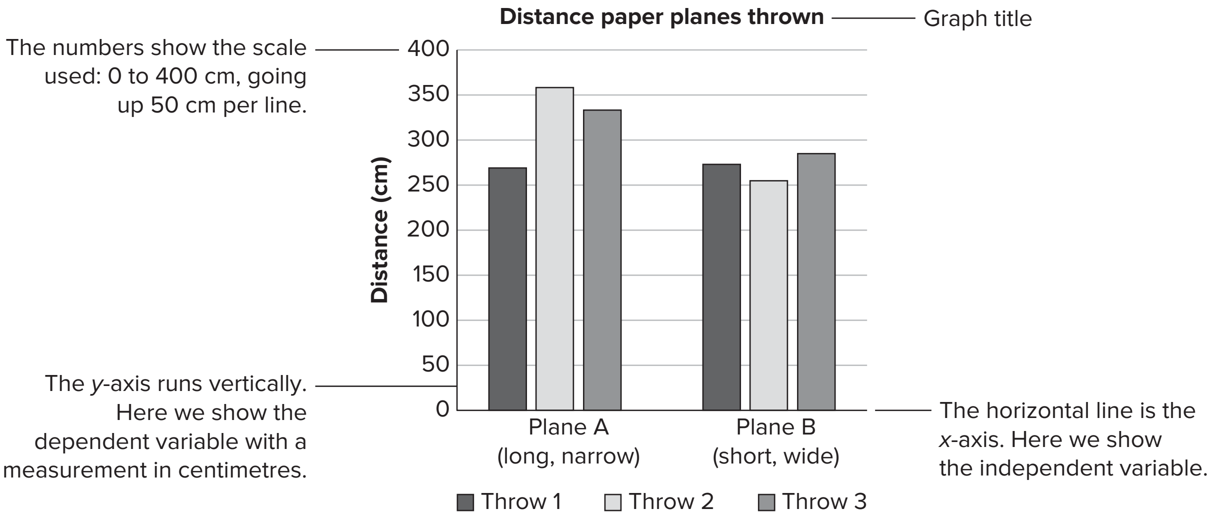


Figure 5.3: A column graph showing the results of the paper plane investigation

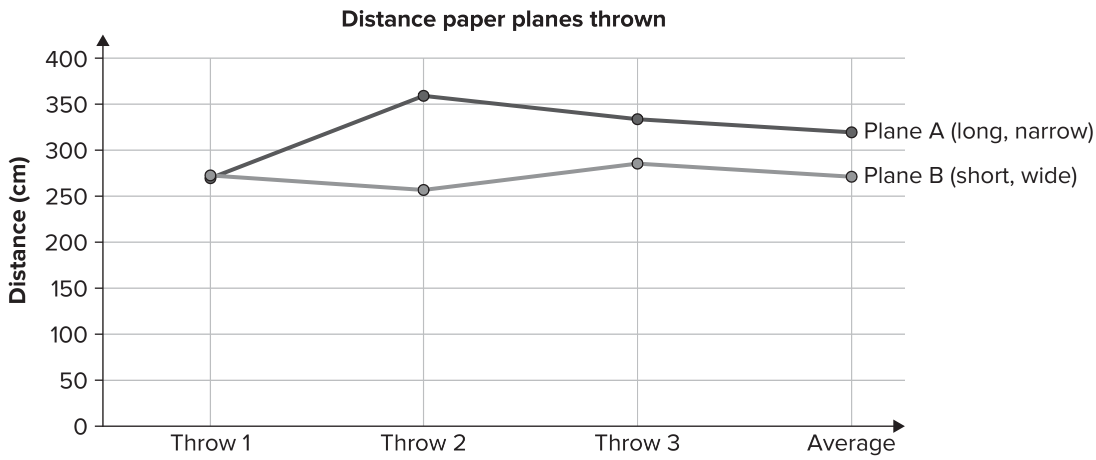


Figure 5.4: A line graph showing the results of the paper plane investigation.

Think about it

Another common type of graph is a pie chart. It is usually used to show parts of a whole. Why wouldn't a pie chart be the best way to display the results of your paper plane investigation?

Analysing your data

You can now analyse your results to find out if your hypothesis was correct. First, find the average (the mean) of the data.

Add up the three distances for Plane A and divide it by 3:

$$269 + 358 + 333 = 960$$

$$960 \div 3 = 320$$

The average distance for Plane A is 320 cm.

Add up the three distances for Plane B and divide it by 3:

$$273 + 255 + 285 = 813$$

$$813 \div 3 = 271$$

Add this information to your results table.

Table 5.2: Results table for throw distance of paper planes, including average distance

Plane design	Throw distance (cm)			
	Throw 1	Throw 2	Throw 3	Average
Plane A	269	358	333	320
Plane B	273	255	285	271

It is clear the paper plane that was long and narrow flew further than the plane that was short and wide. Your hypothesis was correct!

5.6 Reporting your findings

The final step of any investigation is to report what you have discovered. In your investigation report, this part is called the discussion. You need to summarise your findings and draw a conclusion about what you have learned. You could also discuss anything that went wrong or anything you might like to improve on.

In your report, you should state the following.

- What you know about aeroplane design generally.
- What you discovered (Which plane flew furthest?) and what that might mean. For example, you could explain what the differences in flight distance might mean. Other factors to consider are air resistance, weight distribution and the shape of the wings.
- Was your hypothesis correct? Why or why not?
- Was your investigation accurate and precise? Were your results reliable?
- What could you do to improve your experiment?

You could also look at ways to make the investigation results **accurate** and **precise**. These terms have specific meanings in an investigation.

Key facts

An investigation can be accurate, precise, neither or both!

Something is **accurate** if it is as close to the correct value as possible. For example, if you shoot three arrows and they all land around the centre circle of a target, your shots are accurate.

Something is **precise** if its measurements are very close together. For example, if you shoot three arrows and they all land next to each other on one side of the target, your shots are precise.

When measuring, you need to be careful that your equipment is working properly, and you are using it correctly. For example, if you measured the length of your paper plane flights but didn't place the tape measure exactly on the throwing line, your measurements might be precise, but they would not be accurate.

If you shoot three arrows and they land all over the target, with none in the centre circle, then you are neither accurate or precise.

You want to be both accurate and precise: you want your arrows to land close together in the centre circle.

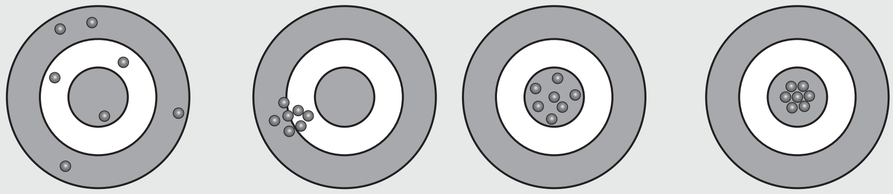


Figure 5.5: Examples of precision and accuracy

If your results are accurate and precise, and particularly if you have conducted your test multiple times, your results can be said to be **reliable**.

To make sure the paper plane investigation is reliable, you should do multiple throws of each paper plane to gather more results and ensure that you measure the distance travelled from the throwing line precisely. You could even use a laser measuring tool instead of a tape measure, if one was available, to increase the precision of your measurements.

For example, you could do six throws for each plane instead of three to collect more data, or two people could throw each plane three times, to make sure one person's throwing technique wasn't influencing the experiment.

Your discussion might look something like the following.

Discussion

Aerodynamics is the way objects move through air. The rules of aerodynamics explain how a paper plane can fly. Anything that moves through air is affected by aerodynamics.

The results show that Plane A, the long and narrow design, flew the furthest on average. This supports my hypothesis that a longer and narrower design would perform best. It is more aerodynamic. Plane B, the wide and short design, had a shorter average flight distance, which was probably due to the increased **air resistance** caused by its wider shape.

One factor that could have influenced the results is variations in the throwing technique. Repeating the experiment with two people throwing each plane three times might help by providing more data and varying how the planes are thrown.

Key terms

aerodynamics	the study of air and how it moves, and the interaction between the air and objects moving through it
air resistance	a force that slows down objects as they move through the air

Conclusion

Write a conclusion to sum up your investigation and results. For example:

'In conclusion, the design of a paper plane significantly affects its flight distance. The long and narrow Plane A flew furthest, demonstrating the importance of aerodynamics in paper plane design. This experiment highlights how small changes in design can lead to big differences in performance.'

Tell the world

Although discovery is the most vital element of science, communication comes a very close second. It is important to share your discoveries so people can learn from and build on your work. Scientists use information reports and scientific posters to clearly communicate their investigations and results. Figure 5.6 shows an example of a scientific poster. Note the use of clear headings, diagrams and tables, and short, snappy text.

Scientific research poster

Authors: Adbi, Miranda and Tran

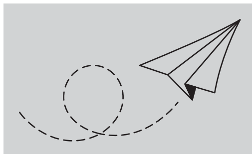
(Say who you are)

Introduction

A poster is a popular way to present research findings visually. Posters are commonly used at science conferences. Start by introducing the subject of your research, the questions you were asking, your aim and your hypothesis.

Materials

List the equipment you used. You can include one or two pictures.



Method

Outline your procedure to let people know how you did your study. It helps to list each step in a list.

- Step 1:
- Step 2:
- Step 3: and so on

Include diagrams, pictures or photos to make your poster more engaging. For example, include an image of the thrower about to toss a plane.

Results

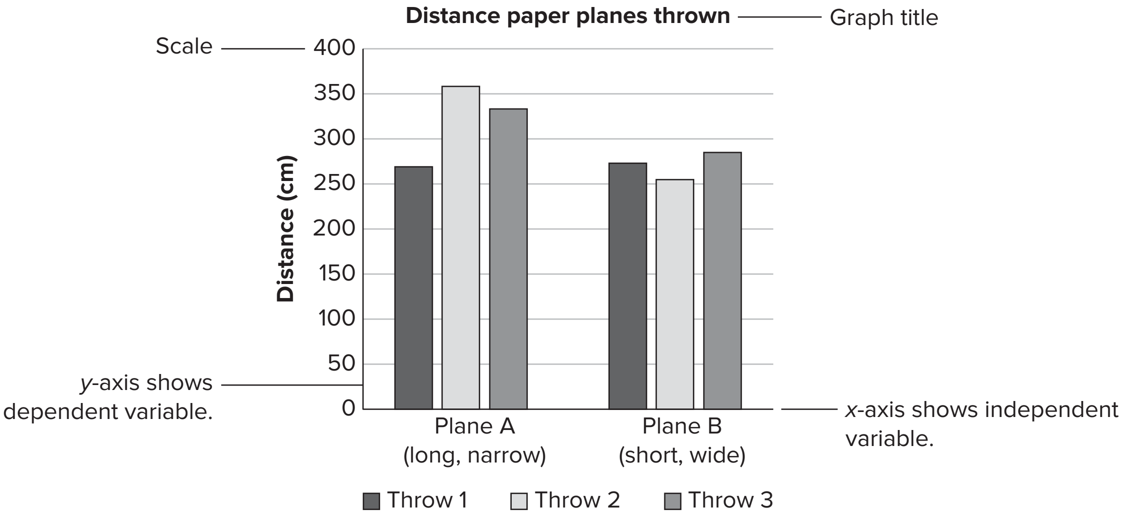
Here you can show your results table, or just the final averages.

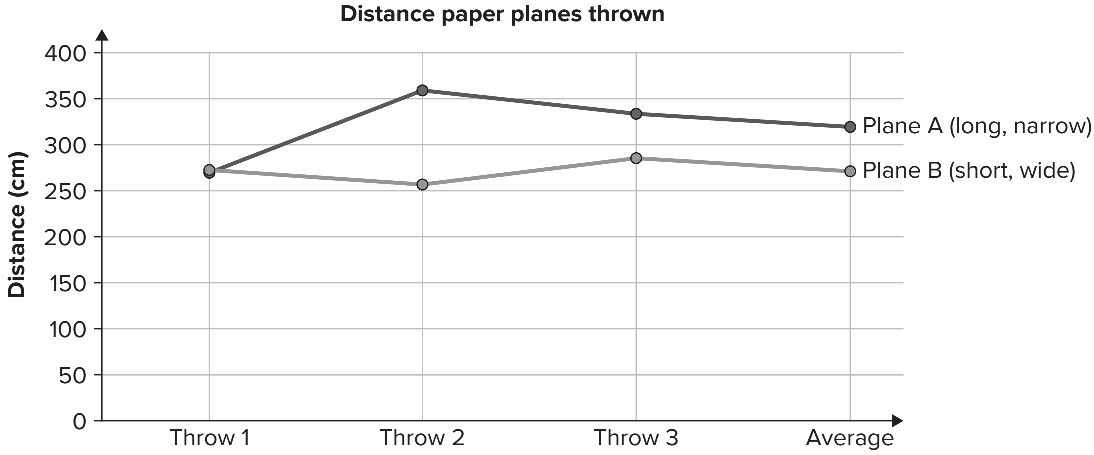
Results table for throw distance of paper planes, including average distance

Plane design	Throw distance (cm)			
	Throw 1	Throw 2	Throw 3	Average
Plane A	269	358	333	320
Plane B	273	255	285	271

Discussion

Expand on your findings by discussing how you analysed your data. Keep it simple and direct. Use bullets for emphasis. Include key graphs, tables, illustrations and other images that support the study and show a visual analysis of the data. Make sure they are large enough to be seen from a distance but don't clutter the poster.





Conclusion

Summarise your study and let the readers know the key findings.

Figure 5.6: A sample scientific poster

More often, you will put your findings in a scientific report. It will be similar to a poster, but you can write more in depth. Remember to include clear headings to guide the reader, label all your tables and graphs, and write clearly and concisely.

Chapter 6 – Study and test preparation

6.1 Studying science in Year 7

Ways to learn

Learning by doing

A lot of us need to get our hands dirty to really understand something. And while it's not always practical to run investigations for every concept, see how much you can apply science to real life to learn through experience. For example, you could look into the paper plane investigation and ask more questions.

- What forces affect the flight of a paper plane?
- What other designs might fly further?
- How do things that fly, such as birds, insects and helicopters, use aerodynamics in different ways?

Other ways to learn by doing include creating diagrams and pictures. Draw diagrams of processes like photosynthesis or the water cycle, or create mind maps of particular concepts.

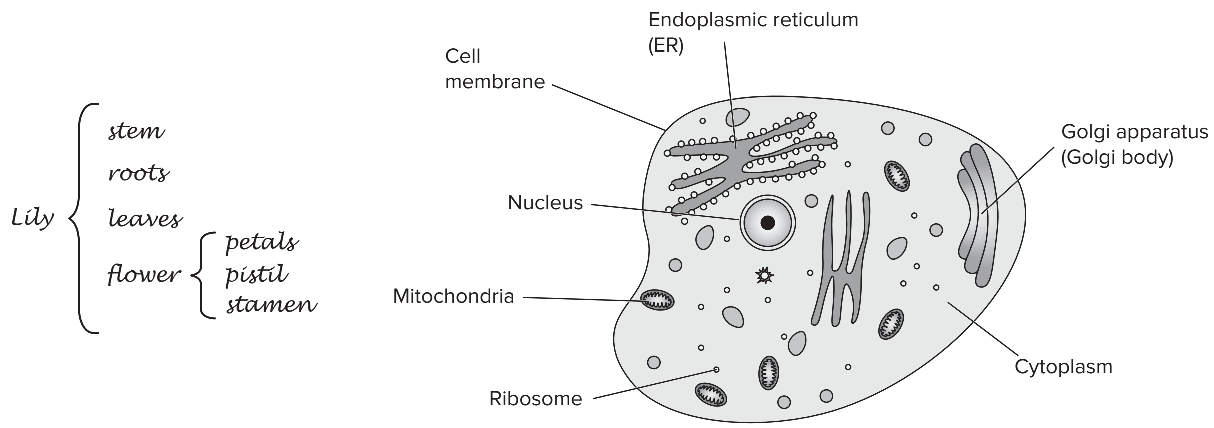


Figure 6.1: Creating diagrams and mind maps are great ways to learn by doing. They can be as simple or complex as you like.

Remember, it is okay to make mistakes and sometimes it is the best way to learn. Keep trying new things.

Social learning

Talking over a concept can help fix it in your mind. Of course, if you don't understand something, ask your teacher. But sometimes they might not explain something in a way you understand. Other social ways to learn about a new concept are:

- form a study group with some friends
- watch an online video explaining the concept (e.g. Khan Academy) and post follow-up questions in an online community
- talk to an older student or sibling; often someone close to your own age can explain something in a way you'll understand.

The other part of social learning is that you can really reinforce your understanding by teaching others. This helps you learn to explain concepts clearly and think about them in different ways.

Focused learning

Sometimes you need to really focus on your studies. Focused learning involves setting a particular goal, such as learning all the parts of a cell, and then reading deeply, asking questions and testing yourself until you feel confident in your knowledge. People often use the 'Pomodoro technique', which involves studying solidly for 25 minutes and then taking a break for 5 minutes.

> **Fun fact**
>
> 'Pomodoro' means tomato in Italian! The technique was named after a timer that looked like a tomato.

Sometimes it can be hard to get started but try to study for a few minutes and see how you go. Often, once you start you can keep going.

Learning by rote

Rote learning refers to memorising basic facts. Often, people learn by rote by repeating things and testing themselves. Although deeper, focused learning is often preferable, rote learning has a place. For example, it is good to understand how different multiplication techniques can be applied, but it is also useful to memorise that $7 \times 9 = 63$ and not have to work it out every time.

> **Key fact**
>
> Setting a study schedule will pay off in the future – not just with the knowledge you gain, but with the habits you are creating.
>
> Set aside regular time for science study each week and break your study sessions into manageable chunks, ideally 25 minutes or so, but even 10 minutes going over your notes in the afternoon will help.

Apply science to your life

Ultimately, science is about understanding the world around us. Look for ways you can connect what you are studying with your own life.

For example:

- Chemistry: baking a cake or making a sauce involves mixing substances and applying heat.
- Biology: get out into the garden and study your own ecosystem.
- Physics: think about travel. How do you stay up on a bike? How does a plane stay in the sky?
- Geology (Earth science): think about your local area. What are the rocks in your area made of? Has the land in your area been affected by erosion?

This helps make science more engaging and easier to understand.

6.2 Preparing for a test

Your teacher has announced a test on what you have just covered in class. What is the best way to prepare for it?

- Do example questions or a practice test – see how you go at the start and then test yourself again after you have worked to memorise the material.
- Summarise your class notes. In particular, note any tricky words or formulas you might need to remember.
- From memory, draw a diagram about the scientific concept you need to know. Then go back and study the parts you couldn't remember.
- Get together with a friend to quiz each other, explain concepts and motivate yourselves.
- Use **mnemonics**. For example, if you need to learn Kingdom, Phylum, Class, Order, Family, Genus, Species, one mnemonic is: **K**ing **P**hilip **c**an **o**nly **f**ind **g**reen **s**ocks.

Key term

mnemonic	a short saying to help you remember something. The first 'm' is silent – it's pronounced 'neh-MON-ic'. A common one helps us remember the order of the compass points north, east, south and west: Never Eat Soggy Weetbix.

The night before

- Eat a nutritious meal and drink enough water – a healthy body will help your brain function.
- Try to get enough sleep. Go to bed on time.
- If you can't sleep, do some box breathing to relax. Or try to think about the most boring things you can. Rate boring things from 10 to 1!

Box breathing

This is a tried-and-true method to help your body and mind de-stress.

- Inhale through your nose for four counts, expanding your ribs to take a full breath.
- Hold for four counts.
- Exhale gently through your mouth for four counts, emptying your lungs.
- Hold with empty lungs for four counts, then repeat the steps till you feel more calm.

During the test

- Don't worry about being nervous. It is natural. If your mind goes blank, take a deep breath and remind yourself that you have studied the material.
- Read the question carefully. Circle key words to ensure you understand what is being asked. Watch out for negatives such as 'not' that require you to give an opposite answer.
- If you don't know the answer to a question, skip it and come back later if you have time. Don't waste time getting bogged down.
- If you only know part of the answer, write that down to show your teacher what you do know. You will still get some marks.
- If you get the time, go back and review your answers. Check that your answers match what the key words of the question have asked you to do.

If you don't get the marks you were hoping for, try not to become discouraged. Focus on **what you are learning** about the topic rather than on how much you know. For example, you could ask yourself, 'What did I understand about aerodynamics before my paper plane investigation? What did I learn by conducting the investigation?' rather than 'Who got the highest mark in the aerodynamics and forces test?'

Remember, science is about discovery. As long as you stay curious, you can be a scientist!

Answers

Chapter 1 Biology

Activity 1.2.1

Answers will vary.

Activity 1.3.1

Answers will vary.

Activity 1.4.1

Object	Living	Non-living
e.g. torch		✓
Tree	✓	
Rock		✓
Butterfly	✓	

Activity 1.4.2

Answers will vary.

Activities 1.7.1–1.7.4

Answers will vary.

Activity 1.8.1

Answers will vary.

Revision questions

1. B
2. D
3. B
4. C
5. B
6. Latin is a universal language in science. This ensures that scientific names are understood worldwide, regardless of local languages.
7. Firestick farming clears dead vegetation, promotes new plant growth and reduces the risk of destructive wildfires, maintaining healthy and biodiverse ecosystems.
8. A dichotomous key is a tool that uses a series of yes or no questions to identify organisms based on their characteristics. It helps classify organisms by narrowing down their traits step by step.
9. Animal 1: Bird; Animal 2: Amphibian; Animal 3: Fish

10. Sun → tree (producer) → caterpillar (primary consumer) → bird (secondary consumer)

11. For example:

Habitat destruction, such as deforestation, removes food and shelter for species. For example, if eucalyptus forests are cleared, koalas lose their primary food source, leading to population declines. This affects predators such as dingoes, disrupting the entire food web.

12. Food webs should include the following elements (drawn or written):

Grass is eaten by grasshoppers and kangaroos.

Grasshoppers are eaten by lizards and snakes.

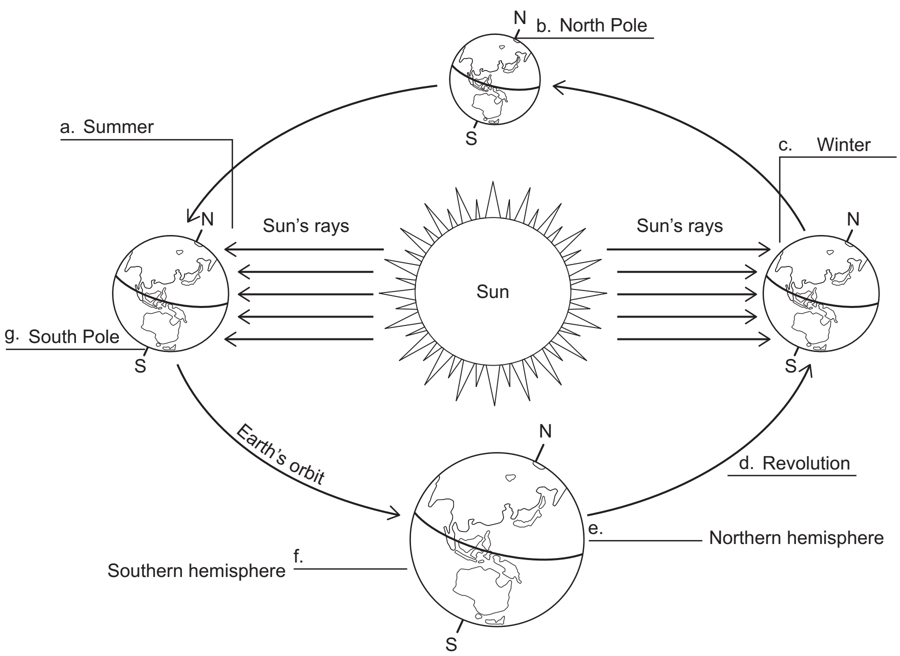
Kangaroos are prey for eagles.

Snakes are also eaten by eagles.

13. Cane toads poison native predators such as snakes and birds, causing their populations to decline. This disruption allows prey species, such as rodents and insects, to overpopulate, further upsetting the balance of the ecosystem.

Chapter 2 Earth and space

Activity 2.3.2



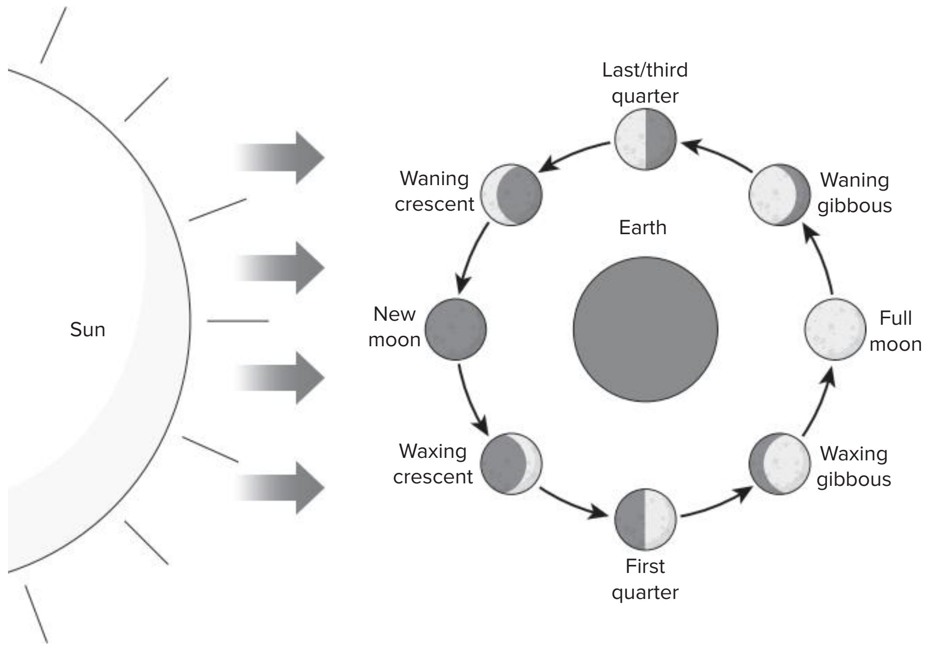
Activities 2.4.1

Answers will vary.

Activities 2.6.1

Answers will vary.

Revision questions

1. B
2. A
3. D
4. B
5. In December, the southern hemisphere is tilted towards the Sun and receives more direct sunlight. This causes longer days and warmer temperatures, resulting in summer.
6. 

7. The gravitational pull of the Moon and the gravitational pull of the Sun.
8. A solar eclipse occurs when the Moon passes between Earth and the Sun, blocking sunlight from reaching Earth. A lunar eclipse happens when Earth passes between the Sun and the Moon, blocking sunlight from reaching the Moon.
9. For example, First Nations peoples use the lunar cycle to guide fishing, hunting and seasonal planning.
10. Spring tides occur when the Sun, the Moon and Earth align, and their gravitational forces combine to create higher tides. Neap tides occur when the Sun, Earth and the Moon form a right angle, partially cancelling out their gravitational effects.
11. **a.** In Canada, it is summer because the northern hemisphere is tilted towards the Sun, receiving more direct sunlight.

    b. In Australia, it is winter because the southern hemisphere is tilted away from the Sun.
12. The next phase is the first quarter, where half of the Moon's lit side is visible. After that is the waxing gibbous, where more than half of the lit side is visible but not yet full.
13. Indigenous knowledge can guide scientists in understanding natural patterns, such as when certain fish are most abundant or breeding, helping create sustainable fishing practices and protecting ecosystems.
14. The diagram should show Earth between the Sun and Moon. The Moon appears reddish because Earth's atmosphere bends sunlight, scattering shorter wavelengths and allowing red light to reach the Moon.

Chapter 3 Physics

Activity 3.2.1

1. The source of a contact force touches the object it acts on (e.g. a shot-put thrower holds the shot-put before launching it), whereas a non-contact force acts on an object without touching the object (e.g. the Moon exerts gravity on Earth but does not touch Earth).
2. a. If a piece of iron is placed in a can and the magnet touches it, that is a contact force. If you keep the magnet at a distance and move it before the can reaches it, that is a non-contact force.
   b. Blowing on a can is a contact force. Even though you cannot see the air particles, the can is moving because of the collisions with the air particles.
3. Objects falling due to gravity, electrostatic attraction of hair towards a charged balloon

What forces can do

1. When the Blu Tack hits the floor, its shape changes. It does not bounce because its energy is absorbed as its shape changes.
2. The ping-pong ball does not change shape like the Blu Tack, so it bounces from the surface.
3. The block comes to rest fairly quickly.
4. The force causes a spinning motion. It can spin for a long time.
5. The band becomes narrower as it stretches. The colour of the elastic changes.

Activity 3.3.1

1. A force is a push, pull or twist. It can change the motion of an object.
2. Gravity, electrostatic force, magnetism
3. a. Buoyancy
   b. Magnetism
   c. Friction
   d. Gravity
   e. Electrostatic
4. A stronger southerly force is present (e.g. a fast-flowing current).
5. a. Gravity acts down, lift from the wings acts up, thrust acts in the left (forwards) direction and air resistance (drag) opposes thrust.
   b. No, the plane is accelerating because the forward force is greater than the drag.
   c. Yes – the two vertical forces are equal and opposite.
6. Examples are putting items in your school bag, pushing bread down in a toaster, using a spoon and walking.
7. Gravity down, reaction force up, pull of the rope right, water resistance (drag) to left
8. a. B
   b. A and F
   c. E and C

Activity 3.5.1

1. **a.** Gravity and the elastic force of the spring in the balance
   b. Yes
   c. Gravity acts on the fruit sitting on the balance to push the fruit down. The elastic force of the spring resists the force of gravity. The heavier the fruit, the more the spring is deflected.
2. Elastic bands vary in their thickness and elasticity. They will all stretch at different rates.
3. **a.** Friction
   b. The surface of the tub rubs on the surface of the bench. This opposes the motion and generates heat.
4. **a.** Low friction, to enjoy the slide
   b. High friction, so you don't slip over
   c. High friction, to brake and corner
   d. High friction, or your hand will slip
   e. Low friction, for fast skating

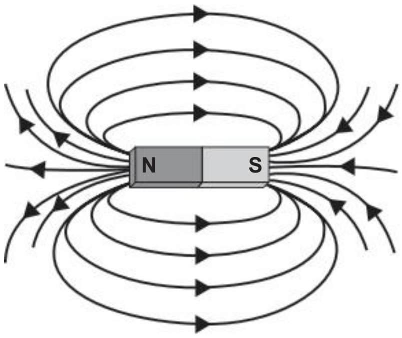
Activity 3.7.1

1. **a.** Repel (arrows pointing away from each other)
   b. Attract (arrows pointing towards each other)
   c. Attract (arrows pointing towards each other)
   d. Repel (arrows pointing away from each other)
   e. Attract (arrows pointing towards each other)
2. Like poles repel, unlike poles attract.

Activity 3.7.2

1. Nail, fridge door
2. Aim it at both poles of another magnet. If a repelling force is exhibited, the item is a magnet.
3. Fridge door, bank card, computer hard disk, maglev train
4. Two
5. **a.** Top and bottom
   b. End of each arm
   c. Both ends
   d. Contains many aligned small magnets
6. It can easily demagnetise bank cards or train travel cards.

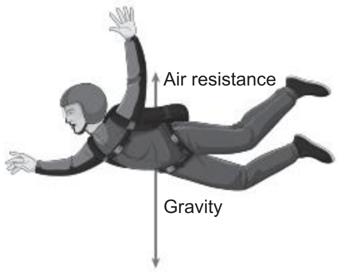
7.



8. **a.** Repulsion
   b. Attraction
9. You could hang the magnet horizontally on a piece of string. It will align itself north–south. You would then need to use the position of the Sun to judge which direction was north and which was south. (In the southern hemisphere, the Sun is in the northern part of the sky.) Then, if you face north, east is in the direction to your right.
10. For example – check the iron level of your cereal if it claims to be high in iron!

Revision questions

1. **a.** 10 N to the right
   b. 15 N to the right
2. **a.**



   b.

c.

3. a. The Moon is held in orbit by the force of gravity between the Moon and Earth. The Moon's orbit is roughly circular.

   b. 10 kg (one-sixth of your weight on Earth)

   c. They reach the ground at the same time because there is no air on the Moon to cause air resistance.

4.

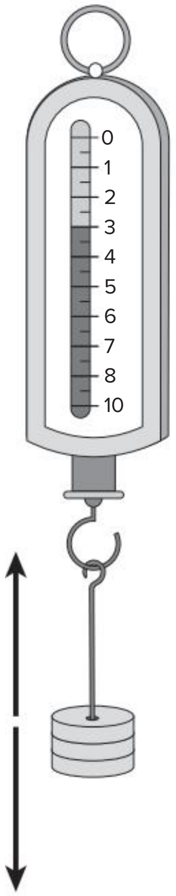
Force	Contact/non-contact	Example
Buoyancy	Contact	Boat floating
Magnetism	Non-contact	Fridge door held shut
Gravity	Non-contact	The planets around the Sun
Electrostatic	Non-contact	Sliding on plastic playground equipment

5. a. They will hit the ground close to the same time unless the building is very high.

   b. They will hit the ground close to the same time.

   c. The pencil will hit the ground first because of higher air resistance.

6. a.



b. Yes

c. 7

d. Yes

7. a. Attract

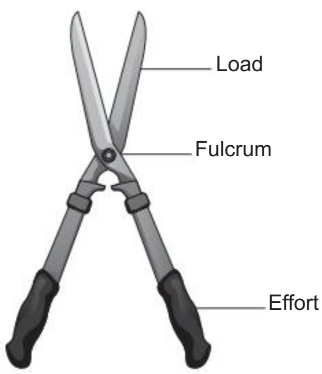
b. No – coins are not magnetic and are unlikely to contain iron.

8. a. The heavier the block, the more the surfaces push together, and therefore more friction.

b. The opposite direction to motion

c. Polish the surface or lubricate it.

9. a.



b. Mechanical advantage refers to how much a force is increased by using the garden shears. It is the ratio between the effort you put in and the load your effort produces.

Chapter 4 Chemistry

Activity 4.3.1

1. Melting points of substances vary significantly. For example, the melting points of tungsten and oxygen differ by more than 3500°C.
2. **a.** Butter is a solid, so it is easier to handle. You can cut it to weigh it and add it to other ingredients easily.

   b. Oil can be stored at room temperature and does not need to be refrigerated. You can add it to other ingredients without needing to heat it to a liquid first.
3. **a.** The particles in lead are vibrating, as particles in solids do. They do not change position, but they do vibrate.

   b. At room temperature (e.g. 20°C), the lead particles are vibrating but are not moving around. On heating to 80°C, the particles are vibrating more but are still not free to move around.

   c. Tungsten has a higher melting point than lead because the bonding between tungsten particles is stronger than the bonding between lead particles.

   d. When lead melts, the particles start to move around each other. They are still attracted to each other but they are not held in a fixed position.

Activity 4.3.2

Answers will vary.

Activity 4.4.1

1. **a.** We know it takes energy to convert water from a liquid to a gas because we can only make this happen if we add heat energy to the process; for example, boiling water in a kettle, hanging wet clothes outside to dry in the Sun and using a clothes dryer.

   b. The energy of particles overcomes the attractive forces at the boiling point.
2. **a.** Liquid to gas

   b. Liquid to solid

   c. Gas to liquid

   d. Liquid to solid

Activity 4.4.2

1. **a.** A sample of ice is being heated. When the temperature increases to 0°C, the ice melts to a liquid.

   b. The temperature of the liquid is increasing until it reaches the boiling point.

   c. The liquid is turning into a gas.
2. **a.** Time A: The temperature of the ice increases from about –10°C until it reaches its melting point at 0°C.

   b. Time B: The temperature of the water is increasing and has reached 40°C.

   c. Time C: the liquid water is changing to a gas.

3. The boiling point is 100°C.
4. Once it goes beyond 98°C, the water turns to a gas as it hits boiling point. So the temperature stops increasing until the water has boiled away.

Activity 4.4.3

1. Melting
2. In diagram B it is a liquid – the particles move freely but stay close together. In diagram A it is a solid – the particles are vibrating in a fixed position. (The wax is a solid, but after heating it becomes a liquid in which the particles can move.)
3. Solidification/freezing
4. **a.** 24.5 – 4.5 = 20 g

   b. 20 + 15 + 2 = 37 g. The mass of the solid does not change when it becomes a liquid – the same particles are still there.

   c. 22 g – The mass does not change when the wax changes from solid to liquid to solid.

   d. No, because the same particles are there the whole time.

   e. Yes
5. The mass does change when the candle burns because the wax reacts with oxygen in the air to form new substances.
6. Melting is a change from fixed particles to moving particles. Burning is a chemical reaction in which the particles in wax react with air to form carbon dioxide and water. Some of the particles in the candle leave the candle and form gases in the air.
7. The candle will burn well at first but then gradually go out. The reason is that the oxygen in the beaker needs to react with the wax for burning. Once the oxygen is used up, the candle will go out.

Activity 4.5.1

1. Diffusion is the movement of particles from an area of high concentration to an area of lower concentration. It is the spread of particles from one substance through another.
2. **a.** No, the movement of the vanilla scent is slow but random. The scent will arrive at different students at different times.

   b. The particles of a gas move rapidly in straight lines, colliding with other particles. The result is they move randomly throughout the room.

Activity 4.6.1

1. **a.** Metals: dense, strong, heavy, conduct electricity, ductile

   b. Glass: hard, brittle, transparent, high melting point, non-conductor
2. **a.** Melting point is the temperature at which a substance changes from a solid to a liquid, whereas flammability refers to how easily a substance burns.

   b. Hardness is a measure of a material's resistance to scratching, whereas strength is a measure of how much stress a substance can withstand before it bends or breaks. For example, glass is hard but not necessarily strong.

   c. Electrical conductivity refers to the conduction of electricity, whereas thermal conductivity refers to the conduction of heat.

3. a. Transparent, tough
   b. Heat resistant, low toxicity
   c. Transparent, tough
4. a. Plastic will melt or burn too easily. Iron is better but be careful of it conducting the heat to your hand.
   b. Nylon will be much stronger and it will not biodegrade as easily.
   c. Copper will conduct electricity, whereas string will not.
5.

Which item(s) can you see through?	Test tube
Which item do you think is the densest?	Nail
Which item will melt first in a hot pan?	Plastic comb
Which item(s) are magnetic?	Nail
Which item(s) conduct electricity?	Nail
Which item(s) can dissolve in water?	Salt

Activity 4.6.2

1. The lead cube will be much heavier even though the volume is the same.
2. Density is the amount of matter in a given volume. The formula for density is:

   $$\text{Density} = \frac{\text{mass}}{\text{volume}}$$
3. Density refers to more than mass; it is the mass in a given volume.
4. Measure the side length of each cube and use this to calculate the volume ($V = l^3$). Then weigh the blocks to find their mass and use the formula $d = \frac{m}{V}$.
5. The particles in foam are lighter than the particles in lead but they are also further apart. This makes the density of foam less than the density of lead.
6. a. High-density materials tend to be strong, making them useful for building materials, for example.
   b. Low-density materials are useful for making aeroplanes and cars to improve fuel efficiency, for example. They are also useful for objects that need to float.

Activity 4.6.3

Item	Density (g/cm^3)	Mass (g)	Volume (cm^3)
Nail	5.3	20	3.8
Water	0.98	0.85	0.87
Gold	15.5	118	7.6
Oil	0.88	28.4	32.3
Plastic	0.76	0.052	0.068

Activity 4.6.4 – extension

1. $d = \frac{m}{V} = \frac{2.8}{3} = 0.93\ g/cm^3$
2. Instead of adding one nail, add 10. The volume change will be easier to measure. Divide the volume change by 10.

Activity 4.7.1

Substance	Pure or mixture?	Comments
Pond water	Mixture	Water, dirt, insects; it varies with different ponds
Sugar	Pure	
Orange juice	Mixture	Seeds, pulp, vitamins, water
Iron nail	Pure	
Salad dressing	Mixture	Oil, water, vinegar

Activity 4.8.1

1. Soft drink, vinegar, disinfectant
2. a. How much solute is dissolved in a given volume. The more that is dissolved, the higher the concentration.
   b. Pure vinegar (undiluted acetic acid) would be dangerous on food, medications might be dangerous if too concentrated.
3. a. Solvent, alcohol; solute, ink; solution, the marker fluid
   b. Solvent, water; solute, ground coffee or instant coffee; solution, final coffee
4. a. The salt clumps will break down to individual particles as the salt dissolves. The chalk stays as a clump because it is insoluble.
   b. Soluble – sugar, fructose, soluble aspirin, jelly crystals, salt, fertiliser. Insoluble – chalk, rocks, shells, bones, wood.

Activity 4.9.1

Answers appear in Chapter 4 text.

Activity 4.10.1

Answers will vary.

Revision questions

1. **a.** Freezing or solidification
   b. Diffusion
   c. Sieving or filtration
   d. Condensation
   e. Compression
   f. Distillation
   g. Dissolving
   h. Winnowing
2. **a.** Measuring cylinder
   b. Beaker
   c. Gauze mat
   d. Evaporating basin
3. Gas diffusion is the movement of one gas through another gas. The random motion of the particles of onion vapour gradually allows them to spread through the air – alerting people in the carpark to the barbecue.
4. Solute, solvent, solution
5. 57°C
6. **a.** Homogeneous: any solution (e.g. salt water, ink)
   b. Heterogeneous: sand, gravel, mixed lollies
7. **a.** The particles in steam are moving faster than in water. They are not interacting with each other in steam. They can move all through the container.
   b. As the water gets hotter, the energy of the particles increases. The particles gain enough energy to break free from each other and travel all through the room.
   c. The forces of attraction do not change but the energy of the particles has increased enough for the particles to break free of each other.
8. Particles in a solid do not change position, but they can vibrate.
9. **a.** The orange intensity drops – the juice does not look as concentrated.
   b. The taste is not as acidic or as intense.
10. **a.** Solute, tablet; solvent, water; solution, antacid in water.
    b. Antacid is soluble in water but chalk is not. The antacid particles cannot be seen once the tablet dissolves. The chalk solution remains a cloudy white as the chalk particles are spread through it.

11. $V = l^3 = 5^3 = 125 \text{ cm}^3$

$$d = \frac{m}{V}$$

$$= \frac{468}{125}$$

$$= 3.74 \text{ g/cm}^3$$

12. A magnet could be used to draw the nails from the mixture. The remaining mixture could be stirred into water. The sugar would dissolve but the sand would not. The sand could be removed by filtering. The water could then be evaporated away to get the sugar back.

13. a. The particles in steam act like any gas, moving rapidly all through the container.

b. As a liquid, the particles are still moving but are still held close together by attractive forces. As a solid, the particles are vibrating and held in a fixed position. Drawings should reflect this.

c. Condensation, freezing/solidification

14. a. The different dyes have different solubilities in water. The more soluble dyes move further up the paper.

b. Orange is a mix of red and yellow dyes. Green is a mix of blue and yellow dyes. The same yellow dye is used in both lollies.