Working with scientific data

1

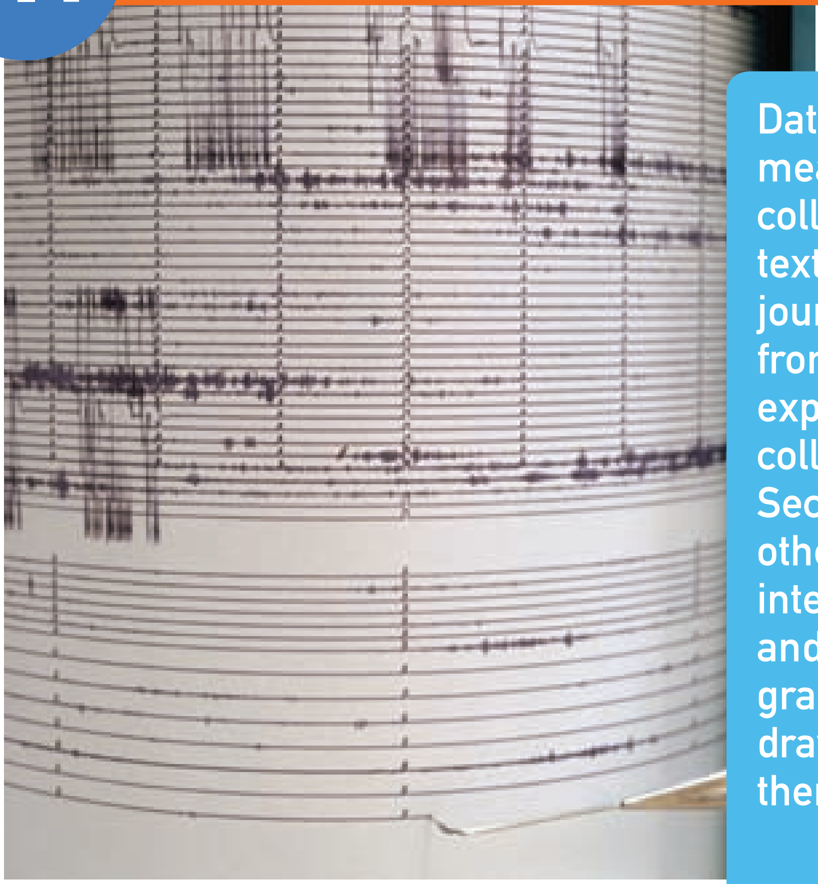
HAVE YOU EVER WONDERED…

- what the difference is between a mistake and an error?
- why scientists take multiple measurements?
- what the .com, .au, .org or .edu at the end of a website address means?

After completing this chapter students should be able to:

- construct graphs, keys and models to represent and analyse patterns or relationships
- apply strategies and techniques for effective research using secondary sources, including use of the internet
- use digital technologies to access information
- identify controlled, dependent and independent variables
- identify scientific problems to investigate
- work collaboratively to assess how best to approach an investigation.

1.1 First-hand data



Data is all the information and measurements that are collected by scientists from textbooks, encyclopedias, journals and the internet, or from carrying out their own experiments. First-hand data is collected from experiments. Second-hand data comes from other sources such as the internet. Scientists collect data and organise it into tables and graphs. They analyse the data, draw conclusions from it and then write it all up so that other scientists can understand it.

Data

Data is the term given to all the observations and measurements that can be used to describe something. For example, you could be described by your personal data. This would include your height and weight, your hair, skin and eye colour, distinguishing features (such as a scar, birthmark or severely broken nose), when and where you were born and the names of your parents. Data on the parrot in Figure 1.1.1 would include its colour and sex.

Types of data

Much of the data you find will be measurements that are written as numbers with units attached to them. This type of data is known as **quantitative data**. Other data can only be described in words. This data is **qualitative data**. Take as an example data about Mt Kosciuszko in New South Wales shown in Figure 1.1.2.

Figure 1.1.1

Data on this parrot would include its size and mass, the environment it lives in, what it eats, its body temperature, the number of tail feathers it has, the average number of eggs it lays, the type of nest it uses and the age at which it first flies.

Figure 1.1.2 Mt Kosciuszko is 2228 metres high (an example of quantitative data) and its main rock type is granite (an example of qualitative data).

- Quantitative data include its coordinates (36°27´S, 148°16´E), its height (2228 metres above sea level) and average temperatures (–6°C in July, 21°C in January).
- Qualitative data include its Aboriginal name (Tar-Gan-Gil), rock type (granite), the animals that live there (wombats, spotted-tailed quoll, pygmy possum, corroboree frog, flame robin, mountain galaxia and wingless grasshopper) and the wildflowers found there (alpine stackhousia, hoary sunray and snow beard heath).

Data can also be classified according to where you obtain it from.

- **First-hand data** is data that you or your practical team personally find out by running your own experiments. Any measurements that you take are first-hand data.
- **Second-hand data** is data that comes from work of other people. Second-hand data is the measurements and information that you find on the internet, TV, DVD and video, encyclopedias and textbooks, newspapers and magazines. Second-hand data can also be obtained by interviewing experts.

SciFile

A near disastrous mistake!

In 2009, an Airbus A340/500 jet was taking off from Melbourne with 275 people on board bound for Dubai. It ran out of runway, scraped its undercarriage, shattered a landing light and only just missed the boundary fence. It's suspected that the pilots mistakenly entered a wrong number into the on-board computer, making the plane 'think' that it was 100 tonnes lighter than it really was!

Collecting your own data

You can generally trust first-hand data since you collected it yourself from experiments that you ran. If the data is wrong, then it's probably because you made a mistake.

Mistakes are things that can be avoided if you take a little more care. Mistakes happen whenever you spill material, use the wrong equipment (or the right equipment wrongly), carelessly read an instrument or incorrectly write or copy the measurement down. All these are obvious mistakes since all are careless and can be easily avoided.

Errors are not mistakes. Errors are small and unavoidable variations that naturally occur in measurements. Errors will always happen no matter how careful you are. This means that nothing is exact—even 'accurate' measurements have small variations and errors in them.

Some common forms of errors are:

- **parallax error**—your eye can never be exactly over the marking of a measuring device. Everyone looks at markings at slightly different angles so everyone will take slightly different readings. This is shown in Figure 1.1.3.

SciFile

Discovery by mistake

Mistakes and accidents have led to some important scientific discoveries including an artificial sweetener (saccharine), the first antibiotic (penicillin) and the first plastic (Bakelite). Accidental discoveries have also changed the way we use products. Coca-Cola® and Viagra® both started off as relief for headaches and microwave ovens started off as radar!

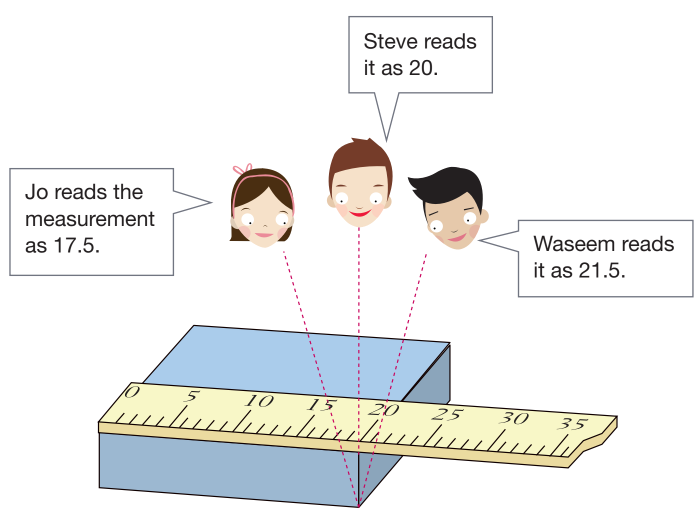


Figure 1.1.3 Parallax errors can be reduced by keeping your eye in line with the measurement.

- **reading errors—**measurements often fall between the markings of a measuring device. So you need to estimate your measurement as shown in Figure 1.1.4.

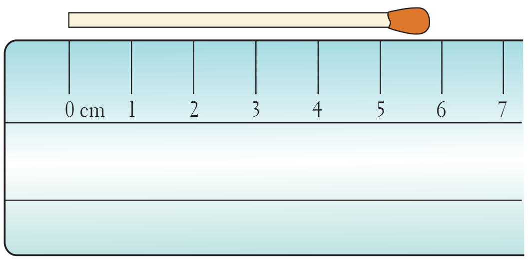


Figure 1.1.4 This match is not quite 6 cm long, but is it 5.7, 5.8 or 5.9 cm?

- **instrument errors**—sometimes an instrument may be faulty and will never give the right reading. Some instruments give correct readings only at certain temperatures and will give small errors if used at any other temperature. For example, a metal ruler expands when hot, pushing its markings further apart. As Figure 1.1.5 shows, this makes measurements taken on a hot day slightly smaller than those made on a cold day.

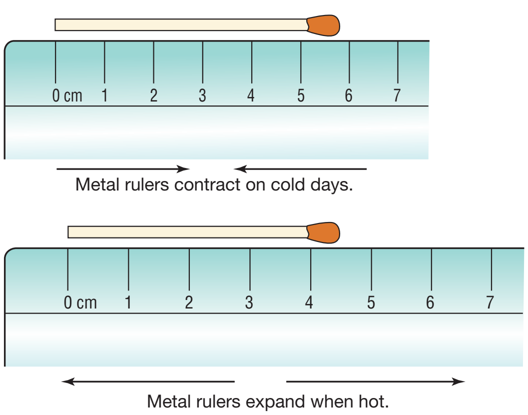


Figure 1.1.5 Metal rulers give different measurements on different days. Although exactly the same, this match will appear 'longer' on cold days.

- **human reflex**—a stopwatch typically reads to one-hundredth of a second (0.01 second). The best human reaction time is around 0.110 second and so stopwatches are much more accurate than us. Everyone has different reflex times and so everyone will measure times slightly differently when using a stopwatch.

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- **zero errors**—an instrument such as a beam balance or electronic balance should read zero when nothing is placed on it. If it doesn't read zero, then everything you measure will be a little out and all measurements will have a zero error. Balances can usually be adjusted to read zero once more.

SKILL BUILDER

Tare

When you **tare** an electronic balance, you are re-setting it to read zero when something like a beaker is placed on it (Figure 1.1.6). You can then add material without having to worry about the mass of the beaker since it has already been subtracted from the total mass.

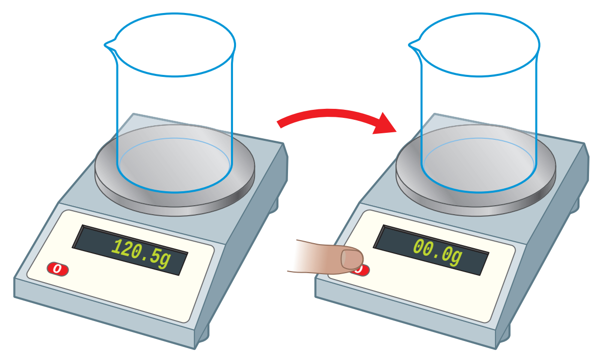


Figure 1.1.6 The tare button on an electronic scale re-sets its zero so that you don't have to worry about the mass of the beaker that is on it.

Improving first-hand data

Errors always exist and each person in a team will probably take slightly different measurements of exactly the same quantity. No-one is wrong (unless they made a mistake) and everyone's measurement is 'correct'.

One easy way of improving the accuracy of your data is to repeat your measurements. For example, each member in your practical team could take the same measurement so that they can be compared and obvious mistakes eliminated. Once a collection of different measurements is taken, an **average** or **mean** can be obtained.

2 p10

A little give and take

It is useful to write measurements with an estimation of how big the error might be. Scientists allow a little 'give and take' by showing the error as ± (standing for 'plus or minus').

Figure 1.1.8 on page 6 shows the temperature on a thermometer. The exact temperature falls between the markings and a little guesswork is needed to measure it. It looks as though it should be about 27°C, but it could be a little higher or lower, perhaps by as much as 1°C. The measurement might be written as 27°C 'give or take' 1°C. Scientists write this as 27 ± 1°C.

SKILL BUILDER

Finding averages

To find an average:

1. Delete the highest and lowest measurements. They are the measurements most different from all the others and so mistakes may have been made when taking them.
2. Add the rest of the 'good' measurements together.
3. Divide by how many 'good' measurements were taken.

INQUIRY science 4 fun

Internet reaction times

Yes

How fast can you react?

Do this …

1. Use the key words *reflex tester* or *reaction time* in your internet search engine to find interactive games that will measure your reaction time.
2. Although most of the games involve detecting a change in colour of the webpage, some shoot tranquiliser darts into sheep while in others you play baseball! Try as many as you can to determine your average reaction time.

Record this …

Describe what happened.

Explain why you think this happened.

WORKED EXAMPLE
Calculating an average

Problem

The members of a prac team each measured the length of the mouse's tail in Figure 1.1.7. Their measurements are shown below.

Team member	Length (cm)
Karen	8.1
Evan	8.4
Rebecca	7.9
Alicia	8.2
Mark	8.5
Andrew	12.9

Every member of your team will take slightly different measurements because of errors. This scientist is using the correct, humane way to pick up a mouse.

Figure 1.1.7

Andrew's and Rebecca's results can be ignored since they are the highest and lowest measurements and are most likely to be inaccurate.

To obtain the most accurate measurement, average the other four 'good' results:

$$8.1 + 8.4 + 8.2 + 8.5 = 33.2$$

Four 'good' results were taken, so this sum needs to be divided by 4:

$$\text{Average length} = \frac{33.2}{4} = 8.3 \text{ cm}$$

No-one actually measured 8.3 cm but this is the average and is the most accurate measurement based on the data collected.

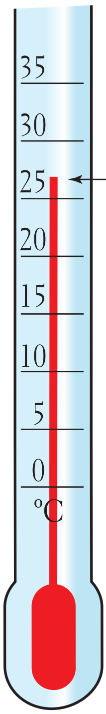


Figure 1.1.8 The temperature shown on this thermometer might be written as 27 ± 1°C. To cover all types of errors (and not just reading errors), scientists usually increase their error estimates. They make the error half of the smallest of the divisions of the instrument they are using. The markings on the thermometer are 5 degrees and so the maximum error is 2.5°C. This means that scientists would usually write this measurement as 27 ± 2.5°C

WORKED EXAMPLE

± errors

Problem

In the previous Worked Example, six students measured the length of the tail of a mouse. Present this measurement as an average ± error.

Solution

Based on the 'good' results obtained, the mouse tail ranged from 8.1 to 8.5 cm with an average of 8.3 cm. This result could be written as 8.3 cm but the highest good measurement was 0.2 cm higher than this. Likewise, the lowest good measurement was 0.2 cm lower than the average. The result could therefore be written as 8.3 cm 'give or take' 0.2 cm but is better written as 8.3 ± 0.2 cm.

SKILL BUILDER

Safety

Running experiments can be dangerous and so every laboratory has a set of safety rules that must be followed. One common rule is shown in Figure 1.1.9. Others common to all laboratories are:

- Always follow instructions from your teacher or laboratory technician.
- Move about the lab in a safe way. Do not run, push or shove.
- Always wear safety glasses when using chemicals.
- Unless instructed to do so by your teacher or lab technician, do not eat, taste, drink or sniff anything in the lab.
- Always tell your teacher if you break something or if you are unsure about what to do.
- Turn on the tap before placing anything under it. Otherwise the pressure might break whatever you are holding.
- When heating something, always tie back long hair. Otherwise it's a fire risk!
- If you need to leave a Bunsen burner, then turn it to a visible yellow safety flame
- Only use matches to light Bunsen burners. Do not use lighted scraps of paper.
- Always use tongs to pick up objects that have been heated.
- Hotplates, Bunsen burners, tripods and gauze mats remain hot for a long time. Allow them to cool before packing them away.

Figure 1.1.9 When heating a test-tube, ensure that it is pointed away from everyone (including you).

1.1 Unit review

Remembering

1 **State** whether the following statements are true or false.

- **a** All measurements are exact.
- **b** An average is also called the mean.
- **c** A mistake is the same as an error.
- **d** A measurement of 56 ± 2°C means that the measurement is somewhere between 54 and 58°C.
- **e** Human reflexes are always fast and accurate.

2 For Mt Kosciuszko, **state** three pieces of:

- **a** quantitative data
- **b** qualitative data.

3 **Name** four types of errors.

4 **State** the biggest and smallest values these measurements could be.

- **a** Elvir wrote that the length of an insect as 2.1 ± 0.1 cm.
- **b** Mang measured the temperature of the lake as 12 ± 3°C.

5 **State** what these measurements would be with a ± error.

- **a** The volume of a glass of soft drink was measured by Kim as 185 mL give or take 5 mL.
- **b** Iona measured the temperature that salt water boiled at as somewhere between 102 and 104°C.

Understanding

6 **Explain** why errors cannot be avoided.

7 Scientists generally take multiple measurements for the same quantity. **Explain** why.

8 Metal rulers are inaccurate in extremely hot and cold temperatures. **Explain** why.

Applying

9 **Identify** whether the measurement made with a metal ruler will be too high or too low on a:

- **a** hot day
- **b** cold day.

10 Eliminate the highest and lowest measurements and then **calculate** the average for the remaining 'good' measurements:

- **a** 39 mm, 61 mm, 38 mm, 42 mm, 41 mm, 30 mm, 40 mm
- **b** 25.3°C, 26.8°C, 38.1°C, 27.4°C, 21.2°C
- **c** 45 mL, 39 mL, 47 mL, 46 mL, 58 mL, 46 mL.

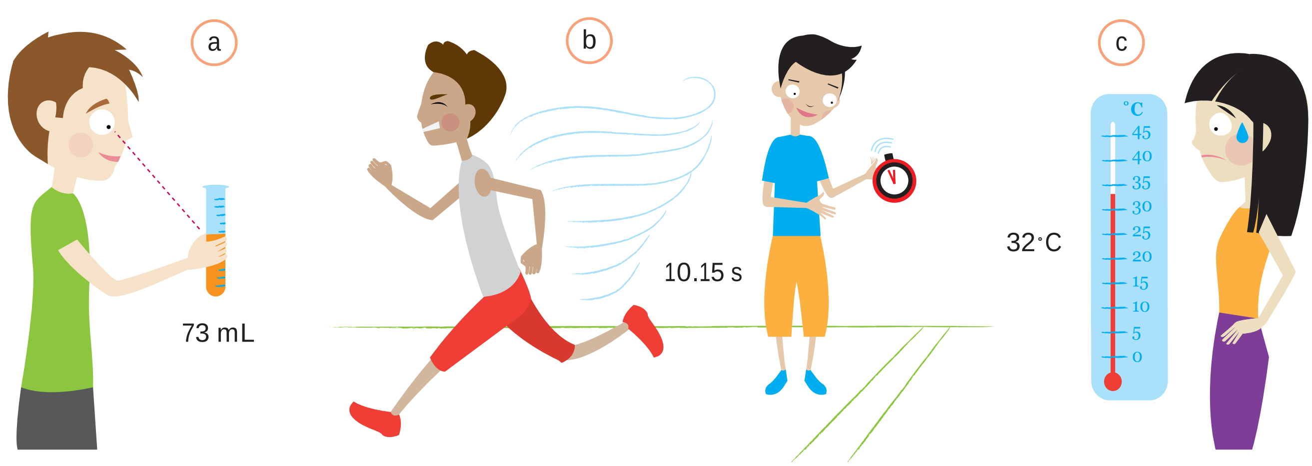
11 The time a ball took to drop down a 15.0 m cliff was measured by different members of a prac team. Their results are shown below:

Rebecca	1.61 s	Frank	1.74 s
John	3.23 s	Stavros	1.83 s
Christine	1.68 s		

- **a** **Identify** who most likely made a mistake.
- **b** **Calculate** the average drop time of the ball.
- **c** **Identify** the error that is likely to be the most important in this experiment.

12 **Identify** the types of error shown in Figure 1.1.10.

Figure 1.1.10



1.1 Unit review

Analysing

13 **Classify** the following as either mistake or error.
- **a** Liz poured water from a measuring cylinder but could not get every drop out.
- **b** Sam spilt some of the chemicals he was to use in an experiment.
- **c** Jon didn't bother cleaning the dirt off the balance he used.
- **d** Liana found it difficult to decide on measurements that fell between the markings on a tape measure.
- **e** Michael's electronic scale was reading 0.1 g when empty and he didn't 'zero' it.

14 **Classify** the data on the parrot listed in Figure 1.1.1 (on page 2) as quantitative or qualitative.

Evaluating.

15 Suppose a watch-glass has a mass of 50 g. **Propose** a way of measuring 10 g of salt onto a watch-glass:
- **a** without using the tare button
- **b** with the tare button.

16 **Propose** reasons why you should:
- **a** not run or push others in the laboratory
- **b** always wear safety glasses when using chemicals
- **c** leave hotplates or Bunsen burners for a while before packing them away.

Creating

17 **Construct** diagrams to explain these types of errors:
- **a** parallax errors
- **b** reading errors.

Inquiring

1 The Mars Climate Orbiter (also known as the Mars Surveyor '98 Orbiter) crashed onto Mars in 1999 because of a silly and easily avoided mistake. Research this mission and:
- **a** state its launch date, country of origin and the cost of the mission
- **b** describe where and when it was supposed to land on Mars
- **c** describe what the Mars Climate Orbiter was supposed to do on Mars
- **d** describe the mistakes made in planning the mission that meant that the Mars Climate Orbiter could never land successfully.

2 Research the internet for measurement games that test how well you can take measurements. Use them to test how good you are.

3 Accidents caused the following discoveries to be made or caused another use for them. Research one of them:
- bakelite (Leo Hendrik Baekeland)
- Coca-Cola® (John Pemberton)
- heart pacemaker (Wilson Greatbatch)
- microwave oven (Percy L. Spencer)
- penicillin (Alexander Fleming)
- radioactivity (Henri Becquerel)
- Teflon® (Roy Plunkett)
- saccharine (Constantin Fahlberg)
- vulcanised rubber (Charles Goodyear).

Whichever one you choose:
- **a** state the year of the discovery
- **b** describe the accident that caused it to be made
- **c** describe the current use of the discovery
- **d** list biographical details about its discoverer.

Figure 1.1.11 Many important scientific discoveries have been made by accident. For example, mould (like that found on this bread) led to the discovery of the first antibiotic, penicillin.

1.1 Practical activities

1 Reaction times

Purpose

To determine your reaction time.

Materials

- 30 cm ruler
- access to a calculator
- stopwatch

Procedure

1. Construct a table like that shown in the Results section in your workbook.
2. Work with a partner. Hold the ruler vertically with its zero in line with the top of your partner's hand, as shown in Figure 1.1.12.
3. Without warning, let go of the ruler. Your partner needs to catch it as quickly as possible with their fingertips.
4. Note the reading of the ruler (in centimetres) at the top of your partner's open hand.

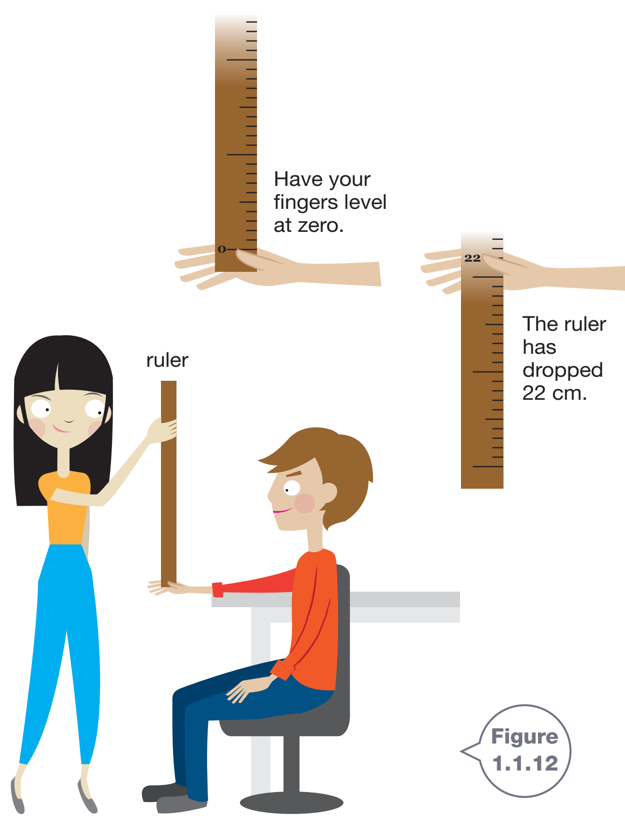


Figure 1.1.12

4. Have two trial runs and then record in your table the distance dropped for the next three runs.
5. Repeat the experiment, but this time count down the ruler drop.
6. Try again, but have another student distract your partner (such as by talking to them or tickling them).

Results

1. Record all your results in a table like that shown below.

Experiment	Distance ruler dropped (cm)			Average ruler drop (cm)	Average reaction time (s)
No distractions, no warnings					
With countdown					
With distractions					

2. Calculate your reaction time using the mathematical formula:

$$t = \sqrt{\frac{d}{490}}$$

To do this, follow these steps on your calculator:

- ÷ your average ruler drop by 490.
- Push the = button.
- Push the √ (square root) button.

The final answer is the time in seconds that you took to react.

Discussion

1. Digital stopwatches normally measure to the nearest 0.01 second. **Compare** this with your reaction time.
2. Your measurements using a stopwatch should never be thought of as perfect. **Explain** why.
3. **List** other factors that affected your reaction time. Specify whether they made it better or worse.

2 Repeated measurements

Purpose

To take repeated measurements and calculate their averages.

Materials

- measuring tape
- thermometer
- stopwatch

Procedure

Measure each of the following as carefully as you can. Have each member of your prac team do the same.

- Length of the laboratory
- Temperature of tap water
- Number of heartbeats in a minute
- Time it takes for a pen to drop 2 metres to the floor
- Time it takes for a flat piece of A4 paper to flutter from a height of 2 metres to the floor

Discussion

1. **Explain** why scientists repeat their measurements instead of taking just one.
2. **Calculate** the average for each measurement.
3. **State** each measurement as average ± error.

Figure 1.1.13 How to measure your pulse. Each pulse represents one heartbeat.

1.2 Second-hand data

You don't always need to run your own experiment to obtain accurate data. Sometimes it is impossible to collect it yourself and you will need to get your data from somewhere else. It is easy to find second-hand data, particularly from the school resource centre or internet. However, you need to be careful because some of the second-hand data you find will be out of date or incorrect.

Data that's ready to go

You cannot always run your own experiments or take your own observations and data. This could be for a number of reasons.

- Many experiments require training that is well beyond Year 8 Science. This is why science is offered as a subject throughout secondary school and into university. You learn a bit more each year, allowing you to run more and more of your own experiments and collect more of your own data.
- Many experiments require equipment that is not available at school because of its expense, size and maintenance requirements. For example, your school might have a powerful optical telescope that allows you to see the Moon and planets but it won't have a radio telescope such as that in Figure 1.2.1, which allows you to see into the deeper universe. Likewise, your school will have optical microscopes but not more powerful electron microscopes.

Figure 1.2.1 Your school is unlikely to have a radio telescope such as this one at Parkes, New South Wales. This means that you can only use second-hand data to find information about the wider universe.

- Other experiments take far more time than that available in Year 8 Science. For example, a forest takes many years to grow after a bushfire and you will need that long to study it. Genetic diseases pass from generation to generation and so studying the inheritance of them will take generations to do properly.
- Other observations can only be made in swamps, on top of mountains, in the frozen Antarctic, at the bottom of the ocean or in space. It is unlikely that you will ever go there, especially to run a science experiment.

If you can't run your own experiment, then you need to turn to second-hand data. Second-hand data is information that has already been found out by other scientists. This data and the scientific analysis of it can easily be found in textbooks and encyclopedias, scientific magazines and journals and on the internet. All this information is second-hand data. You might be using the data right now but it once belonged to someone else.

Figure 1.2.2 Data on climate change is changing so rapidly that it quickly becomes out of date. These two photos were taken from the same spot of the same Swiss glacier in 2002 and 2003.

Improving second-hand data

Second-hand data is easy to find but is not always accurate. Simple checks can ensure that the data you find can be trusted.

How old is the data?

Some data never changes. Ice, for example, melts at 0°C at sea level and will always do so. Hence, it doesn't matter where you get the information from or how old the information is. However, other data quickly becomes out of date and will not accurately describe what is happening right now. For example, climate change is happening much quicker than scientists first thought. As Figure 1.2.2 shows, glaciers and Arctic and Antarctic icesheets are melting faster than predicted and so data describing them must be as recent as possible for it to be accurate: data from a year ago is already so inaccurate that any predictions based on it are bound to be wrong.

You can check how old data is by finding the **imprint page** of the book or magazine, such as that shown in Figure 1.2.3. This page can usually be found in the first few pages of any book, magazine or journal. Websites should have the date they were created and last updated at the bottom of their opening pages.

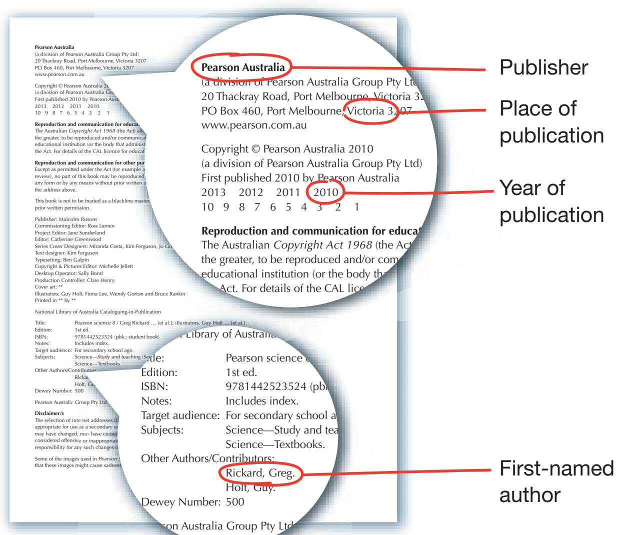


Figure 1.2.3 The imprint page shows who published the book or magazine and when it was published.

Where did it come from?

Encyclopedias, scientific journals and science textbooks can usually be trusted to provide accurate data. As discussed earlier, however, the data may be old.

Data can also be trusted if it comes from respected scientific magazines such as *New Scientist*, *COSMOS*, *Scientriffic*, *Scientific American* and *National Geographic*. Many of these magazines will be found in your school's resource centre or your local library.

Gossip and celebrity magazines cannot be relied on to provide accurate data and information.

What's the URL?

The internet will probably be your first choice when looking for data and information. However, some of what you find will be incorrect. Links that don't work are one sign of a suspicious site. More information comes from the last part of its **URL** address (referred to as its **domain**). This tells you who created the website and it gives you some idea whether it can be trusted or not.

Australian sites (.au)
Sites that have URLs ending in .au are based in Australia and need to meet Australian laws. The origin of other sites can also be determined by their domain. A few are shown in Table 1.2.1.

Table 1.2.1 Country domains

Country	Domain
USA	None
Australia	.au
United Kingdom	.uk
Canada	.ca
India	.in
United Arab Emirates	.ae

SciFile

TIM and the www

Before 1989, the only people able to use the internet were the US military, organisations such as CSIRO and various universities around the world. In that year Tim Berners-Lee, an English computer scientist working at the CERN laboratory in Switzerland, wrote software that allowed anyone to access the net. He called his system TIM! We now know it as the world wide web (www).

Educational institutions (.edu)
URLs ending in .edu indicate that the website is hosted by an educational institution such as a school, college, university or even kindergarten. Most of the material you find there can be trusted. However, students can sometimes use the school server and .edu domain to construct their own personal webpages. That expert on brain surgery you've found online might be another Year 8 student!

SciFile

Mentos + Diet Coke = nothing!

Plenty of video clips on the internet show the eruption that occurs when Mentos® are added to Diet Coke®. However, try it yourself and nothing much happens. This is because most of the video clips come from the USA where Mentos are different from those you can buy here. This shows that you should always check where your information comes from.

Government (.gov or .gov.au)
Governments have multiple sites ranging from health, finance, immigration and the arts to science. If the URL ends in .gov, then the site belongs to a branch of the government of the USA. If it is an Australian government site, then the URL will end in .gov.au. The data on government sites can be considered to be accurate and up to date.

Commercial businesses (.com)
Businesses want you to buy their products. Their websites will usually be accurate but will be biased towards their products, making them look good. They are unlikely to include links to negative reviews or compare their product with opposition products.

Organisations (.org)
The first site that comes up in most searches is Wikipedia. This is an example of an .org site. Wikipedia is a not-for-profit site that allows anyone to enter information. The accuracy is checked later by others. Most of the information on Wikipedia is accurate and up to date. If it isn't, then it is usually quickly deleted.

Figure 1.2.4 Zoo websites are .org sites and can be trusted to have accurate and up-to-date data about animals and their welfare.

Other .org sites that can be trusted are the Australian Red Cross, the United Nations, zoos such as Taronga Zoo (New South Wales) (Figure 1.2.4) and Healesville Sanctuary (Victoria), the WWF (World Wildlife Fund for Nature) and various help groups for diseases such as cancer and multiple sclerosis.

However, some .org sites display a strong bias and only provide information that will support their point of view. Websites regarding evolution, stem cell research and abortion are often biased for or against the issue and so they need to be treated with care.

Networks (.net)

These domains include all the other sites that don't fit within one of the other domains. Many of them will be personal sites. If so, then their URL is likely to include a ~ (tilde). Many of these websites will be biased and some will contain incorrect information.

1 p16 2 p17

The need to compare

All second-hand data should be checked against data found in other sources. If it agrees, then it is probably accurate. If it doesn't match up, then you need to keep looking until you find sets of data that do match.

Data is best collected from a range of resources. In research assignments and projects, try and gather material from at least one:

- textbook
- encyclopedia (it could be an online or CD-version)
- trustworthy internet site.

Resource lists

A resource list (sometimes called a **bibliography**) is a list of every textbook, encyclopedia, scientific journal and webpage from which you collected information or used to check the accuracy of data you found. Although each type of resource is listed in their own special way, you should try to include the following.

Author(s):

- Write the author's surname first.
- If the author's name is not given, then try and find the editor instead and write 'ed.' after their name.
- Encyclopedias often do not have authors or editors listed. In this case do not include any author.

Title:

- If you are using a magazine or newspaper, then you should also give the title and page numbers of the article you used.
- If you are using a website, then you should give its title and its URL.
- Always underline the title or URL.

Year or date of publication:

- Give the year or date of publication or the date of its most recent update.

Publisher:

- This is the group or the institution that put it all together. The domain in a website's URL will help you here.

Place:

- Include the city or place that the resource has come from (if known).

Some possible entries in a resource list are shown in Figure 1.2.5.

Book: Hopler, Paul and Torok, Simon, Amazing Science, 2005, ABC Books, Sydney.

Encyclopedia: Visual Encyclopedia of Science, 2004, Dorling-Kindersley, London.

Magazine: Catchpole, Heather, 'The atom factory'. COSMOS, 2007, Volume 014, p77.

Newspaper: Medew, Julia, 'Insurance fears deter gene tests', The Age, 7 September 2009, p3.

Website: www.wecare4rabbits.com/rabbits.asp

Figure 1.2.5 Entries in a resource list

1.2 Unit review

Remembering

1 **State** what the following domains stand for.
- a .gov
- b .gov.au
- c .au
- d .com
- e .edu

Understanding

2 **Explain** why:
- a .net sites need to be treated with care
- b .com sites cannot be expected to give a fair assessment of their products.

3 **Predict** whether the following magazines could be trusted to give accurate scientific data.
- a *New Idea*
- b *COSMOS*
- c *Woman's Day*
- d *Popular Scientist*
- e *Dolly*

4 **Explain** why some data is known as second-hand.

5 **Explain** why it would be difficult to run your own experiment to:
- a measure the weathering and erosion of rocks
- b detect signals from the outer universe
- c measure the wind speeds on top of Mt Everest
- d determine the mathematical equations that describe the movement of water down a creek.

Applying

6 **Identify** whether you would use first-hand or second-hand data to find:
- a the types of shops that are in your town or suburb
- b how tall your classmates are
- c the population of the major cities of Australia
- d how long an ice cream takes to melt
- e the length of Australia's coastline.

7 For the following resources, **identify**:
- i what the resource is (e.g. text, website, magazine)
- ii its author(s)
- iii the title of resource
- iv the year of publication.
- a Devlin, Jacinta, Helen Cochrane, Rhonda Coffey, *Heinemann Science Links 1*, 2005, Heinemann, Port Melbourne.
- b Govindasmay, Siva, 'Ready for take-off', *Flight International*, 1–7 September 2009, p46.

Evaluating

8 **Assess** whether the following websites are likely to give unbiased information.
- a www.dubbo.org/explore/western-plains-zoo
- b www.antiabortion.org/helpline
- c www.pretendwecare.net
- d www.chrissolarpanels.com.au
- e www.physics.unitas.edu.au
- f www.doctors4stemcellcures.org
- g www.en.wikipedia.org/wiki/frdi
- h www.donkey.org.it/~guido

9 You should use a range of resources to collect second-hand data. **Propose** reasons why.

Creating

10 Gary used the resources shown in Figure 1.2.6 to complete a science assignment. From his rough list, **construct** a resource list.

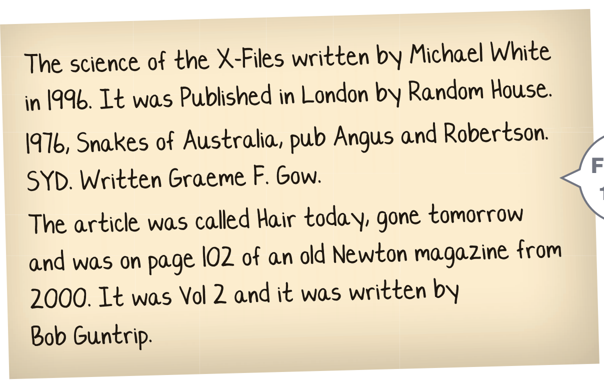

The science of the X-Files written by Michael White in 1996. It was Published in London by Random House.
1976, Snakes of Australia, pub Angus and Robertson. SYD. Written Graeme F. Gow.
The article was called Hair today, gone tomorrow and was on page 102 of an old Newton magazine from 2000. It was Vol 2 and it was written by Bob Guntrip.

Figure 1.2.6

Inquiring

1 Most secondary schools have their own guidelines for constructing a resource list. Ask your school librarian or resource centre manager for your school's guidelines on how you should construct yours. Summarise what you find out.

2 Search the internet for videos on:
- a elephant toothpaste
- b cartesian divers.

3 Investigate ways in which chemical waste is disposed of from homes and schools. This waste would include leftover paint, oil and insecticides from home, and toxic and organic chemicals from school laboratories.

1.2 Practical activities

1 Elephant toothpaste

Purpose

To make elephant toothpaste and then search the internet to find out what happened.

Materials

- empty 500 mL plastic soft-drink or water bottle
- 3–6% solution of hydrogen peroxide
- dishwashing detergent
- food colouring
- live powdered yeast
- very warm water
- 100 mL measuring cylinder or plastic cup
- plastic teaspoon
- funnel
- beaker
- newspaper or tray to 'catch' the toothpaste
- safety glasses

SAFETY

Hydrogen peroxide is an irritant if it gets in your eyes. It is also a bleach. Wear gloves and safety glasses at all times.

Procedure

1 Place the tray on your workbench or cover the bench with newspaper. Alternatively, perform the prac outside.

2 Place about 8 teaspoons of very warm water into the beaker and add about 1 teaspoon of yeast powder. Mix with the plastic teaspoon and then allow the mixture to sit for about 5 minutes.

3 Insert the funnel into the opening of the plastic bottle and use it to pour 100 mL (about half a cup) of hydrogen peroxide solution, a good squirt of dishwashing liquid and three or four drops of food colouring. Swirl to mix thoroughly.

4 Place the bottle on the tray or newspaper or take it outside. Then add the yeast mixture all at once. Quickly remove the funnel and stand back.

5 Once the reaction has started, feel the sides of the plastic bottle.

Discussion

1 **Describe** what you saw.

2 **Describe** what you felt when you touched the bottle.

3 Search the internet to obtain the following data regarding this prac.
- **State** the address of the website you obtained it from.
- **Identify** what type of site it was (for example, government, educational or commercial).
- **Assess** whether the information you found was able to be trusted or not.

Find:

a the chemical formulas for hydrogen peroxide and water

b the reaction in which hydrogen peroxide breaks down

c what a catalyst is and what it does (yeast is a catalyst in this experiment)

d what an exothermic reaction is.

4 The 'toothpaste' formed in this prac is just bubbles of oxygen, water and food colouring. **Assess** whether it is safe to touch.

5 **Propose** reasons why the 'toothpaste' grew out of the bottle.

2 Cartesian diver

Purpose

To construct a cartesian diver and use it to demonstrate buoyancy.

Materials

- 2 L soft-drink bottle
- a 'diver' such as:
  – an eye-dropper or Pasteur pipette
  – plastic straw, paperclip and Blu-Tack®
  – lid of a ballpoint pen and Blu-Tack
- digital camera or mobile phone with video function (optional)

Procedure

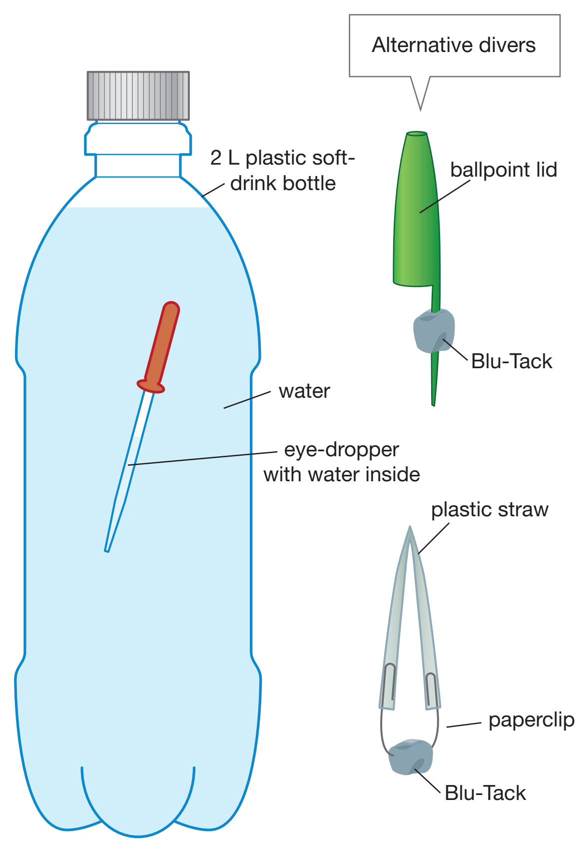
1. Completely fill the 2 L bottle with water.
2. Prepare your diver. Your diver needs to be heavy enough so that it just floats upright in water. To do this:
   - draw water into the eyedropper
   - attach Blu-Tack to the end of the lid of the ballpoint pen as shown in Figure 1.2.7
   - bend the plastic straw over and hold it in place with the paperclip as shown in Figure 1.2.7. Add Blu-Tack to the paperclip.
3. Slip your diver into the bottle and screw the cap on tightly.
4. Squeeze gently on the sides of the bottle and observe what happens to the diver.
5. Watch what happens when you release the bottle.
6. Perhaps video what you see using a digital video camera or mobile phone.

Discussion

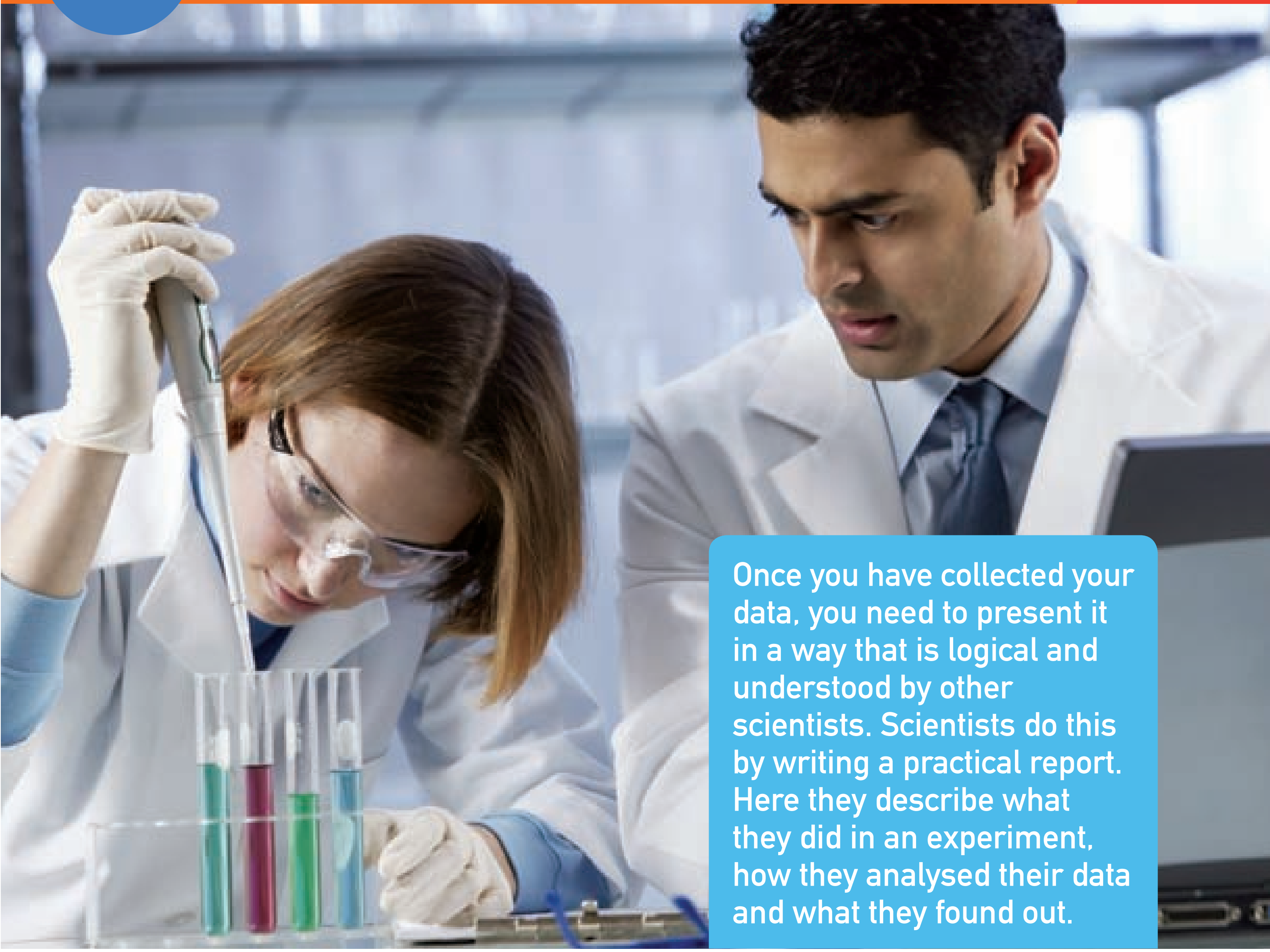
1. **Describe** what happened to the diver when you:
   a. squeezed the bottle
   b. released it.
2. Search the internet to obtain the following data regarding this practical activity.
   - **State** the address of the website you obtained it from.
   - **Identify** what type of site it was (for example, a government, educational or commercial site).
   - **Assess** whether the information you found was able to be trusted or not.

   Find:
   a. what buoyancy is
   b. why the diver moved up and down in the bottle
   c. other designs for a cartesian diver that use a soy-sauce 'fish' and a tomato sauce sachet
   d. who the word 'cartesian' is named after
   e. what cartesian coordinates are.

Figure 1.2.7



1.3 Presenting and analysing data



Once you have collected your data, you need to present it in a way that is logical and understood by other scientists. Scientists do this by writing a practical report. Here they describe what they did in an experiment, how they analysed their data and what they found out.

Prac reports

Prac reports should include the following sections.

Heading

In your heading, include the name and date of the prac activity and a list of partners who were in your team.

Purpose or aim

The **aim** or **purpose** is where you describe briefly what you are trying to do.

Hypothesis

You generally have some idea of what will happen in an experiment from your previous experiences and what you have already studied in science. A **hypothesis** is an educated guess about what might happen in an experiment and what might be found out.

Materials, equipment or apparatus

This is a comprehensive list of everything that you used in the experiment. Use the correct names for scientific equipment and specify their size if they come in different sizes (such as a 100 mL beaker).

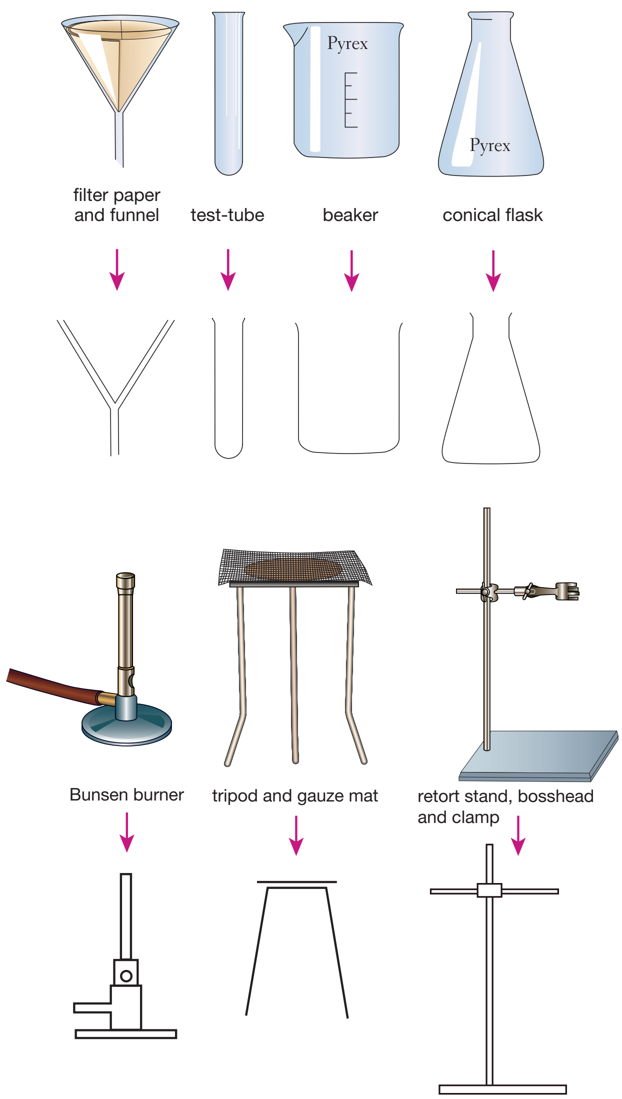
SKILL BUILDER

Identifying laboratory equipment

Figure 1.3.1 shows some of the equipment commonly found in the laboratory and how the equipment is usually represented in a diagram. Some pieces are used to take measurements (quantitative data) while others are used to run experiments in.

1.3

Figure 1.3.1 Equipment commonly found in the laboratory



Procedure or method

The **method** or procedure is a description of everything that you did in the activity, perhaps as a list or series of dot points. A labelled diagram is a good way to describe how equipment was set up.

1.4

SKILL BUILDER

Writing a good procedure

The method you write should not be a story and should not be a recipe. Recipes give a set of instructions for someone else to follow and do not record what you or your team did. Follow these guidelines to write a good method.

1. Write procedures in the past tense. Use words such as *was* and *were*.

   A measuring cylinder was used to measure out 100 mL of water. ✔

   Use a measuring cylinder to measure out 100 mL of water. ✗

2. Your procedure should state what equipment was used.

   A trundle wheel was used to measure the length of the oval. ✔

   We used a trundle wheel to measure the length of the oval. ✔

   The length of the oval was measured. ✗

   We measured the length of the oval. ✗

3. Include quantities and units with all your measurements.

   The water was heated until it reached 40°C. ✔

   We heated the water until it reached 40°C. ✔

   The water was heated. ✗

   We heated the water. ✗

Results and observations

This includes a complete list of your observations and your measurements. The best way to display your measurements is in a table.

Analysis or discussion

This is where you:

- analyse your results
- plot graphs
- calculate required quantities (such as averages, the slope of a graph, speed)
- discuss what you think your results show
- include second-hand data that relates to the activity
- describe the problems encountered and what was done to overcome them
- include ideas for further experiments.

Conclusion

The **conclusion** is a brief summary of what you found out in the experiment.

Writing a good conclusion

A good conclusion is short (no more than two short sentences) and directly answers the Purpose.

As expected, cooking oil flowed slower than water but faster than honey. ✔

The experiment was fun and we learnt a lot. ✗

Resource list

A report sometimes ends with a list of all resources used in gathering information about the experiment. This is sometimes called a **bibliography**.

Tables of data

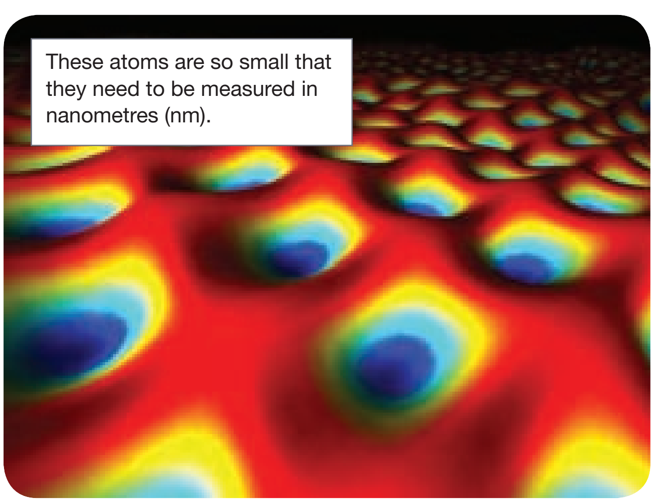
Quantitative data (measurements) is best shown in a table or computer spreadsheet. This makes any patterns that may exist more obvious.

Units

The measurements in your results tables are useless unless you specify the units they are measured in. In science, most of your measurements will be measured using metric or SI (Système Internationale) units. Length is measured in metres (m), mass in grams (g), liquid volumes in litres (L) and time in seconds (s). Other units, such as newtons (N) for weight and force, and joules (J) for energy, depend on these units. Sometimes, however, measurements will be too big or too small to be sensibly measured with these units. Other units have been developed from them using a series of letters before the unit name. These letters are known as prefixes, the most common of which are milli, centi and kilo. They are shown in Table 1.3.1. There are other prefixes that are used to measure extremely large or small quantities such as those shown in Figure 1.3.2.

Table 1.3.1 Common metric unit prefixes

Prefix symbol	Prefix name	Size	Decimal notation	Example
G	giga	one billion	1 000 000 000	GL
M	mega	one million	1 000 000	ML
k	kilo	one thousand	1000	km
c	centi	one-hundredth	$\frac{1}{100}$ or 0.01	cm
m	milli	one-thousandth	$\frac{1}{1000}$ or 0.001	mg
µ	micro	one-millionth	$\frac{1}{1\,000\,000}$ or 0.000 001	µg
n	nano	one-billionth	$\frac{1}{1\,000\,000\,000}$ or 0.000 000 001	nm



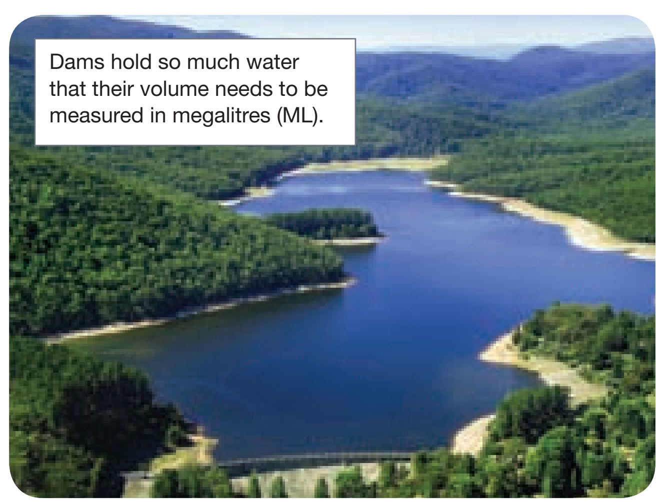


Figure 1.3.2 Prefixes allow scientists to measure extremely small and extremely large quantities.

Drawing line graphs

Graphs are better at showing patterns in measurements than tables are. Pie graphs and bar and column graphs are useful but cannot be used to predict missing measurements or ones that were never actually taken in the experiment. Only line graphs can do this.

Line or curve of best fit

Sometimes your data will produce perfect straight lines or perfect curves. At other times, your data might produce something that looks more like a dot-to-dot picture. This is when you try and construct a **line of best fit** or **curve of best fit**.

All experiments have errors in them. This means that the points on your graph have errors too and their positions are not exact. Connecting up the points in a dot-to-dot manner suggests that there is no error. It is more sensible to draw a straight line or smooth curve roughly through the 'centre' of your points. These lines or curves of best fit make patterns in your results easier to see. They also allow you to predict any missing measurements.

Figure 1.3.3 shows how a baby mouse (Figure 1.3.4) grew over its first week or so of life. The pattern in this data is shown by a line of best fit.

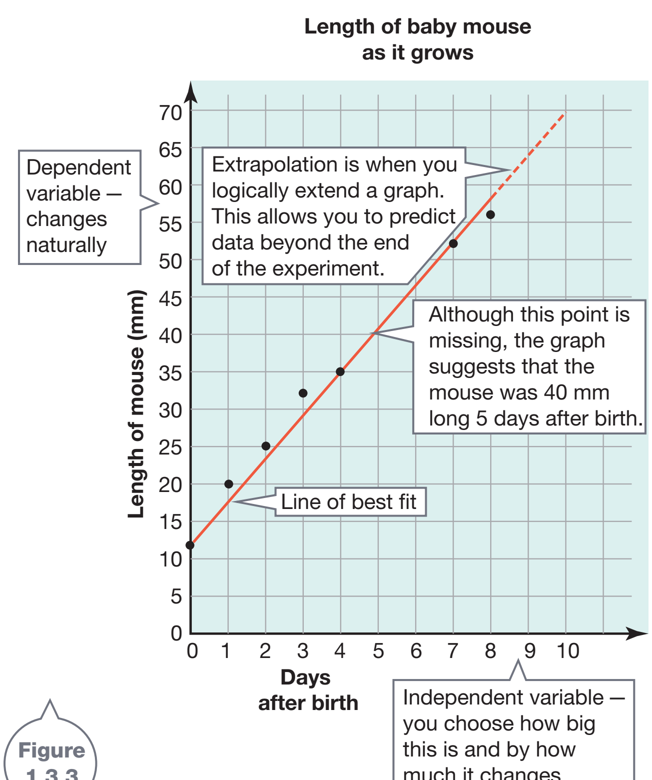


Figure 1.3.3 Do not connect the points up dot to dot but draw a straight line or curve through their 'centre'. This gives you a line of best fit.

Figure 1.3.4 Baby mice grow quickly. A line graph best displays their growth.

A line of best fit doesn't explain the cooling of water, however. Figure 1.3.5 shows that the pattern in its data is displayed better by a curve.

Line graphs can also be extrapolated. **Extrapolation** is when a line graph is extended beyond its final measured value, allowing you to predict further measurements.

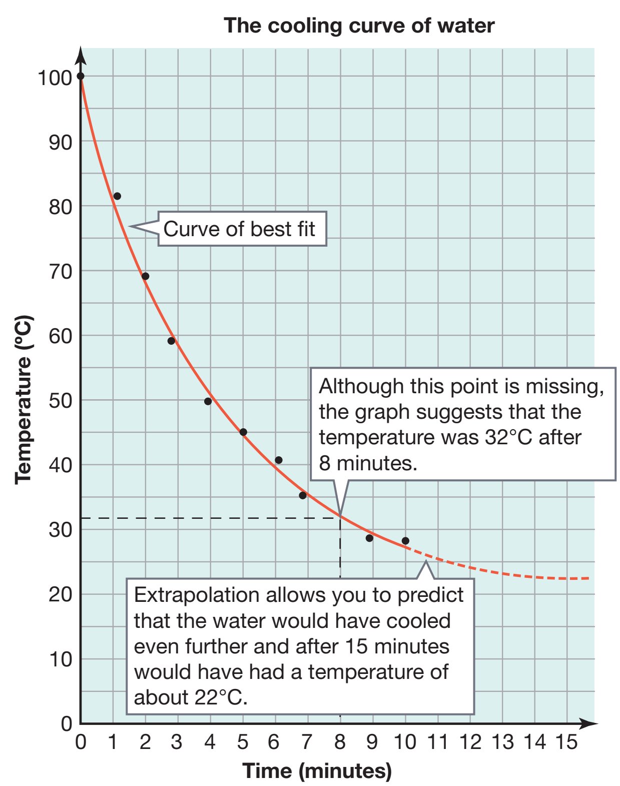


Figure 1.3.5 Lines and curves of best fit can be used to predict data that was never actually collected in the experiment.

SKILL BUILDER

How to avoid making common mistakes in line graphs

Some of the most common mistakes made by students in plotting line graphs are shown in Figure 1.3.6. It also shows the correct way of plotting them.

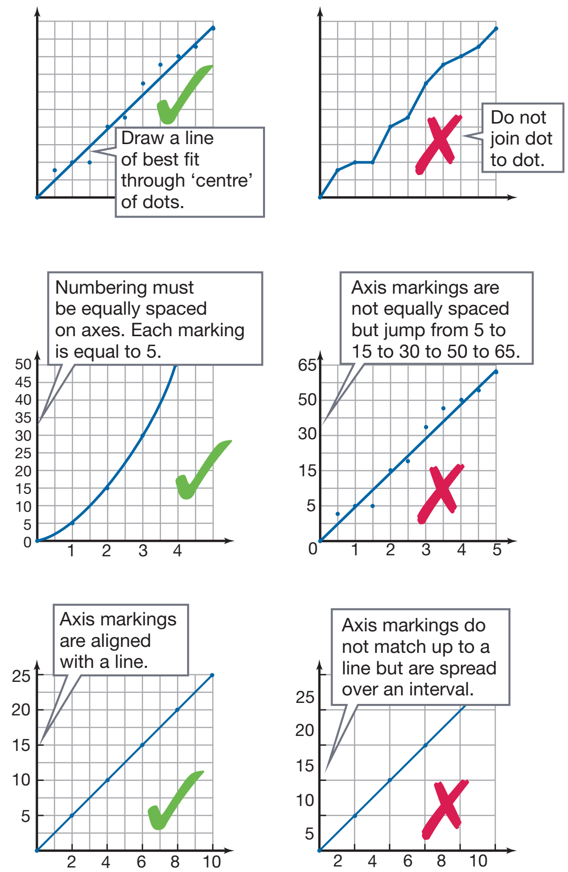


Figure 1.3.6 Correct and incorrect ways of plotting line graphs

Describing patterns

Graphs that produce straight lines or logical curves indicate that there is a pattern, rule or relationship between the variables that you tested. Some ways of describing these rules are shown in Figure 1.3.7.

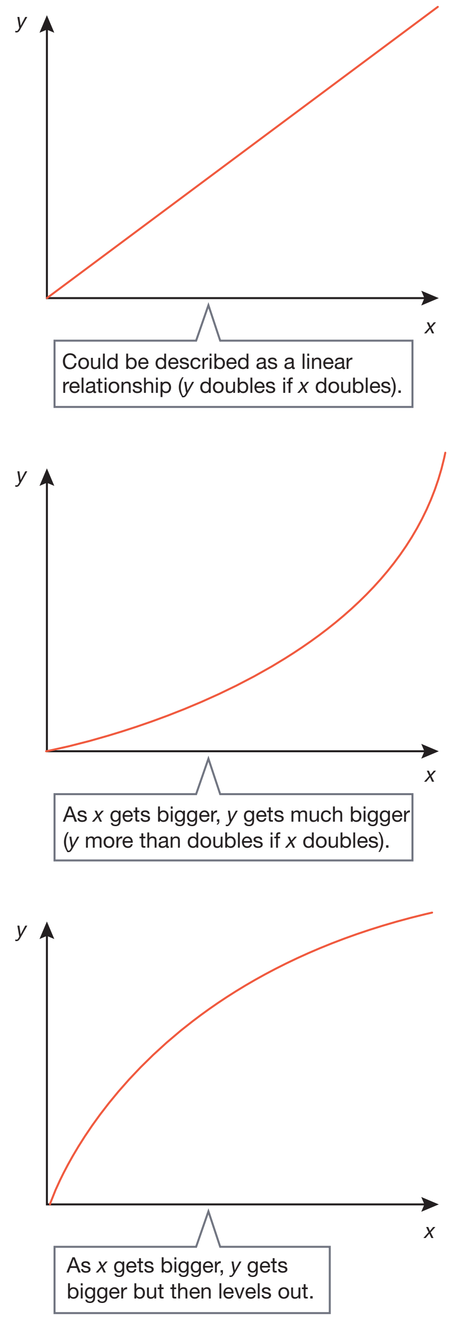


Figure 1.3.7 Three ways of describing the shape of a line graph

1.6 p25 p26

1.3 Unit review

Remembering

1 **List** in order the features that must be included in a practical report.

Understanding

2 **Describe** the shape of the line graphs in Figure 1.3.8.

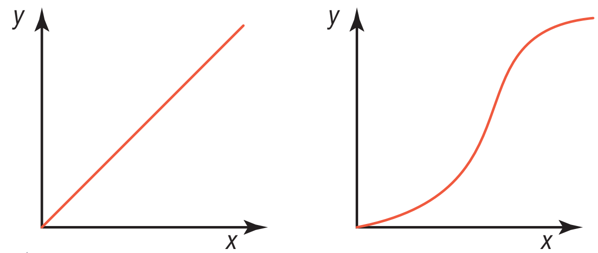


Figure 1.3.8

Applying

3 Below are four similar sentences that could be used in a method. **Identify** which one is best.
- A Measure the temperature of the water.
- B We measured the temperature of the water.
- C A thermometer was used to measure the temperature of the water.
- D We are going to measure the temperature of the water.

4 A Year 8 prac had the purpose 'To find out if snails remember a path leading to food'. **Identify** which of the following four possible conclusions is best.
- A I learnt a lot about snails from this prac.
- B Snails cannot remember a path that leads to food.
- C Snails like food.
- D The prac was fun and I would do it again.

5 **Use** the graph in Figure 1.3.3 on page 21 to **predict**:
- a how long the mouse is likely to be after 10 days
- b when the mouse is likely to be 45 mm long.

6 **Use** the graph in Figure 1.5.5 on page 21 to **predict** the:
- a likely temperature of the water at 4.5 minutes
- b time at which the temperature was likely to be 25°C.

7 a **Identify** the point that is probably a mistake in the graph in Figure 1.3.9.
- b Ignoring this mistake, **describe** the shape of the graph.

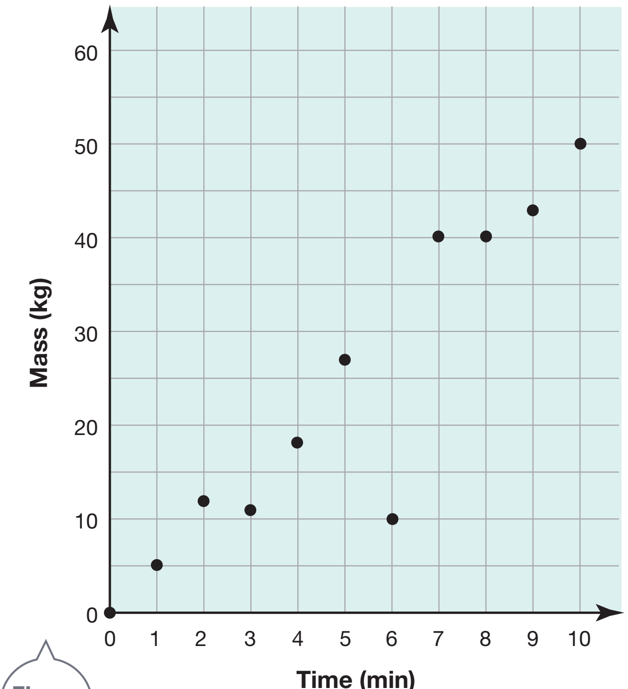


Figure 1.3.9

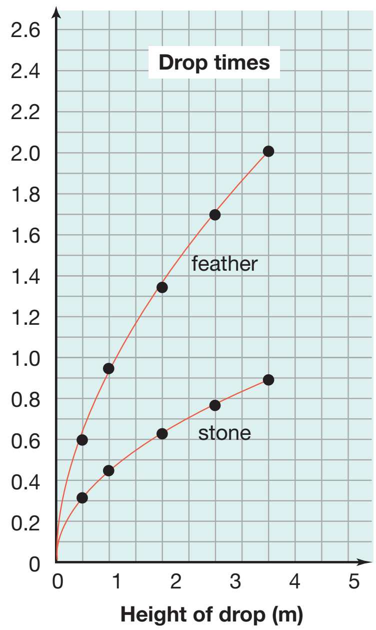
Analysing

8 **Use** Table 1.3.1 on page 20 to **convert** the following units.
- a 5 ML into litres
- b 37 mL into litres
- c 500 000 mm into metres
- d 6 000 000 000 nm into metres

9 The metric prefixes milli, centi, kilo and mega are not used for time. If they were, then **calculate** what these times would be equivalent to.
- a 1 kilosecond or 1 ks
- b 1 centiminute or 1 cmin
- c 1 kiloday or 1 kd
- d 1 megasecond or 1 Ms

1.3 Unit review

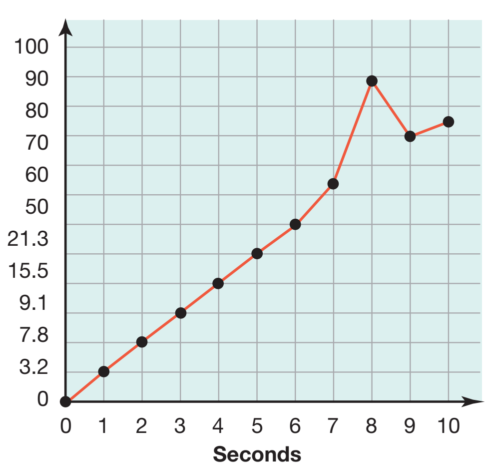
Figure 1.3.10



10 Nell measured the times it took for a feather and a stone to fall from different heights so that she could compare them. She came up with the graph shown in Figure 1.3.10.

- **a** **Use** her graph to **predict** the drop time for the feather and stone from:
  - **i** 1.5 m
  - **ii** 2.5 m
  - **iii** 5.0 m.
- **b** **Use** her graph to **predict** the height the feather and the stone were dropped from if it took this long to fall.
  - **i** 0.5 s
  - **ii** 0.8 s
  - **iii** 1.0 s

Figure 1.3.11



11 **Analyse** the graph in Figure 1.3.11 and **identify** five things that are wrong about it and the way it is plotted.

Evaluating

12 **Propose** reasons why:

- **a** you need to include the names of your partners in a prac report
- **b** all scientists use the same units for their measurements.

13 The World Health Organization recommends people eat 10.9 MJ of food each day. On average in Australia we eat 13 500 kJ.

- **a** **Calculate** what these numbers represent in joules.
- **b** **Use** this information to **assess** the diet of Australians. Do we eat too little, just enough or too much?

Creating

14 **Construct** a table to show the data contained in Figure 1.3.9 on page 23.

Inquiring

1. Research what the following unit prefixes mean.
   - **a** deci (d)
   - **b** pico (p)
   - **c** tera (t)
2. Find what a tonne is and state how many kilograms it is equivalent to.
3. Find what the following units are used to measure.
   - **a** megatonne (Mt)
   - **b** decibel (dB)
   - **c** gigabytes (Gb)
4. Use the key words *skillswise unit conversion* to find games on the internet that test how good you are at converting units.
5. Advertising often uses data to make claims about particular products. Describe an advertisment that does this and outline how the data is used to make the product look good.

1.3 Practical activities

1 Candles and rising water

Purpose

To plot a line graph and use it to make predictions.

Materials

- 6–8 birthday candles
- matches
- small lump of plasticine or Blu-Tack
- 2 elastic bands
- shallow pan
- 250 mL beaker, gas jar or tall, narrow drinking glass
- 30 cm ruler

Procedure

1. Make a small mound of plasticine or Blu-Tack in the centre of the pan and then fill the pan with water.
2. Stick one candle in the plasticine. Place both elastic bands around the glass and then place the glass over the candle as shown in Figure 1.3.12. If using a beaker, ensure that the water level is well over its pouring lip.
3. Roll the lower elastic band down to mark the water level.
4. Remove the glass, light the candle and quickly replace the glass over the candle.
5. Roll the other elastic band to mark the new water level.
6. Use the ruler to measure the change in water level. Record the change in a table like that shown in the Results section.
7. Repeat the experiment with three, five and seven candles. Each time, record the change in water level in your results table.

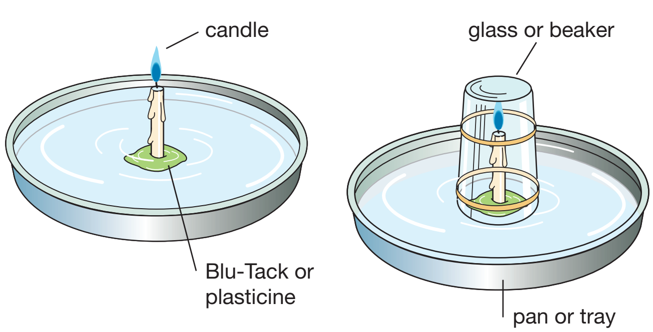


Figure 1.3.12

Results

1. In your workbook, construct a table like the one shown below.

Number of candles	Rise in water level (mm)
1	
2	
3	
4	
5	
6	
7	
8	

2. Plot a line graph showing what happened to the height of the water as more candles were added.
3. Use the graph to predict the water rise for two, four, six and eight candles.
4. Run the prac again for four, six and eight candles to check your predictions.

Discussion

1. **Describe** the shape of the graph your plotted.
2. Does your graph suggest a relationship between the number of candles and the rise in the water level? **Justify** your answer.
3. **Predict** what would happen if you kept the number of candles the same but changed the following instead:
   a. the volume or depth of water in the tray
   b. the height or diameter of the gas jar
   c. the amount of plasticine.
4. **Propose** a reason why the water rose in this experiment.

1.3 Practical activities

2 The greenhouse effect

Purpose
To demonstrate the greenhouse effect.

Materials
- 2 thermometers
- clear plastic bag
- A4 sheet of white cardboard
- sticky tape
- stopwatch, watch or clock

Procedure
1. Cut the A4 sheet of cardboard in two.
2. Stick one thermometer on each half so that they have a stiff backing.
3. Place one thermometer inside the plastic bag as shown in Figure 1.3.13. Tie it tightly so that no air can escape.
4. Place the plastic bag and the other thermometer side by side in direct sunlight.
5. Record the reading of each thermometer every minute for 15 minutes. Record the temperatures in a table like that shown in the Results section.
6. After 15 minutes, shift both to the shade to let cool. Continue reading each thermometer every minute for another 15 minutes.

Results
1. In your workbook, construct a table or spreadsheet similar to the one shown below.

Time (min)	Temperature in plastic bag (°C)	Temperature in the open (°C)

2. On the same set of axes, plot a line graph for the measurements from each thermometer.

Discussion
1. **Identify** the thermometer that showed the faster increase in temperature.
2. **Identify** the thermometer that showed the faster drop in temperature.
3. **Describe** the shapes of each graph.
4. **List** the errors involved in this experiment.
5. Most scientists think that global warming and climate change are being caused by the enhanced greenhouse effect. **Propose** ways in which this experiment relates to global warming.

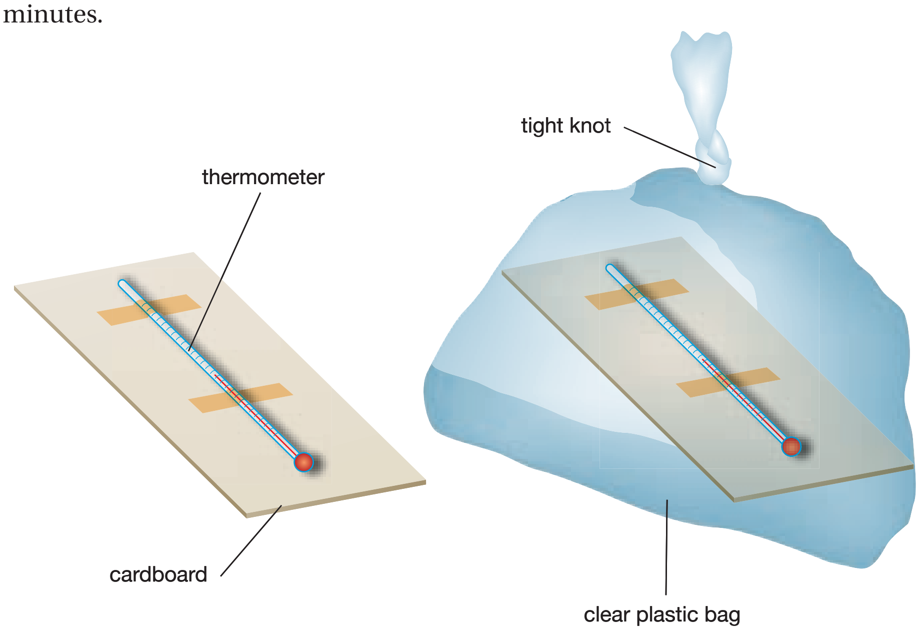


Figure 1.3.13

1.4 Planning your own scientific research

Science would never progress if scientists only ever used second-hand data. Progress happens because brand-new, first-hand data is obtained through experiments and scientific research. This research must be carefully planned or else the data obtained will not be trustworthy.

Variables

Variables are factors that might have some influence on an experiment.

As an example, think of a simple experiment in which you are trying to determine the time it takes to toast a slice of bread. How long this takes will depend on many factors or variables.

A few are:

- the type of bread (Is it light and fluffy or heavy and dense?)
- the thickness of the slice (Is it thick, thin or in-between?)
- how dry the bread is (Is it old, dry and stale or new, fresh and moist?)
- the make of toaster (Is it Sunbeam, Breville or another brand?)
- the age of the toaster (Is it new or old?)
- how clean the toaster is. (Is it clean or covered in crumbs?)

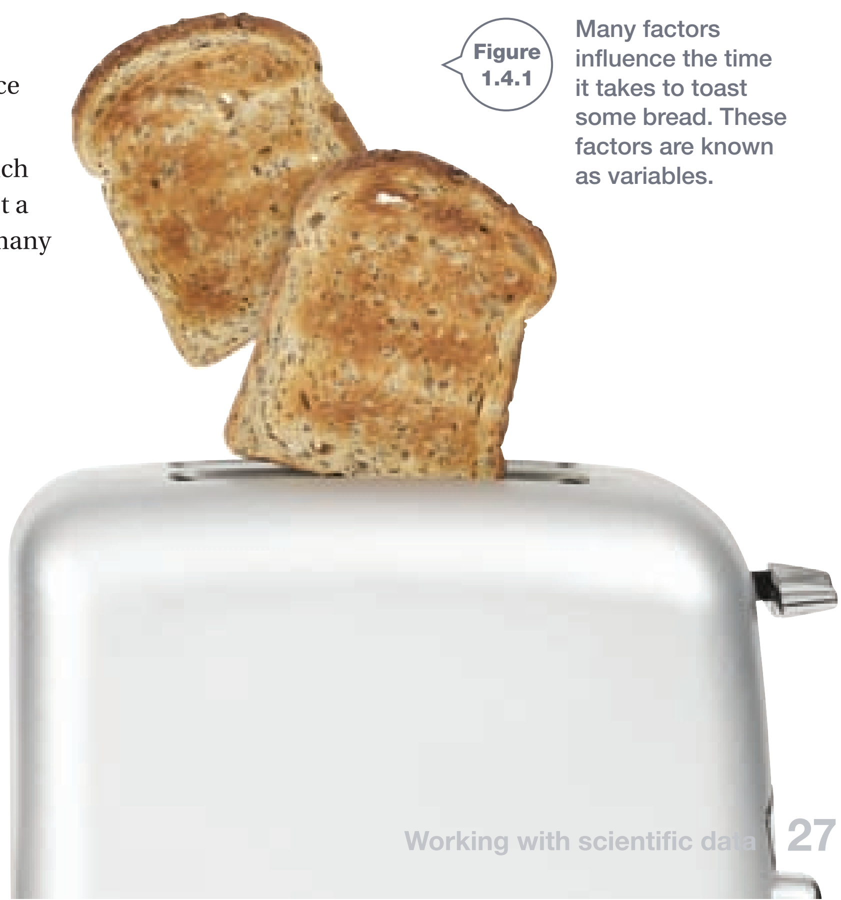


Figure 1.4.1 Many factors influence the time it takes to toast some bread. These factors are known as variables.

Not all variables are equally important. Some will greatly influence the experiment while others will have little or no effect. Important variables here are the type of bread, its dryness and thickness and the type of toaster (Figure 1.4.1 on page 27). The cleanliness and age of the toaster will have some effect (old and dirty ones will have crumbs on their elements that might affect their performance) but not as much as other variables.

Independent variables

Once you have identified all the variables involved in an experiment, you then need to pick one to test. The variable you choose is known as the **independent variable**. It is the one you are going to change.

For the toast experiment, you might choose the thickness of the slice as your independent variable. You would change the thickness of the slice and test its effect on the cooking time (Figure 1.4.2).

Figure 1.4.2 The thickness and type of bread will affect how long it takes to toast it.

Dependent variable

What you are trying to test is known as the **dependent variable** (because it depends on the independent variable). Change the size of the independent variable and the size of the dependent variable is likely to change too. The dependent variable in the toast experiment is the time it takes to toast the slice—it *depends* on the thickness of the slice.

Controlled variables

Any experiment that you run needs to be a **fair test**. This means that only one variable should be changed at any time. All the other variables need to be controlled and held constant. For this reason, these variables are referred to as **controlled variables**. If they were changed too, then you would never know which variable caused changes in the experiment.

In the toast experiment, the controlled variables would be:

- the type of bread (choose one type of bread and use it throughout the experiment)
- how dry the bread is (all the bread you test would need to be the same dryness and age)
- the make, age and cleanliness of the toaster (stick with one toaster and don't change it).

Scientific research

An experiment only changes one variable at a time. If you want to change another variable, then you need to run another experiment. This means that you could potentially run six or more different experiments to fully investigate the time it takes to toast bread!

A group of related experiments such as this is known as **scientific research**. Each new experiment changes another variable (with all the others kept constant) until you have tested them all.

Scientists do not carry out unrelated experiments but carry out scientific research on the one topic. This gives them a thorough understanding of it and allows them to become experts in it.

Teamwork

Scientists generally do not work by themselves but work as part of a **team** like the one in Figure 1.4.3. Everyone is good at something and teamwork allows these strengths to be shared. Equally, we all perform less well at some things and teamwork allows others to help out when one of their members is struggling.

There are many different ways that teams can be organised. One that works well in the school laboratory is the following model in which there are four team members.

Figure 1.4.3 You will usually work as part of a team when carrying out scientific prac work.

- Manager—this team member oversees the whole team and prac. They make sure that everyone is on task and that the prac work is completed on time.
- Communicator—this team member communicates with the teacher and laboratory assistant. All communication to and from the team should pass through the communicator. The teacher may, for example, gather all the communicators together to go through the safety concerns of the prac or to show them how to use a particular piece of equipment. The communicator then passes on this information to the team.
- Equipment specialist—this team member collects all the required equipment and materials and makes sure the equipment is cleaned and returned to the correct spot at the end of the prac. They report any broken equipment to the communicator who passes on the information to the teacher.
- Recorder—this team member records all the observations and measurements that are taken throughout the prac. They also ensure that all the other team members have their own copy of results before they leave the laboratory.

1.7 p34

INQUIRY science 4 fun

Researching on your own

Yes

Which paper towel and toilet paper are the most absorbent?

Collect this ...

- a collection of different absorbent paper towels and toilet papers
- equipment such as glasses or beakers
- equipment that can be used to measure volumes of water (e.g. eyedroppers, teaspoons, 10 mL measuring cylinders)

Do this ...

1. Brainstorm the variables that would influence how absorbent paper towels are.
2. Design and run two pracs that will test two of these variables.

Record this ...

Describe what happened.

Explain why you think this happened.

SCIENCE AS A HUMAN ENDEAVOUR

ENDEAVOUR

Use and influence of science

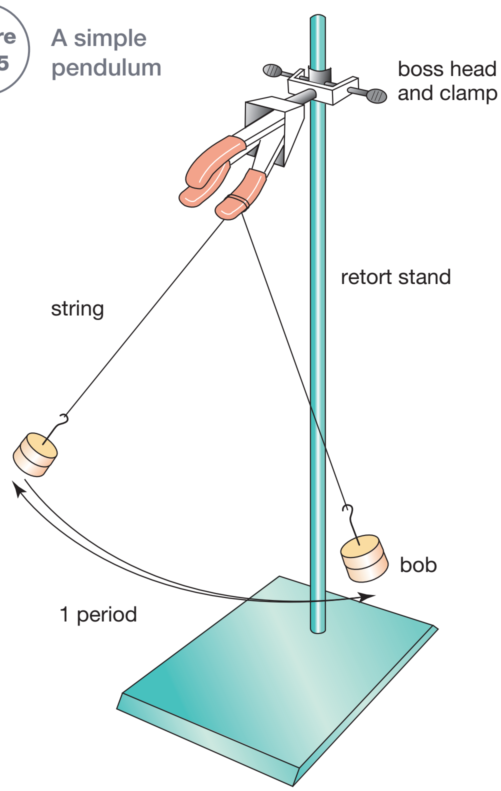
The pendulum

Figure 1.4.4 Pendulums are used in metronomes and some clocks.

A **pendulum** is a mass (called a **bob**) attached to a rod, chain or rope that swings back and forth repeatedly.

A typical pendulum is shown in Figure 1.4.5. The **period** of a pendulum is the time it takes to complete one entire swing, back and forth. Its **frequency** is the number of complete swings it makes every second. Period is measured in seconds (symbol s) and frequency is measured in **hertz** (symbol Hz).

Figure 1.4.5 A simple pendulum



Foucault's pendulum

Every swing a pendulum makes is in a slightly different direction due to Earth's rotation about its own axis. After 24 hours, the pendulum returns to its original direction. A pendulum that does this is known as Foucault's pendulum and it is evidence that Earth is spinning.

WORKED EXAMPLE

Period and frequency

Problem

A pendulum swings 10 times in 5 seconds. Calculate its period and frequency.

Solution

Period = time it takes to complete one swing

$= \frac{5}{10} = 0.5\,\text{s}$

Frequency = number of complete swings per second

$= \frac{10}{5} = 2\,\text{Hz}$

Pendulum variables

Important variables that could affect the period of a pendulum are the:

- length of the string
- mass of the bob
- angle of the bob from the vertical at the start.

Gravity is another important variable but it is unlikely that you will ever be able to change it or test it. Without gravity, a pendulum would never swing. Gravity is the force that causes the bob to swing back and forth. The higher the gravity, the faster the bob will swing (giving a shorter period and an increased frequency).

2 p35

3 p35

1.8

History of the pendulum

In 1602, the Italian scientist Galileo Galilei studied the pendulum and its variables in detail. His findings allowed scientists of the seventeenth century to develop new instruments and ways to measure the world around them.

Timekeeping

Pendulums swing regularly back and forth when allowed to swing from angles of less than 10° from the vertical. This fact allows pendulums to be used in clocks. Before 1656, clocks were often 'out' by as much as 30 minutes. However, in that year, Dutch scientist Christian Huygens built a pendulum-based clock that was accurate to within a few seconds. Pendulums are still used to regulate the timing of grandfather and older-style mantle clocks. The bob of a grandfather clock is shown in Figure 1.4.6.

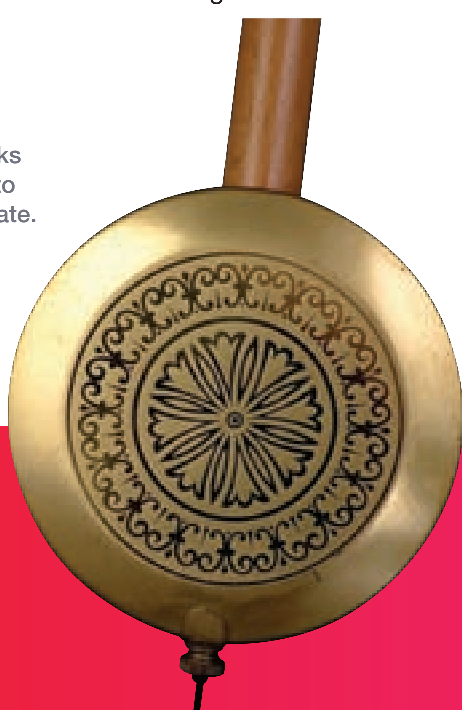


Figure 1.4.6 Grandfather clocks use a pendulum to keep them accurate.

Figure 1.4.7 A metronome is an 'upside-down' pendulum. Its period matches the timing of the music being practised.

SciFile

Metronomes

Musicians use metronomes to keep in time when practising. A typical metronome is shown in Figure 1.4.7. A metronome uses a pendulum to regulate its time. The pendulum can be made to go quicker by sliding the mass down the rod and go slower by pushing it upwards.

Navigation

Early explorers were often unsure of where they were on Earth because they had no way of accurately measuring their longitude (how far they were east or west on Earth). The invention of accurate clocks gave them the technology to measure time accurately. They set their clocks when they left port against standard Greenwich Mean Time. At noon, the Sun is directly overhead and the clock should read 12. If it didn't, then it meant that they had travelled east or west. Every hour their clock was 'out' represented another 15° they had travelled from longitude 0°. From this early explorers were able to calculate their longitude.

Determination of the shape of the Earth

Gravity is one of the variables on which the period of a pendulum depends. The swings of a pendulum can therefore be used to measure the value of gravity around the globe. Pendulums swing a little slower at the Equator than at the poles. This proves that Earth is not perfectly spherical but is thicker at the Equator.

1.4 Unit review

Remembering

1 **Recall** the different types of variables by matching them with their correct descriptions:

independent	fixed
dependent	changes naturally
controlled	changed by you

2 **List** four variables that are likely to influence the period of a pendulum.

3 **List** three areas in which pendulums assisted scientists in their understanding of Earth.

Understanding

4 a **State** how many variables should be changed in the one experiment.
b **Explain** why.

5 **Define** the following terms.
a pendulum
b bob
c period
d frequency

6 **Explain** how explorers can use a clock to determine where they are on Earth.

7 **Explain** how seventeenth-century scientists determined that the Earth was not a perfect sphere.

Applying

8 A pendulum takes 20 seconds to swing 40 times. **Calculate** its:
a period
b frequency.

9 Foucault's pendulum changes its direction continually but repeats its motion every 24 hours. **Use** the Earth's rotation to **explain** why.

Analysing

10 **Analyse** the following experiments and **identify**:
i the dependent variable
ii two independent variables that are likely to be important.
a Prac A: To determine the amount of sugar that can be dissolved in water.
b Prac B: To determine the amount of time a pet dog sleeps per day.
c Prac C: To determine how long a parachute takes to drop 50 metres.
d Prac D: To determine the growth rate of a plant seedling.

11 **Contrast** scientific research with an experiment.

Evaluating

12 **Propose** advantages that the managerial model brings to the:
a team
b teacher.

13 Someone in your team just got hurt in a prac. You want to tell the teacher but your team is organised on the managerial model and you're not the communicator. **Propose** what you should do.

14 A pendulum is used to control the timing of a grandfather clock.
a For this pendulum, **predict** its period and frequency.
b **Justify** your predictions in Part a.

Inquiring

1 Search available resources such as textbooks, encyclopedias and the internet to complete the following tasks.
   a Construct a timeline of the major discoveries involving the pendulum.
   b Research how pendulums were used to prove that gravity differs slightly around the Earth.
   c Research how pendulums caused clocks to become more and more accurate.
   d Construct a diagram of a compound pendulum.

2 A pendulum normally swings back and forth directly under its support. However, if you start it swinging 'off-line' (not directly under its support), then it will swing around, tracing loops and circles.
   a Use the ideas shown in Figure 1.4.8 to design a pendulum that could draw sand pictures.
   b Check your design with your teacher and then construct it.

3 Construct a series of diagrams or collect a series of photos that show how the parachute has changed over time. Label each diagram or photo with its date.

4 Search the internet to find videos showing:
   a how pendulum clocks work
   b parachute drops and skydiver formations.

Figure 1.4.8

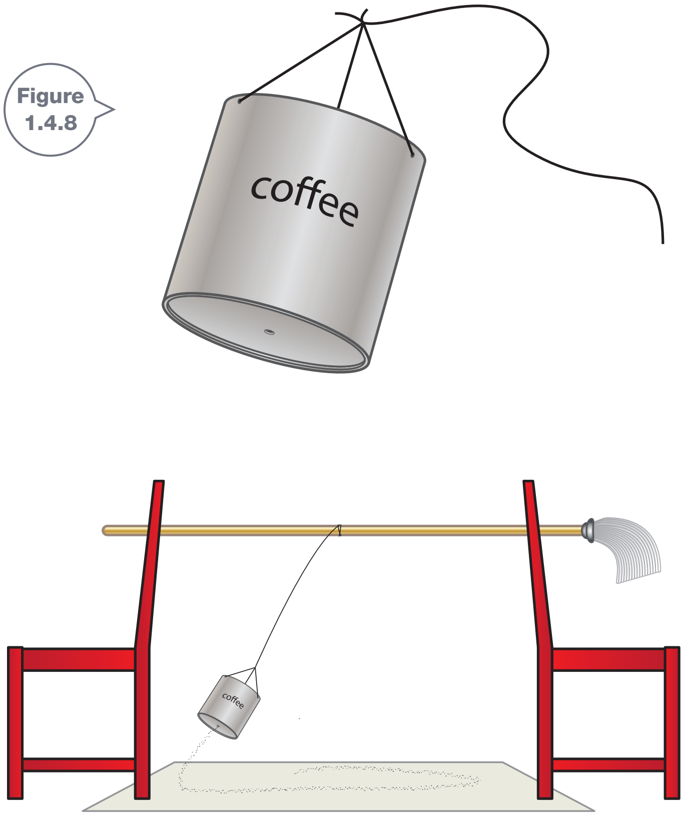


Figure 1.4.9 Skydivers in formation

1.4 Practical activities

1 Parachute drop time

Purpose

To determine what influences the drop time of a parachute.

Materials

- lightweight materials (such as tissue paper, plastic sheet from garbage bags, newspaper)
- fine cotton
- access to a hole punch
- sticky tape
- small masses (plasticine or paperclips are ideal)
- access to electronic balance
- stopwatch
- metre ruler or tape measure

Procedure

1. Brainstorm all the variables that could affect the drop time of a parachute.
2. Select the two variables that your prac team thinks will have the most effect.
3. Design two experiments that will test your two variables. Remember to keep everything else the same.
4. When constructing your chutes, reinforce the string holes with patches of sticky tape like the one shown in Figure 1.4.10.
5. Drop your chutes from a height of at least 2 metres.
6. Make repeated measurements of the time they take to hit the ground, recording them in a table or spreadsheet.

Results

1. Construct a line graph for each experiment.

Discussion

1. **List** the variables that your prac team thought may be important in this experiment.
2. **Explain** why you chose the variables you tested and not others.
3. **Describe** the shape of all graphs you plotted.
4. **Construct** conclusions for both experiments.

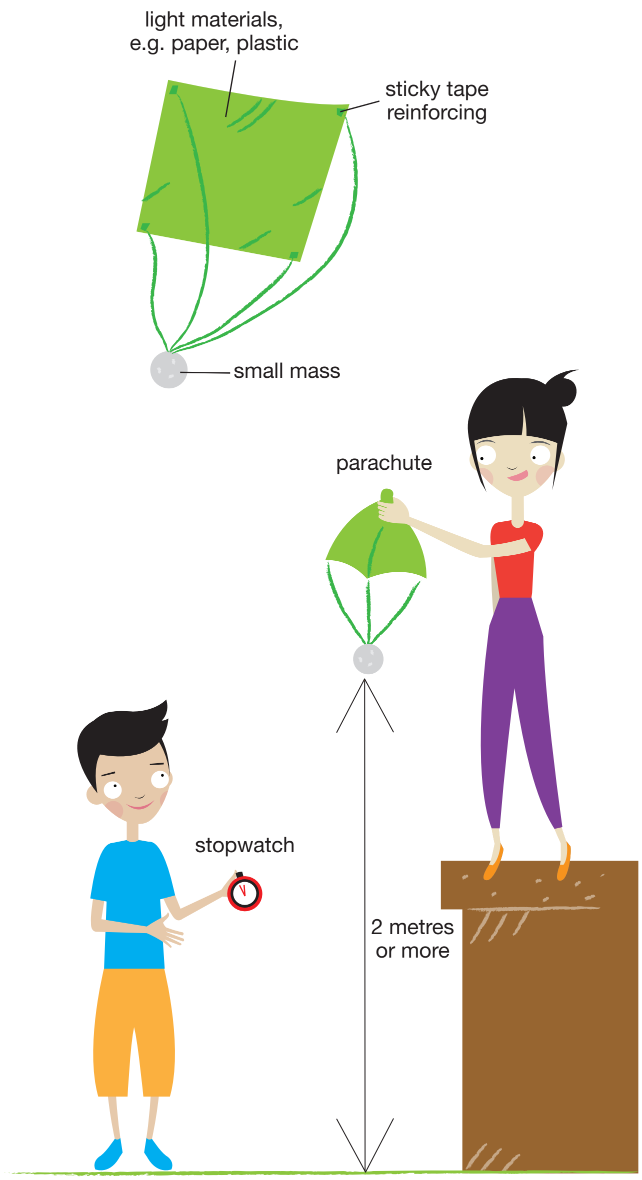


Figure 1.4.10

2 The pendulum and length

Purpose
To test how the length of a pendulum affects its period.

Materials
- materials to construct a pendulum
- stopwatch or appropriate datalogging equipment
- protractor (optional)

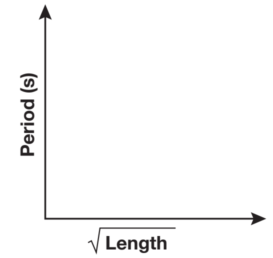
Procedure
1. The independent variable here is the length of the pendulum and so you need to keep the mass and the angle the pendulum is swung from the same throughout the prac. Decide what values you will use.
2. Decide on the lengths that you will test. At least five different lengths should be tested.
3. You need to repeat measurements for the time taken for ten complete swings. Decide how many times you will repeat each experiment.
4. Run your experiment, recording the time taken in a table.

Results
1. Construct a table or spreadsheet for the measurements you take.
2. Calculate the average time for ten swings and for one swing (the period).
3. Plot a graph of period versus length.

Extension: One aim of a scientist when analysing results is to try and get a straight line when plotting graphs. If you didn't get a straight line, then try the next few steps.

4. Make another column in your table. Use a calculator to take the square root √ of the lengths you used and enter these into the new column.
5. Plot a new graph of period versus square root of length like that shown in Figure 1.4.11.

Figure 1.4.11



Discussion
1. **Describe** the shape of each graph that you plotted.
2. **List** the controlled variables in this experiment.
3. **State** the independent and dependent variables in this experiment.
4. **Construct** a conclusion for what you found out.

3 The pendulum, mass and starting angle

Purpose
To test if mass and starting angles change the period of a pendulum.

Materials
- materials to construct a pendulum
- stopwatch
- protractor

Procedure
1. Your task is to design and report on an experiment that tests how starting angle or mass affects the period of a pendulum.
2. Whatever variable you test, include in your report a line graph of period versus your variable.

Discussion
1. **Explain** how you controlled all the variables other than the starting angle in this experiment.
2. **Construct** a conclusion that summarises what you found out.

1 Chapter review

Remembering

1 **State** whether the following are true or false.
- a A measurement ranging from 10°C to 14°C could be written as 12 ± 2°C.
- b A measurement of 21 ± 1 cm spreads from 21 to 22 cm.
- c Human reactions cannot be faster than 0.5 seconds.
- d A line of best fit connects its points dot to dot.
- e 'The prac was fun' is a good conclusion for an experiment.
- f The period of a pendulum is the time it takes for it to swing from one side to the other.

2 **List** three pieces each of qualitative data and three pieces of quantitative data that would help describe where you live.

3 **List** five types of errors.

4 **Name** the variable that:
- a is changed by you
- b varies naturally as the experiment proceeds
- c is fixed.

5 **List** four variables that might be expected to influence:
- a the period of a pendulum
- b a person's fitness
- c the time it takes to fry a sausage
- d the temperature reached inside a parked car.

Understanding

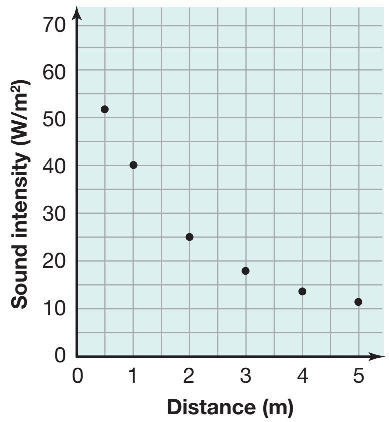
6 **Define** the following terms.
- a purpose
- b hypothesis
- c conclusion
- d bibliography
- e pendulum

7 **Explain** what a fair test is.

Applying

8 **Use** the graph in Figure 1.5.1 to **predict** the sound intensity (measured in watts per square metre) at:
- a 2.5 m
- b 3.5 m
- c 150 cm

Figure 1.5.1



9 Extrapolate the graph in Figure 1.5.1, extending it logically backwards to zero. **Use** your extrapolation to predict what the sound intensity at a distance of 0 metres would be.

10 **Use** the graph in Figure 1.5.1 to **predict** the distance at which the sound intensity was:
- a 45 W/m^2
- b 15 W/m^2

11 **Identify** the variables that could logically influence:
- a how much liquid paper towelling absorbs
- b how quickly iron rusts
- c how quickly a banana ripens
- d how often you go to the toilet to urinate
- e how good you are at sport.

Analysing

12 Consider the following list of volumes: 87 mL, 82 mL, 90 mL, 86 mL, 97 mL, 93 mL
- a **Identify** the results that should be eliminated.
- b **Calculate** the average.

Creating

13 **Construct** a labelled diagram showing the parts of a simple pendulum.

1.9

14 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

data	internet	experiment
first-hand	second-hand	variable
independent	dependent	fair test
controlled		

Thinking scientifically

Anila ran an experiment in which she measured the period of a pendulum. This is the time it takes for a mass on a length of string to swing back and forth once. The data she obtained is shown in the table below.

Mass of bob (g)	Length (cm)	Angle swung from	Time for 10 complete swings (s)	Average period (s)
50	50	10°	142	1.42
50	100	10°	201	2.01
50	150	10°	246	2.46
50	200	10°	283	2.83
50	250	10°	317	3.17

Q1 Identify the two variables that Anila controlled in her experiment.

A Mass and length
B Length and angle
C Mass and angle
D Average period and time for ten swings

Q2 State which is the most likely aim for her experiment.

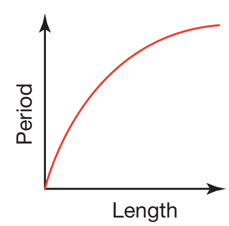
A To test the effect of changing mass on the period of a pendulum
B To test the effect of changing length on the period of a pendulum
C To test the effect of changing angle on the period of a pendulum
D To test the effect of changing times for ten complete swings on the period of a pendulum

Q3 Anila did not try to time a single swing but instead timed ten complete swings. Identify the most likely reason explaining why she did this.

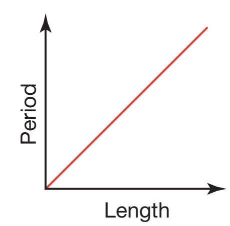
A She can count to ten.
B It reduced the effect of errors in her timing.
C The change in period only becomes noticeable after ten swings.
D It was the only way to test her chosen variable.

Q4 Identify which of the four sketch graphs A–D best describes her results.

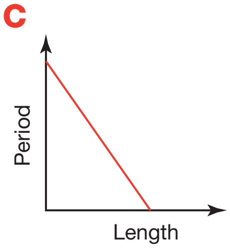
A



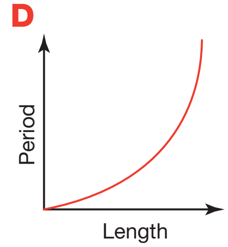
B



C



D



Q5 Identify the best conclusion for her experiment based on her results.

A Pendulums control the timing of grandfather clocks.
B A pendulum will swing faster if it is started at a greater angle.
C Heavier masses cause a pendulum to swing faster.
D Increasing the length of the pendulum increases its period.

Glossary

Unit 1.1

Average: mean; add up all the 'good' values and divide by how many there are

Data: measurements and observations about something

Errors: small changes to measurements that cannot be avoided, even with care

First-hand data: data you collect yourself from an experiment

Instrument error: error due to a faulty instrument or using it at a temperature it is not designed for

First-hand data

Mean: average; add up all the 'good' values and divide by how many there are

Mistakes: can be avoided with care; mistakes are not errors

Parallax error: error caused by not having your eye directly in line with the measurement

Qualitative data: observations that are descriptive only

Quantitative data: measurements that use numbers (and usually units)

Reading error: error due to guesswork needed when a measurement falls between an instrument's markings

Second-hand data: data you have not found through an experiment; comes from textbooks, encyclopedias, internet etc.

Tare: changing the zero on an electronic balance

Zero error: error due to instrument giving a small reading when it should read zero

Unit 1.2

Bibliography: resource list

Domain: last part of a website's address or URL

Imprint page: includes all relevant data about a book such as publisher and year of publication

URL

URL: website address

Unit 1.3

Aim: purpose; what you are trying to do in an experiment

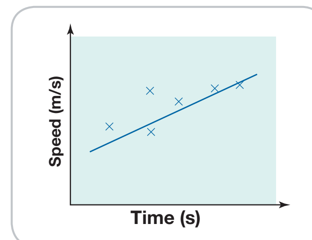
Bibliography: resource list

Conclusion: a short summary of what you found out in an experiment

Extrapolation: logical extension of a line graph

Hypothesis: an 'educated guess' about what might happen in an experiment

Line or curve of best fit: straight line or curve drawn through the 'centre' of points on a graph



Line of best fit

Method: a description of what you did in an experiment

Purpose: aim; what you are trying to do in an experiment

Unit 1.4

Bob: the mass on the end of a pendulum

Controlled variable: the variable kept constant throughout an experiment

Dependent variable: the variable you are measuring; it changes as the independent variable changes

Fair test: when only one variable is changed in an experiment

Frequency: the number of complete swings of a pendulum in 1 second

Hertz: the unit for frequency (symbol Hz)

Independent variable: the variable changed by you; it will probably cause a change in the dependent variable

Pendulum: a mass that swings back and forth

Period: time taken for pendulum to complete one swing, back and forth

Scientific research: a series of experiments on the one topic

Team: your prac partners and you

Variables: factors that may influence an experiment