



7

PEARSON Science

STUDENT BOOK | VICTORIA

SERIES CONSULTANT AND LEAD AUTHOR
GEOFF QUINTON

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Pearson

Year

7

Pearson **Science** STUDENT BOOK VICTORIAN CURRICULUM



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We respect the living cultures of Aboriginal and Torres Strait Islander peoples and their ongoing connection to Country across lands, sky, seas, waterways and communities.

We celebrate the richness of Indigenous Knowledge systems, shared with us and with schools Australia-wide.

We pay our respects to Elders, past and present.

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PEARSON SCIENCE 7

Victorian Curriculum

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Table of contents

How to use Pearson Science Victoria	vi
-------------------------------------	----

Science inquiry toolkit ■	ix
----------------------------------	----

Topic 1: Forces and simple machines ■

Prior knowledge	2
1.1 Practical investigation: Forces in action	3
1.2 Representing forces	7
1.3 Practical investigation: Measuring forces	14
1.4 Practical investigation: Investigating air resistance and gravity	17
1.5 Friction	20
1.6 Practical investigation: Friction and mass	25
1.7 Inquiry activity: Investigating friction	28
1.8 Balanced and unbalanced forces	32
1.9 Simple machines: Levers as force multipliers	39
1.10 Practical investigation: Investigating force and distance	43
1.11 Inquiry activity: Action and uses of pulleys	46
1.12 Simple machines used by First Nations Australians	49
1.13 Action of inclined planes, wedges, wheels, gears and screws	52
1.14 Practical investigation: Using ramps	59
1.15 Practical investigation: Investigating simple machines on a bicycle	61
Topic review	64

Topic 2: Systems in space: The Earth, Sun and Moon ■

Prior knowledge	67
2.1 The Earth, Sun and Moon system	68
2.2 Causes of seasons	69
2.3 Practical investigation: Investigating the changing angle of the Sun	74
2.4 Seasonal calendars	83
2.5 Tides	86
2.6 Effects of tides	92
2.7 Phases of the Moon	97
2.8 Practical investigation: Modelling the phases of the Moon	106
	111

2.9 Lunar eclipses	113
2.10 Inquiry activity: Cultural influence on knowledge about lunar eclipses	120
2.11 Solar eclipses	122
Topic review	127

Topic 3: Particle theory and properties of substances ■

Prior knowledge	132
3.1 Three states of matter	133
3.2 Practical investigation: Matter and mass	137
3.3 Matter and particles	141
3.4 Practical investigation: Matter under pressure	147
3.5 Heat and particles	149
3.6 Practical investigation: How a thermometer works	154
3.7 Particles and changes of state	157
3.8 Density of solids and liquids	162
3.9 Practical investigation: Density column	167
3.10 Practical investigation: Investigating effect of heat on viscosity	169
3.11 The process of evaporation	171
3.12 Practical investigation: Rates of evaporation	174
3.13 Freezing and condensing	177
3.14 Practical investigation: Exploring condensation	182
3.15 Practical investigation: Heating curve for water	184
Topic review	187

Topic 4: Mixtures and methods of separation ■

Prior knowledge	193
4.1 Diffusion and particle theory	194
4.2 Pure substances and mixtures	195
4.3 Practical investigation: Soluble and insoluble substances	200
4.4 Practical investigation: Filtration and decantation	204
4.5 Solutions	207
4.6 Practical investigation: Investigating the rate of dissolving	210
	215

4.7	Evaporation and crystallisation	217
4.8	Practical investigation: Using evaporation and crystallisation	224
4.9	Practical investigation: Distillation	227
4.10	Practical investigation: Chromatography	230
4.11	Practical investigation: Magnetic separation	234
4.12	Separation techniques used by First Nations Australians	236
4.13	Inquiry activity: Testing separation techniques	241
4.14	Influence of cultural perspectives on scientific research	243
Topic review		247

Topic 5: Classification and biodiversity

Prior knowledge		252
5.1	Introduction to classification	253
5.2	Practical investigation: Recognising similarities and differences in objects and living things	259
5.3	Introduction to keys for identification	261
5.4	Practical investigation: Creating dichotomous keys	267
5.5	Linnaean classification system	270
5.6	Levels of classification in the animal kingdom	277
5.7	Levels of classification in the plant kingdom	285
5.8	Practical investigation: Creating and using keys for Linnaean classification	290
5.9	Fieldwork as a part of science inquiry	296
5.10	Practical investigation: Using the Linnaean classification system and a dichotomous key in fieldwork	300
5.11	First Nations Australians' classification systems	302
5.12	Inquiry activity: Changing classification systems	307
Topic review		309

Topic 6: Matter and energy in ecosystems

Prior knowledge		314
6.1	Survival needs	315
6.2	Inquiry activity: The Australian environment today	321

6.3	Inquiry activity: Scientific communication	324
6.4	Practical investigation: Organisms and habitats in the school grounds	326
6.5	Food chains	331
6.6	Biomass pyramids	336
6.7	Food webs	342
6.8	Practical investigation: Food web in an Australian ecosystem	348
6.9	Human impacts on ecosystems	350
6.10	Cultural understandings and sustainable practices	356
6.11	First Nations land management using fire	362
6.12	Practical investigation: Detergents in waterways	367
Topic review		369

Topic 7: Earth's resources

Prior knowledge		374
7.1	Renewable and non-renewable resources	375
7.2	Formation of fossil fuels	380
7.3	Fossil fuels in Australia	386
7.4	Inquiry activity: Changes to the Victorian coal industry	393
7.5	Inquiry activity: Comparing energy use in vehicles	396
7.6	Practical investigation: Modelling aspects of the water cycle	399
7.7	Desalination	403
Topic review		408
Index		xxx
Attributions		xxx

Key

-  Science inquiry skills
-  Physical sciences
-  Earth and space sciences
-  Chemical sciences
-  Biological sciences

How to use Pearson Science Victoria

Pearson Science components

Each Pearson Science 7-10 Victoria student book provides students with a complete offline version of all corresponding digital lessons in Pearson Digital Hub, while the student companions offer a convenient write-in resource. This blended solution offers teachers and students the perfect balance of online and offline learning.

The Student Book (also available as an eBook) has been provided to minimise digital distraction and screen fatigue. In addition to all the theory lessons, practical investigations and inquiry activities from Pearson Digital Hub, it includes:

- a science inquiry toolkit
- a valuable prior knowledge lesson at the start of each topic
- completely new questions (prior knowledge, check your understanding, lesson review, topic review)
- new Scifiles and Science in Society features to engage learners with real-world examples and to support differentiation
- topic summaries and end-of-topic glossaries.

Pearson Digital Hub: a one-of-a-kind digital product designed to simplify teaching and energise learning, with high-quality content created by experienced Australian educators who know how to engage students.



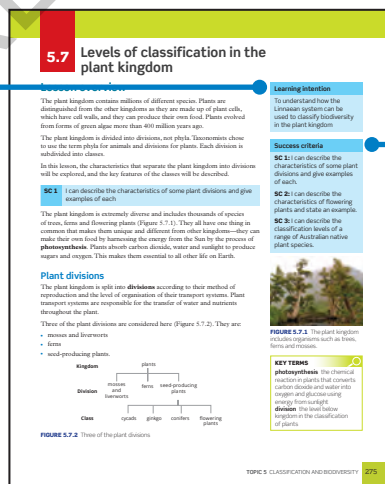
The Student Companion: a write-in workbook designed to reinforce the scaffolding of learning provided in the corresponding Pearson Digital Hub lessons. The Student Companion also supports the creation of a bound reference or portfolio of learning over the year.

Chunking with learning intentions and success criteria

The structure and relationship between each of the three components in the Pearson Science series (Pearson Digital Hub, the Student Book and the Student Companion) have been designed to manage students' cognitive load. Chunking has been used to break complex concepts and strategies into smaller, more manageable sections, defined by the success criteria.

Across the three components, the chunking of content directly supports explicit success criteria in a 'read a little, do a little' approach.

Learning intentions are learning goals or objectives aligned to the relevant curriculum. Each of the lessons in Pearson Digital Hub has been developed around a single purpose for learning. The learning intentions are communicated using student-friendly language and are mirrored in each of the corresponding lessons in the Student Book and Student Companion. They describe what learners should know, understand or be able to do by the end of the lesson.



Success criteria clarify expectations and describe what success looks like. They are used to determine how well a student has met the learning intention. The Pearson Science lesson design is based on cognitive load principles and, as such, each lesson has 1-3 success criteria. The success criteria are specific, concrete and measurable so learners can actively engage with and reflect on their evidence of learning within each lesson. The success criteria form the basis of all three components - Pearson Digital Hub, the Student Book (and eBook) and the Student Companion - to ensure they are consistent throughout the lessons and to provide the basis for feedback.

Student book features

Science inquiry toolkit

Science inquiry skills are supported by a Science inquiry toolkit at the beginning of the book, referenced throughout the text with 'Go to' icons.

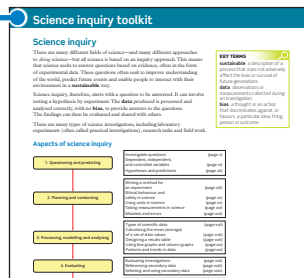


Theory lessons

Theory lessons provide content in short, accessible chunks. Questions to check learners' understanding are provided at regular intervals throughout the lesson. Each theory lesson ends with a lesson review that includes 3-6 questions.

Practical investigations

Practical investigations offer learners the chance to design and conduct experiments, record results, analyse data, and prepare evidence-based conclusions.



5.1 Introduction to classification

Lesson overview

Classification is an important concept in science. It is used to understand how you think about how you represent and store information. Just as the way a computer is used to store data in a library is organised, scientists can represent a vast range of living things in a way that is easy to understand.

Living things are grouped into categories based on their characteristics. This is done by scientists who study the characteristics of living things to group them into categories.

Classification is used to group living things into categories. It is a way of organising information about living things. It is a way of organising information about living things. It is a way of organising information about living things.

Key terms: Classification, taxonomy, hierarchy, binomial nomenclature, species, genus, family, order, class, phylum, kingdom, domain.

5.10 Using the Linnaean classification system as a dichotomous key in fieldwork

Introduction

You have been here to carry out fieldwork effectively and without carrying any heavy loads. The equipment is in the field. You have been here to carry out fieldwork effectively and without carrying any heavy loads. The equipment is in the field. You have been here to carry out fieldwork effectively and without carrying any heavy loads. The equipment is in the field.

Key terms: Dichotomous key, Linnaean classification system, fieldwork, equipment, carrying, heavy loads, field, equipment, carrying, heavy loads, field, equipment, carrying, heavy loads.

5 Classification and biodiversity

Prior knowledge

The key concepts that you will use in this topic are:

- Identify one characteristic that would identify something as 'living'.
- Grouping living things by characteristics.
- Identifying patterns and relationships.
- Using models to represent data and observations.

5.12 Changing classification systems

Introduction

Classification systems can change as scientists discover new information or change their understanding of the relationships between organisms. This is because scientists are constantly discovering new information about the relationships between organisms.

Key terms: Classification systems, scientists, discover, new information, change, understanding, relationships, organisms, constantly, discovering, new information.

5 Classification and biodiversity

Topic summary

The key concepts that you will use in this topic are:

- Identify one characteristic that would identify something as 'living'.
- Grouping living things by characteristics.
- Identifying patterns and relationships.
- Using models to represent data and observations.

Prior knowledge lessons

Each topic begins with a prior knowledge lesson linking the topic key concepts to required knowledge from previous years or topics in the Victorian Curriculum.

Inquiry activities

Inquiry activities are open-ended investigations that encourage learners to plan and design solutions to problems. Learners are encouraged to improve and evaluate their ideas, designs or investigations.

Topic reviews

Each topic finishes with a summary to consolidate key ideas from the topic, questions organised by challenge level to address every learning intention in the topic, and a topic glossary.

Additional features

Hints

5.6 Levels of classification in animal kingdom

Hint: The names of the levels of classification are: Kingdom, Phylum, Class, Order, Family, Genus, Species.

Key terms: Kingdom, Phylum, Class, Order, Family, Genus, Species.

Key terms

Key terms: Kingdom, Phylum, Class, Order, Family, Genus, Species.

Science in Society boxes

5.10 Using the Linnaean classification system as a dichotomous key in fieldwork

Science in Society box: Discuss the importance of classification in understanding biodiversity and the role of scientists in this process.

Skillbuilders

5.12 Changing classification systems

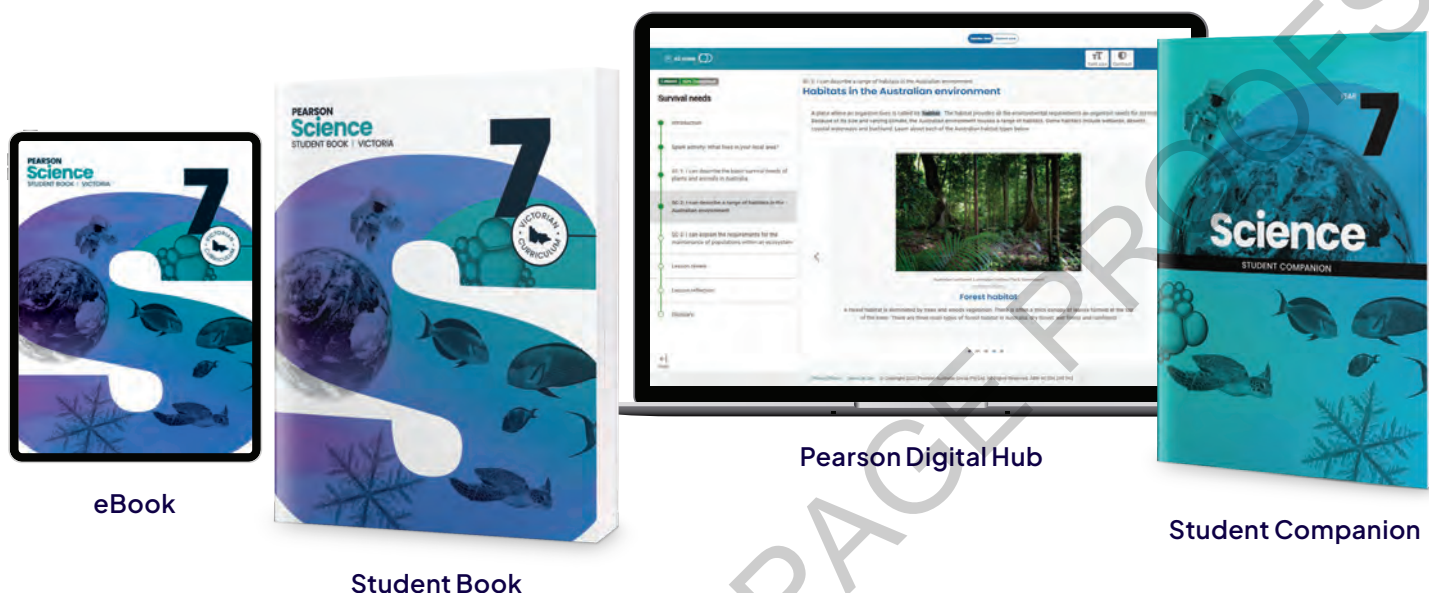
Skillbuilder: Practice using a dichotomous key to identify a plant species.

Scifiles

Worked examples

Pearson Science Victoria

For the Victorian Curriculum Science 7–10 V2.0



Your complete science solution for Years 7–10, created by education experts to support every teaching style and every learning journey.

- ✔ Offers a new, complete, course that is seamlessly connected across the print and online resources, giving you continuity and the flexibility to support different teaching methods and learning styles.
- ✔ Embeds explicit teaching strategies in every lesson to help manage cognitive load and maximise learning outcomes for a range of student abilities.
- ✔ Integrates prior knowledge questions, worked examples and questions throughout to check student understanding and progress.
- ✔ Includes 1000s of unique questions across the series to give you even more choice and flexibility, and to save you time.
- ✔ Provides content written and reviewed by expert Australian classroom educators.
- ✔ Supports each lesson with teaching notes, including differentiation support.
- ✔ Focuses on the practical aspect of science through practical investigations, inquiry activities, skillbuilders and worked examples as well as a chapter-length skills toolkit.



Science inquiry toolkit

Science inquiry

There are many different fields of science—and many different approaches to *doing* science—but all science is based on an inquiry approach. This means that science seeks to answer questions based on evidence, often in the form of experimental data. These questions often seek to improve understanding of the world, predict future events and enable people to interact with their environment in a **sustainable** way.

Science inquiry, therefore, starts with a question to be answered. It can involve testing a hypothesis by experiment. The **data** produced is processed and analysed correctly, with no **bias**, to provide answers to the questions. The findings can then be evaluated and shared with others.

There are many types of science investigations, including laboratory experiments (often called practical investigations), research tasks and field work.

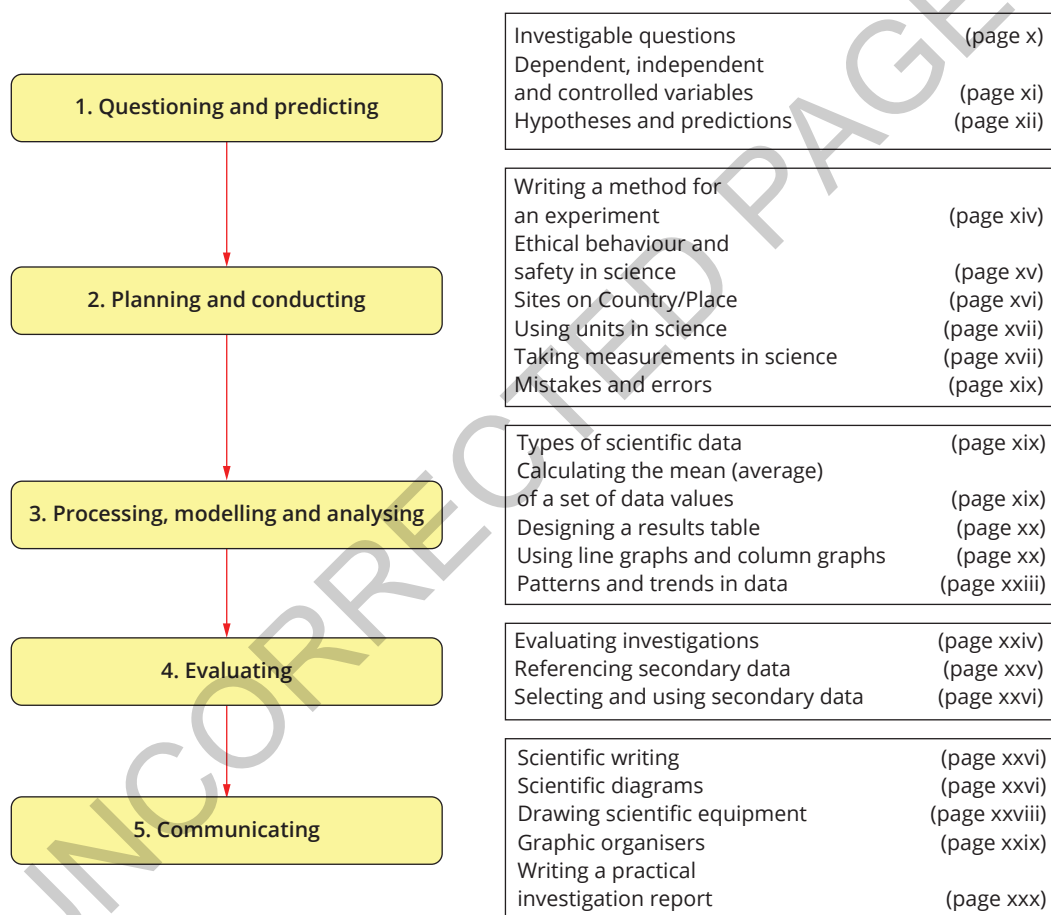
KEY TERMS

sustainable a description of a process that does not adversely affect the lives or survival of future generations

data observations or measurements collected during an investigation

bias a thought or an action that discriminates against, or favours, a particular idea, thing, person or outcome

Aspects of science inquiry



The information and activities in this Science inquiry toolkit will support your learning by describing, explaining and giving examples of science inquiry skills that you will use in Year 7. When carrying out practical investigations and inquiry activities, the knowledge and skills included in this toolkit will help you to succeed with the activities.

1 Questioning and predicting

1.1 Investigable questions

In science, a good question is one that can be answered by carrying out an investigation. This kind of question is called an investigable question. Key types of investigable questions are shown in Table 1.

TABLE 1 Types of investigable questions

Question type		Examples
Descriptive questions	These ask about facts or descriptions.	• <i>How long is the insect?</i> • <i>How many legs does the insect have?</i>
Relational questions	These compare things.	• <i>Which insect is the longest?</i> • <i>Are all the legs on the insect the same length?</i>
Cause-and-effect questions	These ask whether there is a link between two variables.	• <i>Do larger insects have more legs?</i> • <i>Does the colour of the insect depend on the environment it lives in?</i>

KEY TERMS

variable a factor or condition that can change during an experiment and can influence the experiment

investigable question a question that can be answered by conducting a science investigation

Many science investigations seek to answer cause-and-effect questions as scientists seek to find out how certain things are affected by other **variables**.

Developing an investigable question

When you create a question to be investigated, you can use this checklist to help you decide if it is a good **investigable question**.

- Is the question clear and as simple as possible? ☐
- Is finding the answer to this question going to be interesting? ☐
- Will finding the answer to this question improve understanding? ☐
- Is there a way to find the answer to this question? ☐
- Is it possible to answer this question with the materials, resources and time available? ☐

Example of creating an investigable question

Rami wanted to investigate friction (grip) between the tyres of a mountain bike and the ground. Table 2 shows the approach that he could take to develop a good question to investigate. The thinking column describes the thought processes involved. The working column describes how that thinking can be applied to the problem.

TABLE 2 The thinking and working involved in creating an investigable question

Thinking	Working
Consider the variables that may affect the problem being examined.	Friction may be affected by the temperature of the surface, the type of surface, the material of the tyre, the air pressure inside the tyre or how wet the surface is.
Choose one variable that is interesting and will increase Rami's knowledge.	Rami can consider whether the pressure of the tyre affects the amount of friction between the tyre and the ground.
Make sure that the question is clear and as simple as possible.	The question could be 'How does the pressure of the tyre affect the amount of friction between the tyre and the ground?'.
Check that you can answer the question with the resources and time available.	The investigable question can be made more specific, such as 'Which pressure provides the most friction between the tyre and the ground?'.

1.2 Dependent, independent and controlled variables

A variable is a factor that may affect the results of an experiment.

For example, Lin is investigating the growth of a plant (Figure 1) by measuring how tall the plants are after two weeks of growth. The following factors may affect the growth of the plant:

- temperature of the soil
- type of soil
- amount of water given to each plant
- amount of sunlight received by each plant
- amount of fertiliser applied
- type of fertiliser used
- size of the pot in which the plant is grown.

The **independent variable** is the variable that will be changed by the investigator. Lin chooses amount of sunlight as her independent variable and will investigate how well seedlings grow in the dark, in indirect sunlight and in direct sunlight.

Once the independent variable has been selected, the **controlled variables** are all the other variables that might affect the results. These must be kept the same. This ensures that the investigation is fair (**valid**) as it means that only changes to the independent variable will be affecting the results.

The **dependent variable** is the growth of the plant, which she chooses to measure by recording the height of the plants each day. This is called the dependent variable because the height of the plant might 'depend' on the amount of sunlight (see Table 3 for a summary).

KEY TERMS

independent variable the factor that is changed in an investigation to find out how it affects another factor

controlled variable a variable that is kept constant throughout an experiment



FIGURE 1 Many variables will affect the growth of these plants.

KEY TERMS

valid a description of an experiment where all controlled variables are kept the same and the experiment can be considered a fair test

dependent variable the variable that is being measured in an experiment; it can vary as the independent variable changes

TABLE 3 Summary of the three types of variables

Variable type		Examples from Lin's investigation
Independent variable	The variable that will be changed by the investigator	amount of sunlight received by each plant
Dependent variable	The variable that is being observed and measured in an investigation	height of plant
Controlled variables	The variables that are kept the same to ensure a fair (valid) investigation	• temperature of soil • type of soil • amount of water • size of pot

1.3 Hypotheses and predictions

Developing a hypothesis

KEY TERM

hypothesis a statement about the relationship between two variables, which can be tested experimentally

Scientists develop hypotheses to test ideas. A **hypothesis** suggests a link or relationship between an independent variable and a dependent variable. A hypothesis can be considered as a possible answer to the question that is being investigated. A hypothesis is called a 'testable hypothesis' if an investigation can be designed and carried out to see if the hypothesis is supported by results.

A hypothesis can be created by writing a sentence stating what will happen to the dependent variable when the independent variable is changed.

The following structures can be used to write a hypothesis.

<**This change**> in the <**independent variable**> will result in <**this change**> to the <**dependent variable**>.

Examples

A **small increase** in the **temperature** will result in **an increase** to the **growth** of a pea plant.

An **increase** in the **air pressure of a tyre** will result in **a decrease** to the **amount of friction on the road**.

Or:

If <**this happens to the independent variable**>, <**this will happen to the dependent variable**>.

Example

If **the temperature increases**, **the growth of the plants will increase**.

These structures will help you to create a hypothesis. The exact language used can vary, but make sure that the hypothesis does the following:

It clearly states the independent variable.

☐

It describes what change is being made to the independent variable.

☐

It clearly states the dependent variable.

☐

It describes how the dependent variable will change.

☐

It can be answered with the materials, resources and time available to me.

☐

Testing a hypothesis

- If the results from an investigation match what the hypothesis stated, then the results support the hypothesis.
- If the results from the investigation do not match what the hypothesis stated, then the results do not support the hypothesis.

Making a prediction

To help to test a hypothesis, a reasoned **prediction** can be made about what could happen. A prediction describes what is expected to be observed when the independent variable in an investigation is changed. This is usually based on prior knowledge and understanding about the world around us.

An example of a prediction for the hypothesis ‘If the temperature increases, the growth of the plants will increase’ is:

After 7 days, the average height of pea plants that are grown at a temperature of 25°C will be taller than the average height of pea plants that are grown at a temperature of 20°C.

If the prediction is found to be correct, the hypothesis is supported. If what was predicted did not happen, the hypothesis is not supported. (Note that this does not necessarily mean that the hypothesis was wrong—further experiments may be required.)

Figure 2 summarises the processes that can be used to scientifically test an idea or answer a question.

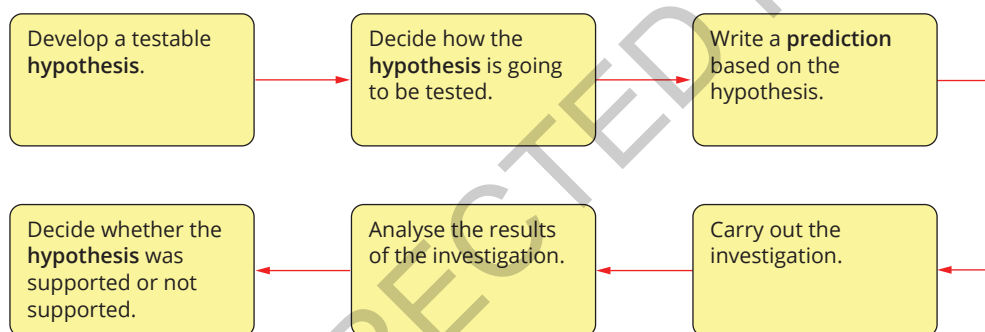


FIGURE 2 Testing a hypothesis

Hypotheses and predictions can be used to evaluate **scientific models**. Scientific models represent real-life scientific processes to help people understand and make sense of the world around them. Often you will notice something that goes on in the world (e.g. the weather). From past experience, you know that on a sunny day, it is unlikely to rain. This is something that you have learnt. To create a scientific model to show this, you could collect data from a weather station (Figure 3) and present it in a poster. People looking at the poster would be able to make predictions based on the information provided. They may predict that in summer, it is less likely to rain on a sunny day than in winter. They could conduct an investigation by sourcing more historical data to identify patterns and support their prediction from multiple weather stations around Victoria. It is important to note that scientific models and theories can change as new evidence emerges from ongoing research.

KEY TERMS

prediction a statement that suggests what will happen in an experiment, normally based on a hypothesis

scientific model a scientific representation that communicates a real-world process that aids scientific predictions and explanations.



FIGURE 3 A weather station is a useful tool for determining rainfall and solar radiation (sunlight).

2 Planning and conducting

Planning scientific investigations is an important part of science inquiry. When planning for an investigation, it is important to consider how the investigation will need to be set up so it will answer your questions and test your hypothesis. As part of this process, you need to examine the location, type of equipment used and procedures undertaken to investigate the effects of the independent variable. This also includes any important safety, ethical and cultural considerations.

2.1 Writing a method for an experiment

The method of an experiment is written as a list of numbered steps. These steps should clearly describe the process to be followed.

Your method must be reproducible. This means that other scientists should be able to use your method to repeat the experiment exactly. It is also helpful to include a diagram that shows how the experiment was set up.

Follow this checklist when writing a comprehensive and accurate method.

- | | |
|---|--------------------------|
| Consider the order in which the actions must be carried out. | ☐ |
| Write the method as a series of numbered steps. | ☐ |
| Include details of the materials, including the sizes of equipment and quantities of substances used. | ☐ |
| Include safety notes where required. | ☐ |
| Make it clear what observations and measurements are required and how they are to be recorded. | ☐ |
| Check that your materials list includes everything required in the method. | ☐ |

Example

Kylie is planning an experiment to investigate the effect of sunlight on seedling growth. Her hypothesis is that sunlight will increase the rate of growth of seedlings. Her prediction is that seedlings left in direct sunlight will grow taller in 10 days than seedlings grown in the shade. Her method is given below.

Method

1. Germinate 10 pea seeds on damp cotton wool.
2. Choose six of the germinated seedlings to grow that have a height of approximately 12 mm each.
3. Plant one seedling in each of six pots of the same size. For each pot, use 80 g of quality potting mix, and water with 10 mL of tap water.
Safety note: ensure that gloves and a mask are worn when handling potting mix, as it may contain harmful microbes.
4. Place three pots next to a window that gets direct sunlight. Place the other three pots in a shaded area of the room.
5. Using a ruler, measure the height of the tallest part of the plant from the surface of the soil to the nearest millimetre. Draw up a results table and record the results for each pot in the column for day 0.
6. Measure the height of the plants in the same way 2 days later. Record the results for each pot in the column for day 2.
7. Immediately after measuring, give each plant 10 mL of water.
8. Repeat steps 5 and 6 every 2 days for the next 10 days, keeping the plants in the same position to maintain lighting conditions.

Safety notes

Make sure that gloves and a mask are worn when handling potting mix, as it may contain harmful microbes.

Materials

- 10 pea seeds
- 500 g potting mix
- tap water
- cotton wool
- 6 plant pots
- 30 cm ruler
- 25 mL measuring cylinder
- electronic balance

10 seeds are used in case some do not germinate (start to grow).

Kylie has selected a number of plants and ensured that they all start at similar heights.

The size of the pots, the amount of soil and water are **controlled variables**, which she is keeping the same.

It is important to include safety notes when needed.

The amount of light is the **independent variable**. Kylie is varying this by placing the plants in different positions.

It is clear what measurements are made, and how **accurate** they should be.

She always clearly states how much water is used.

2.2 Ethical behaviour and safety in science

The following are key ethical considerations that need to be considered when carrying out science inquiries.

Science investigations should not cause harm

Some investigations have risks associated with them, which you need to consider and manage.

It is the responsibility of the person designing the investigation to ensure the method is a safe one. When you are conducting the investigation, it is your responsibility to ensure your own safety and those around you (Figure 4). Before starting any investigation, make sure you understand the safety rules and possible risks. This will enable you to reduce the chance of something going wrong and someone becoming injured.



FIGURE 4 Wearing eye protection, gloves, having hair tied back and following instructions carefully are examples of how to reduce the risk of harm in science investigations.

Science investigations should respect people's rights to make decisions

Anybody taking part in a science investigation should not only be physically safe, but also should not be asked to do anything they are uncomfortable with. For example, many people will not want to be involved with an investigation that results in the death or harm to an animal or plant, and they should have the opportunity to not participate. Asking participants if they would like to be involved is an important part of this.

Science investigations should promote the good

The expected benefits of the science investigation should outweigh the risks, damage, or financial or environmental cost of the investigation. Science investigations should result in better understandings of the world around us.

Science investigations should be fair

This does not just mean that the investigation is a fair test. It also means that there should be equal opportunities for people to be involved and the results of the investigation should be made available to others, as this promotes equality and different perspectives that enhance science understanding. All work by others should also be acknowledged. This includes referencing the source of information used in the investigation (see Toolkit section 4.2).

Science investigations should consider culture and the environment

Field investigations often take place outside of the laboratory in the natural environment. They are an important part of understanding scientific processes as they happen in the real world, rather than relying on scientific models.

When conducting field investigations, it is important to consider cultural sensitivities and respect nature. This includes:

- gaining permission and acting according to guidelines when accessing cultural sites and examining artefacts of First Nations Australians
- reducing environmental impacts when visiting nature sites
- ensuring that when you leave a field site, it is in the same condition as when you entered it.

2.3 Sites on Country/Place

First Nations peoples of Australia have a profound connection to and responsibility for Country/Place. 'Country' is a term often used by First Nations peoples to describe the lands, waterways, seas and skies they have a cultural connection to. These places may hold deep spiritual and cultural significance.

Within these areas, there are specific heritage sites that hold special meaning for First Nations peoples. The laws governing access to these sites are managed by state and territory governments, who collaborate with First Nations peoples to identify and protect them. These heritage sites are listed in online databases, such as the Queensland Aboriginal and Torres Strait Islander Cultural Heritage Database and Register, and in South Australia, the Register of Aboriginal Sites and Objects, which forms part of the state's Central Archive.

When conducting scientific fieldwork, identifying cultural heritage sites is crucial. These sites may include ceremonial grounds, traditional work sites, rock art, ancient caves, burial sites, waterways and scar trees (trees from which bark has been removed to create items such as canoes, shelters and containers). It is vital to respect the cultural significance of these areas by adhering to specific guidelines (see Figure 5).



FIGURE 5 A cultural significance sign at Uluru

You must obtain permission before entering heritage sites. Some may have restricted access; for example, only to members of specific First Nations groups. If access is granted, you must take care not to damage the cultural sites or any artefacts. Furthermore, the significance of these sites should be acknowledged in any reporting or publication of research or experiments conducted at these locations.

2.4 Using units in science

The International System of Units, or SI units, is a standard way of measuring things and is used by scientists around the world. It's like a universal language for measurements based on seven base units. Some examples of these that you will use in science are shown in Table 4.

TABLE 4 Examples of SI base units used in science

SI base unit	Used to measure	Notes
metre (m)	length or distance	1 m = 100 cm
kilogram (kg)	mass	1 kg = 1000 grams (g)
second (s)	time	There are 60 seconds in a minute.

There are other units that are not base SI units but are commonly used (Table 5).

TABLE 5 Examples of other common units used in science

SI base unit	Used to measure	Notes
degree celsius (°C)	temperature	based on the SI unit kelvin (K)
millilitre (mL)	volume	1000 mL = 1 litre (L)
newton (N)	force	named after Isaac Newton

2.5 Taking measurements in science

When taking a measurement, make sure the following guidelines are followed.

- Check the measuring instrument; for example, does it read zero correctly? ☐
- Use the most **accurate** measuring device available. For example, to measure 6 mL of a liquid, do not use a 100 mL measuring cylinder. ☐
- Look straight at the measuring scale. Your eyes should be at right angles to the scale (see parallax error below). ☐
- Check your measurement. Was the scale measured correctly? ☐
- Record the measurement straight away. Were the measurements recorded correctly? ☐
- Check that the numbers of your data are written in a consistent format; for example, to the same number of decimal places. ☐

KEY TERM

accurate how close the measured value is to the true value of the quantity that is being measured

volume the amount of space that a substance or an object occupies

error the difference between a measured result and the true value (see Toolkit section 2.6)

Measuring volume of liquids

When the **volume** of a liquid is being measured, the surface of the liquid forms a curved shape in the container. For example, in the measuring cylinder shown in Figure 6, the liquid curves down in the middle. This curved surface is known as a meniscus.

To take an accurate measurement in this example, always measure from the bottom of the curve. In this case the value measured would be 220 mL.

Parallax error

A **parallax error** is caused by reading dials and instruments from an angle instead of looking straight at the measuring scale, giving inaccurate readings.

Example

The three students look at the ruler from three different angles and each one reads a different measurement, between 18 cm and 22 cm (Figure 7).

Always read instruments straight on so as not to cause parallax error.

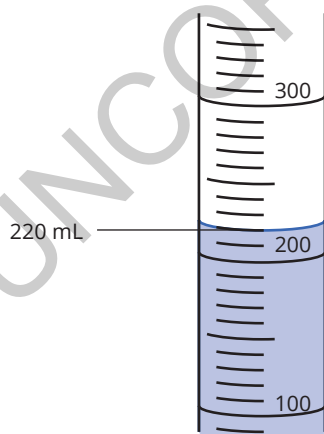


FIGURE 6 A measuring cylinder containing 220 mL of solution

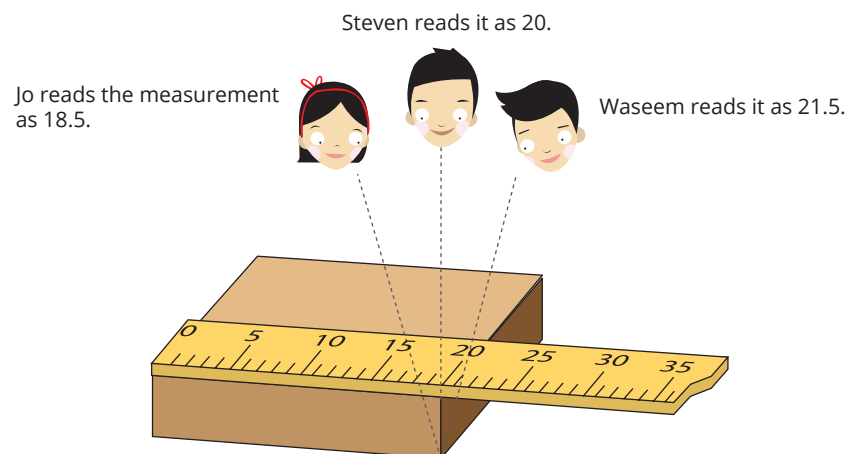


FIGURE 7 Parallax error is caused by taking the measurement from a different angle.

2.6 Mistakes and errors

Mistakes and errors are not the same thing.

Errors will always happen in science—they are unavoidable. As a scientist, it is your aim to make errors as small as possible. Errors occur when taking measurements and may be systematic or random errors.

TABLE 6 Types of experimental error

Type of error	Cause of error
Random errors are not the same every time.	They can be made worse by using equipment that is not accurate enough.
Systematic errors are similar each time the measurement is taken.	They can be caused by an instrument that is not calibrated (set up or adjusted) correctly.

KEY TERMS

data set a set of results from an experiment

data value an individual result from an experiment

Mistakes occur when the experimenter does something incorrectly. Mistakes usually happen because the experimenter did not accurately follow the method or take enough care when taking or recording measurements.

3 Processing, modelling and analysing

3.1 Types of scientific data

Results that are collected during a science investigation can be either quantitative or qualitative data.

TABLE 7 Types of scientific data

Type of data	Example
Quantitative data is produced when a quantity or amount of something is measured and recorded. Quantitative data can be continuous or discrete.	Continuous data can have any value, including a decimal value.
	Discrete data can only have separate values (normally whole numbers).
Qualitative data is produced when the characteristic (or 'quality') of something is observed and recorded.	the height of a plant, e.g. 11.5 cm the number of leaves on a plant the colour of the leaves or the smell of the plant

3.2 Calculating the mean (average) of a set of data values

In science investigations, averages, or means, are used to increase the accuracy of results.

Averages are calculated from a set of results (a **data set**), in which each individual result is called a **data value**.

How to calculate mean (average) value

Add the data values together and divide by the number of data values.

Example

Shasma used a newton meter to measure the force required to move an object along the ground. She repeated the test four times (Figure 8).



FIGURE 8 Force being measured with a newton meter

Trial	1	2	3	4
Force (N)	5.2	4.9	5.0	5.1

Total of data values = $5.2 + 4.9 + 5.0 + 5.1 = 20.2$

Mean value = $\frac{20.2}{4} = 5.05 \text{ N}$

Always remember to include a unit in your final answer.

3.3 Designing a results table

Results tables are important for the accurate recording of data. The following method can be used to design a results table.

- Identify what is being recorded in the experiment. This is often the independent variable that is being changed, as well as the dependent variable.
- For any quantitative data used, identify the correct units and add to the column or row title.
- Find out or decide how many results will be recorded.
- If **repeat trials** will be conducted, include room in the table to record these results and calculate the average (mean) value.
- Draw up a table that is large enough to fit all the required results.
- Add the names of the two variables being recorded, along with their units, at the top of the appropriate columns as headings.
- Give the table an informative title and figure number.

KEY TERM

repeat trial a repeat of an individual test or measurement within an experiment or investigation

Example

Rue was investigating the time it takes for sugar to dissolve in water at different temperatures. Rue's results table is shown below (Table 8).

TABLE 8 The time taken to dissolve sugar in water at different temperatures

Temperature of water (°C)	Time taken to dissolve 5 g of sugar in 50 mL of water (s)			
	Trial 1	Trial 2	Trial 3	Average time
20	110	105	102	105.7
45	25.0	24.0	27.0	25.3
80	7.0	10.0	8.0	8.3

Notes:

- To make it easy to compare values, all the times are giving in the same unit, in this case seconds (not minutes and seconds).
- Units are included in the column headings and not with the data in the table.
- Make sure the table has a title that includes the dependent and independent variables.

3.4 Using line graphs and column graphs

Line graphs

Line graphs are used to display quantitative data. Data values are plotted as points on the graph. A line is then drawn through these points that shows the pattern or **trend** in the data. A line graph is often used when a set of data is purely numerical.

KEY TERM

trend a pattern in data that changes in one direction

The axes of a graph are called the x -axis and the y -axis.

- The x -axis is the horizontal axis that points across. The independent variable is placed on the x -axis.
- The y -axis is the vertical axis that points upwards. The dependent variable is placed on the y -axis.

You can use the following questions as a checklist when drawing graphs.

axis	Are the x - and y -axes drawn with a ruler?	☐
scales	Are the scales suitable, so the data fits on the graph?	☐
variables	Is the dependent variable on the vertical (y) axis?	☐
labels	Are the x - and y -axes labelled with the variable and the correct units?	☐
data	Is each data point drawn correctly?	☐
line	Is there a line included that shows the pattern or trend in the data?	☐
title	Does the graph have a title that includes the dependent and independent variables?	☐

Example

Jack was investigating whether there was a connection between the mass of an object (he used sandbags) and the force required to pull it along a bench top. His data is shown in Table 9.

TABLE 9 Force required to move sandbags of different mass across a bench

Mass of sandbag (kg)	Force required to move the sandbag (N)
0.5	4.0
1.0	7.8
1.5	12.0
2.0	15.2
2.5	19.2
3.0	23.0

Mass is the independent variable, so it needs to go on the x -axis. The mass data range is 0.5–3.0, so the x -axis will need a suitable scale to fit this data.

Force is the dependent variable, so it needs to go on the y -axis. The force data range is 4.0–23.0, so the y -axis will need a suitable scale to fit this data.

Jack’s graph could look like Figure 9.

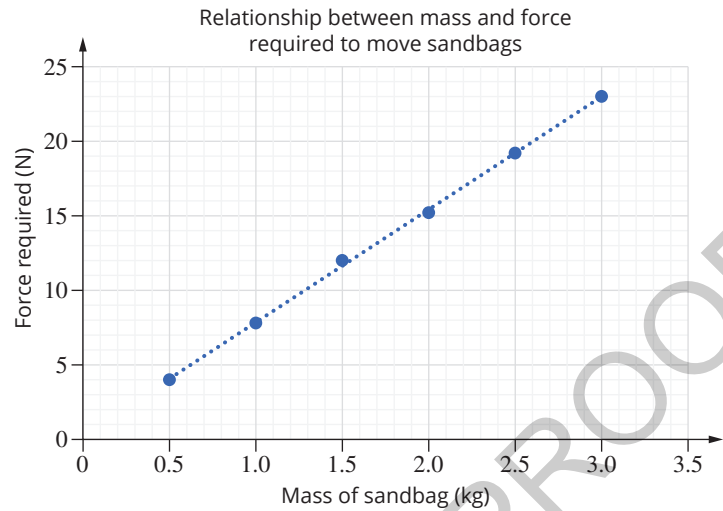


FIGURE 9 A line graph showing the relationship between force and the mass of sandbags

Column graphs

Column graphs are used when some or all of the data is discrete quantitative data or qualitative data.

A column graph displays data using bars.

The length of the bar indicates the data value.

As in a line graph, the independent variable is placed on the *x*-axis, while the dependent variable is placed on the *y*-axis.

Example

TABLE 10 Bird sightings between 2 pm and 5 pm on 3 July, 2024

Bird type	Number of sightings
magpie	4
honeyeater	7
pigeon	11
wren	2
thornbill	2

Kara carried out a survey of different birds seen in her garden during one afternoon to see which type of bird visited the most. She set up a webcam and recorded every instance of the appearance of the birds. Her results are shown in Table 10.

In this example, the type of bird is qualitative data, so a line graph should not be used.

Kara’s graph could look like Figure 10. Note that she has used colour to make it easier to compare the three birds.

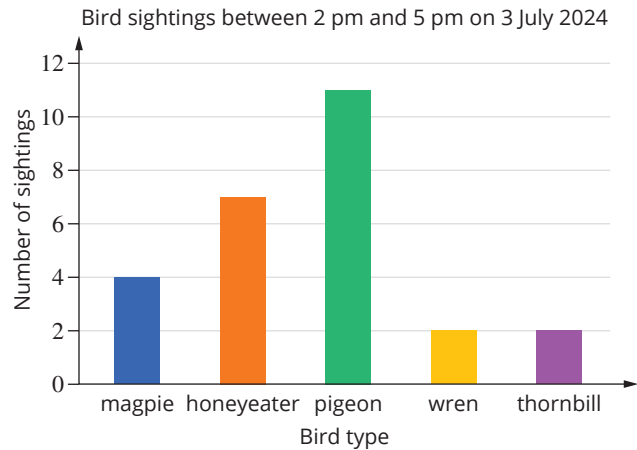


FIGURE 10 A column graph showing the number of sightings of each different bird type

3.5 Patterns and trends in data

A pattern is a repeated occurrence or sequence of results in data. Patterns can be used to predict observations. Patterns in data that you will come across in science include seasonal patterns, cyclical patterns and trends.

Seasonal patterns

A seasonal pattern is when data varies in a predictable way over a certain amount of time, such as a year, season, week or day.

For example, the average monthly temperature in one year in a certain place follows a seasonal pattern. Graphs can be used to identify and compare seasonal patterns for different places (Figure 11).

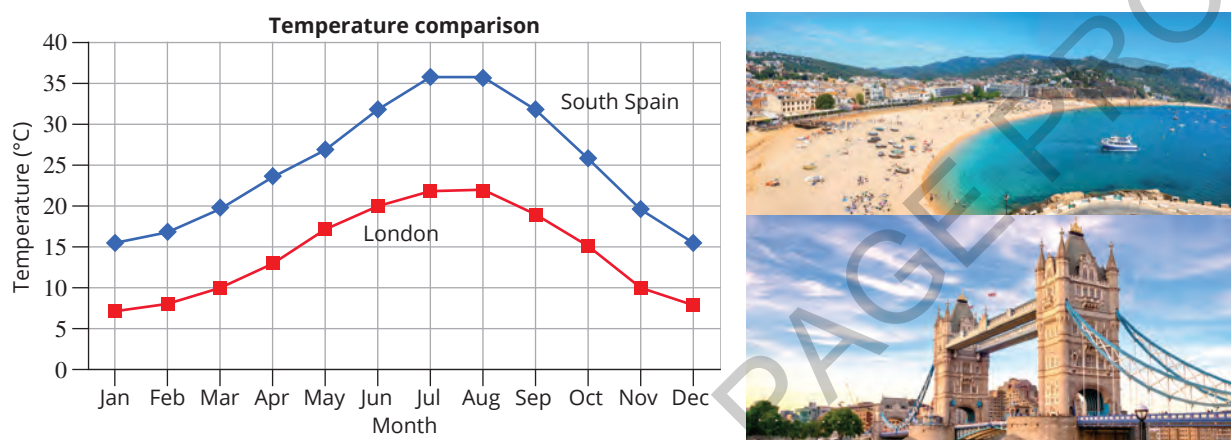


FIGURE 11 The seasonal variation of temperatures in two European locations

Cyclical patterns

A cyclical pattern occurs when the changes in the data repeat in a predictable way. Cyclical patterns are different from seasonal patterns because they are not directly linked to a fixed amount of time.

For example, the number of animals (the population) in an ecosystem may vary in a predictable way (Figure 12).

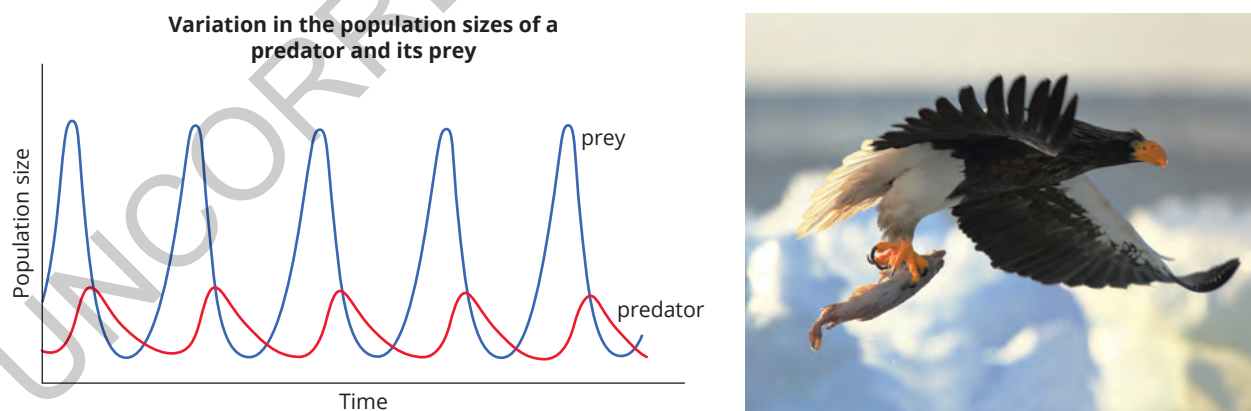


FIGURE 12 The cyclical variation in the population of a predator such as a sea eagle and its prey

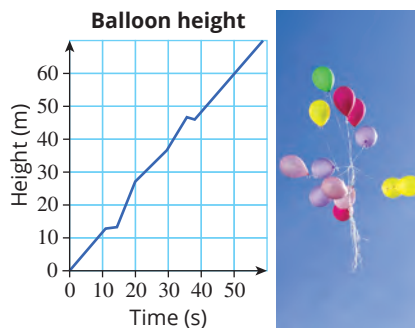


FIGURE 13 The height of the balloon is showing an upward trend.

KEY TERM

evidence data that can be used to support a conclusion or an answer to a question

Trends

A trend is seen when the dependent variable changes in one direction (always increasing or always decreasing).

For example, the increasing height of a helium balloon shown in Figure 13 is a trend because the balloon will keep rising.

4 Evaluating

4.1 Evaluating investigations

The aim of most investigations is to produce data that is used as **evidence** to support, or not support, a hypothesis, often by testing a prediction. Scientists need to have confidence in the data from an investigation before using it as evidence to develop conclusions or make decisions. Science investigations are evaluated by the quality of the data that they produce. It is important that when analysing the data produced from investigations that generalised assumptions are based on factual evidence and not just a gut feeling or a guess.

How to evaluate data from investigations

Data can be evaluated using the four main criteria shown in Table 11.

TABLE 11 Criteria for evaluating data from investigations

Criteria	Definition	Example question	Top tip	Notes
Accuracy	How close a measured value is to its actual value	Was the most accurate measuring cylinder available used to measure the volume of a liquid?	Use equipment that is best suited to measure what you are wanting to measure to get accurate measurements.	Accuracy and precision are more about individual measurements.
Precision	How well multiple measurements of the same thing, made under similar conditions, give similar values	Was the electronic balance checked to see if it gave the same results when it was used to weigh the same object three times?	Take multiple measurements of the same thing to check that your measurements are precise.	
Reliability	How well repeated experiments, observations or measurements produce similar results	When the experiment to test the distance that different models of toy car travel when pushed was repeated with the same force, were the results similar in each experiment?	When repeating an experiment, it is important to use the same method and conditions as the original experiment.	Reliability and validity are more about the overall results from the investigation.
Validity	How well the investigation tests the question, hypothesis or prediction that it was designed to test	When investigating a car travelling down a ramp from different heights, were all the controlled variables constant during the investigation (e.g. the angle of the ramp) and was only the independent variable changed?	Only change the independent variable and keep all other variables constant. This allows you to measure the effect of the independent variable on the dependent variable. (This is what the investigation aims to test.)	

4.2 Referencing secondary data

Secondary data is any information created by someone else (such as a book, website and government statistics). Part of ethical behaviour in science is to acknowledge (give credit for) the work of others by correctly referencing the source of all secondary data used. It is important to understand the data before using it, to ensure the data is not accidentally misrepresented or changed.

In an investigation or in research, remember to include the source of all secondary data used, and include an alphabetised list of your reference materials (called a reference list or **bibliography**) at the end of your report. These should be formatted in a consistent style and include all necessary information for another person to be able to access the source.

A common referencing style used in Australia and around the world is the American Psychological Association (APA) style. In your work, you might not need to use APA style, but your references must be consistently formatted so that they are easy to understand and use.

There are tools available to help generate your references, such as Microsoft Word's Citations and Bibliography tool (available in the References tab of Microsoft Word).

The key information that should be included in a reference is:

- author or organisation name that produced the information
- date the information was published (use 'n.d.' if not known)
- name of the website (if different from the organisation name)
- webpage
- weblink.

Example

Sascha was investigating ecosystems and used information from the website Atlas of Living Australia to find out about bottlebrush plants (*Callistemon*) (Figure 14).

Sascha's reference is shown here. It includes the name of the organisation and website (which is the same in this case), n.d. as the date is not known, the name of the page and the weblink.

Atlas of Living Australia, (n.d.). Callistemon R.Br. <https://bie.ala.org.au/species/https://bie.ala.org.au/species/https://id.biodiversity.org.au/taxon/apni/51366602>

If Sascha also used a book for her research, the reference would include the authors, the year and place of publication and the name of the publishers as shown here.

Wrigley, J W, Fagg, M. (2009). *Australian Native Plants*. New Holland Publishers

KEY TERMS

secondary data data that someone has acquired from an experiment that they have not carried out themselves

bibliography a list of all sources of information that were used in a science inquiry



FIGURE 14 Bottlebrush plants (*Callistemon*) are native to Australia and found in many regions.

4.3 Selecting and using secondary data

When planning and conducting investigations, you will often need to do some research, which will involve identifying and using of secondary data.

When looking for resources, try to draw from a wide variety of source types, including books, websites, magazines/journals and videos (Table 12). However, the focus should always be on selecting the best resources for the task.

TABLE 12 Advantages and disadvantages of information sources

Type of resource	Advantages	Disadvantages
Book	- Information is easy to find through the table of contents and index. - Has been edited by an editor. - Is usually well researched and written by an expert.	- Information can be outdated. - Can take time to locate the exact information you require.
Website	- Provides access to a huge amount of information on the one topic. - Information can be updated easily.	Anyone can publish on the internet, so it can be difficult to work out what information is accurate and reliable.
Magazine/journal	Information is usually up to date and contains recently researched information.	- Can be very technical and difficult to understand. - Can be biased.
Video/documentary	- Can provide first-hand accounts of events and situations. - Engaging and easy to watch.	- Can be difficult and time-consuming to find specific information. - May not be accurate and can be biased.

5 Communicating

5.1 Scientific writing

Scientific writing is factual. This means that it provides information or facts that are known to be true. Factual writing does not use emotions or feelings when describing or explaining things. Scientific writing is also formal and does not use ‘conversational language’.

Example

	Scientific writing	Non-scientific writing
Example 1	Sewage, which is wastewater from kitchens and bathrooms, can be recycled to make potable water suitable for human consumption.	Sewage, which is wastewater from kitchens and bathrooms, can be recycled but it is disgusting, and I would not drink it.
Example 2	Children were told the risks of using the Bunsen burner and importance of using exactly 5 cm of magnesium ribbon for the experiment.	The kids were told to watch it using the Bunsen burner and to get about 5 cm of magnesium ribbon for the experiment.

5.2 Scientific diagrams

Scientific diagrams are used to present written information in a more simplified, visual way. A good diagram will provide a lot of information in a concise way that is quick and easy to understand. Scientific diagrams can show complex information in a simplified way that is visually easier to evaluate and analyse.

Example

General drawings and diagrams (Figure 15 and 16)	• These are accurate representations reflecting shape, colour and proportions. • Labels, notes or a key can describe and identify features. • Arrows are used to show direction of processes (as Figure 15). • Arrows are not used to label parts and features.
Experiment report drawings (Figure 17)	• These are two-dimensional (2D) with carefully ruled lines, in correct proportions (see also Toolkit section 5.3). • Equipment is labelled and connected to the object with a pointer line. • Labels are written in clear print.

Figures 15–17 demonstrate features of scientific diagrams and drawings.

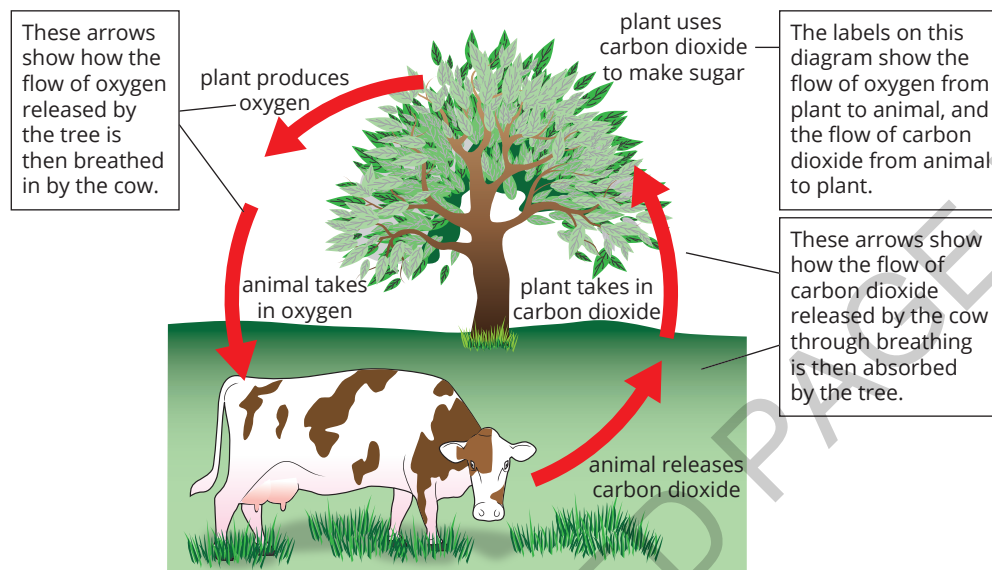


FIGURE 15 A diagram demonstrating the processes of the carbon cycle. It is simple and clearly labelled. The arrows identify the stages in the carbon cycle; different coloured arrows could be used to show movement of carbon dioxide and movement of oxygen.

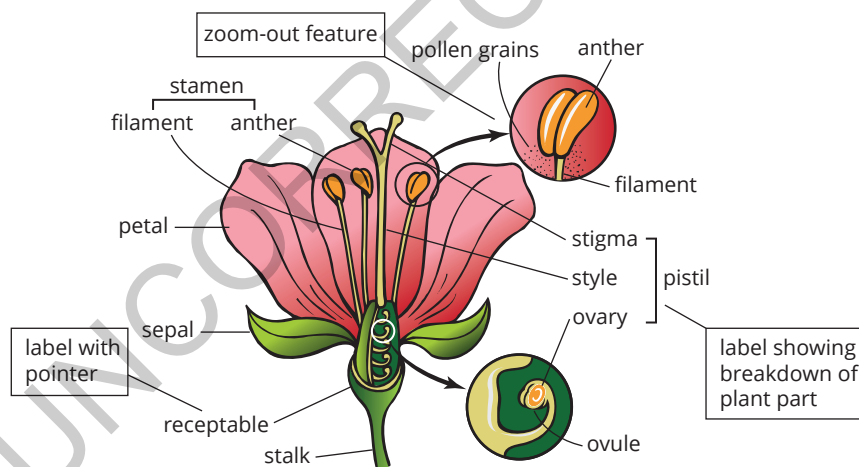


FIGURE 16 An accurate representation of the parts of a flower. Pointers are used to link to a zoom-out feature. All features are clearly labelled.

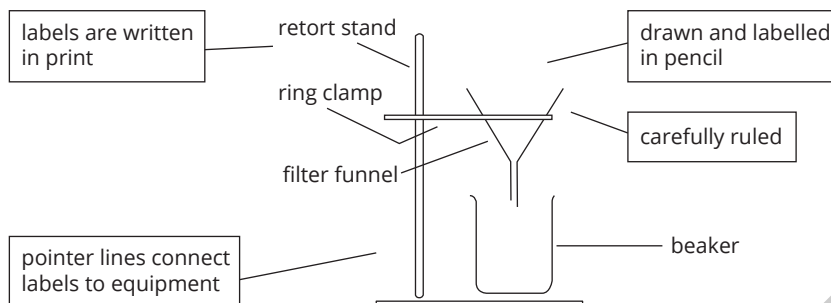


FIGURE 17 An example of a two-dimensional (2D) diagram in an experiment report showing equipment set-up

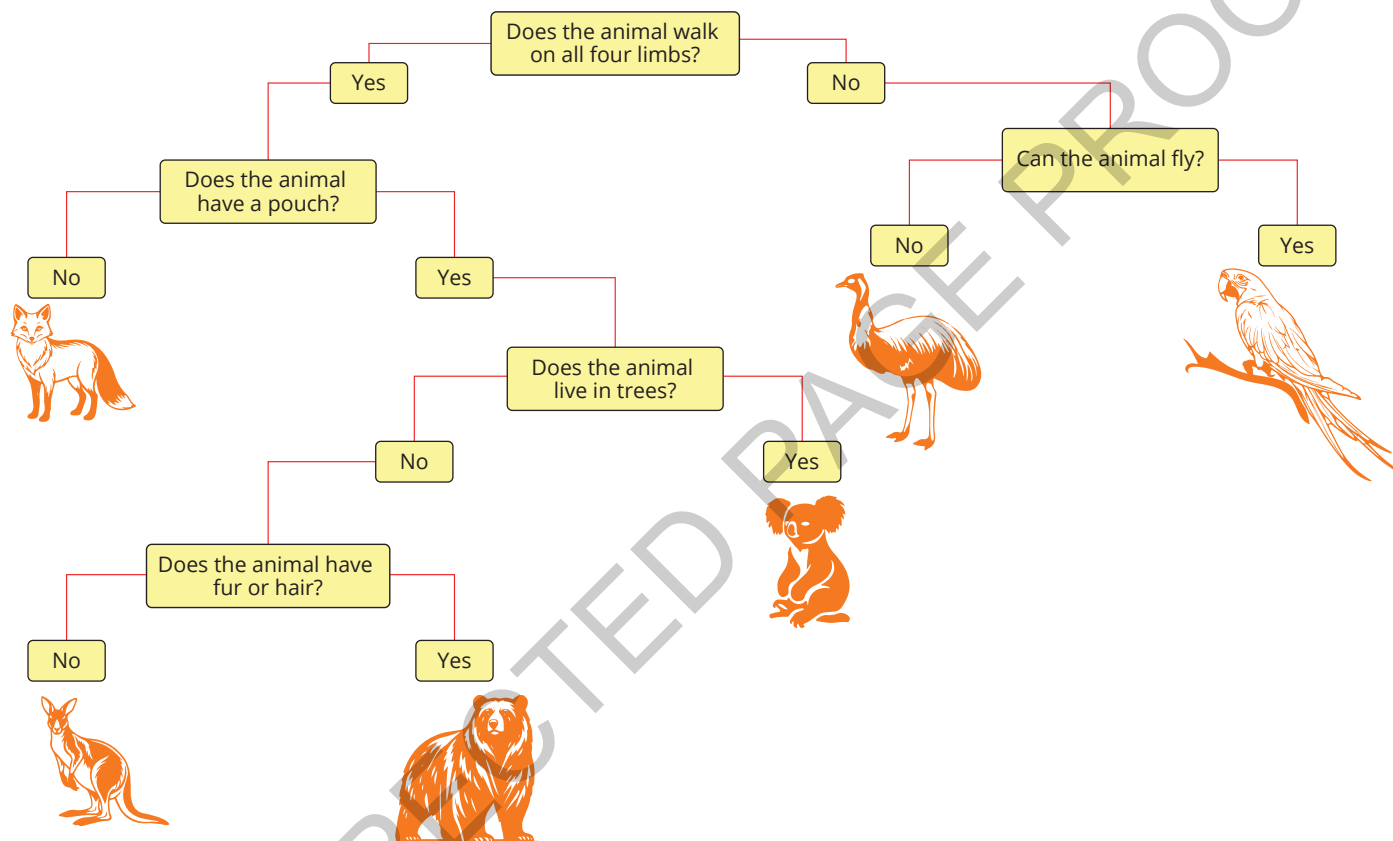


FIGURE 18 Keys are a useful way of displaying complex information.

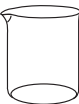
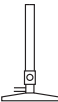
Scientists use keys to show relationships, such as those seen in the biological key for classifying Australian organisms in Figure 18. Having keys constructed allows scientists to determine patterns, make predictions and evaluate new research ideas.

5.3 Drawing scientific equipment

School laboratories contain common equipment that is used for several experiments. This equipment includes instruments for measuring, tools, glassware and personal protective equipment.

See Table 13 for examples of how to draw some common science equipment.

TABLE 13 Examples of scientific diagrams of laboratory equipment

Equipment name	Illustration	Scientific diagram	Equipment name	Illustration	Scientific diagram
beaker			filter funnel		
Bunsen burner			test tube		
conical flask			tripod and gauze mat		

Note how each piece of equipment is drawn in simple two-dimensional (2D) style as a ‘cross-section’ (splitting the equipment down the middle).

These individual pieces of equipment can be combined to create an experimental set-up. The same style of diagram should be used to show the full set-up (Figure 19).

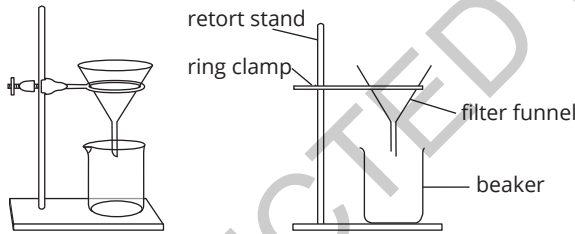


FIGURE 19 A scientific diagram showing a filtration experiment that uses a retort stand, a filter funnel, a ring clamp and a beaker

5.4 Graphic organisers

Graphic organisers are charts or diagrams that are used to help organise and present information or ideas. Graphic organisers can be very helpful for visual learners. There are several commonly used graphic organisers.

Flow charts

A flow chart uses boxes and words, as well as images, to demonstrate the sequence of events in a process or the way things are connected with each other (Figure 20).

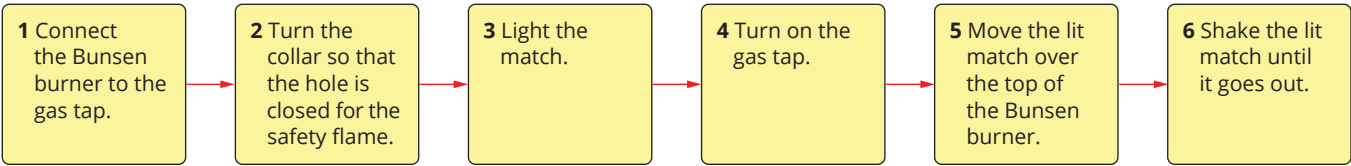


FIGURE 20 A flow chart showing the sequence for lighting a Bunsen burner

KEY TERM

hierarchical arranged in order of importance

Concept maps

A concept map organises ideas in a **hierarchical** branching structure. It uses words and captions.

Ideas are linked by arrows. Ideas may also be linked with phrases such as ‘leads to’, ‘results in’ and ‘impacts on’. The concept map in Figure 21 shows the relationships between water management and water shortage.

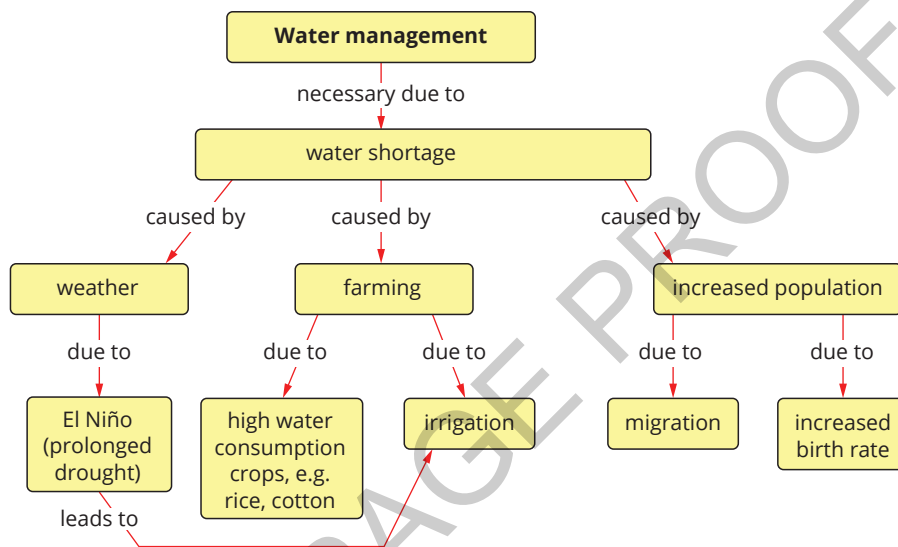


FIGURE 21 A concept map for the need for water management in an ecosystem

KEY TERM

scientific method the process of establishing facts and improving understanding by carrying out experiments

5.5 Writing a practical investigation report

The **scientific method** helps scientists report on what they did, what happened and how their findings contribute to a better understanding of the subject. The reports you complete in class should aim to do the same thing. A report should include all the key aspects of the investigation, such as the aim, the hypothesis and/or prediction if required, a materials list, safety notes, the method used, results, a conclusion and often an evaluation of the method and the results obtained.

Investigation report

Growing cress from seed

Aim

To investigate the germination of cress seeds in closed and open environments

Hypothesis

If cress seeds are grown in a closed environment, then they will grow at a faster rate than when grown in an open environment.

- Independent variable: presence or absence of a lid
- Dependent variable: number of leaves on individual cress plants
- Controlled variables: type and size of containers, amount of water, nutrients or fertiliser in the water, age and number of seeds, how closely the seeds are planted. You might think of more.

Prediction

If cress seeds are germinated in a container with a sealed lid, then there will be more leaves on the plants after seven days of growth than on seeds germinated in a container with no lid.

Safety

Sometimes fungus, such as mildew, can grow in seed-planting containers. Mould can destroy the seeds and seedlings. The fungal spores are a health hazard if they are breathed in. Wear a dust mask as soon as mould is seen and discard the experiment into a sealed bag for disposal in landfill.

Materials

- 2 plastic containers of the same shape and size, one with a lid
- 1 packet of cotton wool
- 100 mL measuring cylinder
- water
- 1 packet of cress seeds
- dust masks for each person (may not be needed)

Reason for doing the investigation

Write a hypothesis, based on your aim. It can be written as an 'if..., then ...' statement. You can note all of the variables here.

Prediction specific to the investigation, including what measurements of the dependent variable will be recorded

Warn of any hazards, why each is a hazard and how you can reduce the risk.

List all materials, including amounts, and any equipment required

Describe exactly how the experiment was done, with clear numbered steps.

Record your results. Data can also be shown in graphs, sketches and photographs.

If you take several readings of the dependent variable, you can calculate the mean (average). Then your results will be more reliable.

The conclusion relates back to the aim, and, if there is a hypothesis, whether the results from the experiment support the hypothesis. Suggested explanation for the findings can be included.

This can address questions such as:

- How well do the results support the hypothesis?
- Is there a reason for the results not being as expected?
- Were there any problems during the experiment?
- What did you do to overcome them?

Method

1. Cotton wool was placed into the bottom of two similar plastic containers.
2. Using a measuring cylinder, equal amounts of water were added to both containers, so the cotton wool in both was equally damp.
3. Thirty cress seeds were spread evenly in each container.
4. A lid was placed on one container, and then both containers were placed side by side on a well-lit windowsill.
5. The water lost by evaporation was replaced, so that equal moisture content was maintained in both containers. The amounts of additional water added are shown in the results.
6. Each day, the number of leaves was counted on at least 10–20 plants to avoid errors due to sick or diseased plants.

Results

A sample table (only partly shown):

Time (days)	Number of leaves on each plant											
	Covered with lid						No cover or lid					
	A	B	C	D	E	Average	A	B	C	D	E	Average
1												
2												
3												

Conclusion

The results showed that, after 7 days, cress plants in the covered container had more leaves than plants in the uncovered tray. The numerical results were an average of 4.6 leaves per plant when covered, compared to 3.7 leaves per plant when uncovered.

Cress seeds grown in a sealed container had 24% more leaves than cress seeds grown in an open container. This supports the hypothesis that cress seeds will grow more in a closed environment. This could be because the access to more oxygen reduces the rate of growth.

Evaluation

The results strongly supported the hypothesis because a 24% increase in leaf development is a significant difference and all plants except one in the containers with the closed lids had more leaves on than the plants with no lids. Other groups conducting the same experiment also had similar findings to ours, which indicates that the data is reliable. One plant stopped growing and died during the experiment. If we had used more plants, the effect of one plant failing to grow would have been reduced.

Glossary

accurate a how close the measured value is to the true value of the quantity that is being measured

bias a thought or an action that discriminates against, or favours, a particular idea, thing, person or outcome

bibliography a list of all sources of information that were used in a science inquiry

continuous data quantitative data that can have any value

controlled variable a variable that is kept constant throughout an experiment

data observations or measurements collected during an investigation

data set a set of results from an experiment

data value an individual result from an experiment

dependent variable the variable that is being measured in an experiment; it can vary as the independent variable changes

discrete data quantitative data that can only have separate or specific values

error the difference between a measured result and the true value

evidence data that can be used to support a conclusion or an answer to a question

hierarchical arranged in order of importance

hypothesis a statement about the relationship between two variables, which can be tested experimentally

independent variable the factor that is changed in an investigation to find out how it affects another factor

investigable question a question that can be answered by conducting a science investigation

precision how well multiple measurements of the same thing, made under similar conditions, give similar values

prediction a statement that suggests what will happen in an experiment, normally based on a hypothesis

qualitative data observations that are descriptive only (no quantity or number)

quantitative data data produced by recording a quantity or amount of something

random error an error that affects measurements in an unpredictable way; measured values can be higher or lower than the true value

reliability how well repeated experiments, observations or measurements produce similar results

repeat trial a repeat of an individual test or measurement within an experiment or investigation

scientific method the process of establishing facts and improving understanding by carrying out experiments

scientific model a scientific representation that communicates a real-world process that aids scientific predictions and explanations

secondary data data that someone has acquired from an experiment that they have not carried out themselves

sustainable a description of a process that does not adversely affect the lives or survival of future generations

systematic error an error that affects measurements in a predictable way; measured values will always be higher or lower than the true value

trend a pattern in data that changes in one direction

valid a description of an experiment where all controlled variables are kept the same and the experiment can be considered a fair test

validity how well the investigation tests the question, hypothesis or prediction that it was designed to test

variable a factor or condition that can change during an experiment and can influence the experiment

volume the amount of space that a substance or an object occupies



Forces and simple machines

Forces describe the interaction between objects. Usually, forces act when objects are in contact with each other, but some forces can act between objects that are not touching.

Forces can cause objects to change their speed, change direction, stop or start moving.

Simple machines, such as levers and pulleys, help us harness these forces to make tasks easier. These machines have been used for centuries, including by First Nations Australians, to solve everyday problems.

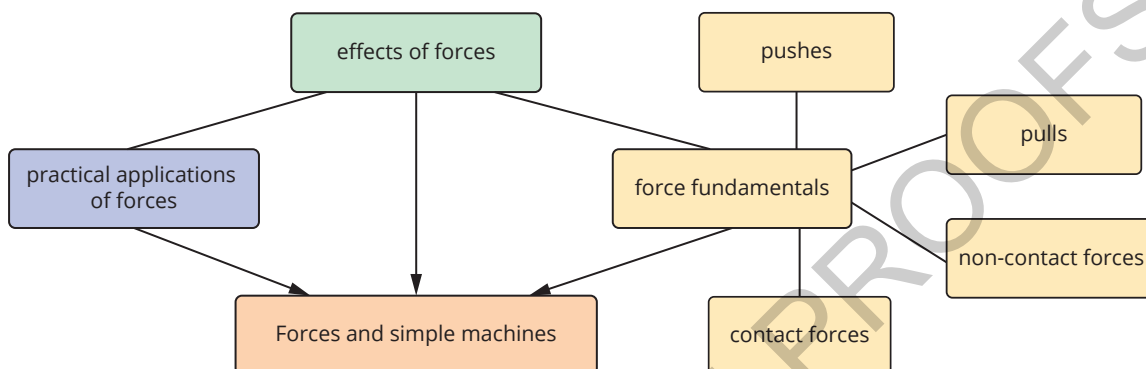
In this topic, you will learn about the effects of forces on objects. You will also explore simple machines and their applications, including levers, pulleys and inclined planes.

Learning intentions

- ☐ To be able to describe the effect of forces on objects **3**
- ☐ To understand that arrows are used to show relationships between strength and direction of force **7**
- ☐ To be able to measure and record forces using the correct equipment and units **14**
- ☐ To be able to conduct reproducible investigations to answer questions and test predictions **17**
- ☐ To understand the role of frictional force **20**
- ☐ To be able to investigate a relationship between friction and the mass of an object **25**
- ☐ To be able to conduct an investigation that analyses an aspect of friction **28**
- ☐ To understand that forces on an object can combine to result in balanced and unbalanced forces **32**
- ☐ To understand how levers can change the magnitude or direction of a force **39**
- ☐ To be able to analyse data to identify relationships **43**
- ☐ To be able to construct pulley systems and describe their actions **46**
- ☐ To be able to describe the use of simple machines by First Nations Australians **49**
- ☐ To understand the actions and uses of inclined planes, wheels, gears, wedges and screws **52**
- ☐ To be able to investigate how ramps affect the force required to raise an object **59**
- ☐ To be able to investigate the simple machines used in a bicycle **61**

Forces and simple machines

The key concepts that you will use in this topic:



The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

Force fundamentals

- 1** A tennis ball is sitting on the ground at rest. Explain what will happen to the ball if a force pushes it to the right.
- 2** Dropped objects always fall down towards the ground. Explain why gravity always makes objects fall 'down'.
- 3** If you push or pull on an object, you are applying a contact force. Magnetic forces on the other hand are considered non-contact forces.
 - a** Contrast contact and non-contact forces.
 - b** Identify whether gravity is a contact or non-contact force. Provide an example that supports your answer.

Effects of forces

- 4** When a ball is rolled across the ground, it will eventually come to a stop. Explain why this occurs.
- 5** Imagine walking on ice or a very slippery surface. Describe the presence of friction when walking on these surfaces.

Practical applications of forces

- 6** Skydivers fall through the air quickly when they jump from the plane. Parachutes are used to slow their fall before they land. Explain why using a parachute reduces the speed of the skydiver.
- 7** When flying a kite, you need a steady breeze to keep it in the air. Using the words 'push' and 'pull':
 - a** describe the forces acting on the kite from the wind
 - b** describe the forces acting on the kite from the string
 - c** explain how these two forces act together to keep the kite in the air.

1.1 Forces in action

Introduction

There are many different types of forces that you see in action every day. Forces act in a variety of ways. Forces are a ‘push’ or ‘pull’, and may change the shape, speed or direction of travel of an object.

In this practical investigation, you will experience a range of forces, learn how to describe their effects and classify them as contact or non-contact forces.

Background

Forces act all around you, all the time. Whenever an object’s shape or motion changes, you know that a force caused that change. The following section will help you describe changes in motion in this investigation.

Speed and velocity

Speed is how fast an object is moving. **Velocity** is also how fast something is going. However, when you describe velocity, you must also include the direction the object is travelling in.

For example, you can say that the eagle in Figure 1.1.1 is flying at a speed of 5 m/s, or you can say that the bird has a velocity of 5 m/s travelling south.

Velocity as a vector quantity

A **vector** is something that has **magnitude** and direction. If its direction changes, the vector will change. Velocity, for example, is a vector quantity.

Consider this example. Satellites, such as the International Space Station (ISS) shown in Figure 1.1.2, orbit Earth at very high speeds. Although their speed stays the same, satellites in orbit around Earth have a velocity that is constantly changing as they move in a circular motion – their direction is constantly changing, so their velocity is constantly changing.



FIGURE 1.1.2 The ISS maintains an altitude of approximately 408 km above the surface of Earth, and has an orbital circumference of 42 650 km. While the speed of the ISS in its orbit is constant, its velocity is not.

Learning intention

To be able to describe the effect of forces on objects

Success criteria

SC 1: I can describe situations of acceleration, deceleration and constant velocity.

SC 2: I can define and give examples of contact and non-contact forces.



FIGURE 1.1.1 An eagle flying has both a speed and a velocity.

KEY TERMS

speed the rate of change of distance

velocity the speed and direction of an object

vector a quantity that has magnitude and direction

magnitude a measure of the size or strength of something

Acceleration

Acceleration is when an object is increasing in speed or velocity. Acceleration can happen when an object begins to move. For example, when you kick a ball (Figure 1.1.3) or drop something, it begins to accelerate. When a vehicle moves faster, it accelerates.

Deceleration

Deceleration is when an object is reducing in speed or velocity. Deceleration includes when an object stops moving. For example, when a bike hits a barrier, it decelerates really quickly (Figure 1.1.4).



FIGURE 1.1.3 The soccer ball is just about to accelerate towards the goal.



FIGURE 1.1.4 The bike decelerated very quickly!

KEY TERM

constant velocity the movement of an object at the same speed and in the same direction

Constant velocity

If the velocity of an object is not changing, it is described as having **constant velocity**. It is not decelerating or accelerating. It stays at the same speed travelling in the same direction. If an object stays exactly still, it has a constant velocity of zero.

If a table tennis ball remains exactly still in the flow of air from a hair dryer (Figure 1.1.5), it can be described as having zero velocity.



FIGURE 1.1.5 As a table tennis ball is light, only a small force is required to keep it in the air.

Aim

To observe a range of forces in action and to describe the effect of the forces using correct scientific language

Materials

- lump of modelling clay
- hair dryer
- ruler
- textbook
- table tennis ball
- paperclip

- tennis ball
- balloon
- bucket
- woollen fabric
- drinking straw
- spring with hanging mass
- pencil case
- magnet
- retort stand and clamp

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

- 1 Copy the following table into your notebook and use it to record your observations. Consider the instructions for each task in the table.
- 2 Complete each task in the table, recording your observations as you work through the experiment.
- 3 Use scientific terms such as speed, velocity, acceleration, deceleration and direction in the descriptions of your observations as much as possible.

SAFETY NOTES

- ▶ Follow the instructions for each task carefully.
- ▶ Turn the hair dryer off after use so it does not overheat.
- ▶ Ensure the water from the bucket does not create a slip hazard.
- ▶ Keep water away from electrical appliances.

Results

Task	Changes observed in the motion or shape	What produced the force?
Prop up one end of a textbook with your pencil case or another object to make a ramp. Roll a tennis ball down the ramp.		
Rub woollen fabric against an inflated balloon and bring the balloon towards someone's hair.		
Point an end of a bar magnet towards a paperclip.		
Drop a tennis ball and try to catch it when it bounces.		
Blow a table tennis ball across a bench using a clean drinking straw.		
Using a ruler, push a book or other solid object across the bench at a constant speed.		
Squash a lump of modelling clay.		
Push an inflated balloon into a bucket of water and then let the balloon go.		
Suspend a hanging mass from a spring fixed to a retort stand. Carefully pull the mass down 2 cm, stretching the spring, and then release the mass.		
Balance a table tennis ball in a stream of warm air directed upwards from a hair dryer.		

Conclusion

As observed in this investigation, forces can be categorised into contact forces, where the objects must touch to apply the force, or non-contact forces where the objects do not need to touch.

Some common contact and non-contact forces are included in Table 1.1.1.

TABLE 1.1.1 Examples of contact and non-contact forces

Contact	Non-contact
Frictional force Air resistance force Applied force Spring force	Gravitational force Electromagnetic force Nuclear force

Remember that forces may change the shape, speed or direction of travel of an object.

Write your conclusion to the experiment and include answers to the following.

Review the results table and describe:

- a** at least three situations where forces caused objects to accelerate
- b** at least two situations where forces caused objects to decelerate
- c** at least one situation where forces caused objects to change direction
- d** at least one situation where forces caused objects to change shape
- e** at least one situation where there was no change to the object's speed, direction or shape
- f** all the contact forces that you observed in action
- g** all the non-contact forces that you observed in action.

1.2 Representing forces

Lesson overview

Forces act all around you.

They can have different directions and strengths and, often, multiple forces act on the same object at once. Some forces involve direct contact, such as a hand pushing a door. Others act at a distance, such as gravity pulling a plane toward Earth.

With so many types, strengths, and directions of forces at play, scientists use a clear and simple way to represent them. In this lesson, you will learn how to use arrows called vectors (Figure 1.2.1) to represent forces. This will help you understand which forces are acting and predict their effects.

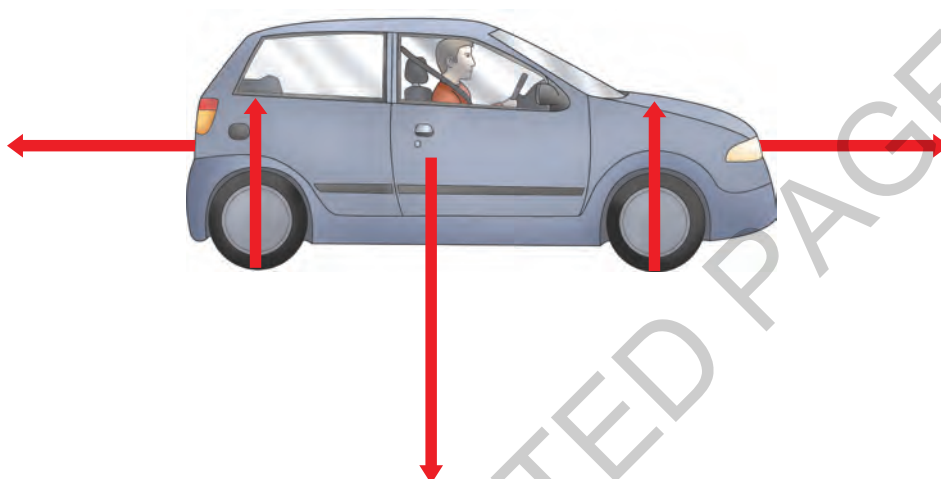


FIGURE 1.2.1 There are lots of different forces acting on this car.

SC 1 I can use a ruler to draw force arrows of different lengths to represent the magnitude of a force

Representing the magnitude of a force

Forces can range from large forces, such as those required to get a car moving, to the small force that a driver uses to turn the steering wheel to keep the car moving in the correct direction. When representing forces in diagrams, it is important to show the different magnitude (or strength) of the forces, as the strength of the force will determine the effect of the force.

Measuring the strength of a force

The strength of forces is measured in **newtons** (N). This unit is named after the English scientist Isaac Newton. Newton was one of the first scientists to consider the idea of gravity as a force, and he also developed a range of laws that linked forces to the motion of objects (Figure 1.2.2).

Learning intention

To understand that arrows are used to show relationships between strength and direction of force

Success criteria

SC 1: I can use a ruler to draw force arrows of different lengths to represent the magnitude of a force.

SC 2: I can draw force arrows in the direction of the force relative to a direction convention.

SC 3: I can position force arrows correctly on a diagram, with the tail of the arrow at the point of contact, or at the centre of the object for non-contact forces.

KEY TERMS

force any interaction that will change the motion of an object when unopposed; for example, a push or a pull
newton (N) the unit used to measure force

HINT

Vector and force diagrams can be created on photographs as well as other types of images. By adding vectors, the image becomes more informative.

KEY TERMS

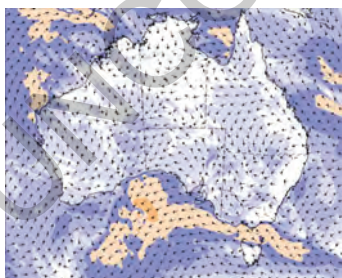
vector diagram a diagram that uses arrows to represent the effect of one or more vectors

force diagram a diagram that uses arrows to show one or more forces acting on an object

Scifile

Wind power

Weather maps use arrows to show wind direction and speed. The direction the arrows point represents the direction the wind is travelling, and the number of arrows represents how strong the wind is. When you see a long line with lots of arrows on a weather map, it means strong winds are blowing in the direction indicated. Weather maps help meteorologists predict the weather.



Representing forces in a diagram

Forces are represented as arrows in a diagram. The arrow shows the direction in which the force is acting. The arrows should be straight lines. Arrows that show the direction of something are often called **vectors**.

Diagrams that indicate the size, direction and location of vectors are called **vector diagrams**. **Force diagrams**, as seen in Figure 1.2.3, are a type of vector diagram that are used, specifically, to represent forces.



FIGURE 1.2.2 Observing apples falling from a tree due to gravity is said to have inspired Isaac Newton's gravitational theory.



FIGURE 1.2.3 A runner experiences both a running force (the push from their leg muscles) and an air resistance force acting on them.

Representing the strength of a force

The strength of a force can be represented by using larger arrows for stronger forces and smaller arrows for weaker forces. Some scientists use wider arrows and narrower arrows instead.

In this lesson, longer arrows are used for stronger forces and shorter arrows are used for weaker forces. The lengths of the arrows can also be drawn to scale based on the strength of the forces. If the strength of a force is known, the arrow can be labelled with the strength (such as 11 N, as shown in Figure 1.2.4).

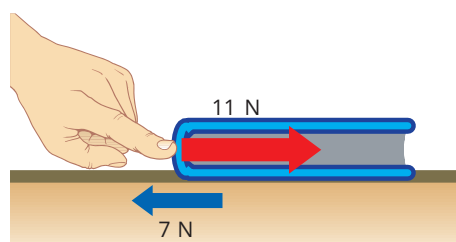


FIGURE 1.2.4 The applied force must be stronger than resisting forces (such as friction) to make an object move.

Describing arrows

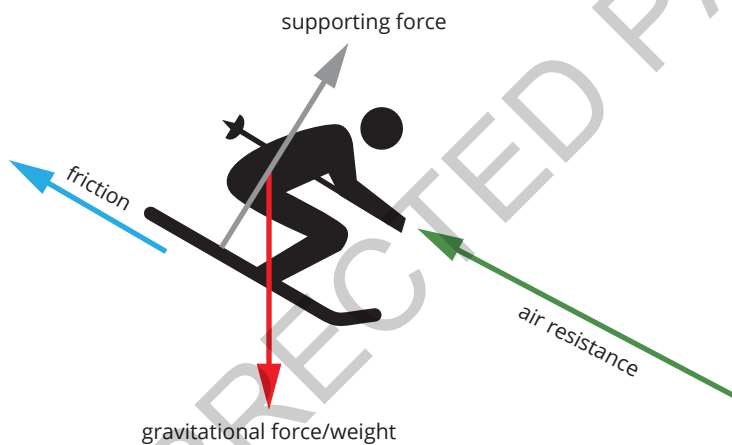
An arrow has two parts: the head, or arrowhead (the pointy part), and the tail (the straight part). If you say, 'The arrow starts at the tree and ends at the apple', it means the tail of the arrow is on the tree, and the arrowhead is pointing at the apple.

SkillBuilder

Drawing a force diagram

- 1 Identify the object the forces are acting on.
- 2 List all the forces that are acting on this object.
- 3 Work out the direction of each of the forces acting on the object and draw one arrow for each force.
- 4 Draw the arrows so they start at the place where the forces are acting. (For drag forces such as air resistance, the arrows can finish at the place where they are acting or start from the centre of mass.)
- 5 Label each arrow with the type of force it represents and, if known, the size of the force in newtons (N).
- 6 If you know the strengths of the forces, the length of the arrow should represent the strength of the force. For example, stronger forces should be represented with a longer arrow than weaker forces.
- 7 Check that you have included all the forces acting on the object.

For example, Chloe was asked to draw a force diagram showing the forces acting on a skier travelling down a snowy slope. She was told that the main forces acting were a small amount of friction between the skis and the snow, the weight of the skier, the force of the snow supporting the skier and air resistance that was about twice as strong as the friction force. Chloe created the following force diagram to represent the forces acting on the skier.



Worked example

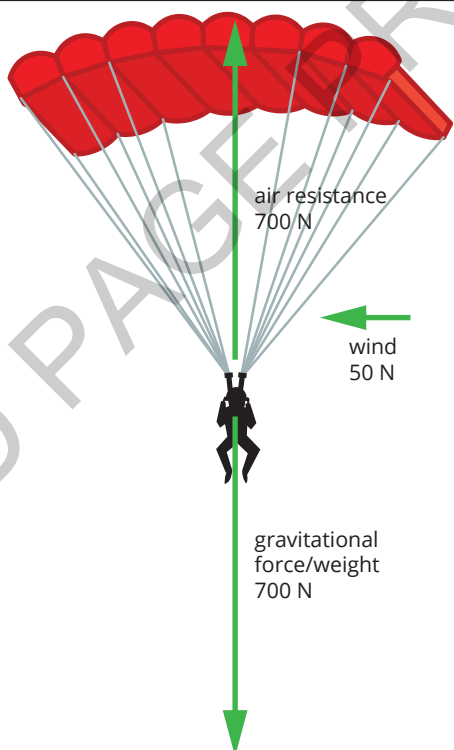
Drawing a force diagram

Problem

Use the following information to draw a force diagram that shows the forces acting on a parachute.

Geronimo was descending using a parachute. The gravitational force acting is 700N, the air resistance against the parachute is 700N and there is a side wind blowing from the right to the left, which is giving a horizontal force of 50N.

Solution

Thinking	Working
What are the forces and in what direction are they acting on the parachute?	gravitational force (weight) (down) air resistance (up) wind (from the right side)
Are the values of each force different or the same?	The gravitational force and the air resistance are both the same (700 N), so the arrows representing these forces should be the same length. The wind force is much smaller (50 N), so the arrow representing this force should be smaller than the other arrows.
Have all the forces acting on the parachute been included?	yes
Draw the force diagram.	

Try yourself

Use the following information to draw a force diagram that shows the forces acting on a car.

The weight (gravitational force) of a small car is 9000 N. The force of the engine driving the car forward is 400 N, the air resistance of the moving car is 250 N, the friction force slowing the car down is 90 N and the force of the road supporting the car is 9000 N.

SC 1 CHECK YOUR UNDERSTANDING

Explain how the length of a force arrow relates to the magnitude (strength) of the force.

SC 2 I can draw force arrows in the direction of the force relative to a direction convention

Representing the direction of a force

If you have ever got lost trying to follow someone's directions, you will understand that directions can mean different things to different people. This means that when you show a direction, you need to be very clear, especially if the object is moving, such as the objects in Figure 1.2.5.

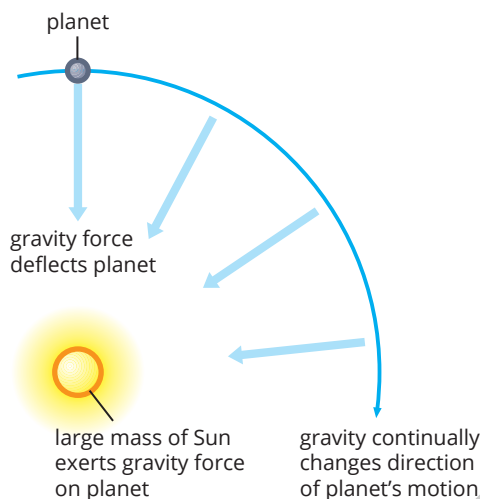


FIGURE 1.2.5 The direction of the force of gravity may change as an object moves; for example, as a planet orbits the Sun.

Points of reference

One way to make descriptions of directions clear is to use a **point of reference**. This is an example of a **scientific convention**. The point of reference is chosen, and all other directions are described relative to that position. For example, if the centre of Earth is used as the point of reference, forces can be described as away from, or towards, the centre of Earth.

Points of the compass

Compass points are a common way to describe direction using a reference point. The main points of the compass are north, east, south and west as seen in Figure 1.2.6. North is the reference point and other directions can be described using words, such as south or north-west.

Right and left

Right and left seems an easy way to describe direction, but only if all observers are looking at something from the same direction. For example, if you go out of a room through a sliding door, you might slide the door to your left to open it, but if you turn around and come back into the room, you now slide to the door to your right. But the door is moving in the same direction each time! So be careful when using left and right.

Forwards and backwards

As with right and left, forwards and backwards can be used (see Figure 1.2.7 on the following page)—but you must make sure everyone is clear on which way is 'forwards' and which way is 'backwards'.

KEY TERMS

point of reference something that is used for comparison
scientific convention an agreed way to carry out an action or communicate information



FIGURE 1.2.6 Compass points can be used to describe the direction of forces.

For example, you could use a wall as a reference point, so your observations would be ‘away from the wall’ or ‘towards the wall.’ This only works if there is only one wall though, so take your time when selecting your point of reference.

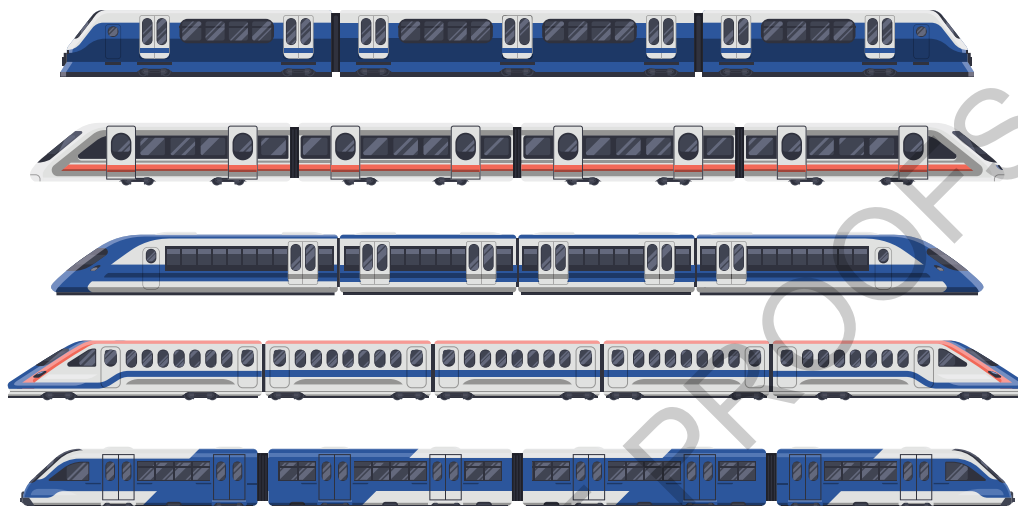


FIGURE 1.2.7 These Japanese bullet trains look the same going ‘forwards’ or ‘backwards’, which means using the words ‘forwards’ and ‘backwards’ to describe their movement is not the best system. A point of reference can be added, or a different system used.

Drawing force diagrams

When drawing force diagrams, ensure that the directions are clearly shown. For example, Figure 1.2.8 shows clearly the various forces acting on a truck driving on a road.

Note that the size of the arrows for the driving force and the friction force are the same length because they are the same strength (they are both 500 N).

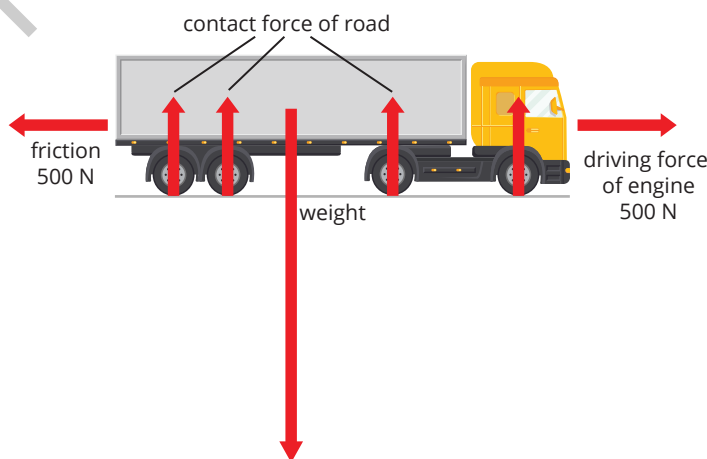


FIGURE 1.2.8 The forces acting on the truck are shown in four directions: to the right, to the left, upward, and downward.

GO TO

Toolkit section 5.2, Scientific diagrams

SC 2 CHECK YOUR UNDERSTANDING

Explain why a point of reference can be useful for describing the direction of forces.

SC 3 I can position force arrows correctly on a diagram, with the tail of the arrow at the point of contact, or at the centre of the object for non-contact forces

Drawing force arrows for contact and non-contact forces

Forces cause the movement of objects to change. In force diagrams, it is important to show the position at which the force acts on an object, as this helps explain how the force will affect the object.

The scientific convention used for where to draw force arrows is described below for contact and non-contact forces.

Contact forces

If the force is a **contact force**, the tail of the arrow should start at the point where contact between the two objects is causing the force, as shown in Figure 1.2.9.

Non-contact forces

If a force is a **non-contact force**, the arrow should start at the centre of the object being affected, as shown in Figure 1.2.10.

Drag forces

Air resistance and the resistance of water are called **drag forces**. They are both contact forces, but because air is a gas and water is a liquid, it may be difficult to decide where to show the contact. In this case, you can start the arrow in the centre of the object, in the same way as for a non-contact force, or show the drag force in front of the object as shown in Figure 1.2.11.

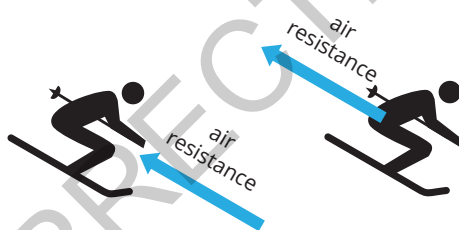


FIGURE 1.2.11 A skier experiences air resistance as their movement pushes air out of the way.

SC 3 CHECK YOUR UNDERSTANDING

Describe where the tail of a force arrow should be placed when drawing a contact force.

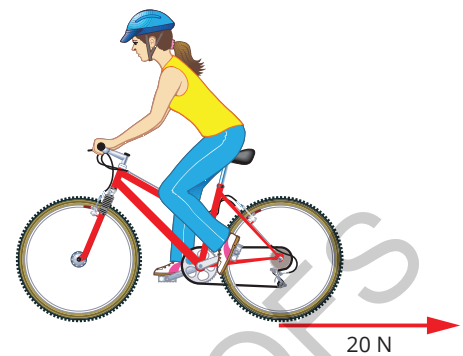


FIGURE 1.2.9 The wheels of a bike push along the ground, creating a contact force.

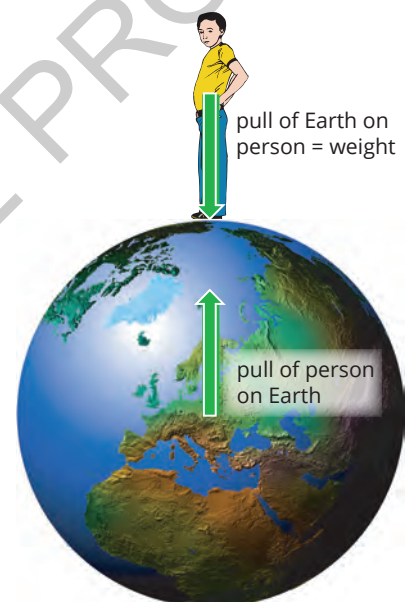


FIGURE 1.2.10 Gravitational forces are non-contact forces between objects that have mass.

KEY TERMS

contact force a force that acts between two objects that touch each other

non-contact force a force that acts on an object from a distance

drag force a force created by an object moving through a gas or liquid

Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 Describe what is meant by 'direction convention' when drawing force arrows.
- 2 Contrast two force arrows, one representing a 3 N force and another representing a 6 N force.
- 3 Draw a force diagram to show a soccer ball being kicked to the right.
- 4 Draw a force diagram to show the gravitational force acting on a falling apple.

1.3 Measuring forces

Learning intention

To be able to measure and record forces using the correct equipment and units

Success criteria

SC 1: I can correctly use a newton meter to collect data.

SC 2: I can predict the amount of force required for a range of activities.

SC 3: I can consider ways to reduce error when measuring forces.

KEY TERM

newton meter a device used to measure the strength of a force; often called a spring balance



FIGURE 1.3.1 This spring balance measures up to 10 N.

SAFETY NOTE

- Ensure that the objects used in the experiment are not dropped or allowed to fall off benches or tables.

Introduction

Normally it is possible to estimate the strength of forces from how much effort you need to apply. Estimating is a valuable skill in science. For example, it can help you to predict the results of an experiment so that you can choose the correct equipment to use. In science, you should also know how to measure forces accurately so you can investigate the strength of different forces.

In this practical investigation, you will estimate the amount of force required to complete a range of tasks. You will then use a **newton meter** (also known as a spring balance, shown in Figure 1.3.1) to check your predictions. You will also consider how to improve the accuracy of your estimates and measurements.

Background

The unit of force is the newton (N).

A newton meter is an instrument that measures pulling forces. Newton meters have different measurement ranges for measuring different-sized forces.

Aim

To estimate and then measure the size of some common forces

Prediction

You will be predicting the strength of forces in this experiment. To help you, extend the newton meter to see what 1 N, 5 N and 10 N feel like. This will help you with your estimates later.

Materials

- newton meter (spring balance)
- 10 slotted 50 g masses and base/hook
- selection of items found in the laboratory or classroom (see the results table for suggestions)

Assessment of risk

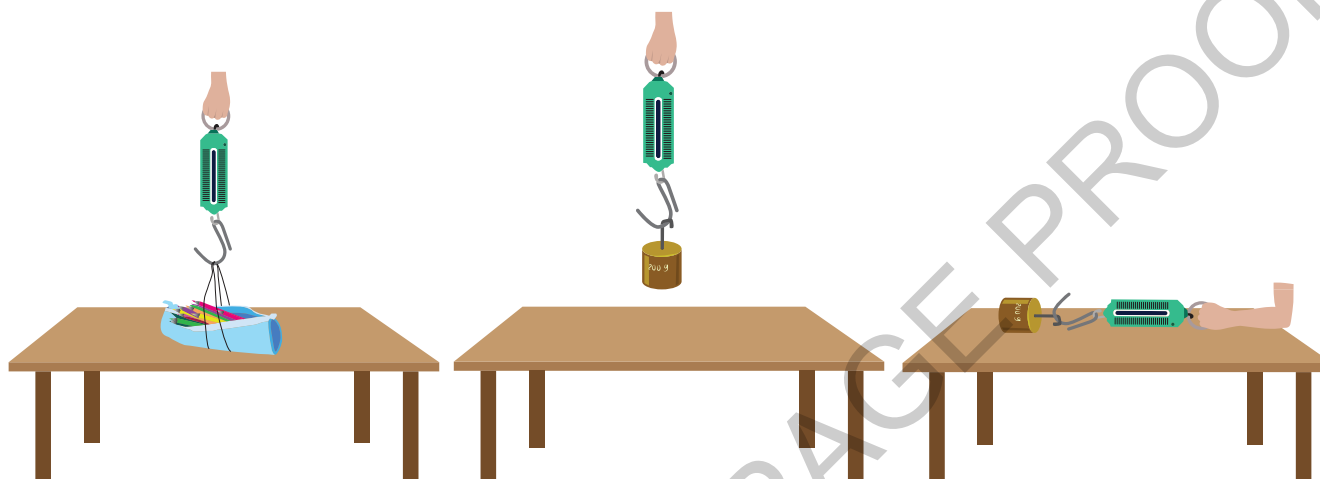
Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

- 1 Consider the results table. If some of these items are not available, use an alternative but similar item. You can also add some other items or tasks. Record all your measurements in the table as you work through the experiment.
- 2 Estimate the size of each force and record your estimate in the table. Then measure the force for each situation. Some possible set-ups for the measurement of the force are shown in the diagram.

GO TO

Toolkit section 2.4, Taking measurements in science



Results

Copy the following table into your notebook and use it to record your results.

Task	Estimate of size of force required (N)	Measured force (N)
pulling a pencil case along a bench		
lifting a test tube rack		
lifting a laptop lid		
unzipping a laptop bag or pencil case		
lifting a 100 g mass		
lifting a 200 g mass		
lifting a 300 g mass		
dragging a 300 g mass along a benchtop		

Conclusion

Write your conclusion to the experiment and include answers to the following.

- 1** How accurate were your estimates?
- 2** Suggest why you needed to use a larger force to lift the 300 g mass than to drag it along a benchtop.
- 3** Compare the force needed to lift the 100 g, 200 g and 300 g masses to the size of the masses.
- 4** Use your answer to question 3 to propose a relationship between the size of the mass and the force needed to lift it.
- 5** Use your answer to question 4 to predict the amount of force required to lift the following objects into the air:
 - a** 500 g mass
 - b** 60 kg person.

Evaluation

Evaluate your practical investigation. Include responses to the following.

- 1** Comment on how accurate your estimates were and suggest how you could improve the accuracy of your estimates.
- 2** Suggest how you could improve the accuracy of your measurements.

GO TO

Toolkit sections 2.5, Mistakes and errors and 4.1, Evaluating investigations

1.4

Investigating air resistance and gravity

Introduction

Gravity is the force that accelerates objects towards Earth. The greater the mass of an object, the greater the force of gravity acting on the object.

Air resistance is a force that acts to oppose the force of gravity as an object is falling. A spinning object can be designed to increase the air resistance it experiences. For example, a maple seed (Figure 1.4.1) has evolved to spin, causing it to take longer to fall to the ground. This gives the spinning object more chance of landing further away from the parent tree.

In this practical investigation, you will use a robocopter to investigate the effects of air resistance and gravity.

Background

Gravity is the non-contact force that pulls all objects towards Earth.

Air resistance is friction (a contact force) that occurs between an object and the air it passes through. Air resistance acts as an opposing force to gravitational pull. A spinning object can increase air resistance if it spins fast enough, with the surface area being effectively increased by the rotation of the object. Air resistance, being a type of friction, will oppose an object's motion.

Aim

To make a robocopter and then determine how changing one variable affects the time that it takes the robocopter to fall

Materials

- A4 sheets of light cardboard
- metre ruler
- pencil
- scissors
- stopwatch
- paperclips
- chair

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Learning intention

To be able to conduct reproducible investigations to answer questions and test predictions

Success criteria

SC 1: I can follow a method to set up scientific equipment to conduct an investigation about gravity and air resistance that is reproducible.

SC 2: I can identify variables in an investigation.

SC 3: I can develop and test a prediction based on a falling object.

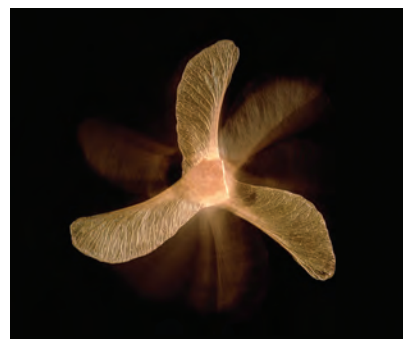


FIGURE 1.4.1 A maple seed spinning as it falls through the air

SAFETY NOTE

- ▶ Ensure that the person dropping the robocopter is safe and there is no risk of falling.

Method for preliminary trials

- 1 A template for a robocopter is shown in Figure 1.4.2, along with a diagram of the completed model.

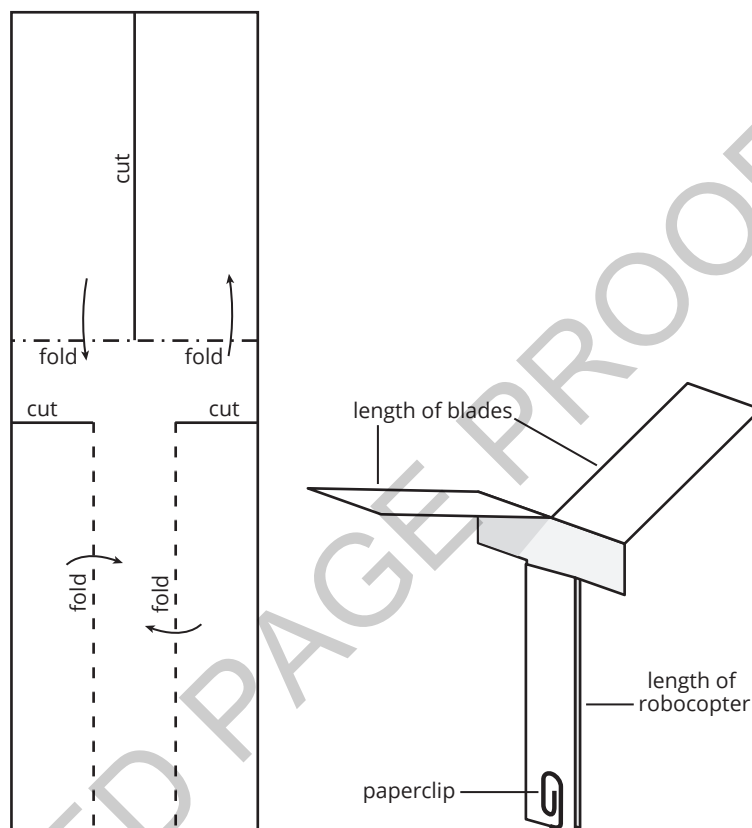


FIGURE 1.4.2 To build your robocopter, draw a copy of the template onto an A4 piece of light cardboard (cut lengthways).

- 2 Cut along solid lines and fold along dashed lines as shown by the arrows.
- 3 Place a paperclip at the base to complete the robocopter.
- 4 To conduct **preliminary trials** drop this robocopter from the same height three times. Measure how long it takes to fall to the ground in each case. Calculate an average time.
- 5 Construct a table to record the three times and the average.

GO TO

Toolkit sections 3.2, Calculating the mean (average) of a set of data values and 3.3, Designing a results table

KEY TERM

preliminary trial a trial of an experiment used to test a method

GO TO

Toolkit sections 1.2, Dependent, independent and controlled variables and 1.3, Hypotheses and predictions

Prediction

The time it takes for the robocopter to fall to the ground is the dependent variable in this investigation.

Now that you have tested the method, you can investigate what can affect the drop time of the robocopter.

First, decide which variable you will change. For example, you could:

- change the length of its blades
- add more paperclips to its base
- make different-sized robocopters
- make robocopters from different thicknesses of paper or cardboard.

The variable that you chose to change is the independent variable for this investigation.

Once you have decided which variable you will change, predict what effect the change will have on the time it takes for the robocopter to reach the ground.

Method

Design a step-by-step method for your investigation that you will use to test your prediction. Explain how your investigation will be reproducible.

GO TO

Toolkit sections 2.1, Writing a method for an experiment and 3.3, Designing a results table

Results

Record your results in a table.

Conclusion

Write your conclusion to this experiment. Include answers to the following questions.

- 1 Name the dependent and the independent variable in your experiment.
- 2 How accurate was your prediction? Use evidence from your experiment in your answer.
- 3 Use your knowledge of forces to suggest a reason for your results.

1.5 Friction

Learning intention

To understand the role of frictional force

Success criteria

SC 1: I can define frictional force.

SC 2: I can describe everyday uses of frictional force.

SC 3: I can analyse different scenarios to determine if frictional force is useful.



FIGURE 1.5.1 Speed skaters will try to reduce friction once they are moving—but they need friction to get started.

KEY TERM

friction a force that acts against an object's motion

Lesson overview

Friction is one force that is almost impossible to avoid. It will always occur between two surfaces that are in contact with each other. Sometimes you want to increase friction; for example, when riding a mountain bike on a slippery track. Other times you might want to reduce friction; for example, when trying to move fast across the surface of an ice rink (see Figure 1.5.1). In all situations, friction will act in the opposite direction to the motion of an object.

In this lesson, you will learn about where friction exists and to identify where you can use friction for your advantage.

SC 1 I can define frictional force

Rock climbing is a sport where climbers use **friction** to help them climb a wall or rockface. The holds on the wall are rough so climbers can grip them. Hands that get wet with sweat reduce the friction between the climber's hands and the holds, so chalk is used to absorb the sweat. Climbers can also wear climbing shoes with a special sole to increase the friction against the wall or rocks.

What is friction?

- Friction is a contact force that is always present when two surfaces are in contact with each other.
- It exists because bumps on two surfaces resist the movement of the touching surfaces as they slide past each other.
- There may also be some attractions between the chemicals that the surfaces are made from.

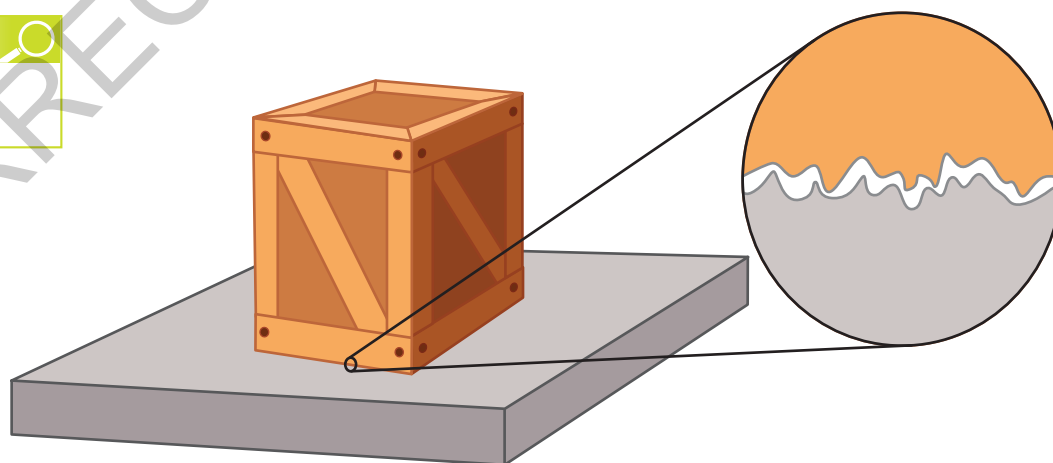


FIGURE 1.5.2 Although it may look like the box and the ground have smooth surfaces, they are rough at a microscopic level.

The diagram in Figure 1.5.2 shows a close-up view of where the surface of the box is touching the floor surface. See how the bumps on the surfaces will slow or stop the box from moving over the floor.

What direction does friction act in?

Friction will always act in the opposite direction to the movement of the object on a surface, as demonstrated in Figure 1.5.3.

SC 1 CHECK YOUR UNDERSTANDING

Describe the direction in which frictional forces always act.

SC 2 I can describe everyday uses of frictional force

The following pieces of equipment demonstrate how friction can be used in everyday life, including for bicycle tyres (Table 1.5.1), rock climbing equipment (Table 1.5.2) and bicycle brakes (Table 1.5.3).

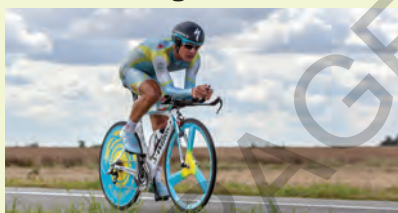
TABLE 1.5.1 Understanding friction informs the design and choice of tyre treads

Mountain bike



Tyres on a mountain bike are designed with a deep tread to maximise the interaction between the moving wheel of the bike and the rough surface of the trails.

Racing road bike



Tyres on a racing road bike are quite smooth because the road's surface is smooth. Because the surfaces are similar, the area of contact between the two surfaces is maximised.

TABLE 1.5.2 Understanding friction informs the design and choice of shoes

Crampons



Climbers attach crampons to the soles of their shoes. The crampons can bite into the snow and ice, creating more friction. This allows the climber to grip on to the icy surface.

Rock climbing shoes



Rock climbing shoes are smooth. This gives them more contact surface with the rock. They are also made of a type of chemical that is slightly sticky, which increases the force between the shoe and the rock.

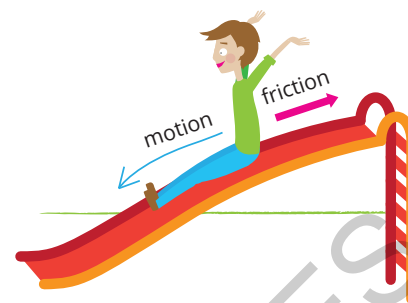


FIGURE 1.5.3 A person on a slide will experience friction that acts backwards on them as they move down the slide.

TABLE 1.5.3 Understanding friction informs the design of braking mechanism on bicycles**Rim brakes**

Traditional rim brakes on bikes work as the rubber block is pressed against the metal rim of the bike's wheel. This creates enough friction to slow the wheel down and stop the bike.

Disc brakes

Disc brakes on bikes work as the block is pressed against the metal disc in the middle of the wheel. More friction force can be applied because the disc is flatter and presents more surface to the brake block than in a rim brake. The discs are also less likely to get wet or muddy than the rim of the bike wheel.

Scifile**Smooth writing**

When you write with a pencil, friction between the pencil tip and paper allows the graphite to leave marks. You can leave a darker mark with your pencil by increasing the friction between the tip and the paper, either by applying more pressure when writing or using a different type of paper with a rougher surface. Some pencils are also considered 'soft lead' pencils, because they leave more graphite behind with little friction. Without friction, writing or drawing would be a lot more challenging!

SC 2 CHECK YOUR UNDERSTANDING

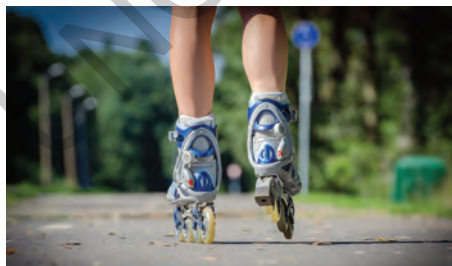
Describe how frictional forces are used by bike brakes to slow a bike down.

SC 3 I can analyse different scenarios to determine if frictional force is useful

Friction will always oppose the motion of one surface moving across another surface. Sometimes this can help us, but sometimes the friction might not be useful.

Not-useful friction

If you want things to move fast, or for a long time, you would want to reduce friction. This can be done by reducing the surface area in contact between two objects or creating a slippery layer to separate two surfaces. Wheels are another method of reducing friction, as the wheels can roll over rough surfaces instead of sliding along them. This reduces the contact between rough edges and allows the wheels to move easily. The equipment shown in Figures 1.5.4–1.5.6 demonstrate how friction can be reduced when necessary.

**FIGURE 1.5.4** Using rolling objects such as wheels**FIGURE 1.5.5** Reducing the area of contact between the two surfaces, and sliding along a very smooth surface**FIGURE 1.5.6** Using a lubricant, such as oil or water, to reduce the friction

Useful friction

There are many situations where friction is helpful.

Friction and shoes

An example where friction is helpful is with the grip of the soles of shoes. Your skeleton acts as a system of levers with muscles providing the force to move your body. When you walk or run, your leg muscles push your feet backwards. If your shoes grip the path, your feet stay in one place and the force from your muscles results in the leg and the body moving forwards, as demonstrated in Figure 1.5.7. If there was not enough friction, your feet would just slide backwards, and you would not move forwards.

Friction in nature

Many animals have evolved to have characteristics that maximise friction used to grip surfaces, which helps them survive. Geckos, like the one pictured in Figure 1.5.8, can climb on smooth surfaces.

Geckos' toes are covered in hundreds of hairs, and each hair contains many bristles. These hairs and bristles mean that the contact area between the feet and the surface is huge. The gecko can control the amount of friction by changing the angle of the hairs. If geckos suddenly want to move (and they can move very fast), they can switch the friction off by moving the hairs to reduce the amount of contact with the surface.

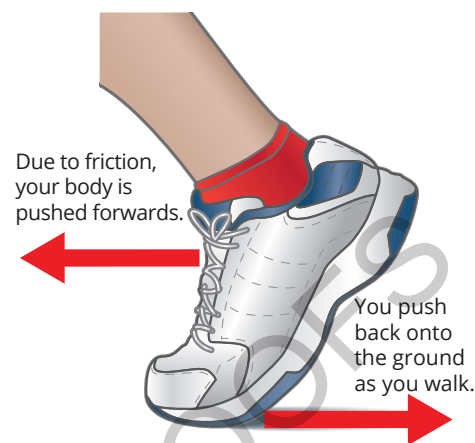


FIGURE 1.5.7 Shoes with rubber soles improve your ability to walk on surfaces by increasing friction.



FIGURE 1.5.8 The hairs on a gecko's foot allow it to climb walls to seek shelter and hunt for prey.



SCIENCE IN SOCIETY

Friction in sports

There are many different strands of engineering. Sports engineering is a specific field of study that combines sport with technology. One important area of study in this field is designing the best equipment for player performance.

In sports, considering how friction is going to interact with gameplay is essential for designing equipment that enhances performance. For example, researchers might investigate the friction between different types of tennis shoes and various court surfaces (Figure 1.5.9). By analysing this friction, they can select materials and design patterns on the soles of shoes that maximise the contact between the shoe and the ground, providing the best grip and support for players.

Similar investigations are conducted for other sports equipment, such as soccer balls, golf clubs and ski gear. Understanding how friction affects performance helps manufacturers create products that give athletes a competitive edge. These investigations often involve testing materials, analysing data and refining designs based on the findings.



FIGURE 1.5.9 Tennis players need to be able to change direction quickly on the court, so strong friction between their shoes and the court is essential.

SC 3 CHECK YOUR UNDERSTANDING

Explain why reducing frictional force is beneficial in sports such as ice skating.

Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 Explain why frictional forces occur.
- 2 Describe how frictional forces help when writing with a pencil.
- 3 Describe the frictional forces of walking on an icy surface compared to walking on the footpath.
- 4 Compare the usefulness of frictional forces when climbing a hill versus sliding down a slide.

1.6 Friction and mass

Introduction

There are many factors that will affect the friction in the situation shown in Figure 1.6.1; for example, the type of surface, the type of shoe, and whether the surface is wet or dry. But what about the mass of the shoe, or the mass of the person wearing the shoe?

This experiment allows you to answer questions such as these.

Background

Friction is a contact force that is always present when two surfaces are in contact with each other. It exists because bumps on two surfaces resist the movement of the touching surfaces as they slide past each other. The greater the mass of an object, the greater the force of gravity acting on that object, pulling it downwards onto the surface that it is resting on.

When conducting a scientific investigation, it is important that you consider the validity and reliability of the method.

A valid method means your investigation measures the intended variable accurately. To ensure validity, you should control as many variables as you can when collecting your data, so your independent variable is the only cause for any changes in your dependent variable.

To ensure reliability, you should have a method that can be easily repeated and will give similar results under similar conditions. If you are getting inconsistent data in an investigation, you should look at your method or equipment to see what can be improved to collect consistent data.

Aim

To investigate how increasing mass affects the size of friction

Hypothesis

Write a hypothesis for your investigation that answers the question: How does mass affect the amount of friction between two surfaces?

Materials

- wooden block with hook
- spring balance or force sensor
- $5 \times 200\text{ g}$ masses

Learning intention

To be able to investigate a relationship between friction and the mass of an object

Success criteria

SC 1: I can propose a hypothesis and write a prediction based on the mass and the friction of an object.

SC 2: I can write a conclusion based on data from an experiment.

SC 3: I can evaluate the validity and reliability of the data from a practical investigation.



FIGURE 1.6.1 A newton meter can be used to measure how much force is required to slide this shoe across the ground.

GO TO

Toolkit section 1.3, Hypotheses and predictions

SAFETY NOTE

- The block may suddenly move, so take care to avoid getting your fingers squashed by the masses or the block. Masses may cause injury if dropped; for example, onto a foot.

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

- 1 Copy the results table into your notebook. Alternatively, construct a spreadsheet with similar columns.
- 2 Place the wooden block on a benchtop.
- 3 Attach the spring balance to the block of wood, as shown in Figure 1.6.2.

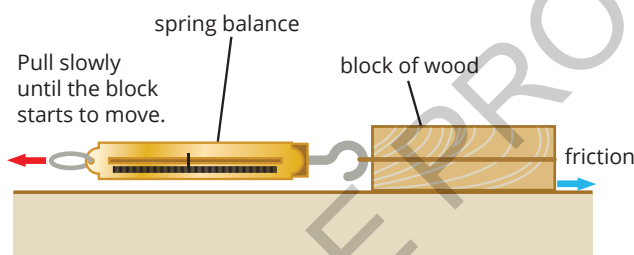


FIGURE 1.6.2 Ensure your spring balance is correctly attached to the block.

- 4 Measure the size of the force needed to keep the block moving at a constant speed. This is equal to the force of friction. Record this in your results table.
- 5 Repeat step 4 twice and record the results.
- 6 Add a 200 g mass on top of the block of wood. Measure the friction between the block and the benchtop three times and add these results to the table.
- 7 Repeat the friction measurements for 400, 600, 800 and 1000 g (1 kg) masses on the block, recording three results for each test.

Results

Copy the following table into your notebook or in a spreadsheet and use it to record results.

Object moving	Friction force (N) measured on blocks of different mass			Average friction force (N)
	Trial 1	Trial 2	Trial 3	
wooden block				
wooden block + 200 g				
wooden block + 400 g				
wooden block + 600 g				
wooden block + 800 g				
wooden block + 1000 g				

- 1 Calculate the average of your results in the table by adding the three forces and dividing by 3. Alternatively, program your spreadsheet to calculate the average for you.
- 2 Construct a line graph showing your results. Place 'Mass added to the block (g)' on the horizontal axis (0, 200, 400, 600, 800, 1000) and 'Average friction force (N)' on the vertical axis.

➤ GO TO

Toolkit sections 3.2, Calculating the mean (average) of a set of data values and 3.4, Using line graphs and column graphs

Conclusion

Write your conclusion to this experiment. Include answers to the following questions.

- 1 What happened to the size of the force of friction as the mass on the wooden block increased?
- 2 Describe a situation in which you have noticed this link between friction and mass.
- 3 Construct a conclusion for your investigation.
- 4 Assess whether your hypothesis was supported or not.

Evaluation

- 1 Comment on the validity of your investigation.
- 2 Comment on the reliability of your investigation.

➤ GO TO

Toolkit sections 3.5, Patterns and trends in data and 4.1, Evaluating investigations

1.7 Investigating friction

Learning intention

To be able to conduct an investigation that analyses an aspect of friction

Success criteria

SC 1: I can develop an investigable question and make reasoned predictions around friction in a real-life situation.

SC 2: I can design an investigation, including constructing appropriate representations to record and organise data.

SC 3: I can process and analyse results to develop a conclusion from primary data.

Introduction

Friction is a contact force. Sometimes people aim to reduce friction; for example, to make a bike go faster. Sometimes people aim to increase friction; for example, to increase the grip of the brakes on the wheels or the grip of the tyres on the ground (Figure 1.7.1).

A range of factors, or variables, will increase or decrease the strength of the force of friction.



FIGURE 1.7.1 An increase in friction, due to the tread on the tyres, gives the rider more control when riding over different surfaces.

In this inquiry activity, you will construct a question around the strength of friction. You will design and conduct an investigation to answer that question. You will be given some guidance on which situation to use and the variable you are investigating.

Background

Finding the answers to questions is what science is all about. Questions can range from ‘How will the climate change over the next 15 years?’ to ‘What type of tyre is the best to use on a mountain bike on wet trails?’ and many, many more.

Before a scientist investigates anything, they normally start with an inquiry question like these. This question will define the investigation, so it is very important to ask the right question.

Checking your inquiry questions

If a question is not clear, the answer to the question may not be very helpful.

If a question is not able to be investigated, it might not even be possible to achieve an answer at all.

If a question is clear and can be investigated, it is called an investigable question.

GO TO

Toolkit section 1.1, Investigable questions

Investigating friction

In this activity, you will have the opportunity to answer a question related to the effect of friction. You can select a situation that interests you and a variable to investigate.

Two examples of an inquiry questions are shown in Table 1.7.1.

TABLE 1.7.1 Examples of how you might create an inquiry question based on your observations

	Example 1	Example 2
Observation	 Surfboards come in different shapes and sizes.	 The sole is the part of the shoe that connects to the ground when running.
Situation and variable	The situation is surfing, and the variable is the shape of the board.	The situation is running, and the variable is the size of the shoe.
Inquiry question	Does a surfboard go faster through the water if the shape of the board is changed?	Does a running shoe's friction increase as the shoe's size increases?

These are both examples of questions about **cause-and-effect relationships**. In Question 1, the variable chosen to be investigated is qualitative because the shape of the board can be described but is not an amount or number. The variable chosen in Question 2 is quantitative because the size of the shoe can be measured.

GO TO

Toolkit section 3.1, Types of scientific data

Factors affecting friction

Several variables may affect the strength of friction between two surfaces. These include the size of the surfaces, the force pressing the surfaces together, the materials and roughness of the surfaces, the wetness of the surfaces or whether there are other materials between the surfaces.

KEY TERM

cause-and-effect relationship a relationship between two variables in which changes to one variable is the reason for changes to the other

Aim

To select a situation where friction is involved, write an inquiry question about how changing a variable will affect the strength of friction and then collect data from an experiment to answer this inquiry question

Plan

Situation

Choose a situation that involves friction that you would like to investigate. Check with your teacher once you have decided on a situation.

GO TO

Toolkit section 1.2, Dependent, independent and controlled variables

GO TO

Toolkit section 2.4, Taking measurements in science

GO TO

Toolkit sections 2.1, Writing a method for an experiment and 3.3, Designing a results table

Independent variable

Decide on the independent variable that you will be investigating. Choose something that can be changed using the resources available to you.

In this investigation the dependent variable is the strength of the friction.

Inquiry question

Once you have chosen your situation and independent variable, write a question that you want to investigate.

Design

You now need to design an investigation that will answer your inquiry question.

Make sure that you have a way to measure the strength of friction. Also, be sure this measurement can be easily repeated so that you can obtain enough data to answer your question.

How to measure the strength of friction

Plan how you will measure the force of friction in your investigation. This may involve the use of newton meters (spring balances) to directly measure the amount of force, or there are other indirect ways that the amount of friction can be compared.

Controlled variables

To start designing your experiment, you will need to decide what the controlled variables will be. A controlled variable is a variable that is kept constant throughout the experiment.

Independent variable

The independent variable is what you will change in your investigation. Once you have decided which variable you will change, decide how to change it during the investigation. If it is a quantitative variable, decide on the range of values you will use and how many trials you will use. You can also decide if you will need to repeat any of the trials.

Method

Once you have identified how to change your independent variable, measure the strength of friction, and keep the controlled variables the same, write a step-by-step method for your investigation.

Include materials that you will use and include a table for your results.

Prediction

Use your knowledge of friction and any other relevant observations to predict the result of your experiment. This is what you think the answer to your inquiry question is.

Conduct

Conduct your investigation according to your method. If you need to alter your method to improve accuracy or safety, make changes and note down what you changed and why you changed it.

Record

Ensure that all data is recorded accurately in your results table.

▶ GO TO

Toolkit section 3.2, Calculating the mean (average) of a set of data values

Conclude

Write a conclusion using your experiment's results to answer your inquiry question. Include actual data from the experiment to support your ideas.

1.8

Balanced and unbalanced forces

Learning intention

To understand that forces on an object can combine to result in balanced and unbalanced forces

Success criteria

SC 1: I can use vector diagrams to show balanced and unbalanced forces acting on objects.

SC 2: I can calculate the size and the direction of the net force and predict the action of this force.

SC 3: I can explain the concept of terminal velocity when forces are balanced.

KEY TERMS

unbalanced forces forces acting on a single object where the force in one direction is not equal to the force applied in the opposite direction

balanced forces forces acting on a single object where the force in one direction is equal to the force applied in the opposite direction

gravitational force the force on an object due to gravity; can be described as the 'weight' of an object

Lesson overview

In almost all situations, more than one force is acting on an object. How the object will move will depend on the combined effect of the forces. Now that you have a good understanding of a range of different contact and non-contact forces, you can consider how these forces act as a combination. In particular, you can consider whether the forces are balanced or unbalanced, as this will have a huge effect on the movement of the object.

In this lesson, you will learn about how forces can combine to result in balanced and unbalanced forces. You will then be able to predict the effect of these forces.

SC 1 I can use vector diagrams to show balanced and unbalanced forces acting on objects

Forces can be represented with force diagrams that use arrows to show the direction and magnitude (strength) of forces acting on an object. These arrows are called vectors. Force diagrams are a type of vector diagram.

When more than one force is acting on an object, there will be multiple vectors shown in the force diagram. In Figure 1.8.1, there is a pushing force of 11 newtons (N) acting to the right and a friction force of 7 N acting to the left. These forces are **unbalanced forces** because the forces are different strengths.

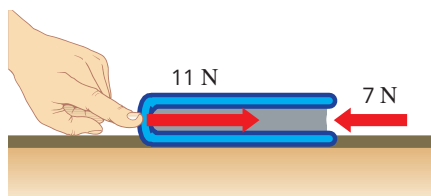


FIGURE 1.8.1 The unbalanced forces acting on the book will make it move across the table.

In Figure 1.8.2, there is a **gravitational force** of 500 N acting downwards and a support force of 500 N acting upwards. These forces are **balanced forces** because the forces are the same strength and act in opposite directions.

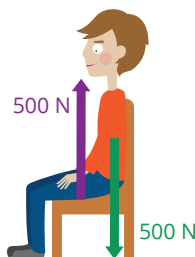


FIGURE 1.8.2 The balanced forces acting on the student means they will remain in the chair.

Forces in multiple directions

Often there will be forces acting on an object in more than two directions. An example is the bike and its rider in Figure 1.8.3.

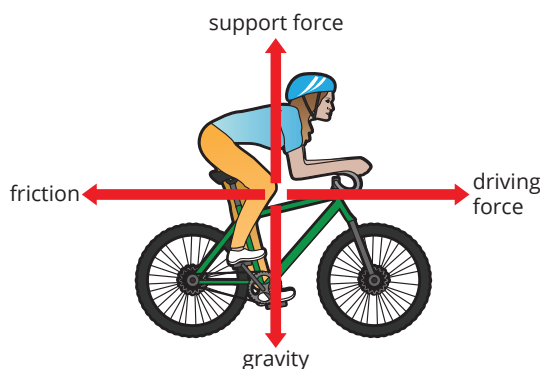


FIGURE 1.8.3 The forces acting on the bike and its rider are equal in size and opposite in direction.

In this situation, there is the driving force to the right, friction to the left, gravity downwards and the support force of the road upwards.

To determine if the forces are balanced or unbalanced, you must consider the forces in pairs; the right and left pair, and the down and up pair.

In this case, the right and left pair (driving force and friction) are balanced because the size of the arrows is the same. The down and up pair (gravity and support force) are also balanced.

SC 1 CHECK YOUR UNDERSTANDING

Explain the difference between balanced and unbalanced forces.

SC 2 I can calculate the size and the direction of the net force and predict the action of this force

When multiple forces act on a single object, the combined effect of these forces is called the **net force**.

If forces are balanced, the net force is zero because the forces cancel each other out.

If forces are unbalanced, you can calculate the net force by adding up the magnitude (strength) of all the forces acting on the object. You must remember that if the forces act in opposite directions, this must be considered.

KEY TERM

net force the combination of multiple forces acting on a single object; also called resultant force

SkillBuilder

Calculating net force on an object

Important information

In most situations, more than one force is acting on an object. The net force is the combination of these different forces. It is the overall force that the object experiences.

If the net force is zero, the forces are balanced.

If the net force is not zero, the forces acting on the object are unbalanced.

Like all forces, the net force on an object will have a direction; for example, up, down, to the right or to the left.

How to calculate net force

Identify all the forces acting on the object.

- 1 Sketch a diagram showing the strength and direction of these forces.
- 2 Decide how you will describe the direction of the forces (for example, up / down / north / south / forwards / backwards / to the right / to the left).
- 3 If forces are acting in the same direction, add the values of the forces together to calculate the total force in that direction.
- 4 If forces act in opposite directions, subtract the smaller force from the larger one to calculate the net force.
- 5 State the value and the direction of the net force.

For example, Reuben was asked to calculate the net force acting on a ball that had been pushed under the surface of a swimming pool.

The buoyancy force was 30 N, and the force due to gravity was 4 N as shown in Figure 1.8.4.

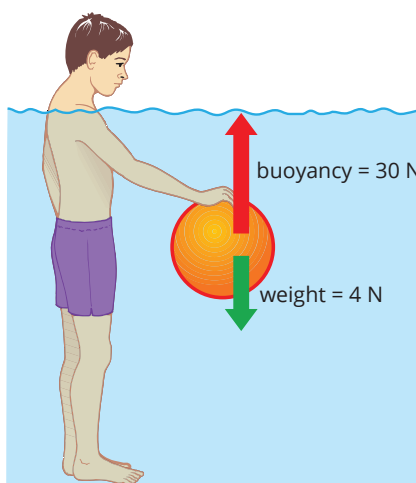


FIGURE 1.8.4 The upwards buoyancy force and the downwards weight force act on the ball.

The forces act up and down in opposite directions, so he calculated the net force by taking the smaller force away from the larger one.

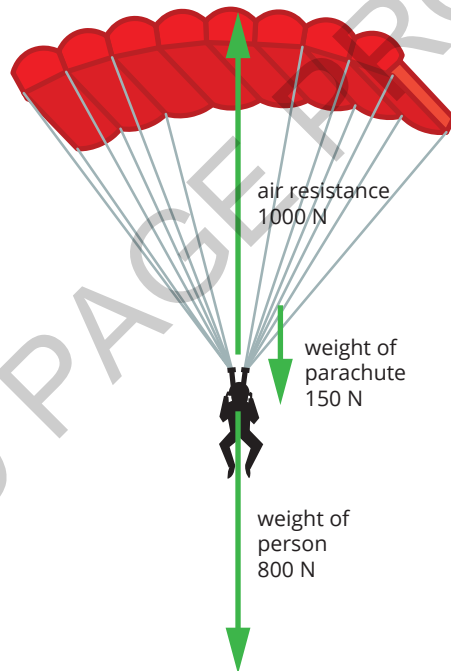
$$\text{net force} = 30 - 4 = 26 \text{ N (upwards)}$$

Worked example

Calculating net force on an object

Consider a parachutist and their parachute falling through the air. The weight of the parachute is 150N, and the weight of the parachutist is 800N. The total air resistance acting on the parachute and the parachutist is 1000N.

Calculate the net force acting on them.

Thinking	Working
Identify all the forces acting on the object.	weight of parachute (150N) weight of the parachutist (800N) total air resistance (1000N)
Draw a force diagram showing the forces acting on the object.	
Add the values of the downward forces together to calculate the total force in that direction.	Total downwards force = $800 + 150 = 950\text{ N}$
Determine the total force acting upwards.	Total upwards force = 1000 N
Determine the net force by calculating the difference between the total upwards and total downwards forces. Note the direction of the largest total force.	Net force = $1000 - 950 = 50\text{ N}$ upwards

Try yourself

A cyclist produces 20N of force to move a bicycle forward. The friction acting against the bike is 10N, and the air resistance caused by a strong headwind is 15N.

Calculate the net force on the bike and cyclist.



FIGURE 1.8.5 Equal and opposite forces act on a student sitting still in a chair.



FIGURE 1.8.6 Although the cyclist may be moving very fast, unbalanced forces are required to make them change velocity (accelerate).



FIGURE 1.8.8 The skydiver will accelerate until they reach terminal velocity.

The effect of the net force on objects

Balanced forces

If the forces on an object are balanced in a given direction, the net force on the object is zero in that direction.

Stationary objects with zero net force

Consider the situation where a zero net force acts on a stationary object. In this situation, the motion of the object will not change—it remains stationary. For example, the student in Figure 1.8.5 does not move up or down because there is a zero net force acting in the vertical direction.

Moving objects with zero net force

If the object is moving, it will stay moving at the same speed and in the same direction because there is no net force to change the motion of the object. This is called constant velocity.

If the force due to gravity acting on the cyclist and bike (Figure 1.8.6) is balanced with friction, there is a net force of zero. They will move down the hill at constant velocity.

Unbalanced forces

When the forces on an object are not balanced, there will be a net force acting on the object. The direction of the net force will cause a change in the motion of the object.

Net force on a stationary object

If the object is stationary, it will start to move in the direction of the net force. The object has accelerated from zero velocity.

For example, the net force on the book (Figure 1.8.7) is 4 N to the right, so the book will start to move to the right.

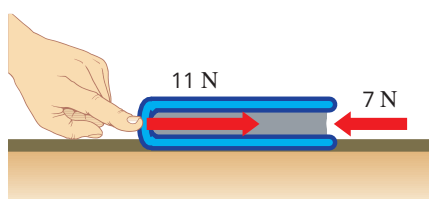


FIGURE 1.8.7 The book will move in the same direction as the larger force.

Object moving in the same direction as the net force

If an object experiences a push or pull in the direction it is already travelling, it will accelerate in the direction of travel.

In Figure 1.8.8, the force due to gravity is greater than the air resistance acting on the skydiver. The net force is acting in the same direction as the movement. Therefore, the skydiver accelerates towards Earth.

Objects moving in the opposite direction to the net force

If an object experiences a push or pull in the opposite direction to which it is travelling, it will decelerate. This means that the object will slow down and possibly stop.

In Figure 1.8.9, the net force on the car is in the opposite direction to its movement. It will decelerate and possibly stop.

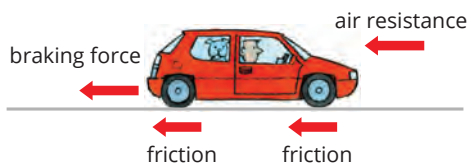


FIGURE 1.8.9 All forces acting on the car are opposite the direction of motion.

Net force acting from the side of a moving object

A moving object experiencing a sideways push or pull, will change direction. This is because the net force causes the object to accelerate in a different direction.

Although it is fired horizontally, the force due to gravity acting on the cannonball causes its motion to be directed towards Earth. The cannonball has changed direction and is accelerating downwards (Figure 1.8.10).

SC 2 CHECK YOUR UNDERSTANDING

Explain how to determine the direction of the net force when multiple forces act on an object.

SC 3 I can explain the concept of terminal velocity when forces are balanced

Some forces that act against the movement of an object, such as air resistance, become stronger as the object travels faster.

If an object is accelerating due to the action of gravity, the object will move faster and faster, and the force acting against the movement will get stronger and stronger.

Eventually, the opposing force (in other words, the air resistance) will become the same strength as the force causing the motion (gravity). At this point, the forces are balanced. The net force is zero.

This can be seen in the graph in Figure 1.8.11.

The object will stay moving at the same speed and in the same direction because there is no net force to change the motion of the object. The speed of the object at this point is called terminal velocity.

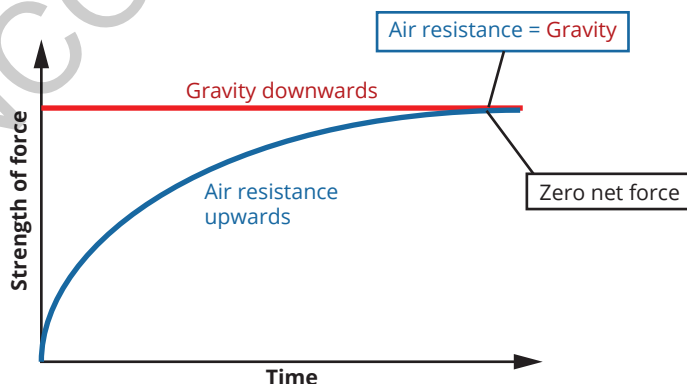


FIGURE 1.8.11 Strength of force over time for an object falling under the effects of gravity

Scifile

Sink or swim

An object in the water has two main forces acting on it: the force due to gravity, which acts downwards, and the buoyancy force, which acts upwards. When the forces are balanced, the object will stay floating. If the forces are unbalanced, the object will sink or rise. This is an important concern for ships, where the maximum load of the ship needs to be calculated carefully. If a ship is accidentally overloaded, it may be at risk of sinking.

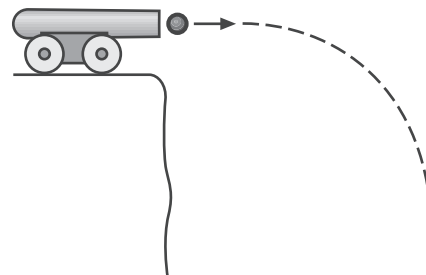


FIGURE 1.8.10 The force of gravity pulling the cannonball down makes it move in a curve.

Terminal velocity of a skydiver

A skydiver will experience terminal velocity as shown in Figure 1.8.12. The smaller the surface area of the skydiver, the faster the terminal velocity.

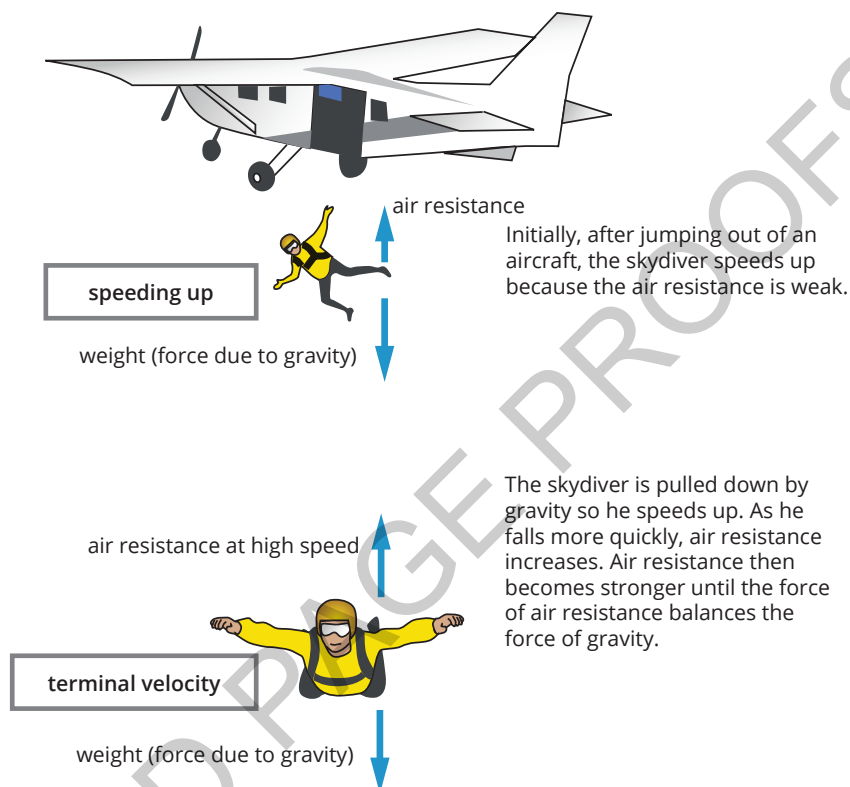


FIGURE 1.8.12 The skydiver reaches terminal velocity when the air resistance is equal in magnitude and opposite in direction to the force due to gravity.

SC 3 CHECK YOUR UNDERSTANDING

Define 'terminal velocity'.

Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 Draw a vector diagram to represent the forces acting on a stationary box on a flat surface.
- 2 Compare vector diagrams of balanced and unbalanced forces acting on an object by describing the length and direction of the force vectors.
- 3 Calculate the net force acting on an object if it experiences a 10N force to the right and a 4N force to the left.
- 4 You are studying the fall of two different objects, a feather and a stone, to understand terminal velocity.
 - a Describe the forces acting on both objects as they fall.
 - b Explain why the feather reaches terminal velocity more quickly than the stone.

1.9

Simple machines: Levers as force multipliers

Lesson overview

Machines are things that make a task easier to do. They can be complex like a car or a computer. They can be simple like a ramp or a wheel. Not all machines involve forces, but many of the ones that do are able to make the output force larger. This means that a relatively small input force can have a relatively large effect, such as the force applied by scissors in Figure 1.9.1.

In this lesson you will learn about how different types of levers can help you to perform tasks more easily.

SC 1 I can identify first-, second- and third-class levers

Components of levers

All **levers** have two main components: a long rigid object, such as a rod, beam, stick or bar, and a point where this long object moves (or pivots) around. This point is called the **fulcrum**.

To understand how a lever works, consider two forces:

- The input force which is applied to the lever. This is called the **effort**.
- The output force from the lever. This force acts on the **load**.

If you can identify the fulcrum, the effort and the load of a lever, as demonstrated in Figure 1.9.2, you can work out what type of lever it is.

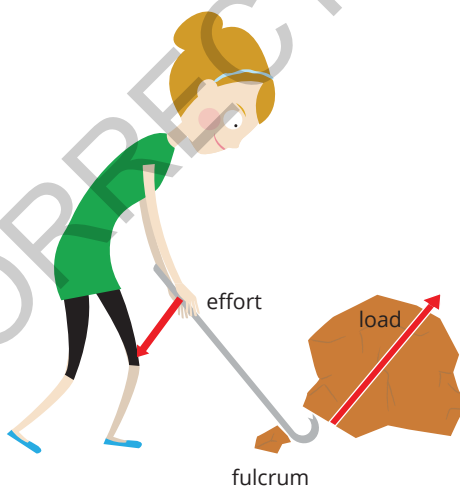


FIGURE 1.9.2 A crowbar acts as a lever; it increases the force you can supply, making it easier to move the rock (the load).

Learning intention

To understand how levers can change the magnitude or direction of a force

Success criteria

SC 1: I can identify first-, second- and third-class levers.

SC 2: I can describe real-life examples of first- and second-class levers being used as force multipliers.

SC 3: I can explain how levers change the magnitude of a force.



FIGURE 1.9.1 A pair of scissors is a simple machine.

KEY TERMS

lever a simple machine consisting of a rigid rod that pivots about a point
fulcrum the point about which a lever pivots
effort a force applied to a lever to overcome the load
load a force, often a weight, on a lever or material

KEY TERMS

first-class lever a lever with effort and loads at each end, and fulcrum in the centre

second-class lever a lever with the fulcrum at one end, the load in the centre, and the effort applied at the other end

third-class lever a lever with the fulcrum at one end, the effort in the centre, and the load at the other end



FIGURE 1.9.4 Wheelbarrows are a common example of second-class levers used to lift heavy loads.

HINTS

The positions of the fulcrum and the forces in the three types of levers can be remembered as:

Eiffel the Elf Fell over

(first-class: Effort Fulcrum Load (EFL); second-class: Effort Load Fulcrum (ELF); third-class: Fulcrum Effort Load (FEL))

Or you can devise your own **mnemonic** (a pattern of letters) to remember the differences between the three types of levers.

First-class levers

In a **first-class lever**, the fulcrum is always between the effort and the load. The effort acts in the opposite direction to the force on the load, as seen in Figure 1.9.3.

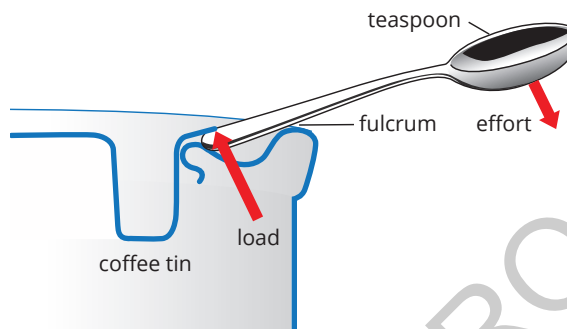


FIGURE 1.9.3 Using a spoon to open a coffee lid is an example of a first-class lever.

Second-class levers

In a **second-class lever**, the fulcrum is always at one end of the lever. The load is closest to the fulcrum, and the effort is further away. In a second-class lever, the effort acts in the same direction as the force on the load as seen in Figure 1.9.4.

Third-class levers

In a **third-class lever**, the fulcrum is always at one end of the lever. The effort is closest to the fulcrum, and the load is further away. In a third-class lever, the effort acts in the same direction as the force on the load as seen in Figure 1.9.5.

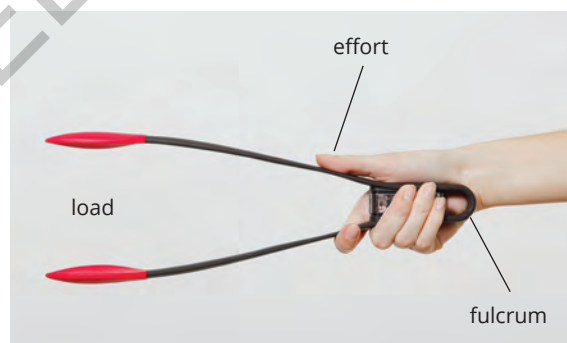


FIGURE 1.9.5 Tongs are a third-class lever as the fulcrum is the furthest point from the load.

SC 1 CHECK YOUR UNDERSTANDING

Explain the difference between a first-class lever, a second-class lever and a third-class lever.

SC 2 I can describe real-life examples of first- and second-class levers being used as force multipliers

Many simple machines, such as levers, can increase the strength of an input force (the effort). These are called **force multipliers**.

First-class levers as force multipliers

A first-class lever can act as a force multiplier by having the distance between the effort and the fulcrum greater than the distance between the load and the fulcrum. In this case, the person in Figure 1.9.6 pushing down on the plank can lift a heavy box. By applying the effort at a greater distance from the fulcrum, less force is required to move a heavy load.

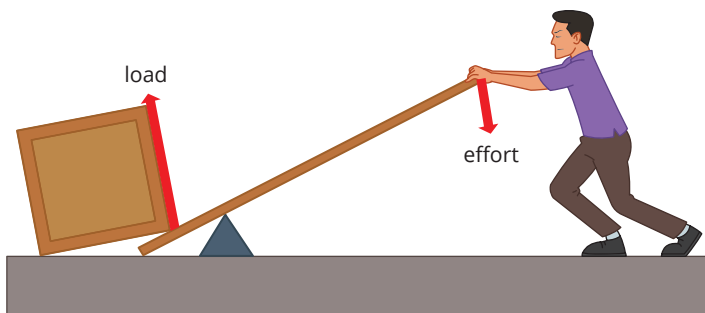


FIGURE 1.9.6 Increasing the distance between the effort and the fulcrum increases the force applied.

Second-class levers as force multipliers

All second-class levers are force multipliers as the effort is always further away from the fulcrum than the load, as seen in Figure 1.9.7.

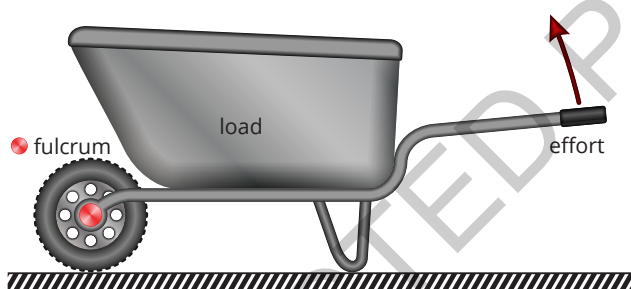


FIGURE 1.9.7 The handle of a wheelbarrow is further from the fulcrum than the load, making it a force multiplier.

Scifile

See-saw science

A see-saw is an example of a first-class lever, as the fulcrum is between the effort (you) and the load (your friend). By sitting further away from the fulcrum while your friend sits closer to the fulcrum, you can lift a friend with less effort. On the other hand, as your friend is closer to the fulcrum than you are it will now take much more effort for your friend to lift you. It is a fun way to see how levers change the magnitude and direction of forces.

SC 2 CHECK YOUR UNDERSTANDING

Describe how a first-class lever can be used as a force multiplier.

SC 3 I can explain how levers change the magnitude of a force

How can a lever increase force?

Force multipliers work by using a weaker force acting over a longer distance to create a stronger force acting over a shorter distance.

For this to happen in a lever, the effort must be further away from the fulcrum than the load.

This means that the effort force will always be acting over a longer distance than the load. This makes the force acting on the load stronger than the effort force.

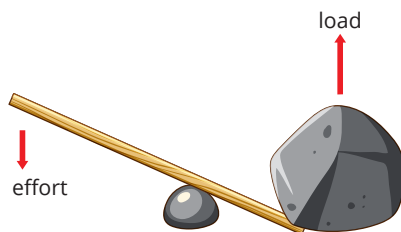


FIGURE 1.9.8 A weaker effort force applied at a greater distance will help move the heavy rock.

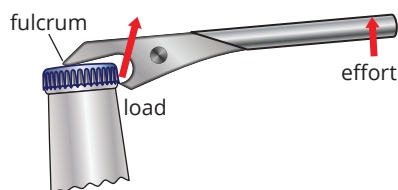


FIGURE 1.9.9 Bottle openers have long handles to open tight bottlecaps with ease.

First-class levers

A first-class lever can act as a force multiplier if the effort force—in this case, the effort pushing down on the pole in Figure 1.9.8—is further away from the fulcrum than the load—in this case, the rock.

Note that a downwards effort (force) changes to an upward force on the load because of the position of the fulcrum.

Second-class levers

All second-class levers are force multipliers since the effort is always further away from the fulcrum than the load. The longer the lever, in this case, the bottle opener, the easier it will be to open the bottle.

Note that in Figure 1.9.9, the fulcrum is where the bottle opener presses down on the bottle top. The load is where the bottle opener lifts the edge of the bottle top. The effort's direction is the same as the force on the load.

Third-class levers

Third-class levers cannot act as force multipliers as the load is always further away from the fulcrum than the effort.

SC 3 CHECK YOUR UNDERSTANDING

Explain why a third-class lever can never be a force multiplier.

Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 Explain how the position of the fulcrum, load and effort determines the type of lever.
- 2 Explain why second-class levers are always force multipliers.
- 3 Compare the ability of first-, second- and third-class levers to act as force multipliers.
- 4 Discuss the advantages of using levers as force multipliers in everyday tasks.

1.10 Investigating force and distance

Introduction

If you have ever sat on a seesaw or seen people on a seesaw, you might know that the distance a person is from the centre of the seesaw (the fulcrum) will change the effect that person has on the balance of the seesaw. For example, a lighter person can balance a heavier person if the lighter person moves further away from the fulcrum (Figure 1.10.1).

In this practical investigation, you will investigate the relationship between the distance of an object from the fulcrum and the effect of that object.

Background

Seesaws are an example of a first-class lever. In first-class levers, the load and the effort (applied force) are on either side of the fulcrum. This experiment uses a model of a seesaw to investigate the relationship between the distance of an object from the fulcrum and the effect of the weight force from that object.

Aim

To investigate how the force required to balance a load on a seesaw is affected as it is moved closer to the fulcrum

Materials

- 1 m ruler
- stiff cardboard square
- 2 plastic cups
- 25×10 g masses (such as slotted masses)
- masking tape
- scissors

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

- 1 Use scissors and a ruler to score two lines so the square piece of cardboard is divided into thirds. Bend the cardboard to make a triangular prism to use as a fulcrum, as shown in the diagram on page xx.
- 2 Tape one of the plastic cups (Cup 1) to the ruler so that the centre of the cup is at the 10 cm mark of the ruler.

Learning intention

To be able to analyse data to identify relationships

Success criteria

SC 1: I can record and process data.

SC 2: I can describe trends in data obtained from modelling a seesaw.

SC 3: I can analyse data to identify relationships between mass and distance from the fulcrum in a lever.

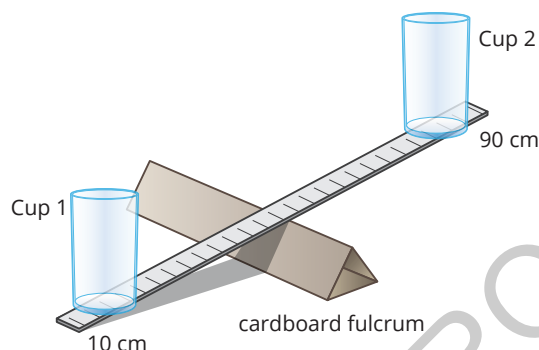


FIGURE 1.10.1 A small child can balance on a seesaw with an adult when the child sits further from the fulcrum than the adult.

HINT

Before you begin, copy the results table below into your notebook. Alternatively, construct a spreadsheet with similar columns.

- 3** Position the ruler so that the fulcrum is half-way along its length. Cup 1 will now be 40 cm from the fulcrum.
- 4** Place Cup 2 on the other side of the seesaw, 40 cm from the fulcrum (this should be at the 90 cm mark).



HINTS

It can be very tricky to get the ruler to balance exactly.

If it will not exactly balance, get it as close as possible to balancing and record the total mass.

HINTS

Always measure the distance from the fulcrum to the centre of Cup 2.

Be careful not to be confused by the measurements on the ruler. They are from the end of the ruler, not the fulcrum.

Throughout the experiment, ensure that the fulcrum is still positioned at the halfway point of the ruler (50 cm mark).

- 5** Add 50 g of masses to Cup 1.
- 6** Add mass to Cup 2 until the seesaw is balanced.
- 7** Record the mass in Cup 2 in your results table or spreadsheet (column 4), and then empty Cup 2.
- 8** Move Cup 2 so that it is 33 cm from the fulcrum (this should be at the 83 cm mark).
- 9** Add masses to Cup 2 until the seesaw is balanced and record the total mass in Cup 2.
- 10** Repeat this process with Cup 2 at 25, 20 and 10 cm from the fulcrum (the 75, 70 and 60 cm marks).

Results

Copy the following table into your notebook and use it to record your results, or record your results in a spreadsheet.

1	2	3	4	5	6
Mass in Cup 1 (g)	Distance of Cup 1 from fulcrum (cm) [D ₁]	Mass in Cup 1 × distance [D ₁]	Mass in Cup 2 (g)	Distance of Cup 2 from fulcrum (cm) [D ₂]	Mass in Cup 2 × distance [D ₂]
50	40			40	
50	40			33	
50	40			25	
50	40			20	
50	40			10	

Conclusion

Write your conclusion to this experiment. Include answers to the following questions.

- 1 Was more or less mass required to balance the load as the effort (Cup 2) moved closer to the seesaw's fulcrum?
- 2 Compare the results in column 3 and column 6 of the results table and describe what you observe.
- 3 Describe a mathematical relationship between the mass required in Cup 2 and the distance of Cup 2 from the fulcrum.

Evaluation

Suggest two improvements to how the data can be measured more accurately in this experiment.

➤ **GO TO**

Toolkit section 4.1, Evaluating investigations

1.11 Action and uses of pulleys

Learning intention

To be able to construct pulley systems and describe their actions

Success criteria

SC 1: I can construct a simple pulley system.

SC 2: I can calculate the force effect of a simple pulley system.

SC 3: I can describe how pulleys are used in everyday life.

Introduction

Pulleys are simple machines that help make lifting heavy objects easier by changing the direction of the effort and, in certain situations, the amount of effort needed. By learning how pulleys work, you can see how they are used in everyday life; for example, in cranes, elevators and even exercise equipment. This will help you understand how simple machines make tasks easier.

In this practical investigation, you will construct a simple pulley system and measure the force needed to lift weights with and without a pulley to determine the force effect of the system.

Background

In this investigation, you will use a compound pulley system. A compound pulley system uses both fixed and movable pulleys (Figure 1.11.1). The movable pulley, with the load attached, reduces the effort needed by sharing the weight between two rope sections. The fixed pulley then changes the direction to make pulling easier.

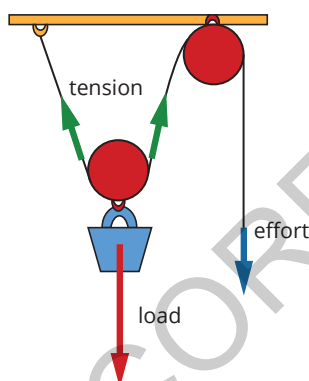


FIGURE 1.11.2 A compound pulley system with load, effort and tension forces labelled

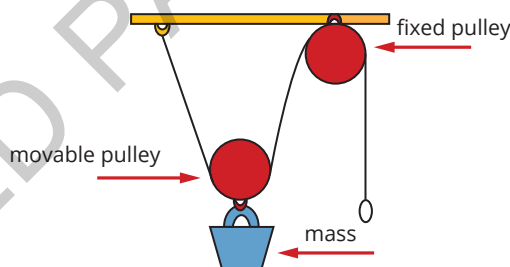


FIGURE 1.11.1 A compound pulley system, showing the movable pulley, fixed pulley and mass (load)

When the load attached to the movable pulley is raised, the load is split evenly between both supporting pieces of rope. One side of the rope is attached to the frame and the other is pulled through the fixed pulley.

This means that as you pull down on the rope through the fixed pulley, the effort force required is approximately half of the load force (Figure 1.11.2).

The trade-off is that to raise the movable pulley 5 cm off the table, you are required to pull 10 cm of rope through the fixed pulley. Thus, you are halving the effort required to raise the mass, but you need to double the distance (length of the rope).

Aim

To investigate how a compound pulley system affects the force needed to lift different masses

Materials

- 2 pulleys
- string
- scissors
- hanging mass
- slotted masses (up to 250 g total mass)
- spring balance (5 N)
- pulley frame or retort stand with clamp

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

- 1 Copy the results table into your notebook.
- 2 Cut a piece of string approximately three times the lifting height of your pulley system.
- 3 Set up the compound system as shown in Figure 1.11.1. You will need to create a loop at the unattached end of the string to attach the spring balance.
- 4 Start with a total mass of 50 g for your hanging mass.
- 5 Measure the force required to lift the mass without the pulley by hooking it directly to the spring balance. Record this in your results table.
- 6 Attach the mass to the movable pulley and insert the hook of your spring balance into the loop at the end of your string.
- 7 Measure how much force is required to lift the mass off the table with your compound pulley system. Record this in your results table.
- 8 Repeat steps 5–7 for 100, 150, 200 and 250 g of mass.

SAFETY NOTES

- ▶ Be aware of falling masses.
- ▶ Keep hair and fingers away from moving pulleys.
- ▶ Use scissors safely and appropriately.

HINT

For more accurate results, keep the string attached to the spring balance as close to vertical as possible.

Results

Record your results in a table like the one shown here.

Mass (g)	Lift force (N)	Pulley force (N)	Force effect
50			
100			
150			
200			
250			

The force effect can be calculated using:

$$\text{force effect} = \frac{\text{lift force}}{\text{pulley force}}$$

Conclusion

- 1 How did the force needed to lift the mass change when using the compound pulley system?
- 2 Was the force effect the same for all masses?

Evaluation

- 1 Why do you think the force effect was not exactly 2.0?
- 2 What could have been done to increase the force effect of the pulley system?
- 3 Where might this type of pulley system be useful in everyday life?

1.12 Simple machines used by First Nations Australians

Introduction

First Nations Australians have developed and used clever technologies for thousands of years. These include various simple machines, such as spear throwers and bows, that make work easier by changing forces. These innovations demonstrate a deep understanding of physics principles among First Nations peoples long before modern scientific explanations were developed.

In this inquiry activity, you will explore how First Nations people use simple machines in their tools and learn how these tools help make tasks easier.

Background

First Nations Australians have used their knowledge of forces and motion to create clever tools and weapons that show how simple machines work. The spear thrower (Figure 1.12.1) is a type of lever that makes the thrower's arm longer, increasing the force and allowing the spear to travel further and faster. Torres Strait Islander peoples created strong bows that store energy when pulled back and release it to send arrows flying. These traditional tools show how simple machines, like levers and other systems, can make work easier—just like wheelbarrows, scissors and bottle openers help in everyday life.



FIGURE 1.12.1 A spear thrower helps throw spears further by working like a longer arm.

Learning intention

To be able to describe the use of simple machines by First Nations Australians

Success criteria

SC 1: I can use a variety of data sources to find information about the use of simple machines by First Nations Australians.

SC 2: I can describe how simple machines used by First Nations Australians alter the direction or magnitude of forces.

Aim

To investigate how First Nations Australians use simple machines to change forces in their traditional technologies, and explain how these machines make work easier

Plan

In this investigation, you will research one traditional tool used by First Nations Australians that demonstrates simple machines in action and create a prototype that demonstrates how the tool changes forces to make work easier. Table 1.12.1 contains some examples to guide your choice. Start brainstorming about how each tool might work as a simple machine.

TABLE 1.12.1 Examples of how First Nations Australians' tools change forces

Tool	Uses
Spear thrower	for hunting larger animals and in combat
Bow	by Torres Strait Islander peoples for hunting birds and smaller animals from a distance
Ground-edge axe	for cutting trees, shaping wood and removing bark to make other tools
Grinding stone	to grind seeds and grains into flour for food
Digging stick	to dig up roots, tubers and small animals for food
Fish trap	to catch fish in rivers and along the coast
Throwing stick	for hunting smaller animals and birds
Fishing spear	to catch fish in shallow waters and streams

Design

- 1 When designing the prototype of your chosen tool, you should research and consider the following.
 - a What is the tool used for?
 - b How is it made?
 - c What is it made from?
 - d How does it demonstrate the properties of a simple machine?
- 2 Identify what available building materials you can use to create your prototype.

Conduct

Create a simple prototype of your chosen tool to demonstrate how it works as a simple machine.

- 1 Build a basic model of your chosen tool.
- 2 Test how it demonstrates force changes.
- 3 Record what does and does not work.
- 4 Take photos or draw diagrams of your prototype.

Assessment of risk

Ensure you are aware of the risks of this inquiry activity and have considered how safety can be improved before carrying out this activity.

Improve

Look at ways to improve how your prototype shows how the tool works as a simple machine.

Evaluate

- 1 What were the most important things you learnt about your chosen tool?
- 2 What was difficult about making your prototype?
- 3 How did making a model help you understand how the tool works?
- 4 What would you do differently if you were to make another prototype?

SAFETY NOTES

- ▶ Make sure your prototype has no sharp edges or points.
- ▶ Keep your prototype small and lightweight.
- ▶ Do not throw or release any parts towards other people.
- ▶ Ask your teacher to check your design before building it.

HINT

Think about the following questions.

- Does your prototype clearly show how forces are changed?
- Is it easy for others to understand how it works?
- What works well?
- What needs improving?

1.13

Action of inclined planes, wedges, wheels, gears and screws

Learning intention

To understand the actions and uses of inclined planes, wheels, gears, wedges and screws

Success criteria

SC 1: I can identify the use of simple machines as force multipliers or distance multipliers.

SC 2: I can describe the benefits of simple machines.

SC 3: I can select an appropriate type of simple machine for a specific task.

Lesson overview

Building on our understanding of levers and their use as force multipliers, we will explore other simple machines that make work easier. For example, when you ride a bike, you use wheels and gears to make pedalling easier (Figure 1.13.1).



FIGURE 1.13.1 Mountain bikes have different gears to help riders get over difficult terrain.

In this lesson, you will learn about different types of simple machines such as inclined planes, wheels, gears, wedges and screws. You will explore how they work, their benefits, and how to choose the right type of simple machine for various tasks.

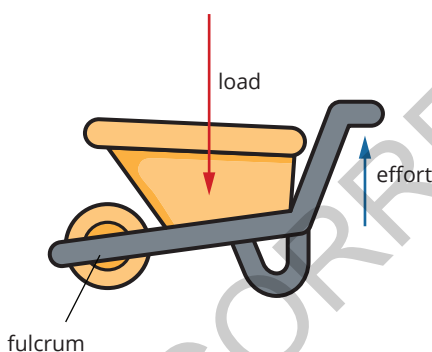


FIGURE 1.13.2 Less effort needs to be applied to a wheelbarrow (a second-class lever) to lift a heavy load.

SC 1 I can identify the use of simple machines as force multipliers or distance multipliers

Simple machines as force multipliers

Simple machines can act as force multipliers, meaning they allow us to apply a smaller force over a greater distance to achieve the same amount of work. We previously learnt that first- and second-class levers can act as force multipliers. The effort can be applied at a greater distance from the fulcrum than the load, making it easier to lift heavy objects (Figure 1.13.2).

Force multipliers in simple machines allow us to apply a smaller force over a longer distance. This means less effort is required, but the amount of work done is the same. If effort decreases, the distance over which it is applied must increase.

Wedges

A **wedge** is a tool with a sharp, pointed edge that can cut or split objects such as a log (Figure 1.13.3). When you push a wedge into something, it spreads the multiplied force over a small area, making it easier to cut or split materials.

Note that the vertical distance the wedge has been driven into the log is greater than the horizontal distance it has split the log, so although the applied force has increased, the distance has reduced.

Inclined planes

Inclined planes are ramps that let you move objects over a longer distance with less force (Figure 1.13.4). Pushing an object up a gentle slope, such as the ramp of a removal truck, requires less effort to move the object to a greater height than lifting it.

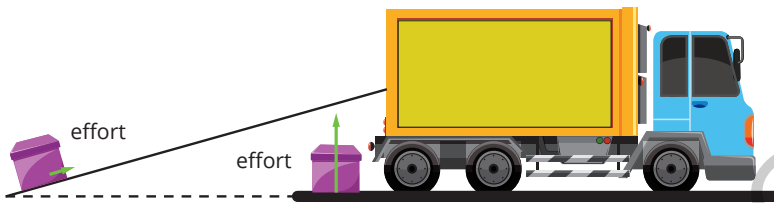


FIGURE 1.13.4 Using a ramp means less effort is required to load a heavy box into a removal truck.

Screws

The threads on a **screw** are like ramps (inclined planes) wrapped around a pole (Figure 1.13.5). When you turn a screw, it pushes into materials or lifts objects with less effort because the threads grip onto the material and spread the force. They also change the direction of the force, as the screw is rotated to move it into the material.

Scifile

Australian innovations in vertical lift machines

Australia has a rich history of innovation in vertical lift machines. Propellers are a type of screw where the inclined planes push against the air as the propeller rotates, generating lift. Engineers and researchers have developed various technologies for vertical take-off and landing (VTOL) aircraft. These machines can hover, take off and land vertically, making them ideal for moving around towns and cities, and search and rescue operations.

One recent example of Australian aerodynamic innovation is Project Vertiia. Vertiia is powered by hydrogen and is being researched in conjunction with CSIRO.

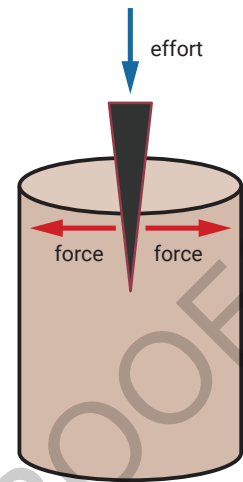


FIGURE 1.13.3 A wedge being driven into a large log to split it in two

KEY TERMS

wedge a double inclined plane that moves through another object, changing the direction of force

inclined plane a simple machine that reduces the effort needed to lift a load by increasing the distance through which it acts

screw a metal shaft with grooves (threads) winding around its surface

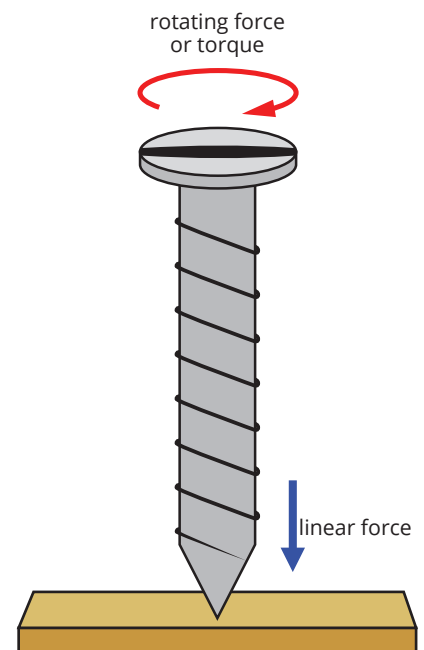


FIGURE 1.13.5 A screw being driven into a plank of wood

KEY TERM

distance multiplier a mechanism or system that applies a larger force over a shorter distance to move an object a longer distance

Simple machines as distance multipliers

Simple machines can also act as **distance multipliers**, which means they can move an object a greater distance by applying a larger force over a shorter distance. If the distance increases, the initial force required must also increase as the amount of work done remains the same.

It is important to note that simple machines can be force or distance multipliers depending on the scenario.

Inclined planes

Inclined planes, such as ramps, can act as distance multipliers. For example, consider a team of removalists who start sliding boxes down the ramp instead of using a trolley. More initial effort is required if they use a long ramp with a low slope, but the boxes will also travel a greater horizontal distance before reaching the ground. If they use a steep, short ramp, then less initial effort is needed, but the box will travel a shorter horizontal distance (Figure 1.13.6).

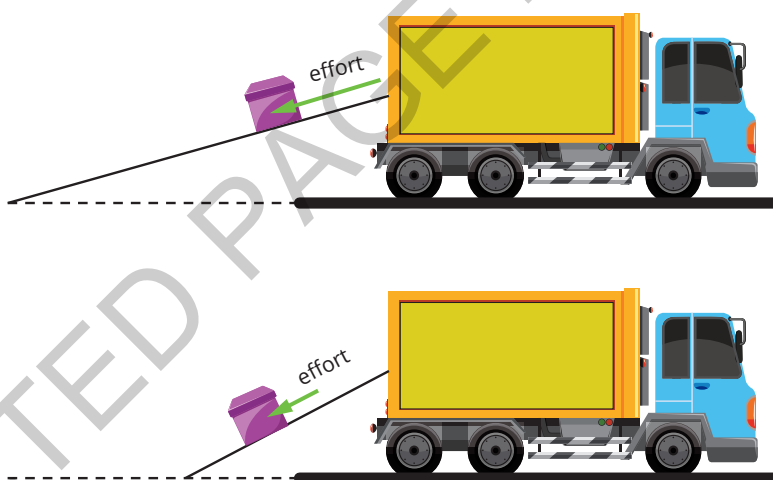


FIGURE 1.13.6 Using a long, low ramp means more initial effort is required, but the distance the box travels is multiplied.

KEY TERMS

wheel a type of lever with an axle acting as its fulcrum
gear a wheel with teeth used to turn another gear wheel

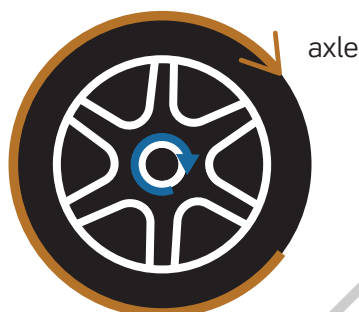


FIGURE 1.13.7 One rotation of the axle is one rotation of the wheel, but the wheel can cover a greater distance.

Wheels

Wheels connected to an axle allow objects to move further when a stronger initial effort is used. The wheel is much larger than the axle, so one rotation of the axle results in a full rotation of the wheel, and a longer distance is covered (Figure 1.13.7). The larger the wheels, the greater the distance covered (and more effort is required to rotate the axle).

Gears

Large **gears** driving smaller gears act as distance multipliers by increasing the distance an object moves with a greater initial effort. Large gears rotate slowly, and smaller connected gears rotate faster because of their smaller size, increasing the distance connected objects can move (Figure 1.13.8). If the order is reversed (the small gear driving the larger gear), then the gears act as a force multiplier.

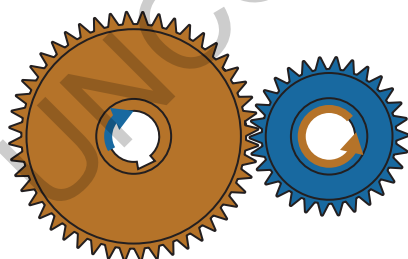


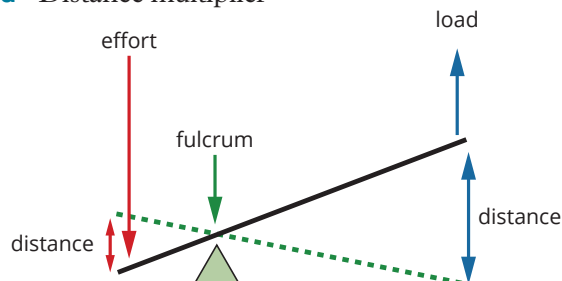
FIGURE 1.13.8 The large gear makes the smaller, connected gear rotate faster.

Simple machines as distance multipliers and force multipliers

As shown with the ramp example, simple machines can be distance multipliers or force multipliers depending on how they are used.

For example, consider a first-class lever such as a seesaw. When the fulcrum is closer to the effort, the lever works as a distance multiplier (Figure 1.13.9a). This is because a greater effort is required, but the load can be moved a higher distance. When the fulcrum is closer to the load, the lever works as a *force* multiplier (Figure 1.13.9b). The effort has to be applied over a greater distance to move the load a smaller distance, but a smaller effort can lift a heavier load.

a Distance multiplier



b Force multiplier

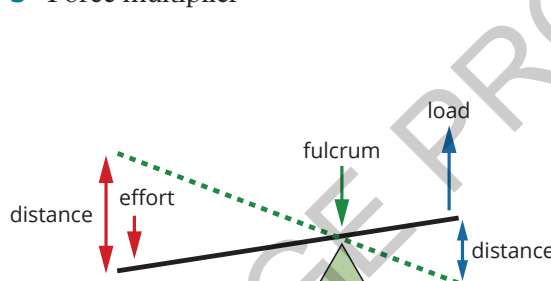


FIGURE 1.13.9 (a) When the fulcrum is moved closer to the effort, the lever can be used to multiply distance. (b) When the fulcrum is moved closer to the load, the lever can be used to multiply force.

SC 1 CHECK YOUR UNDERSTANDING

A simple machine is made with a small gear that is used to rotate a larger gear. Identify whether this machine is acting as a force multiplier or a distance multiplier.

SC 2 I can describe the benefits of simple machines

Simple machines make work easier in our everyday lives in several ways.

Decreasing required force

One of the main benefits of simple machines is that they can reduce the amount of force needed to perform a task. By using a simple machine, you can apply less force, which reduces the physical effort required. For example, opening a macadamia nut is practically impossible with your bare hands. Using a nutcracker makes the task significantly easier (Figure 1.13.10).

Increasing distance or speed

Another benefit of simple machines is that they increase the distance over which force is applied. This principle is particularly useful in transportation and manufacturing where increased speed or distance of movement is important. For example, the gears on a fishing rod mean a small movement with the hands can reel in a longer length of line (Figure 1.13.11).



FIGURE 1.13.10 Opening the hard shell of a macadamia nut is made easier with a lever.



FIGURE 1.13.11 Reeling in a fishing line is made easier with gears.

Change in force direction

Simple machines can change the direction in which a force acts. This means you can push or pull in the direction that is easiest for you, and the machine will make the force work in the direction you need. This can make jobs much easier to do. For example, a car jack can turn rotational motion into an upwards force to lift a car while changing the tyres (Figure 1.13.12).



FIGURE 1.13.12 A small rotational force on a car jack can apply a strong upward force on the car, lifting it off the ground.



FIGURE 1.13.13 The focus knobs on a microscope convert large movements of the knob into much finer movements of the lens.

Making precise movements

Simple machines help us make very careful, exact movements. Sometimes a big movement at one end creates a small, precise movement at the other end. This helps us do detailed work more easily. An example of this in the science classroom is the focus knobs on microscopes, which use screws for precise adjustments (Figure 1.13.13).



FIGURE 1.13.14 The thread at the top of a jar uses a small rotational force to secure the lid.

Holding things in place

Simple machines are great at preventing things from moving. They can convert a small holding force into a much stronger one that keeps things steady and secure. For example, jar lids can be screwed tightly in place (Figure 1.13.14).

SC 2 CHECK YOUR UNDERSTANDING

Describe the benefit of using a wheel and axle system for transport.

SC 3 I can select an appropriate type of simple machine for a specific task

Choosing the right type of simple machine for a specific task depends on the nature of the task and the desired outcome. For example, if you need to lift a heavy object, a lever may be the best choice. If you need to move an object to a higher elevation, an inclined plane may be more suitable. An overview of some of the uses of each type of simple machine is shown in Table 1.13.1.

TABLE 1.13.1 An overview of the uses of simple machines

Simple machine	Uses and benefits	Example
Inclined plane	• moving heavy things up or down • where there is plenty of space • when smooth movement is needed • when the load needs to stay stable	
Wheel	• moving things long distances • when you need smooth motion • reducing friction • converting rotation direction	
Screw	• when space is limited • when you need precise adjustment • when you need strong holding power • converting spinning to straight movement	
Wedge	• splitting or separating • converting force direction • when strong force is needed • simple, low maintenance needs	
Gear	• changing speed or force • when you need precise control • regular repeated motion • power transfer between moving parts	

Selecting the right simple machine can make everyday tasks easier. If you need to move a heavy object up a height, an inclined plane is the best choice. The inclined plane reduces the force needed to move the object, making it easier to transport. However, if space is limited, something with vertical movement like a scissor lift platform that uses screws would be more appropriate (Figure 1.13.15).



FIGURE 1.13.15 Scissor lift platforms are used to access the tops of tall buildings.

SC 3 CHECK YOUR UNDERSTANDING

Select a simple machine that would be most effective for splitting wood. Justify your answer.

Lesson review

Use these questions to check your understanding of the learning intention and success criteria for this lesson.

- 1 Identify a simple machine that can be used as a force multiplier. Justify your response.
- 2 Describe an advantage of using gears in machinery.
- 3 Describe a scenario where a screw could be applied to move an object.
- 4 Describe a scenario where multiplying distance would be useful.
- 5 Select a simple machine that would be most appropriate for raising a flag on a flagpole and explain your choice.

1.14 Using ramps

Introduction

Ramps are one real-world application of inclined planes. Ramps allow you to use less force by moving a longer distance.

In this practical investigation, you will measure how the force needed to move a trolley changes when using ramps of different angles.

Background

People have been using ramps for thousands of years to make work easier. We see them everywhere today—helping people in wheelchairs get into buildings, moving boxes into trucks and even on driveways. By testing how ramps work, we can learn how to use them better.

Aim

To measure the force required to lift a cart vertically and to lift it using ramps of different slopes

Materials

- trolley
- spring balance (or force sensor)
- several books or a couple of blocks or bricks to elevate ramp
- wooden ramp
- meter ruler
- protractor

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

- 1 Copy the results table into your notebook.
- 2 Position a plank of wood on a pile of books (or a brick and some books) to make a ramp that is about 10 cm high, as shown in Figure 1.14.1.
- 3 Attach the trolley to a spring balance (or force sensor). Carefully lift it vertically until it is no longer touching the table. Record this weight as the load force in your results table.
- 4 Measure the angle of elevation of the ramp and the distance from its base to the pile of books. Record these values in the table.
- 5 Slowly and smoothly drag the trolley up the ramp to the pile of books. Record the effort force required.

Learning intention

To be able to investigate how ramps affect the force required to raise an object

Success criteria

SC 1: I can record accurate measurements from an experiment that uses ramps.

SC 2: I can compare and explain the effects of different ramps.

SC 3: I can apply the learning from an experiment involving ramps to a real-world context.

SAFETY NOTE

- Falling books and bricks can cause injury.

- 6 Repeat steps 4 and 5 for four different angles of the ramp. Measure the angle, new ramp length and effort force each time.

HINTS

- Keep the trolley moving at a steady speed when measuring force.
- Make sure your spring balance reading is stable before recording.
- Record all measurements immediately in your table.

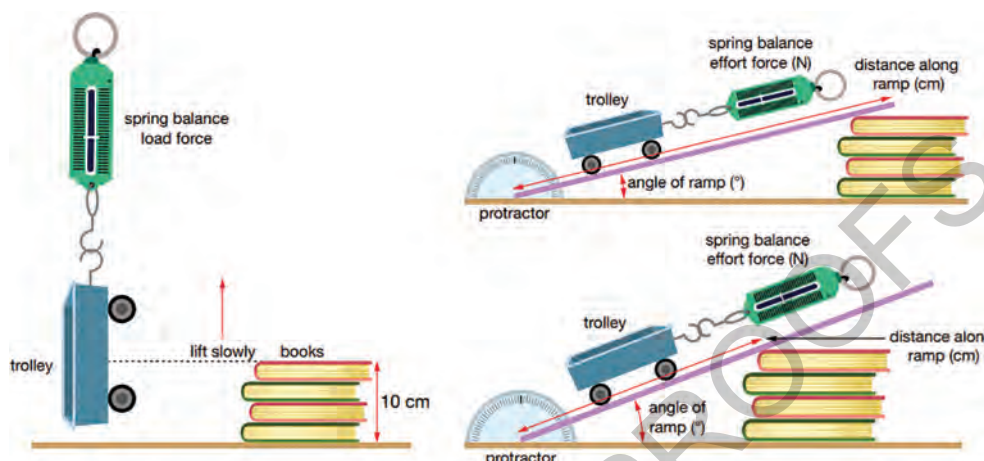


FIGURE 1.14.1 Experimental set-ups

Results

Record your results in a table like the one shown here.

Ramp angle (°)	Ramp length (cm)	Effort force (N)
Load force (N):		

Conclusion

- 1 Which ramp required the greatest effort force?
- 2 Explain your answer to question 1, considering how the length of the ramp varied with the changing angle.
- 3 List three situations when using a ramp at a shopping centre is useful.

Evaluation

- 1 What made it hard to get accurate measurements in this experiment?
- 2 How could you improve the experiment to get better results?

1.15 Investigating simple machines on a bicycle

Introduction

A bicycle is a complex machine made up of many simple machines working together. Levers help us brake and steer, wheels and axles help us move smoothly, and gears help us pedal more easily.

In this practical investigation, you will identify different simple machines on a bicycle and measure how gear combinations affect the way the bicycle works.

Background

Bikes involve several types of simple machines:

- The handlebars, pedals (crank) and handbrakes are levers that are force multipliers.
- The axle and wheel are distance multipliers, which makes movement easier.
- The gears allow cyclists to trade force for speed or speed for force, making it easier to ride under different conditions.

Aim

To examine the gearing combinations of a bicycle and identify the simple machines that make it work

Prediction

- 1 Which gear combination will make the back wheel turn the most number of times for a single rotation of the pedals?
- 2 Which gear combination would be best for riding up a steep hill?
- 3 Where would you find examples of levers on a bicycle?

Materials

- geared bicycle
- bike maintenance stand (or two stools and a broom handle)
- piece of chalk

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

- 1 Copy the results tables into your notebook. Alternatively, construct a spreadsheet with similar columns.
- 2 Look for and list all the levers you can find on the bicycle.

Learning intention

To be able to investigate the simple machines used in a bicycle

Success criteria

SC 1: I can identify and classify types of levers on a bicycle.

SC 2: I can identify and describe the use of wheels and axles on a bicycle.

SC 3: I can calculate the gear ratio for a range of sprocket combinations on a bicycle.

SAFETY NOTE

- ▶ Keep fingers away from moving parts of the bike.

HINT

Turn the pedals slowly when counting wheel rotations.

- 3 Identify whether the levers are first- or second-class levers. Record this in your results table (Table 1).
- 4 Lift the rear of the bicycle off the ground and place it in the bike maintenance stand or support it with a broom handle resting across two stools or benches, as shown in Figure 1.15.1. You may need to ask a friend to hold the front of the bike to keep it stable.
- 5 Select a gear where the front wheel is on the smallest sprocket and the rear wheel is on the largest sprocket.
- 6 Count the number of teeth on the front and rear sprockets and enter this data in Table 2.
- 7 Make a mark with chalk on the rear tyre. Slowly turn the pedals one revolution and count how many revolutions the rear wheel makes in this time.
- 8 Record this data in the first row of your table.
- 9 Repeat steps 5–8 for another four gear combinations.

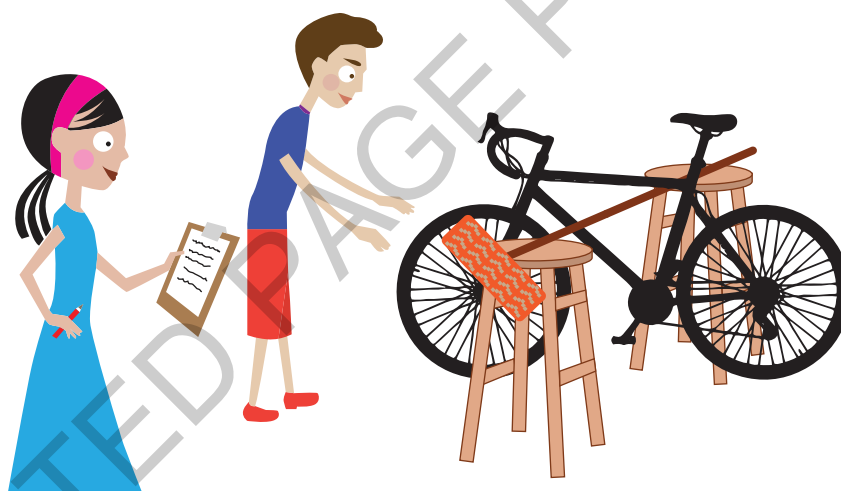


FIGURE 1.15.1 The experimental set-up

Results

Record your results in tables like the ones shown here.

TABLE 1 Lever identification

Lever location	Lever classification

TABLE 2 Gear ratio

Gear combination	Front teeth	Rear teeth	Wheel turns	Gear ratio
1 (low)				
2				
3				
4				
5				

Calculate the gear ratio by using formula:

$$\text{gear ratio} = \frac{\text{number of front teeth}}{\text{number of rear teeth}}$$

Conclusion

- 1 How do the different levers make controlling the bike easier?
- 2 Identify which gear combination is best suited for riding:
 - a uphill
 - b along a flat, easy road.

Use your results table to justify your choices.

- 3 Why are wheels and axles important on a bicycle?

Evaluation

- 1 How could this investigation be improved?
- 2 How do simple machines make cycling easier?

HINT

Recall that in first-class levers, the fulcrum is between the effort and the load (EFL), in second-class levers, the load is between the effort and the fulcrum (ELF), and in third-class levers, the effort is between the load and the fulcrum (FEL).

HINT

Consider what gear ratio would make it easier to move a heavy bike up a hill.

Remember, levers work as force multipliers, whereas wheels and axles work as distance multipliers.

1

Forces and motion

Topic summary

The key concepts included in this topic are:

- Force is measured in newtons (N) and forces can be classified as contact or non-contact forces. Forces can be represented on force diagrams using the size and direction of the arrow.
- If the forces acting on an object are balanced, the object will continue being at rest or moving at a constant speed. If the forces acting on an object are unbalanced, the object will speed up, slow down or change direction.
- Friction is caused by microscopic bumps in the surfaces of touching objects, which act to oppose the direction of motion.
- Levers can be categorised depending on where the effort, fulcrum and load is located. Increasing the distance between the effort and the fulcrum of a lever can magnify the effect of the applied force.
- Pulleys help lift objects by changing the direction of the applied force. Multiple pulleys can be used to magnify a force.
- Inclined planes reduce the force needed to lift objects by increasing the distance over which the force is applied.
- Wheels reduce friction and make it easier to move objects over longer distances.
- Gears are used to transfer motion and force, allowing for changes in speed and direction.
- Wedges are often used for cutting or splitting, by changing a downward force into a sideways force.
- Screws are inclined planes wrapped around a cylinder, which convert rotational force into linear motion.
- First Nations Australians have historically used simple machines, such as levers and wedges, to alter the direction or magnitude of forces.
- Bicycles use a combination of simple machines, including levers, wheels and gears.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

- 1 State the unit of measurement for force.
- 2 What class of lever is a spear thrower?
- 3 Define frictional force.
- 4 Describe the relationship between distance and force for an inclined plane.
- 5 Define the term 'trend' when analysing experimental data.

Understand

- 6 Explain how the length of a force arrow relates to the magnitude of the force.

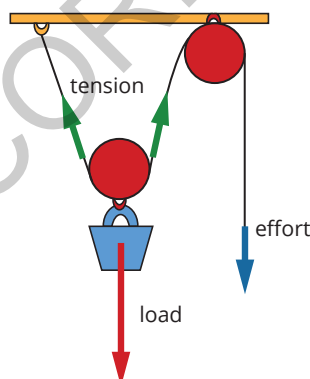
- 7 State the difference between contact and non-contact forces and provide examples of each.
- 8 A bicycle has a 52-tooth chain wheel and a 13-tooth rear sprocket.
 - a Calculate the gear ratio.
 - b Describe the effect this gear combination has on the rear wheel.
- 9 Explain the importance of controlling variables in an investigation. Refer to the reliability of the collected data in your response.

Apply

- 10** Compare the ability of first- and second-class levers to act as force multipliers.
- 11** A folder initially at rest on a table experiences an applied force of 10 N right and a frictional force of 5 N left.
- Draw a force diagram of the applied force and frictional force acting on the folder.
 - Calculate the net force acting on the folder.
 - Determine if the forces are balanced or unbalanced.
 - Identify what will happen to the motion of the folder.
- 12** Propose a hypothesis about the relationship between mass and friction.

Analyse

- 13** Frictional forces play a significant role in motion.
- Explain how frictional forces are important in everyday activities such as walking or driving.
 - Compare the presence of frictional forces when walking on grass to walking on a smooth surface such as ice.
 - Outline an investigation that could be undertaken to test the effect of frictional forces from different surfaces.
- 14** The compound pulley system below multiplies the force on the load as well as changing the direction of the force. Modify this system so that it multiplies force without changing the direction of the force.

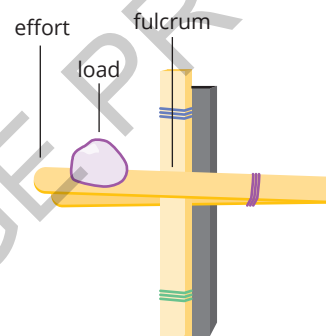


Extension: Design a device

- 15** Catapults are medieval weapons that allow heavy objects to be thrown great distances. They are an example of a force-multiplying lever, as the effort is applied at a greater distance from the fulcrum than the load.

For this extension task, you will design your own catapult using ice-cream sticks, elastic bands and cotton balls.

Make the catapult shown in the image below. Test your device before continuing and make any final adjustments to your elastic bands.



- Arrange your device so the fulcrum is in the centre of your ice-cream sticks. Launch your cotton ball and record the distance travelled.
- Adjust the elastic bands to change the distance between the effort and the fulcrum. Compare the distance between the effort and the fulcrum to the distance your cotton ball travels. Record any pattern in your data.
- Make additional tweaks to the design to explore ways to increase the launch distance of your catapult. Document any changes you make.
- Compete with other students in your class to see who designed the catapult with the greatest launch distance. You might even explore other parameters, such as the stability of the catapult designs.

Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

1

Glossary

acceleration increase in speed (verb: accelerate)

air resistance friction that acts on an object moving through the air

balanced forces forces acting on a single object where the force in one direction is equal to the force applied in the opposite direction

cause-and-effect relationship a relationship between two variables in which changes to one variable is the reason for changes to the other

constant velocity the movement of an object at the same speed and in the same direction

contact force a force that acts between two objects that touch each other

deceleration decrease in speed (verb: decelerate)

distance multiplier a mechanism or system that applies a larger force over a shorter distance to move an object a longer distance

drag force a force created by an object moving through a gas or liquid

effort a force applied to a lever to overcome the load

first-class lever a lever with effort and loads at each end, and fulcrum in the centre

force any interaction that will change the motion of an object when unopposed; for example, a push or a pull

force diagram a diagram that uses arrows to show one or more forces acting on an object

force multiplier machine that increases the force applied for a task, such as a second-class lever

friction a force that acts against an object's motion

fulcrum a point about which a lever pivots

gear a wheel with teeth used to turn another gear wheel

gravitational force the force on an object due to gravity; can be described as the 'weight' of an object

inclined plane a simple machine that reduces the effort needed to lift a load by increasing the distance through which it acts

lever a simple machine consisting of a rigid rod that pivots about a point

load a force, often a weight, on a lever or material

magnitude a measure of the size or strength of something

net force the combination of multiple forces acting on a single object; also called resultant force

newton (N) the unit used to measure force

newton meter a device used to measure the strength of a force; often called a spring balance

non-contact force a force that acts on an object from a distance

point of reference something that is used for comparison

preliminary trial a trial of an experiment used to test a method

screw a metal shaft with grooves (threads) winding around its surface

second-class lever a lever with the fulcrum at one end, the load in the centre, and the effort applied at the other end

speed the rate of change of distance

third-class lever a lever with the fulcrum at one end, the effort in the centre, and the load at the other end

unbalanced forces forces acting on a single object where the force in one direction is not equal to the force applied in the opposite direction

vector a quantity that has magnitude and direction

vector diagram a graphic that uses arrows to represent the effect of one or more vectors

velocity the speed and direction of an object

wedge a double inclined plane that moves through another object, changing the direction of force

wheel a type of lever with an axle acting as its fulcrum